Environmental Assessment of the Alaskan Continental Shelf

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DISCLAIMER

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RECEPTORS-BIRDS

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ANNUAL REPORT

Research Unit # 108

January - March 1980

SIMULATION MODELING OF MARINE BIRD POPULATION ENERGETICS, FOOD CONSUMPTION, AND SENSITIVITY TO PERTURBATION

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I. SUMMARY

The objective of this research program is to explore the sensitivity and response of breeding marine birds in the Kodiak Island region to environmental perturbations. This research includes three phases: (1) the estimation of overall population and community energy demands by the birds and the temporal variations in these demands through the breeding season; (2) the determination of distributional patterns of the major bird species in the marine areas surrounding Kodiak Island; and (3) the use of simulation and analytic models to synthesize energetic, distributional, demographic, and behavioral parameters to project the responses of colonially-breeding marine birds to environmental perturbations, such as might accompany petroleum development. In this report, we consider the distributional patterns of the major bird species occurring in the Kodiak area, using as baseline data censuses obtained by USF&WS personnel during shipboard and aerial surveys conducted during 1975-77.

These censuses exhibit substantial heterogeneity in time of sampling, area of sampling, and method of sampling, and as a consequence of these various discontinuities in the sampling regime, we found it necessary to combine censuses in various ways and to use several weighting procedures in the analysis of census results in order to develop any sort of synthesis of the distributional patterns of the birds. Using such adjusted census results, we analyzed the distributions of five major bird species: Black-legged Kittiwakes (Rissa tridactyla), Glaucous-winged Gulls (Larus glaucescens), murres (primarily Common Murres, Uria aalge), Sooty Shearwaters (Puffinus griseus), and Tufted Puffins (Lunda cirrhata). Analyses of these distributional patterns revealed regions of apparently high density concentrations for these species, and other regions where densities are low. Some density peaks, however, apparently result from single encounters of large aggregations of individuals that were not encountered during subsequent censuses in the same areas. Other regions of high density seem consistent with areas in which concentrations of birds might be expected from knowledge of the locations of breeding colonies or from information on bathymetric features. In general, the areas around the Semidi and Barren islands, over Portlock, North (the eastern end) and South Albatross banks, and the area between the Trinity Islands and Cape Ikolik appear to be important foraging areas for these species. In contrast, Shelikof Strait and the western end of North Albatross Bank have consistently low densities, as do the off-shelf areas for most of the species, especially the two alcids.

To evaluate the level of statistical confidence that can be placed in this analysis, and because standard statistical techniques are not valid for data of this kind, we developed a new method for placing confidence intervals on mean bird densities. We found that, for an analysis based on densities in 20 x 20 km blocks, only about 6% of the region around Kodiak has been sampled with sufficient intensity to generate confidence intervals at all. Of that proportion of blocks, only about 3% has been sampled with sufficient intensity that the upper confidence bounds are within an order of magnitude of the calculated mean density, even though data were pooled over all times of year (thus obviating seasonal changes as a source of variation). This lack of statistical confidence results primarily from basic features of pelagic bird distributions, rather than from observer error. Thus, it is virtually impossible at this point to obtain statistical validation for any conclusions or management decisions based upon pelagic bird census data. We suggest that OCSEAP make an effort to define spatio-temporal regions over which data can be validly pooled in order to develop a stratified sampling regime to overcome this difficulty.

II. INTRODUCTION

Our overall objective in our current research phase is to explore the sensitivity and response of breeding marine birds in the Kodiak area to environmental perturbations such as might accompany petroleum developments. Our approach to meeting this objective parallels our earlier analysis of colonial seabird demography and sensitivity to perturbation for the Pribilof Islands system (Wiens et al. 1979a). This approach combines the use and analysis of field observations on the distributional patterns of the birds and their life history and reproductive attributes with analytic and simulation modeling of population foraging distributions and behavior and population demography. Throughout, patterns of response are organized within the framework of energy flow patterns.

Such research involves several distinct phases. In an earlier report (Wiens et al. 1979b) we have used simulation models to estimate population energy flow patterns for the dominant breeding species in the Kodiak region. In this report we concentrate on distributional patterns of these species about Kodiak Island during the breeding season, and provide a statistical evaluation of the results obtained by censusing seabirds in this region. Such distributional analyses are of fundamental importance to any attempts to model the distributional dynamics of colonially-breeding seabirds, and how these dynamics respond to environmental perturbations. The present analysis is based upon census information obtained by USF&WS personnel during shipboard and aerial surveys conducted during 1975-1977.

For purposes of modeling the potential impacts of offshore development and providing a distributional baseline for management decisions, we have synthesized these data into distributional maps for each of the five major species found in this region: Black-legged Kittiwakes (Rissa tridactyla), Glaucous-winged Gulls (Larus glaucescens), murres (principally Common Murres, Uria aalge), Sooty Shearwaters (Puffinus griseus), and Tufted Puffins (Lunda cirrhata). Carrying out this synthesis was a relatively complex task due to the nature of the bird distributions themselves and the methods used for collecting the data. Four factors greatly complicate the construction of basic density-distribution plots derived from the Kodiak data base: (1) Bird densities are highly variable in both time and space, sometimes varying over 3-4 orders of magnitude during time intervals of hours or days and distances of only 5-10 km. (2) The frequency distributions of transect densities are extraordinarily skewed; i.e. very low densities are most common, but densities orders of magnitude higher occur with regularity (see Fig. 8). This means that standard statistical models such as the normal or Students-t are invalid except for very large sample sizes. (3) Data were collected from both ships and aircraft. Analysis of these data shows that the probability of detection of birds is consistently far greater from ships than from airplanes, making it impossible to combine these two types of transect data directly. (4) Because most of the data were collected from ships of opportunity and because observers were more inclined to collect data in some regions than in others, the distribution of sampling intensity is very patchy. Some regions have been intensely sampled, while others, particularly to the south and west of Kodiak, remain unsampled.

For this report, we have worked within these constraints to develop a synthetic overview of the pelagic bird distributions in the vicinity of Kodiak Island, and to provide statistically valid limits on those density estimates. The results displayed here are designed for use as management tools, and the methods used in deriving them are being used to provide inputs for our own modeling efforts.

III-VIII. RESULTS AND DISCUSSION

Distributional Synthesis

The most accurate and intuitive method of displaying spatial distributions in this context is to construct contour mappings of the observed densities of birds on a species-by-species basis. Such maps consist of series of equal-density isoclines based on point-to-point interpolations of the observed transect densities and clearly display the overall distributional patterns. Their construction, however, requires that there be no major spatial gaps in the data base, i.e. regions where nothing is known of bird densities. Ideally, density mappings should be generated on a seasonal basis, using only one type of transect data (ship or air), and interpolating density values only over short distances--on the order of 5-10 km. Given the data base, however, such maps would consist almost entirely of gaps. Instead, we have opted to pool all available data in such a way as to obtain nearly complete spatial coverage of the Kodiak region. While some information is inevitably lost by such pooling, we feel that the advantages of having an overall distributional pattern outweigh the disadvantages.

Pooling over time.--Combining data collected at different times of year was the first step required in order to derive a high degree of spatial coverage. The ubiquitous question marks on the seasonal density mappings provided in the 1979 Kodiak Interim Synthesis Report demonstrate that it was possible to obtain only fractional coverage of the Kodiak area during any one season. There is every reason to suppose that there is a strong seasonal component to variation in bird densities and distribution; both the requirements of these species and the distribution of their food supply obviously vary widely over the annual cycle. Nonetheless, from the standpoint of potential impact of fixed points of disturbance such as drilling platforms, work camps, pumping stations, etc., it is valid to portray the bird distributions as temporally static, so long as the disturbance itself does not have a strong seasonal component. Mappings based on the full annual cycle will reflect the overall impact of such disturbances on marine bird populations much more accurately than seasonal mappings that, until more data are forthcoming, must remain so fragmented as to be of little use.

Pooling over distance.--For any method of displaying density distributions, it is necessary to average data from all transects occurring within some specified region in order to obtain a single-value estimate of the density within that region. The question is, how large is that area to be? Combining transect values over a relatively large area has the effect of generating a high degree of total coverage, but local and potentially significant variations in density are lost or smoothed over. Combining only values that are relatively close to one another, however, leads to an overall distribution with very poor coverage. We have chosen to use an algorithm that provides density estimates in regions with low sampling intensity, while at the same time minimizing the loss of detailed information in regions with high sampling intensity.

We first divide the Kodiak area into 10-km blocks extending from 55°25' to 59°00' latitude and 147°50' to 156°25' longitude. Blocks are classified as land or sea on the basis of whether they are more or less than 50% land. The distribution of sampling intensity based on 10-km blocks is shown in Figs. 1a and 1b. The intensity of sampling effort rarely exceeds 2-3 transects per 10-km block except in the inshore portion of the North Albatross Bank and Chiniak Trough, and the vast majority of blocks remains unsampled. In order to obtain nearly complete coverage, it was necessary to compute a two-dimensional running average based on all transects

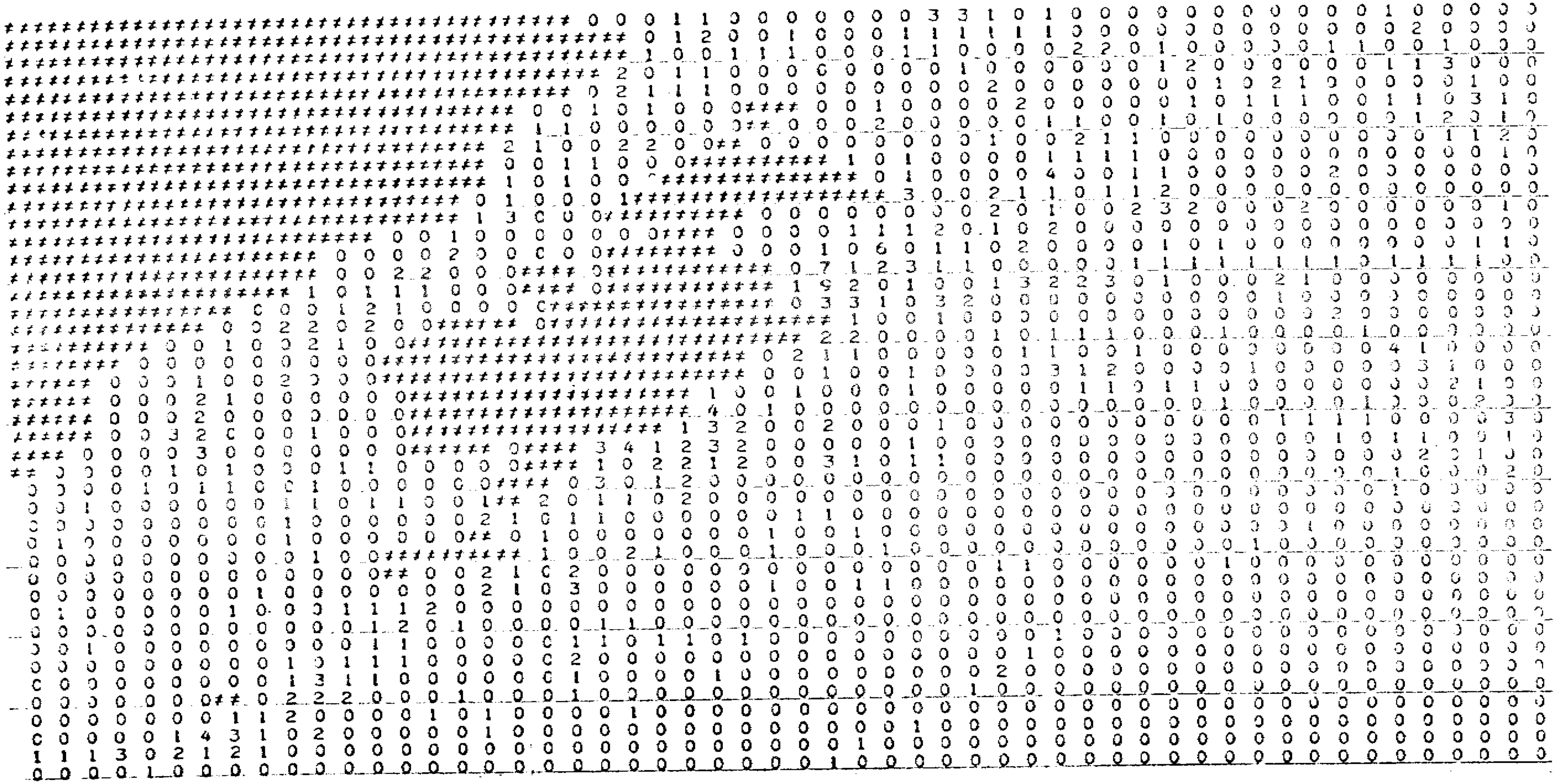


Fig. 1a. The distribution of ship transects on a 10-km grid in the vicinity of Kodiak Island. For each grid vertex, transects are drawn from up to 5 km away. The lower left corner corresponds to 55°25' latitude and 161°25' longitude. Blocks containing more than 50% land are indicated by "#."

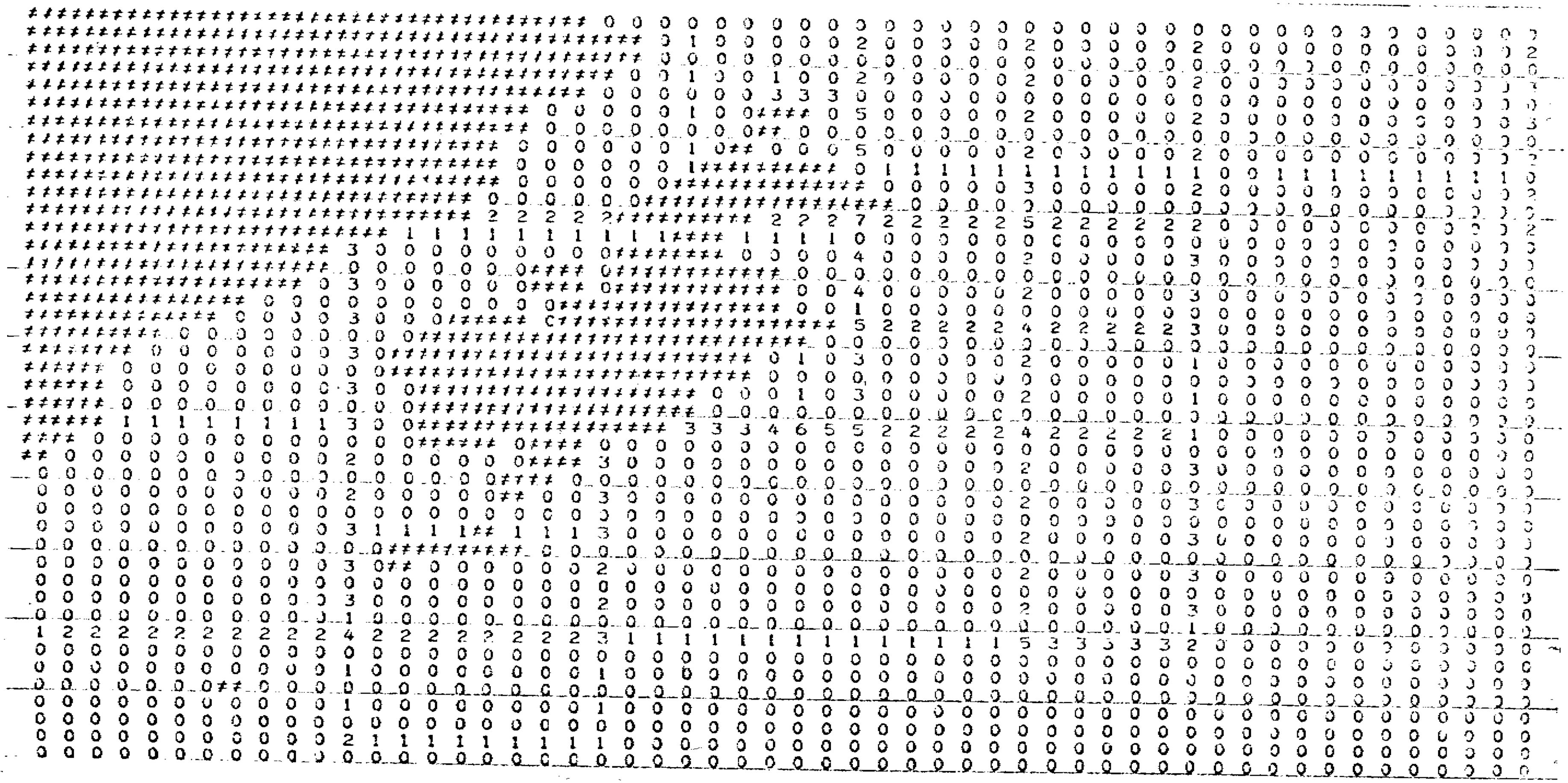


Fig. 1b. The distribution of air transects on a 10-km grid in the vicinity of Kodiak Island. For each grid vertex, transects are drawn from up to 5 km away. The lower left corner corresponds to 55°25' latitude and 161°25' longitude. Blocks containing more than 50% land are indicated by "#."

run within 35 km of the center of each 10-km block. The sample intensities based on this algorithm are shown in Fig. 2. Coverage using this method is almost complete, and sample intensity is high enough to obtain at least a reasonable confidence in their mean density values. Unfortunately, averaging transect densities over a circle of diameter 70 km obviously loses considerable information on local variation, as in some regions (particularly inshore) the distributions are clearly complex. We attempted to minimize this effect in areas with relatively higher sampling intensity by using a weighted average based on the distance from the center of each 10-km block to the midpoint of a given transect. The weighting coefficient ranges linearly from 0-1 for transects from 35-0 km from the block center. Thus, the density in each 10-km block is estimated as the weighted mean density of transects within 35 km of the block center, where the weighting factor of the ith transect, W_i, is computed from D_i, the distance from the transect midpoint to the block center, using the formula:

$$W_i = 1 - D_i/35$$

where $D_i \leq 35$. These values were then used to define densities at the lattice points of a 10-km grid, which was then input to a standard surface contouring display program.

Pooling over transect types.--Ship and air transects frequently give different results in terms of transect densities. Table 1 summarizes the distributions of transect densities for 984 aerial transects and 1,190 ship transects from the Kodiak region for each of the five principal species. (1) In all cases, the probability of detecting no birds is greater for aerial transects than for ship transects. (2) Except for Black-legged Kittiwakes, the mean variance ratio is consistently higher for aerial transects. For both shearwaters and Tufted Puffins, the mean density is much lower for aerial than for ship transects. These discrepancies probably occur because aerial transects are smaller than ship transects (100 m as compared to 300 m) and because birds with only dark plumage (shearwaters and Tufted Puffins) are relatively much more difficult to locate from the air. In view of these problems, it is not valid to combine directly density estimates based on transects of differing types. However, because there are large areas sampled only by one method or the other, we did not consider it acceptable either to discard the less accurate aerial survey data or to treat the two types of data totally independently. The solution that we chose was to utilize aerial data only in the absence of ship survey data. In order to correct the aerial data for diminished probability of detection, we assumed that the means of all aerial transects should be the same as for all ship transects. Then the ratio of the grand mean density for all ship transects over the grand mean of all aerial transects provides a correction coefficient for aerial transect data that should make the two methods of data collection more nearly comparable.

Distributional Patterns of the Major Bird Species

Black-legged Kittiwake.--The distribution of Black-legged Kittiwakes is dominated by two very large peaks (Fig. 3). These may not represent stable concentrations, however. The first (A) exists because of two ship transects conducted on 27 May 1975 that recorded greater than 50 birds each, mostly in a few flocks. Three other ship transects were run in this area during the breeding season, and they recorded very few birds. All aerial transects in this area were conducted during the non-breeding season, and they found virtually no birds. This peak may represent a foraging location for birds breeding on the Semidi Islands, approximately 90 km to the west, but without further sampling effort during the breeding season we cannot be sure of how important it is throughout the season. The second peak (B) was produced by a single transect that recorded 339 birds on 11 November 1976, mostly in two very large flocks. Very few birds were found during other times of the winter, and this peak may thus

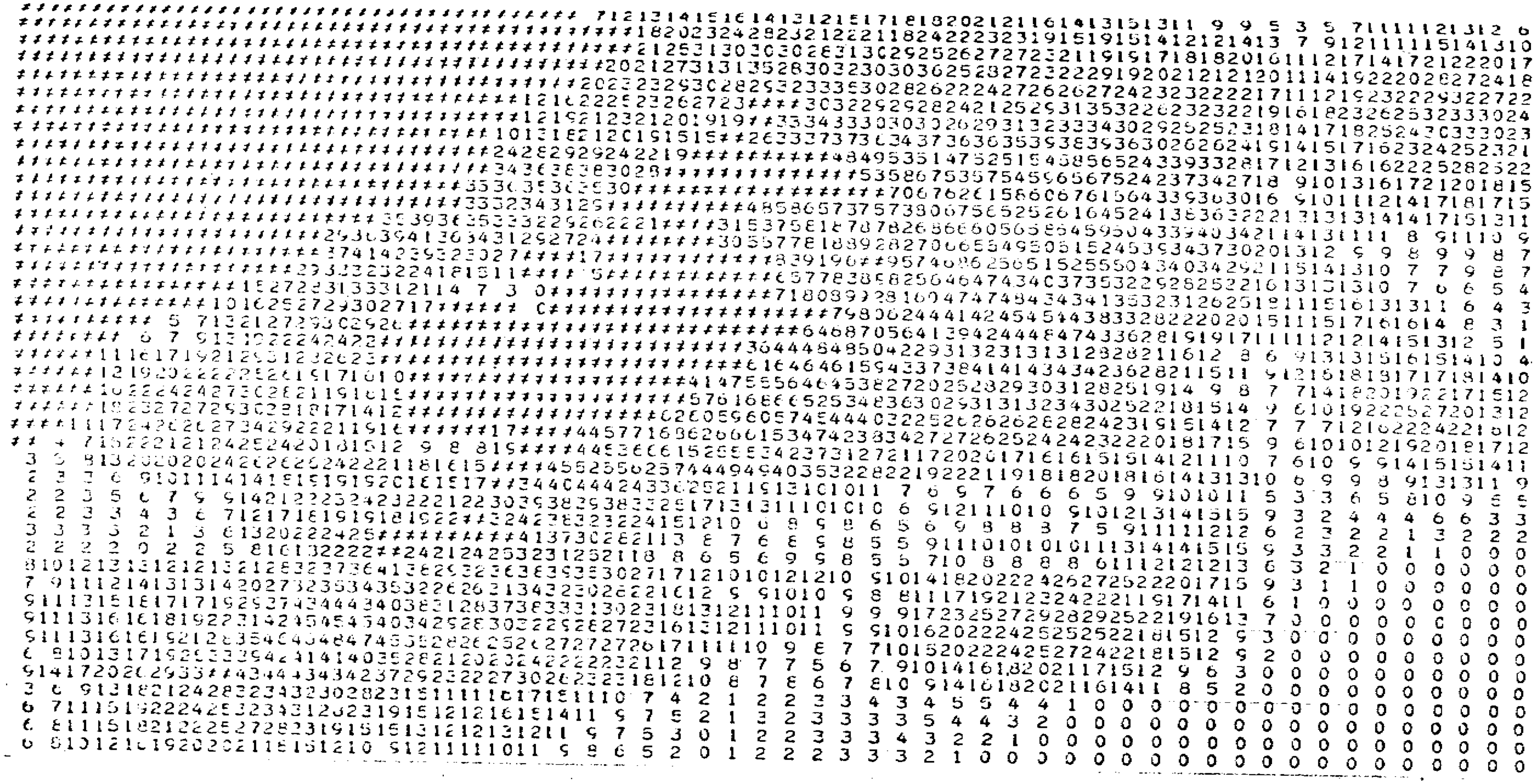


Fig. 2. The distribution of both ship and air transects as in Table 1, except that transects are drawn in from up to 35 km away.

Table 1. Comparison of summary statistics for the distributions of transect densities for ship and aerial transects. Values are expressed in terms of birds per km^2. P is the probability of finding no birds of that species on a transect.

Species	Ship transects			Aerial transects		
	$\bar{x}$	s	P	$\bar{x}$	s	P
Black-legged Kittiwake	2.65	10.63	0.49	2.73	9.66	0.58
Glaucous-winged Gull	1.77	4.56	0.56	1.50	10.17	0.69
Murre	4.10	14.68	0.51	4.71	40.62	0.59
Shearwater	86.29	880.26	0.59	10.26	162.63	0.85
Tufted Puffin	3.05	9.86	0.52	0.57	7.08	0.86

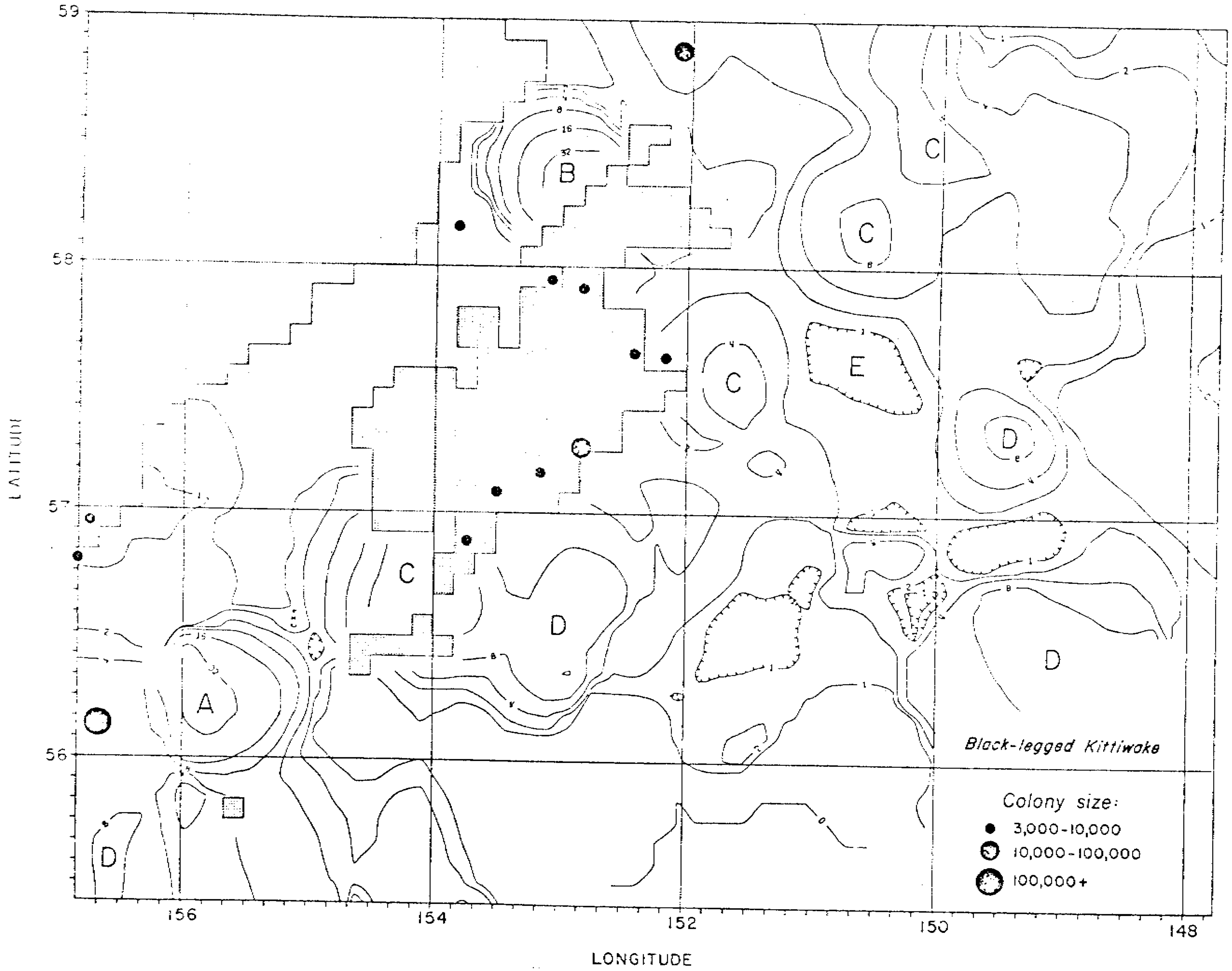


Fig. 3. Contour plots of the densities of (a) Black-legged Kittiwakes, (b) Glaucous-winged Gulls, (c) murres, (d) Tufted Puffins, and (e) shearwaters. [Stippled areas indicate that the region is more than 50% land. Note that the density contours are spaced exponentially (i.e., 1, 2, 4, 8...). Tick marks around a closed region indicate "downhill" slope.]

represent a relatively uncommon aggregation in this area, perhaps due to a fishing vessel. Densities were uniformly low here during the breeding season.

Several of the lower density peaks (C) indicate the existence of stable offshore foraging areas for birds from nearby breeding colonies. In all cases they were over the continental shelf (e.g., Portlock or North Albatross Bank) and well within the foraging range of breeding kittiwakes. Many important foraging areas are in inshore areas (i.e., in the bays and fiords) and are not shown on this figure because the plotting routine excluded them. Other peaks (D) represent the one-time detection of a large number of birds during the non-breeding season. The sampling effort in these areas was inadequate to enable us to decide if these are stable foraging areas. In contrast to the breeding season foraging areas, these are mostly over deep water.

Two areas are characterized by consistently low densities. The first is most of Shelikof Strait, and the second is the valley over the eastern edge of North Albatross Bank (E).

Glaucous-winged Gull.--It appears that Glaucous-winged Gulls restrict their foraging during the breeding season almost entirely to inshore areas. All of the density peaks on Fig. 4 represent non-breeding season concentrations. Although they were not totally absent from offshore areas during the breeding season, usually no more than four birds were detected during a transect, although 14 were recorded on one transect on 25 May 1976. Unfortunately, the data records did not indicate the age of these birds. We suspect they were immature, as they were approximately 110 km from the nearest breeding colony. Two of the peaks (S) appear to be stable non-breeding season foraging areas; one is over Portlock Bank and the other is over the continental slope south of Middle Albatross Bank. As for the Black-legged Kittiwakes, Shelikof Strait and outer North Albatross Bank were areas of consistently low densities of Glaucous-winged Gulls.

Murres.--The distribution of murres (Fig. 5) is fairly simple. It is dominated by just a few peaks and is almost entirely restricted to the continental shelf. Peak A represents large concentrations of birds found during the 1975 breeding season at the edges of Shelikof Trough just east of the Semidi Islands, where large numbers of murres breed. Interestingly, very few birds were found here in 1976, although most of the sampling effort was concentrated more to the southeast of the islands. Unfortunately the area was not sampled during the 1977 breeding season.

Peak B exists mostly because of two large counts made on 14 November 1976; other winter samples are too infrequent to determine whether this is a stable peak. Peak C reflects moderate to large densities recorded during all three breeding seasons; these presumably represent foraging birds from Flat Colony (colony size unknown) or from the few small colonies in Sitkalidik Strait. In addition, densities are moderate to high in this area during the non-breeding season as well. Thus, South Albatross Bank is an important foraging area for murres during all seasons. Likewise, D, E, and F are year-round foraging areas, although it is not clear in the case of E where the birds may be coming from during the breeding season, as the nearest sizeable colonies are approximately 130-140 km away. Peak G, over outer Portlock Bank and the continental slope, appears to be a stable winter foraging area. Peak H is strictly a breeding season concentration, undoubtedly associated with the large colonies nearby on the Alaska Penninsula. Peak I seems to be mostly an area of concentration of murres during the winter.

Shearwaters.--The distribution of shearwaters is fairly easy to interpret because

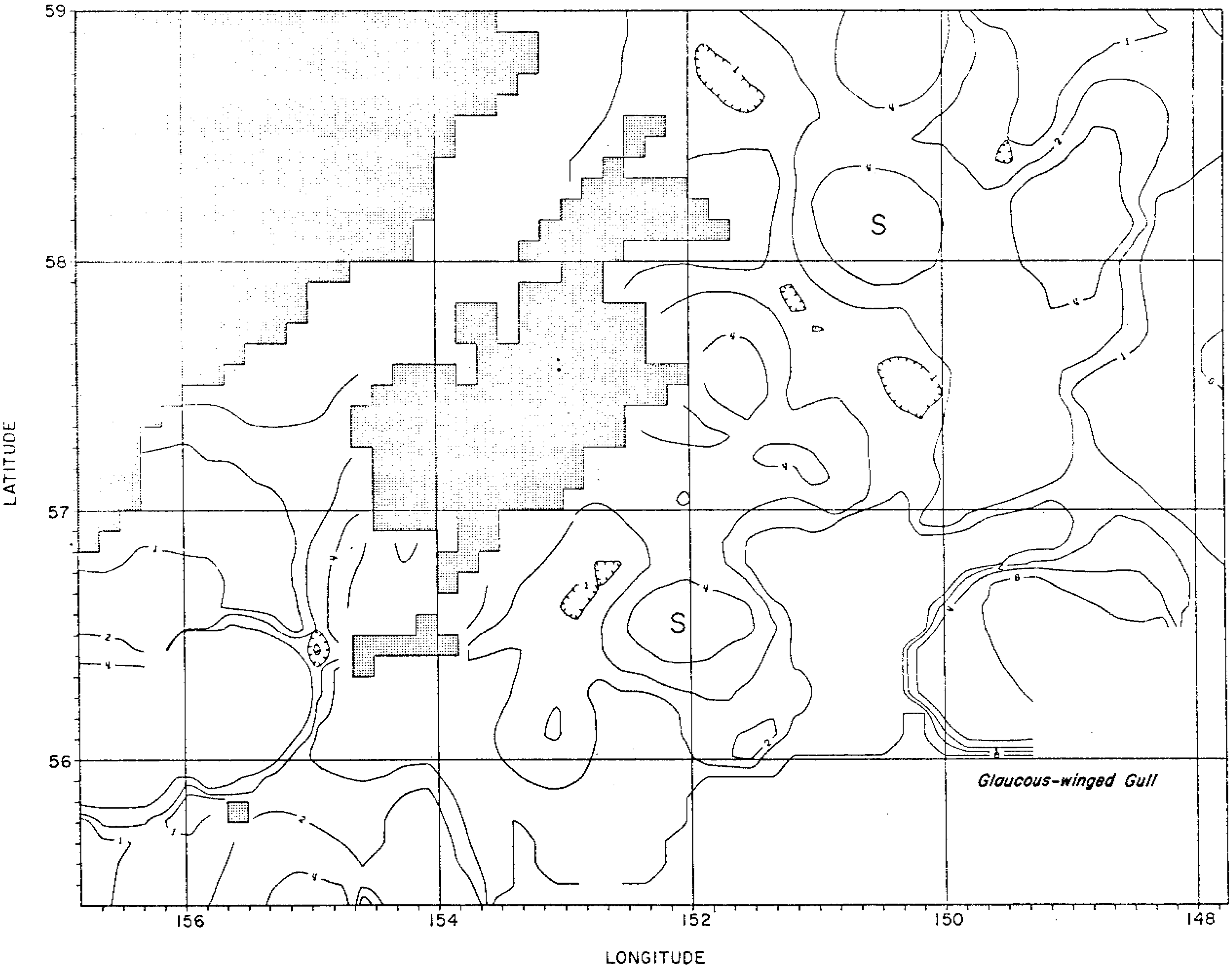


Fig. 4. The spatial distribution of Glaucous-winged Gulls in the Kodiak region. Symbols as in Fig. 3.

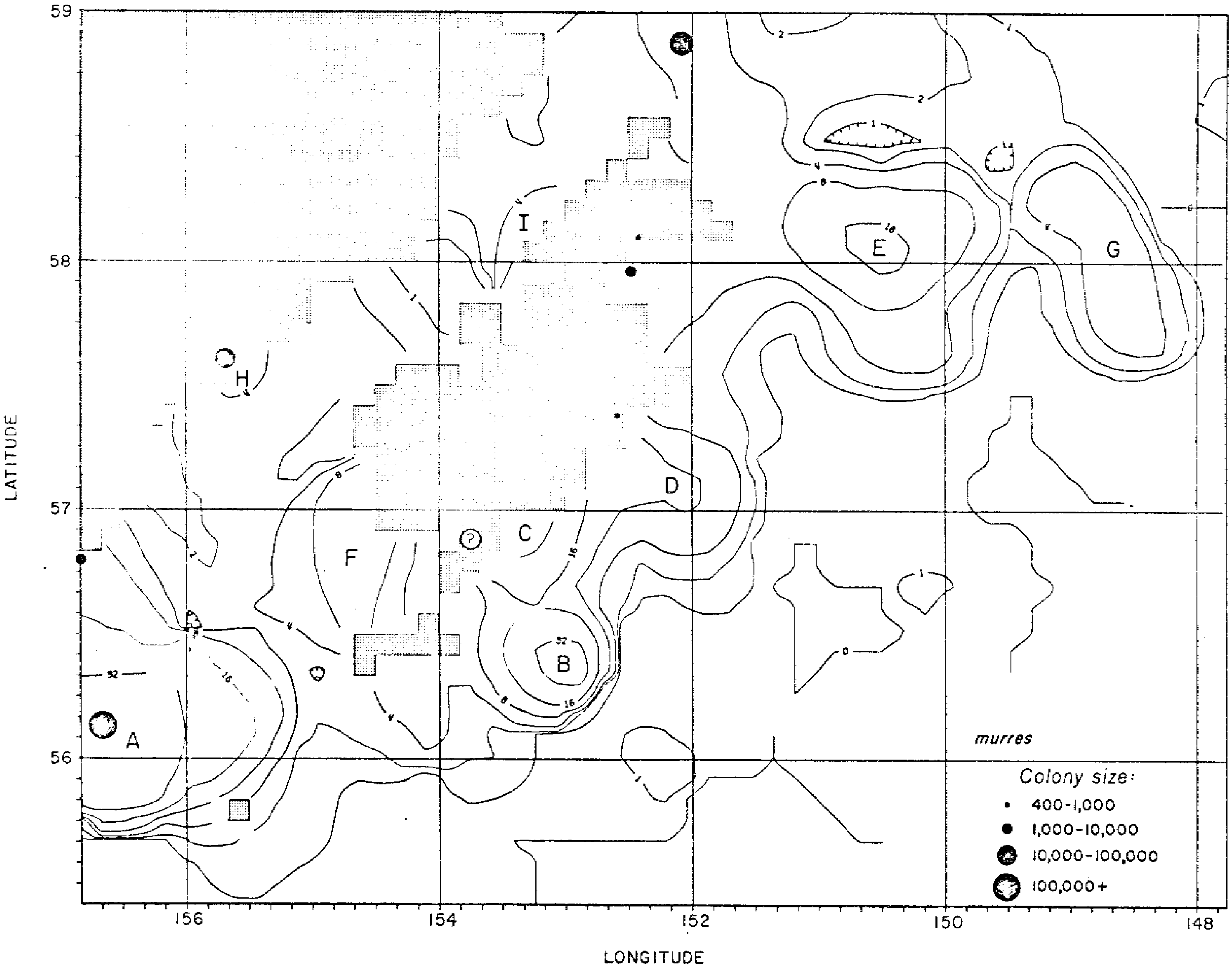


Fig. 5. The spatial distribution of murres in the Kodiak region. Symbols are as in Fig. 3.

they are not a member of the breeding community and because they are not present during the winter. This is somewhat confounded, however, by their tendency to aggregate in extremely large flocks (10,000-50,000) and by the fact that both species appear to migrate through the region but on different time schedules. Because of this flocking behavior, Fig. 6 is mostly a reflection of where observers encounter a large flock by chance. All of the peaks exist because of one or two transects of this type. We know that inshore areas may have a flock present over much of the season (Wiens et al. 1978), but this information is lacking for offshore areas. Judging from the sampling effort and densities on other transects, however, it appears that some of the peaks (S) may represent stable concentrations. In most cases the stable peaks are associated with changing bathymetry (e.g., troughs, the shelf break, or Stevenson Entrance); two exceptions may be the peaks just south of the Trinity Islands and just east of Chirikof Island. Most of the peaks represent shearwater concentrations recorded from April to June; the exceptions are all the peaks in Shelikof Strait, which were recorded from July to November. The temporal distribution of the two species (Lensink et al. 1978) suggests that the former may be mostly Short-tailed Shearwaters, while the latter may be mostly Sooty Shearwaters.

Tufted Puffin.--The distribution of Tufted Puffins, like that of the murres, is restricted almost completely to the continental shelf. Further, Tufted Puffins are virtually absent from the region during the winter (October-April). The peaks on Fig. 7 are in nearly every case near sizeable breeding colonies, and in most cases (B) are probably stable breeding season foraging areas. Again note the very low densities in Shelikof Strait and over outer North Albatross Bank.

Summary.--In general, the areas around the Semidi and Barren islands, over Portlock, North (the eastern end) and South Albatross banks, and the area between the Trinity Islands and Cape Ikolik appear to be important foraging areas for the species discussed here. In contrast, Shelikof Strait and the western end of North Albatross Bank have consistently low densities, as do the off-shelf areas for most of the species, especially the two alcids.

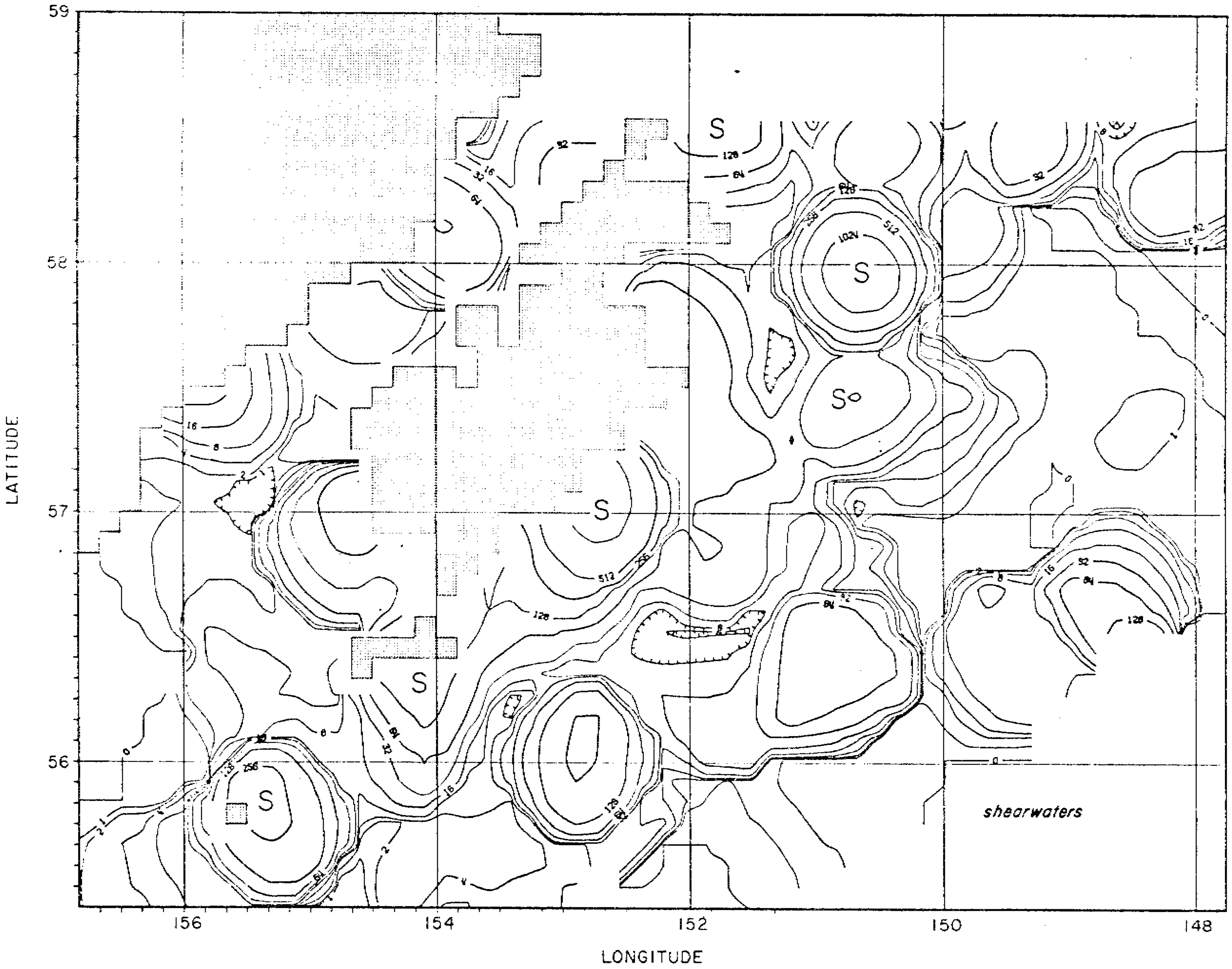


Fig. 6. Spatial distribution of shearwaters in the Kodiak region. Symbols are as in Fig. 3.

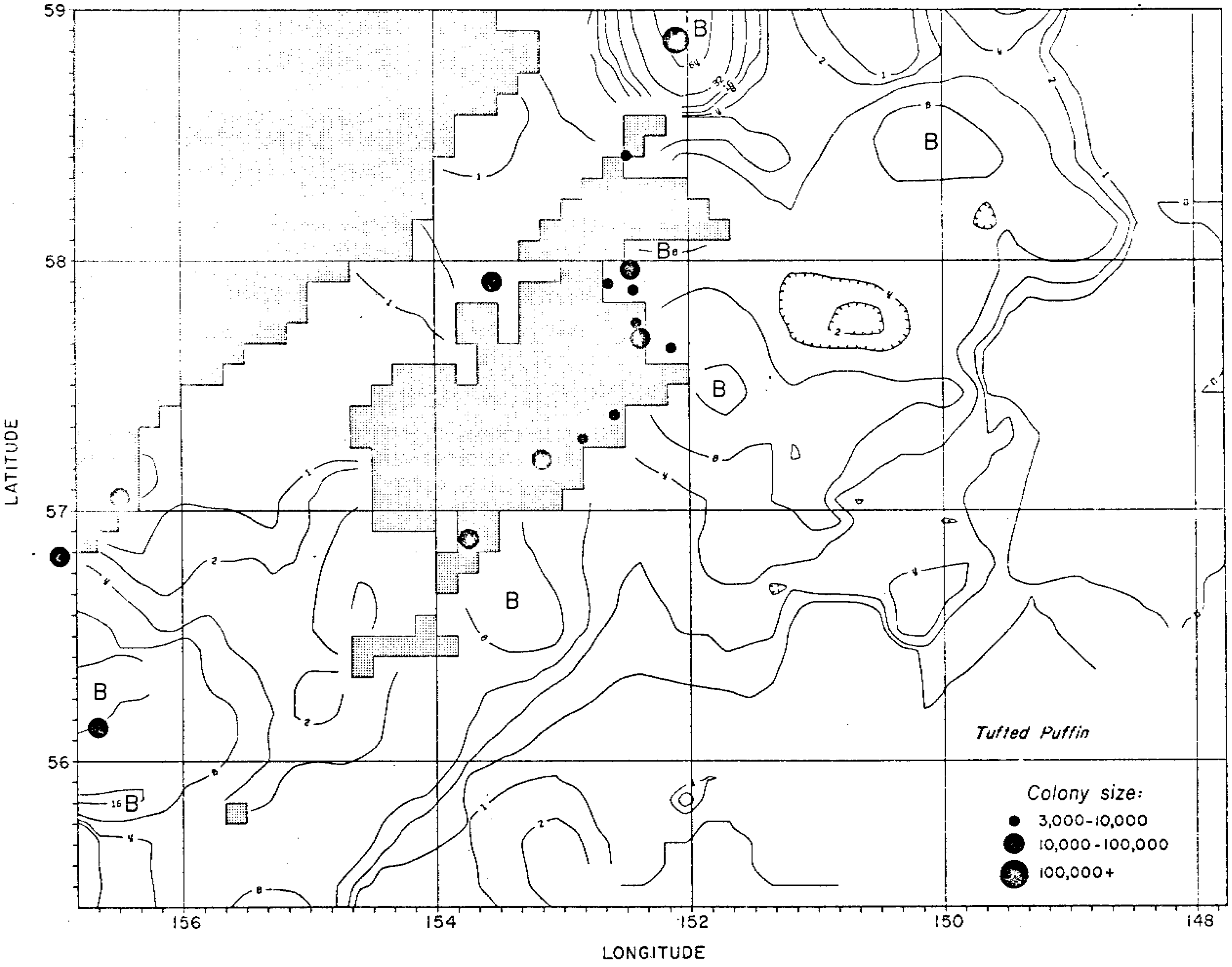


Fig. 7. Spatial distribution of Tufted Puffins in the Kodiak region. Symbols are as in Fig. 3.

Statistical Analysis

The contour plots derived in the preceding section provide a synthetic description of the observed distributional patterns of Kodiak seabirds, given the constraints of the data base. They do not, however, give any hint about the statistical confidence that can be placed in the density values estimated for any specific locale. If the number of transects applicable to any given region were large (i.e., $n > 50$) or the frequency distribution of transect densities approximately normally distributed, it would be a simple matter to place confidence limits on the mean of any given set of transect densities. In this analysis, however, we were confronted with both relatively low sample sizes (Fig. 1) and frequency distributions that were distinctly non-normal (Fig. 8).

For all species, the frequency distribution of transect densities declines very steeply for low densities, then inflects and slowly trails off with increasing density. Under conditions such as these, standard confidence limits using Student's-t distribution are not only technically invalid, but also extremely inaccurate. The true mean will typically exceed the upper 95% confidence limit about 50% of the time and fall below the lower confidence limit about 0.06% of the time. We therefore have devoted considerable effort to deriving a technique for placing confidence limits on the means of small samples drawn from highly skewed distributions such as these.

Statistical model.--We can break the problem of placing confidence limits on samples of transect densities into a two-part problem: (1) what are the confidence limits on the proportion of transects containing any birds at all, i.e., confidence limits on the probability of the zero class? and (2) given that birds are present, what are the confidence limits on the mean density? This breakdown is necessitated by the tendency of seabirds to aggregate and flock. Basically, we are asking what is the probability that a flock (or aggregation) will be present, and, if so, how large will it be? It avoids the necessity of finding a single model that fits both flock size and probability of flock presence or absence, and avoids the problem of a disproportionate zero class. Precise confidence limits on the probability of presence or absence can be found using the binomial distribution. This is a standard statistical technique; placing confidence limits on bird densities, however, is a much more complex problem.

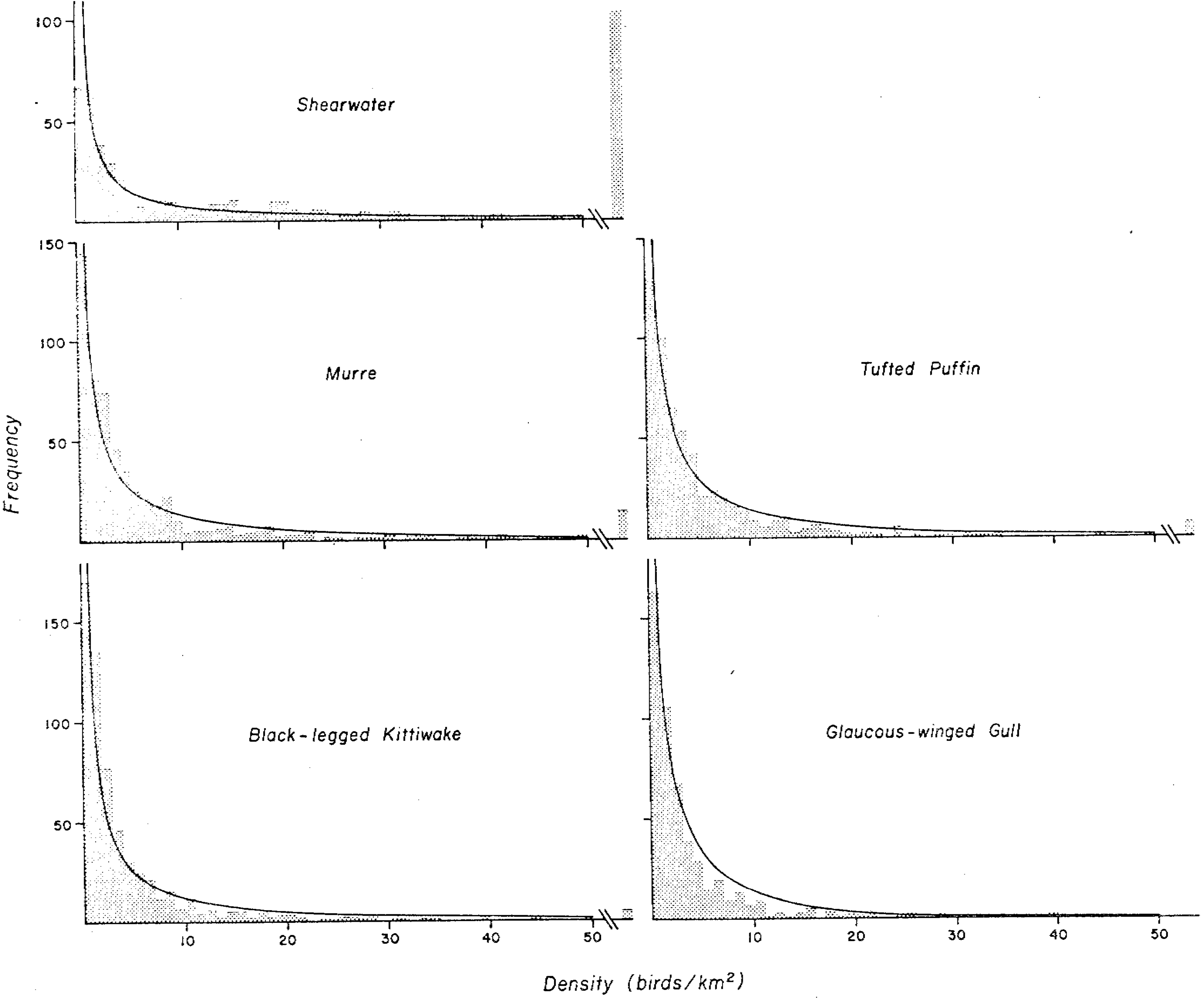
As a statistical model of the distribution of frequency of bird densities, we use the gamma density function. If x is a gamma distributed random variable, then x has the probability density function:

$$f(x) = \begin{cases} \dfrac{\lambda^{\alpha} x^{\alpha-1} e^{-\lambda x}}{\Gamma(\alpha)} & \text{if } x > 0 \\ 0 & \text{if } x = 0 \end{cases}$$

where α is a shape parameter, λ is a scale parameter, and $\Gamma(\alpha)$ is the incomplete gamma function. The gamma distribution is an extremely general distribution that can assume a wide range of forms depending on the value of α (Fig. 9). For $\alpha < 1$, the distribution asymptotically approaches the y axis as $x \to 0$ and the x axis as $x \to \infty$; the steepness of the slope as $x \to 0$ and the thickness of the tail as $x \to \infty$ increase as $\alpha \to 0$. For $\alpha = 1$, the distribution is exponential, and as $\alpha \to \infty$, it approximates the normal. Gamma distributions were fitted to the data of Fig. 8. using the formulae:

$$\alpha = \frac{\bar{x}^2}{s^2} \text{ and } \lambda = \frac{\bar{x}}{s^2} .$$

Fig. 8. Frequency distributions of transect densities for ship transects for (a) Black-legged Kittiwakes, (b) Glaucous-winged Gulls, (c) murres, (d) Tufted Puffins, and (e) shearwaters. The smooth curves are fitted gamma distributions.


Shearwater
Murre
Tufted Puffin
Black-legged Kittiwake
Glaucous-winged Gull
Frequency
150
100
50
10
20
30
40
50
Density (birds/km²)

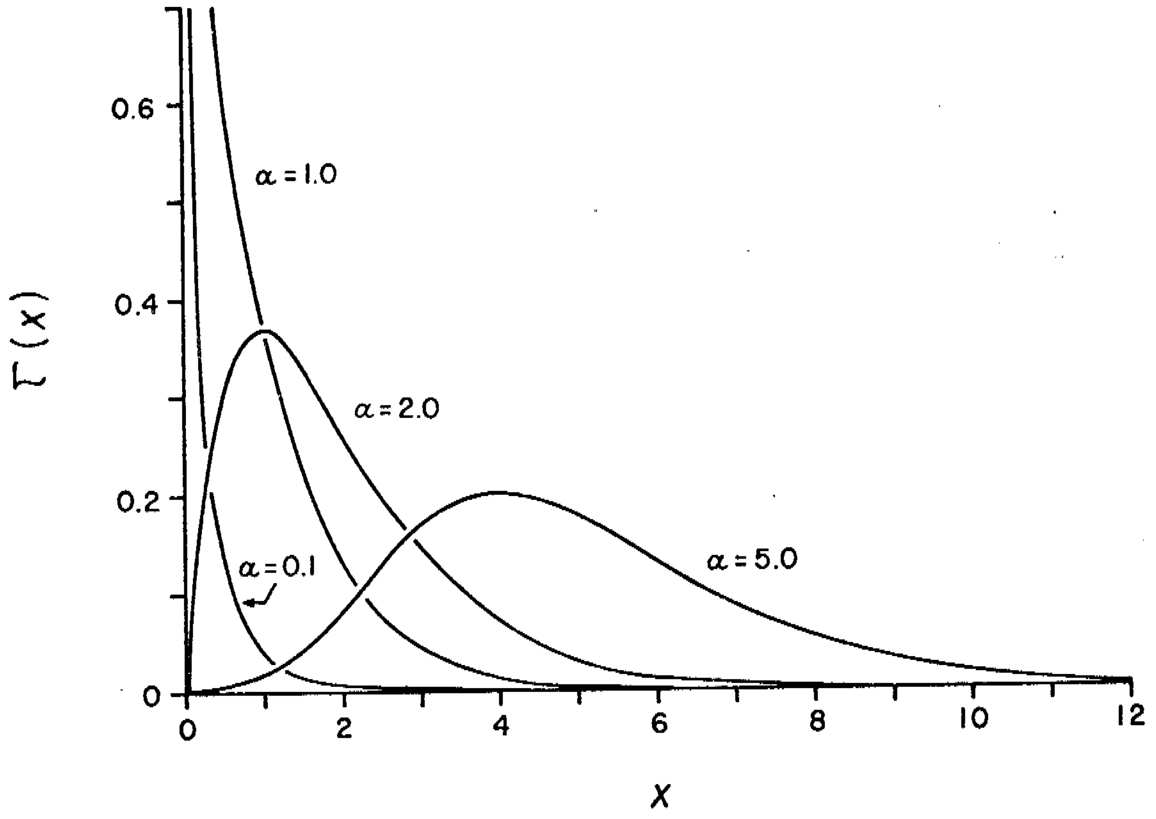


Fig. 9. The variety of forms that can be assumed by the gamma distribution when the shape parameter, α, is varied.

The fitted distributions in general closely approximate the observed distributions, indicating that for data of this type the gamma density function provides a valid statistical model.

The parameter α is a nuisance parameter when one tries to obtain confidence limits for μ, because the lower the value of α, the wider the confidence limits will be. We propose a conservative two-stage scheme where a lower bound on α is estimated first, and then confidence limits on μ are generated assuming the minimal value of α. Let $x_1, x_2, \ldots x_n$ be a set of random variables with the distribution $\Gamma(\alpha, \lambda)$. If α were known, a confidence interval for μ could be based on the fact that $\lambda\sum_{i=1}^{n} x_i$ is gamma distributed with shape parameter $n\alpha$ and scale parameter 1. Denoting the .05 and .95 percentiles of this distribution as $\Gamma_{.05}(n\alpha, 1)$ and $\Gamma_{.95}(n\alpha, 1)$, respectively, we can make the probability statement:

$$P\left[\Gamma_{.05}(n\alpha, 1) \leq \lambda\sum_{i=1}^{n} x_i \leq \Gamma_{.95}(n\alpha, 1)\right] = .90.$$

This is equivalent to:

$$P\left[\frac{n\alpha}{\Gamma_{.95}(n\alpha, 1)}\,\bar{x} \leq \mu \leq \frac{n\alpha}{\Gamma_{.05}(n\alpha, 1)}\,\bar{x}\right] = .90,$$

because $\mu = \alpha/\lambda$ and $\bar{x} = \sum_{i=1}^{n} x_i/n$. Figure 10 shows these confidence limits as a function of α. Note that the confidence limits increase with x so that, as stated before, the widest confidence limits on μ will occur at the minimum possible value of α.

Mann, Schaffer, and Singpurwalla (1974) give the statistic $s = (\Pi x_i)^{1/n}/\bar{x}$, which is sufficient for calculating confidence intervals for α. The distribution of s is free of the parameter λ, but is otherwise difficult to express. However, the distribution of s given α can be readily simulated in order to determine the percentile $s_{.90}(\alpha)$ such that $P[s \leq s_{.90}(\alpha)] = .90$. Since $s_{.90}(\alpha)$ is an increasing function of α, we let $q(s)$ be the corresponding inverse function so that we can state $P[q(s) \leq \alpha] = .90$, providing a one-sided confidence interval for α.

The final step is based on the fact that $n\alpha/\Gamma_{.95}(n\alpha, 1)$ and $n\alpha/\Gamma_{.05}(n\alpha, 1)$ are monotone functions of α within the range of α that concerns us (Fig. 10), so that the worst case of α can be chosen as q. More formally,

$$P\left[\frac{nq}{\Gamma_{.95}(nq, 1)}\,\bar{x} \leq \mu \leq \frac{nq}{\Gamma_{.05}(nq, 1)}\,\bar{x}\right] \geq$$

$$P\left[\frac{nq}{\Gamma_{.95}(nq, 1)}\,\bar{x} \leq \mu \leq \frac{nq}{\Gamma_{.05}(nq, 1)}\,\bar{x},\ \alpha \geq q\right] \geq$$

$$P\left[\frac{n\alpha}{\Gamma_{.95}(n\alpha, 1)}\,\bar{x} \leq \mu \leq \frac{n\alpha}{\Gamma_{.05}(n\alpha, 1)}\,\bar{x},\ \alpha \geq q\right] \geq$$

$$P\left[\frac{n\alpha}{\Gamma_{.95}(n\alpha, 1)}\,\bar{x} \leq \mu \leq \frac{n\alpha}{\Gamma_{.05}(n\alpha, 1)}\right] + P[\alpha - q] = .90 + .90 - 1 = .80.$$

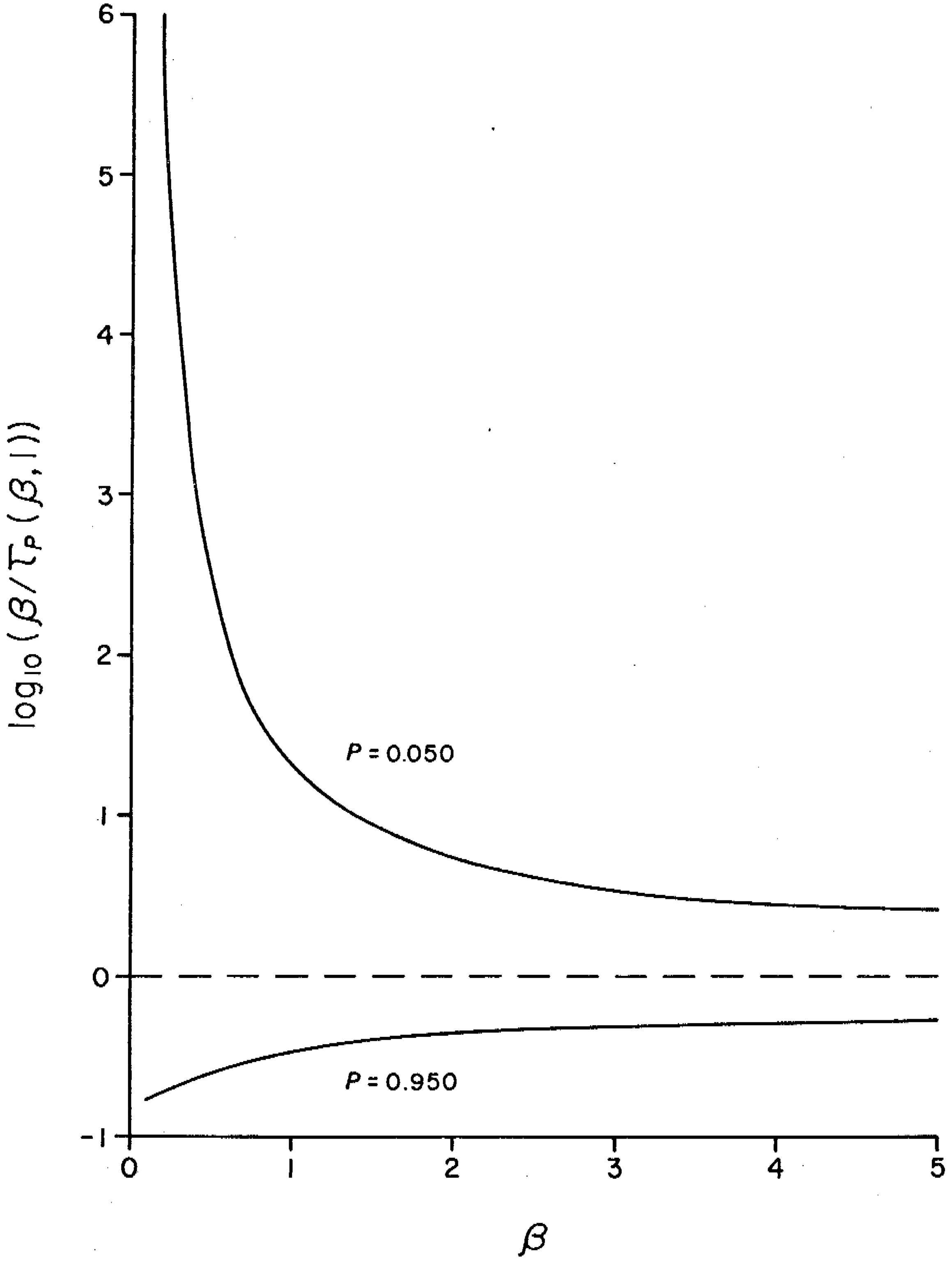


Fig. 10. The function $y = \log[\beta/\Gamma_{P(\beta,\ 1)}]$ for P = 0.5 (upper curve) and P = .95 (lower curve). The log transform is used for plotting convenience only. y is the conficence coefficient for μ and $\beta = nq$ (see text).

Interpretation of statistical analysis.--We tested the effectiveness of this technique on random samples drawn from a range of gamma distributions. For each sample of gamma distributed random variables, we estimated 80% gamma confidence limits and 90% Student's-t confidence limits for μ. The effectiveness of the confidence limits for sample sizes of 3, 5, and 10 was evaluated by counting the proportion of times out of 1,000 trials that the confidence limits did in fact contain μ, the true mean of the distribution. As expected, the gamma confidence limits are conservative, yielding what are in fact slightly greater than 90% confidence limits for a wide range of α values (Fig. 11). Student's-t confidence limits, on the other hand, fail completely within the range of α values found for the data of Table 1, 0.01-0.15. Note that in the range of α where the Student's-t fails, the upper and lower bounds estimated using it are markedly asymmetric, with virtually all of the cases where μ is not contained in the confidence limits occurring at the upper bound and almost never at the lower bound. In other words, as $\alpha \to 0$, upper Student's-t bounds become excessively permissive, and lower Student's-t bounds become excessively conservative.

Gamma confidence limits can be readily calculated using Table 2. Given n, the sample size, and the statistic s where $s = (\Pi x_i)^{1/n}/\bar{x}$, look up c_1 and c_2 from Table 2. The tabled c values correspond to the terms $nq/\Gamma_{.95}(nq, 1)$ and $nq/\Gamma_{.05}(nq, 1)$. The lower confidence bound is then $\bar{x}c_1$ and the upper bound is $\bar{x}c_2$. For example, given a sample where $n = 3$, and $x_1 = .01$, $x_2 = .05$, and $x_3 = .3$,

$$s = [(.01)(.05)(.3)]^{1/3}/[(.01 + .05 + .3)/3] = .44$$

$$\bar{x} = (.01 + .05 + .3)/3 = .12$$

$$c_1 \approx .35$$

$$c_2 \approx 5640.$$

$$\bar{x}c_1 < \mu < \bar{x}c_2$$

$$0.42 < \mu < 676.$$

We applied these statistical techniques to the Fish and Wildlife Service ship transect data base, generating a series of tables showing the 95% confidence limits on the probability of finding birds and 90% confidence limits on the estimated density of birds when present (Tables 3-7). Since the smoothing algorithm used to generate the contour plots (a weighted running average) cannot be used for such analysis, we chose a 20-km x 20-km block size as being the largest reasonable size for lumping transects. Data were analyzed on a species-by-species basis, but were pooled over time. (Note that the sample sizes generated by this algorithm will thus be different from those using the running average.)

This relatively rigorous analysis indicates that our confidence in any estimates of Kodiak area seabird densities is very low. There are two basic problems. First, within the region we have considered (approximately 90,000 km^2) only about 3-6% of the area is sampled with sufficient intensity (i.e., three or more transects with non-zero density) to provide any estimate of density confidence limits. Second, if a block is sampled sufficiently to provide confidence intervals, only 30-80% of these blocks (depending on species) yield confidence limits such that the observed mean and the upper confidence limits are within an order of magnitude of each other. This is a conservative estimate because we are pooling over time, using 90% intervals, and are not taking into account the additional variance resulting from the zero class. The problem is most acute with shearwaters because of their highly skewed distributions; in only 13 blocks do we obtain "reasonable" one-order-of-magnitude upper confidence limits. In addition, the more important foraging areas appear to show more severely skewed distributions for all species, so that our confidence is often lowest where it is most important.

We must emphasize that these problems with the data base are not, in general, attributable to errors on the part of those taking the censuses: they result instead from two factors basic to the system we are trying to describe. First, the pelagic distribution of seabirds in an oceanographically complex region such as this is itself highly complex in both time and space. Given that densities change over orders of magnitude within a matter of hours or days and over distances of 5-10 km, anything resembling a comprehensive census of 90,000 km^2 of ocean is a virtual impossibility under existing resource and logistical constraints. Second, the sampling distribution of flocking birds such as these necessitates much larger sample sizes in order to achieve a reasonable level of confidence in density estimates than would be required by species with more nearly normal sampling distributions. In general, a sample size of 10-20 is minimal for obtaining upper confidence limits within one order of magnitude of the mean.

The only solution to this problem that we can suggest a posteriori is the use of a stratified sampling regime. Biologists familiar with the Kodiak pelagic distributions, using smoothed density mappings such as we have presented, could delineate regions that they had reason to believe a priori to be similar. If large enough regions could be defined, then the data base could be subjected to the kind of statistical analysis used here to generate a meaningful and statistically tenable analysis of pelagic bird densities. Until some such attempt is made, our statistical confidence in any patterns generated from the data base must remain extremely low.

Acknowledgements.--Clifford Qualls helped develop the method for obtaining confidence intervals for the gamma-distribution.

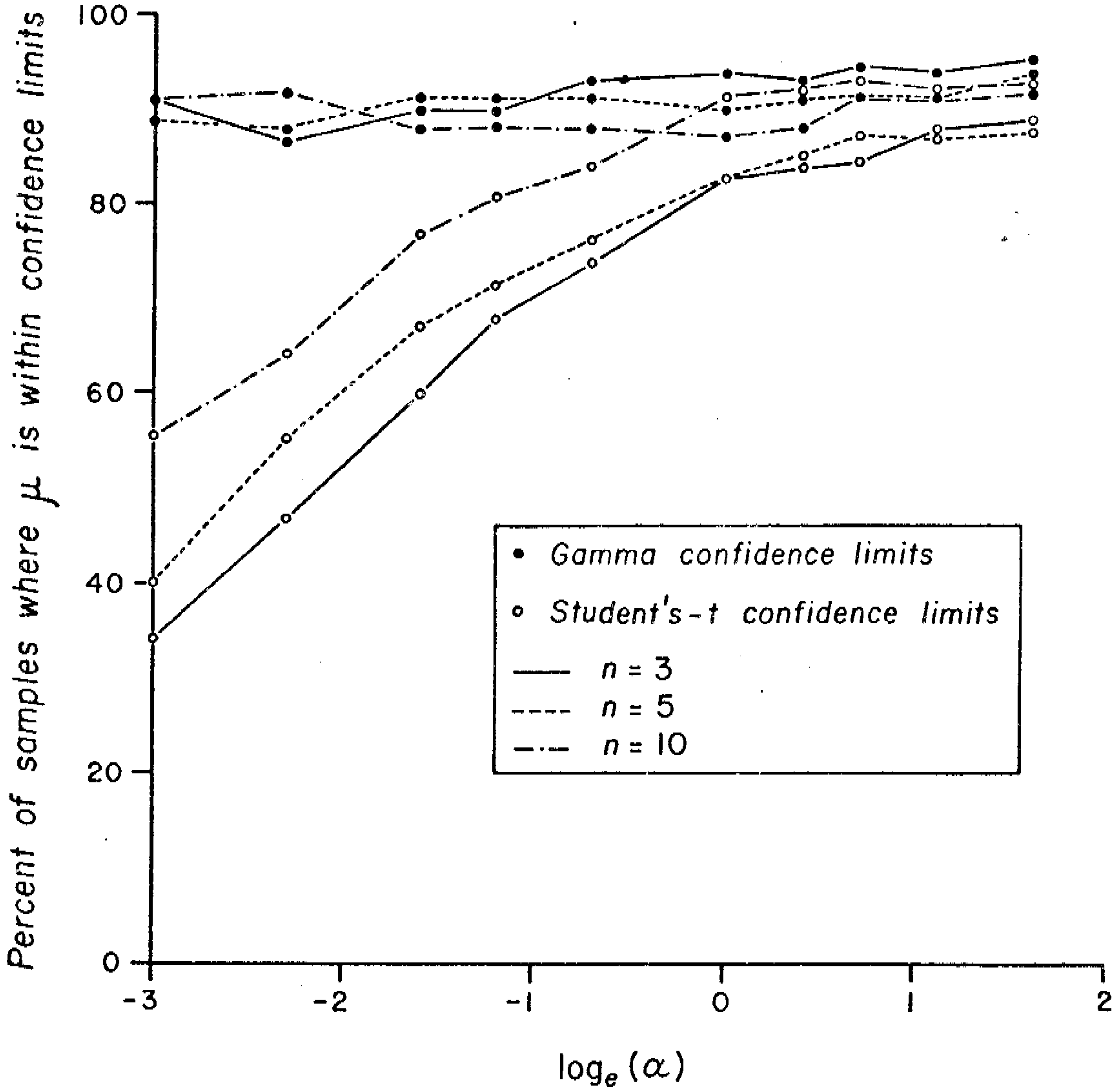


Fig. 11. Comparison of the frequency with which gamma confidence limits and Student's-t confidence limits on $\bar{x}$ contain the true mean, μ, when samples of 3, 5, or 10 are drawn from a gamma distribution with shape parameter α. The x-axis (α) is ln transformed for scaling convenience.

Table 2a. Coefficients for calculating confidence limits based on a gamma-distributed sampling distribution. Lower bounds (c_1) are given. Coefficients are indexed by sample size and the sample statistic, S, where $S = (\Pi x_i)^{1/n}/\bar{x}$. Intermediate values may be linearly interpolated.

	SAMPLE SIZE										
S	3	4	5	6	7	8	9	10	12	15	20
.001	--	--	.351E+00	.334E+00	.337E+00	.354E+00	.362E+00	.373E+00	.389E+00	.411E+00	.406E+00
.002	--	.316E+00	.334E+00	.342E+00	.348E+00	.355E+00	.365E+00	.377E+00	.394E+00	.419E+00	.378E+00
.003	--	.347E+00	.337E+00	.343E+00	.349E+00	.357E+00	.367E+00	.381E+00	.399E+00	.427E+00	.416E+00
.004	--	.368E+00	.337E+00	.343E+00	.350E+00	.358E+00	.369E+00	.385E+00	.404E+00	.432E+00	.480E+00
.005	.320E+00	.363E+00	.337E+00	.344E+00	.351E+00	.360E+00	.372E+00	.389E+00	.408E+00	.424E+00	.515E+00
.006	.333E+00	.362E+00	.338E+00	.344E+00	.351E+00	.361E+00	.374E+00	.392E+00	.413E+00	.415E+00	.516E+00
.007	.346E+00	.361E+00	.338E+00	.345E+00	.352E+00	.363E+00	.376E+00	.396E+00	.418E+00	.406E+00	.518E+00
.008	.359E+00	.361E+00	.338E+00	.345E+00	.353E+00	.364E+00	.379E+00	.399E+00	.423E+00	.398E+00	.520E+00
.009	.360E+00	.360E+00	.339E+00	.346E+00	.354E+00	.365E+00	.381E+00	.403E+00	.428E+00	.389E+00	.522E+00
.010	.360E+00	.360E+00	.339E+00	.346E+00	.355E+00	.367E+00	.383E+00	.406E+00	.433E+00	.381E+00	.523E+00
.020	.367E+00	.354E+00	.343E+00	.352E+00	.365E+00	.382E+00	.402E+00	.432E+00	.402E+00	.409E+00	.540E+00
.030	.370E+00	.348E+00	.347E+00	.358E+00	.375E+00	.394E+00	.421E+00	.422E+00	.389E+00	.455E+00	.557E+00
.040	.368E+00	.342E+00	.350E+00	.365E+00	.384E+00	.406E+00	.428E+00	.412E+00	.375E+00	.501E+00	.568E+00
.050	.365E+00	.336E+00	.354E+00	.372E+00	.393E+00	.413E+00	.433E+00	.402E+00	.387E+00	.520E+00	.573E+00
.060	.363E+00	.331E+00	.359E+00	.379E+00	.398E+00	.418E+00	.426E+00	.392E+00	.417E+00	.527E+00	.578E+00
.070	.361E+00	.332E+00	.364E+00	.385E+00	.402E+00	.422E+00	.420E+00	.383E+00	.446E+00	.533E+00	.584E+00
.080	.359E+00	.334E+00	.369E+00	.388E+00	.406E+00	.427E+00	.413E+00	.373E+00	.473E+00	.539E+00	.589E+00
.090	.356E+00	.335E+00	.371E+00	.390E+00	.409E+00	.432E+00	.406E+00	.384E+00	.498E+00	.544E+00	.594E+00
.100	.354E+00	.337E+00	.374E+00	.393E+00	.413E+00	.431E+00	.399E+00	.405E+00	.516E+00	.550E+00	.600E+00
.150	.341E+00	.345E+00	.386E+00	.406E+00	.431E+00	.406E+00	.380E+00	.508E+00	.537E+00	.573E+00	.614E+00
.200	.331E+00	.352E+00	.395E+00	.420E+00	.419E+00	.391E+00	.455E+00	.528E+00	.555E+00	.590E+00	.627E+00
.250	.335E+00	.360E+00	.405E+00	.433E+00	.400E+00	.400E+00	.516E+00	.542E+00	.571E+00	.603E+00	.643E+00
.300	.339E+00	.367E+00	.416E+00	.421E+00	.381E+00	.464E+00	.529E+00	.557E+00	.583E+00	.614E+00	.664E+00
.350	.343E+00	.374E+00	.426E+00	.406E+00	.399E+00	.516E+00	.542E+00	.572E+00	.601E+00	.627E+00	.682E+00
.400	.346E+00	.382E+00	.431E+00	.385E+00	.454E+00	.528E+00	.559E+00	.588E+00	.611E+00	.640E+00	.692E+00
.450	.350E+00	.390E+00	.415E+00	.381E+00	.509E+00	.542E+00	.576E+00	.602E+00	.621E+00	.655E+00	.703E+00
.500	.353E+00	.398E+00	.398E+00	.427E+00	.526E+00	.563E+00	.591E+00	.610E+00	.631E+00	.672E+00	.723E+00
.550	.357E+00	.407E+00	.381E+00	.491E+00	.545E+00	.578E+00	.603E+00	.620E+00	.650E+00	.692E+00	.737E+00
.600	.362E+00	.423E+00	.399E+00	.527E+00	.564E+00	.592E+00	.614E+00	.641E+00	.678E+00	.709E+00	.750E+00
.650	.370E+00	.428E+00	.486E+00	.545E+00	.578E+00	.609E+00	.635E+00	.666E+00	.693E+00	.725E+00	.760E+00
.700	.379E+00	.409E+00	.524E+00	.562E+00	.603E+00	.629E+00	.659E+00	.685E+00	.707E+00	.736E+00	.768E+00
.750	.391E+00	.370E+00	.540E+00	.595E+00	.623E+00	.652E+00	.681E+00	.697E+00	.721E+00	.753E+00	.794E+00
.800	.412E+00	.461E+00	.584E+00	.617E+00	.644E+00	.675E+00	.700E+00	.727E+00	.752E+00	.779E+00	.814E+00
.850	.422E+00	.538E+00	.610E+00	.636E+00	.685E+00	.714E+00	.736E+00	.754E+00	.774E+00	.799E+00	.829E+00
.900	.378E+00	.585E+00	.658E+00	.697E+00	.725E+00	.745E+00	.760E+00	.778E+00	.801E+00	.827E+00	.863E+00
.950	.543E+00	.655E+00	.720E+00	.753E+00	.773E+00	.798E+00	.818E+00	.834E+00	.858E+00	.893E+00	.899E+00

Table 2b. Coefficients for calculating confidence limits based on a gamma-distributed sampling distribution. Upper bounds (c_2) are given. Coefficients are indexed by sample size and the sample statistic, S, where $S = (\Pi x_i)^{1/n}/\bar{x}$. Intermediate values may be linearly interpolated.

	SAMPLE SIZE										
S	3	4	5	6	7	8	9	10	12	15	20
.001	--	--	.757E+09	.114E+09	.223E+05	.170E+03	.131E+03	.846E+02	.311E+02	.206E+02	.760E+01
.002	--	.405E+17	.267E+05	.154E+05	.725E+04	.164E+03	.121E+03	.654E+02	.287E+02	.166E+02	.566E+01
.003	--	.174E+17	.228E+05	.147E+05	.625E+04	.157E+03	.111E+03	.463E+02	.264E+02	.127E+02	.469E+01
.004	--	.141E+10	.223E+05	.140E+05	.525E+04	.151E+03	.100E+03	.327E+02	.241E+02	.937E+01	.408E+01
.005	.380E+17	.120E+10	.218E+05	.133E+05	.426E+04	.144E+03	.900E+02	.310E+02	.217E+02	.879E+01	.374E+01
.006	.282E+17	.118E+10	.213E+05	.126E+05	.326E+04	.137E+03	.797E+02	.294E+02	.194E+02	.821E+01	.371E+01
.007	.184E+17	.115E+10	.208E+05	.119E+05	.227E+04	.131E+03	.693E+02	.277E+02	.170E+02	.762E+01	.368E+01
.008	.868E+16	.113E+10	.203E+05	.112E+05	.127E+04	.124E+03	.590E+02	.261E+02	.147E+02	.704E+01	.364E+01
.009	.819E+16	.111E+10	.198E+05	.105E+05	.273E+03	.118E+03	.487E+02	.244E+02	.124E+02	.646E+01	.361E+01
.010	.770E+16	.109E+10	.193E+05	.979E+04	.166E+03	.111E+03	.383E+02	.228E+02	.100E+02	.587E+01	.357E+01
.020	.284E+16	.864E+09	.144E+05	.281E+04	.122E+03	.456E+02	.247E+02	.936E+01	.732E+01	.475E+01	.322E+01
.030	.148E+10	.640E+09	.949E+04	.151E+03	.771E+02	.286E+02	.158E+02	.869E+01	.642E+01	.432E+01	.288E+01
.040	.139E+10	.417E+09	.456E+04	.120E+03	.332E+02	.229E+02	.124E+02	.802E+01	.552E+01	.389E+01	.269E+01
.050	.131E+10	.193E+09	.168E+03	.883E+02	.293E+02	.197E+02	.944E+01	.735E+01	.497E+01	.364E+01	.262E+01
.060	.122E+10	.305E+05	.146E+03	.570E+02	.265E+02	.174E+02	.897E+01	.668E+01	.469E+01	.349E+01	.256E+01
.070	.114E+10	.285E+05	.124E+03	.329E+02	.247E+02	.150E+02	.850E+01	.600E+01	.440E+01	.337E+01	.249E+01
.080	.105E+10	.265E+05	.102E+03	.316E+02	.230E+02	.127E+02	.804E+01	.533E+01	.415E+01	.326E+01	.242E+01
.090	.969E+09	.244E+05	.910E+02	.304E+02	.213E+02	.104E+02	.757E+01	.500E+01	.391E+01	.314E+01	.236E+01
.100	.884E+09	.224E+05	.801E+02	.291E+02	.196E+02	.928E+01	.710E+01	.480E+01	.373E+01	.303E+01	.229E+01
.150	.402E+09	.122E+05	.326E+02	.227E+02	.110E+02	.758E+01	.503E+01	.382E+01	.329E+01	.262E+01	.215E+01
.200	.297E+05	.210E+04	.279E+02	.163E+02	.845E+01	.590E+01	.432E+01	.348E+01	.292E+01	.242E+01	.200E+01
.250	.246E+05	.144E+03	.232E+02	.985E+01	.718E+01	.484E+01	.371E+01	.319E+01	.265E+01	.226E+01	.188E+01
.300	.195E+05	.111E+03	.184E+02	.859E+01	.589E+01	.424E+01	.345E+01	.289E+01	.250E+01	.215E+01	.179E+01
.350	.145E+05	.780E+02	.135E+02	.759E+01	.485E+01	.371E+01	.319E+01	.264E+01	.228E+01	.201E+01	.171E+01
.400	.101E+05	.451E+02	.931E+01	.620E+01	.433E+01	.349E+01	.285E+01	.244E+01	.218E+01	.189E+01	.167E+01
.450	.564E+04	.306E+02	.817E+01	.503E+01	.381E+01	.318E+01	.259E+01	.227E+01	.207E+01	.183E+01	.162E+01
.500	.120E+04	.265E+02	.703E+01	.459E+01	.351E+01	.276E+01	.240E+01	.218E+01	.196E+01	.176E+01	.153E+01
.550	.155E+03	.224E+02	.589E+01	.398E+01	.312E+01	.256E+01	.226E+01	.208E+01	.185E+01	.167E+01	.149E+01
.600	.135E+03	.150E+02	.485E+01	.349E+01	.273E+01	.239E+01	.214E+01	.189E+01	.173E+01	.159E+01	.144E+01
.650	.965E+02	.905E+01	.403E+01	.314E+01	.257E+01	.220E+01	.192E+01	.178E+01	.166E+01	.153E+01	.141E+01
.700	.584E+02	.781E+01	.355E+01	.278E+01	.226E+01	.198E+01	.181E+01	.170E+01	.160E+01	.149E+01	.139E+01
.750	.298E+02	.513E+01	.322E+01	.235E+01	.205E+01	.184E+01	.171E+01	.165E+01	.154E+01	.143E+01	.132E+01
.800	.198E+02	.426E+01	.249E+01	.211E+01	.187E+01	.174E+01	.163E+01	.152E+01	.144E+01	.136E+01	.128E+01
.850	.868E+01	.328E+01	.219E+01	.191E+01	.170E+01	.157E+01	.149E+01	.143E+01	.138E+01	.131E+01	.124E+01
.900	.567E+01	.248E+01	.181E+01	.165E+01	.153E+01	.146E+01	.141E+01	.136E+01	.130E+01	.125E+01	.120E+01
.950	.318E+01	.183E+01	.154E+01	.143E+01	.138E+01	.131E+01	.127E+01	.123E+01	.120E+01	.116E+01	.113E+01

Table 3. Confidence limits on the density of Black-legged Kittiwakes by 20-km blocks in the vicinity of Kodiak. N is the number of transects with midpoints contained in the block. P is the probability that any bird would be found on the transect. P CLU and P CLL are the upper and lower limits, respectively, of a 95% confidence interval on P. XBAR is the mean density of transects where birds were found. XBAR CLU and XBAR CLL are the upper and lower limits, respectively, of a 90% approximate confidence interval on XBAR based on the gamma distribution.

		LONGITUDE								
LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
58 50	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 40	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 30	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 20	N	0	0	0	0	0	0	0	0	2
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.50
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 10	N	0	0	0	0	0	0	0	0	2
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	1.00
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 0	N	0	0	0	0	0	0	0	1	4
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.06
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.50
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.94
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

LONGITUDE

LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
57 50	N	0	0	0	0	0	0	2	4	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.01	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.25	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.82	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 40	N	0	0	0	0	0	2	5	1	0
	P CLL	0.	0.	0.	0.	0.	0.	0.27	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.80	1.00	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.99	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.66	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.79	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.98	0.	0.
57 30	N	0	0	0	2	2	5	2	0	0
	P CLL	0.	0.	0.	0.	0.	0.01	0.	0.	0.
	P	0.	0.	0.	1.00	0.50	0.20	0.50	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.73	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 20	N	1	0	0	2	2	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	1.00	0.	0.	0.50	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 10	N	0	0	0	5	0	0	0	0	0
	P CLL	0.	0.	0.	0.50	0.	0.	0.	0.	0.
	P	0.	0.	0.	1.00	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	1.00	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	1.20	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	2.31	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	8.40	0.	0.	0.	0.	0.
57 0	N	0	0	3	5	0	1	0	0	0
	P CLL	0.	0.	0.	0.01	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.20	0.	1.00	0.	0.	0.
	P CLU	0.	0.	0.70	0.73	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
56 50	N	0	0	3	3	0	2	1	0	0
	P CLL	0.	0.	0.08	0.01	0.	0.	0.	0.	0.
	P	0.	0.	0.67	0.33	0.	0.50	1.00	0.	0.
	P CLU	0.	0.	0.99	0.92	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 40	N	1	1	0	0	2	1	2	0	6
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.35
	P	1.00	1.00	0.	0.	1.00	0.	0.50	0.	0.83
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	1.00
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	20.18
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	42.22
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	223.47
56 30	N	2	0	0	0	1	1	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	1.00	0.	0.	0.	0.	1.00	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 20	N	1	0	0	0	1	0	0	0	6
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.03
	P	0.	0.	0.	0.	1.00	0.	0.	0.	0.33
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.79
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 10	N	1	0	0	1	0	1	5	4	0
	P CLL	0.	0.	0.	0.	0.	0.	0.01	0.01	0.
	P	1.00	0.	0.	1.00	0.	1.00	0.20	0.25	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.73	0.82	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 0	N	0	1	0	1	1	1	4	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.06	0.	0.
	P	0.	1.00	0.	1.00	0.	1.00	0.50	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.94	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
55 50	N	0	0	0	1	3	8	1	2	0
	P CLL	0.	0.	0.	0.	0.01	0.46	0.	0.	0.
	P	0.	0.	0.	0.	0.33	0.88	0.	0.50	0.
	P CLU	0.	0.	0.	0.	0.92	1.00	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	2.32	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	3.85	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	8.69	0.	0.	0.
55 40	N	0	0	1	8	7	2	0	1	2
	P CLL	0.	0.	0.	0.24	0.60	0.	0.	0.	0.
	P	0.	0.	1.00	0.63	1.00	1.00	0.	0.	1.00
	P CLU	0.	0.	0.	0.93	1.00	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.83	2.09	0.	0.	0.	0.
	XBAR	0.	0.	0.	1.71	3.34	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	8.18	6.93	0.	0.	0.	0.
55 30	N	3	10	5	5	2	0	0	0	2
	P CLL	0.08	0.34	0.50	0.50	0.	0.	0.	0.	0.
	P	0.67	0.70	1.00	1.00	1.00	0.	0.	0.	1.00
	P CLU	0.99	0.94	1.00	1.00	0.	0.	0.	0.	0.
	XBAR CLL	0.	3.61	1.61	1.15	0.	0.	0.	0.	0.
	XBAR	0.	6.38	2.35	1.91	0.	0.	0.	0.	0.
	XBAR CLU	0.	17.32	4.00	4.36	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
58 50	N	0	0	4	4	3	2	3	4	2
	P CLL	0.	0.	0.06	0.18	0.30	0.	0.08	0.18	0.
	P	0.	0.	0.50	0.75	1.00	1.00	0.67	0.75	1.00
	P CLU	0.	0.	0.94	0.99	1.00	0.	0.99	0.99	0.
	XBAR CLL	0.	0.	0.	0.67	1.23	0.	0.	1.30	0.
	XBAR	0.	0.	0.	1.63	3.33	0.	0.	2.11	0.
	XBAR CLU	0.	0.	0.	34.86	340.78	0.	0.	4.51	0.
58 40	N	0	4	3	2	0	0	0	1	2
	P CLL	0.	0.06	0.01	0.	0.	0.	0.	0.	0.
	P	0.	0.50	0.33	0.50	0.	0.	0.	0.	1.00
	P CLU	0.	0.94	0.92	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 30	N	2	1	1	0	1	0	3	0	2
	P CLL	0.	0.	0.	0.	0.	0.	0.01	0.	0.
	P	0.50	0.	1.00	0.	0.	0.	0.33	0.	0.50
	P CLU	0.	0.	0.	0.	0.	0.	0.92	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 20	N	2	3	2	0	0	1	1	0	1
	P CLL	0.	0.30	0.	0.	0.	0.	0.	0.	0.
	P	0.	1.00	1.00	0.	0.	0.	1.00	0.	1.00
	P CLU	0.	1.00	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.54	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	1.23	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	11.40	0.	0.	0.	0.	0.	0.	0.
58 10	N	1	1	0	0	0	4	4	1	4
	P CLL	0.	0.	0.	0.	0.	0.18	0.01	0.	0.40
	P	1.00	0.	0.	0.	0.	0.75	0.25	1.00	1.00
	P CLU	0.	0.	0.	0.	0.	0.99	0.82	0.	1.00
	XBAR CLL	0.	0.	0.	0.	0.	1.18	0.	0.	1.36
	XBAR	0.	0.	0.	0.	0.	1.52	0.	0.	3.15
	XBAR CLU	0.	0.	0.	0.	0.	2.07	0.	0.	33.09
58 0	N	0	0	0	0	0	1	3	2	3
	P CLL	0.	0.	0.	0.	0.	0.	0.01	0.	0.30
	P	0.	0.	0.	0.	0.	0.	0.33	1.00	1.00
	P CLU	0.	0.	0.	0.	0.	0.	0.92	0.	1.00
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.76
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	2.09
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	239.20

		LONGITUDE								
LAT		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
57 50	N	0	0	0	0	0	11	11	4	2
	P CLL	0.	0.	0.	0.	0.	0.16	0.30	0.06	0.
	P	0.	0.	0.	0.	0.	0.45	0.64	0.50	0.
	P CLU	0.	0.	0.	0.	0.	0.78	0.90	0.94	0.
	XBAR CLL	0.	0.	0.	0.	0.	1.12	1.46	0.	0.
	XBAR	0.	0.	0.	0.	0.	2.08	2.20	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	6.90	3.99	0.	0.
57 40	N	0	0	0	0	1	20	2	5	4
	P CLL	0.	0.	0.	0.	0.	0.27	0.	0.50	0.06
	P	0.	0.	0.	0.	0.	0.50	1.00	1.00	0.50
	P CLU	0.	0.	0.	0.	0.	0.73	0.	1.00	0.94
	XBAR CLL	0.	0.	0.	0.	0.	2.88	0.	0.74	0.
	XBAR	0.	0.	0.	0.	0.	3.83	0.	1.16	0.
	XBAR CLU	0.	0.	0.	0.	0.	5.49	0.	2.25	0.
57 30	N	0	0	0	0	0	10	0	1	1
	P CLL	0.	0.	0.	0.	0.	0.43	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.80	0.	1.00	0.
	P CLU	0.	0.	0.	0.	0.	0.98	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	1.70	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	2.51	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	4.36	0.	0.	0.
57 20	N	0	0	0	2	2	4	1	0	1
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	1.00	0.	0.	1.00	0.	1.00
	P CLU	0.	0.	0.	0.	0.	0.60	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 10	N	0	0	1	5	2	0	1	0	0
	P CLL	0.	0.	0.	0.27	0.	0.	0.	0.	0.
	P	0.	0.	1.00	0.80	0.50	0.	1.00	0.	0.
	P CLU	0.	0.	0.	0.99	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	1.61	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	3.62	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	31.07	0.	0.	0.	0.	0.
57 0	N	0	9	4	10	0	2	1	1	0
	P CLL	0.	0.51	0.06	0.18	0.	0.	0.	0.	0.
	P	0.	0.89	0.50	0.50	0.	1.00	1.00	1.00	0.
	P CLU	0.	1.00	0.94	0.82	0.	0.	0.	0.	0.
	XBAR CLL	0.	3.41	0.	1.11	0.	0.	0.	0.	0.
	XBAR	0.	5.80	0.	1.79	0.	0.	0.	0.	0.
	XBAR CLU	0.	14.16	0.	3.77	0.	0.	0.	0.	0.

```
                                               L O N G I T U D E
LAT   :           :    153 40 :    153 20 :    153  0 :    152 40 :    152 20 :    152  0 :    151 40 :    151 20 :    151  0 :
------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
56 50 :N          :      0    :      4    :      7    :      3    :      0    :      4    :      1    :      1    :      0    :
      :P CLL      :      0.   :      0.06 :      0.10 :      0.01 :      0.   :      0.40 :      0.   :      0.   :      0.   :
      :P          :      0.   :      0.50 :      0.43 :      0.33 :      0.   :      1.00 :      1.00 :      0.   :      0.   :
      :P CLU      :      0.   :      0.94 :      0.83 :      0.92 :      0.   :      1.00 :      0.   :      0.   :      0.   :
      :XBAR CLL   :      0.   :      0.   :     17.40 :      0.   :      0.   :      2.17 :      0.   :      0.   :      0.   :
      :XBAR       :      0.   :      0.   :     51.56 :      0.   :      0.   :      4.36 :      0.   :      0.   :      0.   :
      :XBAR CLU   :      0.   :      0.   : ********* :      0.   :      0.   :     19.33 :      0.   :      0.   :      0.   :
------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
56 40 :N          :      3    :      3    :      2    :      0    :      1    :      1    :      0    :      0    :      0    :
      :P CLL      :      0.30 :      0.30 :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :P          :      1.00 :      1.00 :      0.   :      0.   :      1.00 :      1.00 :      0.   :      0.   :      0.   :
      :P CLU      :      1.00 :      1.00 :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR CLL   :      8.46 :      0.48 :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR       :     24.78 :      1.05 :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR CLU   : 409022.50 :      8.09 :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
56 30 :N          :      2    :      2    :      1    :      0    :      2    :      1    :      1    :      0    :      0    :
      :P CLL      :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :P          :      0.50 :      1.00 :      0.   :      0.   :      0.50 :      0.   :      0.   :      0.   :      0.   :
      :P CLU      :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR CLL   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR       :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR CLU   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
56 20 :N          :      5    :      0    :      0    :      0    :      1    :      1    :      1    :      0    :      2    :
      :P CLL      :      0.01 :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :P          :      0.20 :      0.   :      0.   :      0.   :      0.   :      1.00 :      1.00 :      0.   :      1.00 :
      :P CLU      :      0.73 :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR CLL   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR       :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR CLU   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
56 10 :N          :      0    :      2    :      0    :      0    :      0    :      0    :      0    :      0    :      0    :
      :P CLL      :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :P          :      0.   :      1.00 :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :P CLU      :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR CLL   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR       :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR CLU   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
56  0 :N          :      3    :      1    :      2    :      1    :      0    :      0    :      0    :      0    :      1    :
      :P CLL      :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :P          :      0.   :      0.   :      1.00 :      1.00 :      0.   :      0.   :      0.   :      0.   :      0.   :
      :P CLU      :      0.70 :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR CLL   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR       :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
      :XBAR CLU   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :      0.   :
------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
```

					LONGITUDE					
LAT		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
55 50	N	2	0	0	1	0	0	0	1	2
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	1.00	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 40	N	2	2	0	0	0	0	1	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 30	N	1	0	0	0	1	2	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

LONGITUDE

LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
58 50	N	3	3	1	0	0	2	2	1	0
	P CLL	0.08	0.30	0.	0.	0.	0.	0.	0.	0.
	P	0.67	1.00	0.	0.	0.	0.	0.50	1.00	0.
	P CLU	0.99	1.00	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	6.02	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	13.60	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	118.27	0.	0.	0.	0.	0.	0.	0.
58 40	N	0	1	3	1	3	0	2	6	0
	P CLL	0.	0.	0.08	0.	0.30	0.	0.	0.00	0.
	P	0.	1.00	0.67	1.00	1.00	0.	0.50	0.17	0.
	P CLU	0.	0.	0.99	0.	1.00	0.	0.	0.65	0.
	XBAR CLL	0.	0.	0.	0.	1.50	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	3.29	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	24.85	0.	0.	0.	0.
58 30	N	2	0	2	2	2	0	3	6	2
	P CLL	0.	0.	0.	0.	0.	0.	0.08	0.35	0.
	P	0.	0.	1.00	1.00	0.50	0.	0.67	0.83	1.00
	P CLU	0.	0.	0.	0.	0.	0.	0.99	1.00	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	1.30	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	2.68	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	13.49	0.
58 20	N	4	4	0	0	0	0	0	2	3
	P CLL	0.18	0.40	0.	0.	0.	0.	0.	0.	0.08
	P	0.75	1.00	0.	0.	0.	0.	0.	1.00	0.67
	P CLU	0.99	1.00	0.	0.	0.	0.	0.	0.	0.99
	XBAR CLL	2.22	5.60	0.	0.	0.	0.	0.	0.	0.
	XBAR	5.49	11.06	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	129.42	44.91	0.	0.	0.	0.	0.	0.	0.
58 10	N	5	3	4	0	0	2	0	0	0
	P CLL	0.27	0.30	0.06	0.	0.	0.	0.	0.	0.
	P	0.80	1.00	0.50	0.	0.	1.00	0.	0.	0.
	P CLU	0.99	1.00	0.94	0.	0.	0.	0.	0.	0.
	XBAR CLL	4.31	2.24	0.	0.	0.	0.	0.	0.	0.
	XBAR	9.61	4.94	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	77.75	37.65	0.	0.	0.	0.	0.	0.	0.
58 0	N	3	2	6	0	2	0	0	0	1
	P CLL	0.30	0.	0.60	0.	0.	0.	0.	0.	0.
	P	1.00	1.00	1.00	0.	1.00	0.	0.	0.	1.00
	P CLU	1.00	0.	1.00	0.	0.	0.	0.	0.	0.
	XBAR CLL	3.65	0.	2.01	0.	0.	0.	0.	0.	0.
	XBAR	10.29	0.	3.74	0.	0.	0.	0.	0.	0.
	XBAR CLU	1727.37	0.	12.26	0.	0.	0.	0.	0.	0.

```
                                                 L O N G I T U D E
LAT   !            !  150 40 !  150 20 !  150  0 !  149 40 !  149 20 !  149  0 !  148 40 !  148 20 !  148  0 !
------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
57 50 !N           !  0      !  1      !  3      !  3      !  2      !  1      !  2      !  3      !  1      !
      !P CLL       !  0.     !  0.     !  0.08   !  0.30   !  0.     !  0.     !  0.     !  0.     !  0.     !
      !P           !  0.     !  1.00   !  0.67   !  1.00   !  0.50   !  1.00   !  1.00   !  0.     !  0.     !
      !P CLU       !  0.     !  0.     !  0.99   !  1.00   !  0.     !  0.     !  0.     !  0.70   !  0.     !
      !XBAR CLL    !  0.     !  0.     !  0.     !  1.00   !  0.     !  0.     !  0.     !  0.     !  0.     !
      !XBAR        !  0.     !  0.     !  0.     !  1.60   !  0.     !  0.     !  0.     !  0.     !  0.     !
      !XBAR CLU    !  0.     !  0.     !  0.     !  3.32   !  0.     !  0.     !  0.     !  0.     !  0.     !
------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
57 40 !N           !  4      !  3      !  1      !  0      !  4      !  0      !  0      !  0      !  0      !
      !P CLL       !  0.06   !  0.     !  0.     !  0.     !  0.06   !  0.     !  0.     !  0.     !  0.     !
      !P           !  0.50   !  0.     !  1.00   !  0.     !  0.50   !  0.     !  0.     !  0.     !  0.     !
      !P CLU       !  0.94   !  0.70   !  0.     !  0.     !  0.94   !  0.     !  0.     !  0.     !  0.     !
      !XBAR CLL    !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
      !XBAR        !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
      !XBAR CLU    !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
57 30 !N           !  2      !  1      !  0      !  1      !  0      !  4      !  0      !  0      !  0      !
      !P CLL       !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
      !P           !  0.     !  0.     !  0.     !  1.00   !  0.     !  0.     !  0.     !  0.     !  0.     !
      !P CLU       !  0.     !  0.     !  0.     !  0.     !  0.     !  0.60   !  0.     !  0.     !  0.     !
      !XBAR CLL    !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
      !XBAR        !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
      !XBAR CLU    !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
57 20 !N           !  5      !  3      !  0      !  1      !  0      !  0      !  8      !  1      !  0      !
      !P CLL       !  0.14   !  0.08   !  0.     !  0.     !  0.     !  0.     !  0.02   !  0.     !  0.     !
      !P           !  0.60   !  0.67   !  0.     !  1.00   !  0.     !  0.     !  0.25   !  0.     !  0.     !
      !P CLU       !  0.95   !  0.99   !  0.     !  0.     !  0.     !  0.     !  0.65   !  0.     !  0.     !
      !XBAR CLL    !  1.82   !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
      !XBAR        !  3.82   !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
      !XBAR CLU    !  20.91  !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
57 10 !N           !  1      !  1      !  2      !  1      !  0      !  1      !  0      !  5      !  0      !
      !P CLL       !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
      !P           !  0.     !  0.     !  1.00   !  0.     !  0.     !  1.00   !  0.     !  0.     !  0.     !
      !P CLU       !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.50   !  0.     !
      !XBAR CLL    !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
      !XBAR        !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
      !XBAR CLU    !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
57  0 !N           !  0      !  0      !  0      !  0      !  2      !  3      !  2      !  0      !  6      !
      !P CLL       !  0.     !  0.     !  0.     !  0.     !  0.     !  0.01   !  0.     !  0.     !  0.     !
      !P           !  0.     !  0.     !  0.     !  0.     !  0.50   !  0.33   !  0.     !  0.     !  0.     !
      !P CLU       !  0.     !  0.     !  0.     !  0.     !  0.     !  0.92   !  0.     !  0.     !  0.40   !
      !XBAR CLL    !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
      !XBAR        !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
      !XBAR CLU    !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !  0.     !
------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
```

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                                                 L O N G I T U D E
LAT    ¦            ¦  150 40 ¦  150 20 ¦  150  0 ¦  149 40 ¦  149 20 ¦  149  0 ¦  148 40 ¦  148 20 ¦  148  0 ¦
-------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 50  ¦N           ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦    3    ¦    1    ¦    2    ¦
       ¦P CLL       ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.01 ¦    0.   ¦    0.   ¦
       ¦P           ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.33 ¦    1.00 ¦    1.00 ¦
       ¦P CLU       ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.92 ¦    0.   ¦    0.   ¦
       ¦XBAR CLL    ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR        ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR CLU    ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
-------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 40  ¦N           ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦    1    ¦    0    ¦    0    ¦
       ¦P CLL       ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦P           ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    1.00 ¦    0.   ¦    0.   ¦
       ¦P CLU       ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR CLL    ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR        ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR CLU    ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
-------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 30  ¦N           ¦    0    ¦    0    ¦    0    ¦    1    ¦    1    ¦    0    ¦    0    ¦    0    ¦    0    ¦
       ¦P CLL       ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦P           ¦    0.   ¦    0.   ¦    0.   ¦    1.00 ¦    1.00 ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦P CLU       ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR CLL    ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR        ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR CLU    ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
-------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 20  ¦N           ¦    0    ¦    0    ¦    0    ¦    1    ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦
       ¦P CLL       ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦P           ¦    0.   ¦    0.   ¦    0.   ¦    1.00 ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦P CLU       ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR CLL    ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR        ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR CLU    ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
-------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 10  ¦N           ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦
       ¦P CLL       ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦P           ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦P CLU       ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR CLL    ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR        ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR CLU    ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
-------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56  0  ¦N           ¦    1    ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦    0    ¦
       ¦P CLL       ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦P           ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦P CLU       ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR CLL    ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR        ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
       ¦XBAR CLU    ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦    0.   ¦
-------+------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
```

		L O N G I T U D E								
LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
55 50	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 40	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 30	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table 4. Confidence limits on the density of Glaucous-winged Gulls by 20-km blocks in the vicinity of Kodiak. See Table 3 for definitions of symbols.

LAT		LONGITUDE								
		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
58 50	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 40	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 30	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 20	N	0	0	0	0	0	0	0	0	2
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	1.00
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 10	N	0	0	0	0	0	0	0	0	2
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	1.00
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 0	N	0	0	0	0	0	0	0	1	4
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.01
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.25
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.82
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
57 50	N	0	0	0	0	0	0	2	4	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.01	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.25	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.82	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 40	N	0	0	0	0	0	2	5	1	0
	P CLL	0.	0.	0.	0.	0.	0.	0.14	0.	0.
	P	0.	0.	0.	0.	0.	1.00	0.60	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.95	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.72	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	1.75	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	35.84	0.	0.
57 30	N	0	0	0	2	2	5	2	0	0
	P CLL	0.	0.	0.	0.	0.	0.14	0.	0.	0.
	P	0.	0.	0.	0.50	1.00	0.60	0.50	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.95	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.85	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	1.81	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	10.48	0.	0.	0.
57 20	N	1	0	0	2	2	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	1.00	0.	0.	0.50	1.00	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 10	N	0	0	0	5	0	0	0	0	0
	P CLL	0.	0.	0.	0.27	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.80	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.99	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.89	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	1.55	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	3.97	0.	0.	0.	0.	0.
57 0	N	0	0	3	5	0	1	0	0	0
	P CLL	0.	0.	0.	0.05	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.40	0.	1.00	0.	0.	0.
	P CLU	0.	0.	0.70	0.86	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

```
                                                  L O N G I T U D E
LAT   !             !  156 40 !  156 20 !  156  0 !  155 40 !  155 20 !  155  0 !  154 40 !  154 20 !  154  0 !
------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 50 !N            !   0     !   0     !   3     !   3     !   0     !   2     !   1     !   0     !   0     !
      !P CLL        !   0.    !   0.    !   0.08  !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
      !P            !   0.    !   0.    !   0.67  !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
      !P CLU        !   0.    !   0.    !   0.99  !   0.70  !   0.    !   0.    !   0.    !   0.    !   0.    !
      !XBAR CLL     !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
      !XBAR         !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
      !XBAR CLU     !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 40 !N            !   1     !   1     !   0     !   0     !   2     !   1     !   2     !   0     !   6     !
      !P CLL        !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.21  !
      !P            !   1.00  !   0.    !   0.    !   0.    !   0.    !   1.00  !   0.50  !   0.    !   0.67  !
      !P CLU        !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.97  !
      !XBAR CLL     !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   1.62  !
      !XBAR         !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   3.71  !
      !XBAR CLU     !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !  34.22  !
------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 30 !N            !   2     !   0     !   0     !   0     !   1     !   1     !   0     !   0     !   0     !
      !P CLL        !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
      !P            !   0.    !   0.    !   0.    !   0.    !   1.00  !   0.    !   0.    !   0.    !   0.    !
      !P CLU        !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
      !XBAR CLL     !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
      !XBAR         !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
      !XBAR CLU     !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 20 !N            !   1     !   0     !   0     !   0     !   1     !   0     !   0     !   0     !   6     !
      !P CLL        !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.03  !
      !P            !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.33  !
      !P CLU        !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.79  !
      !XBAR CLL     !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
      !XBAR         !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
      !XBAR CLU     !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 10 !N            !   1     !   0     !   0     !   1     !   0     !   1     !   5     !   4     !   0     !
      !P CLL        !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.14  !   0.18  !   0.    !
      !P            !   1.00  !   0.    !   0.    !   1.00  !   0.    !   1.00  !   0.60  !   0.75  !   0.    !
      !P CLU        !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.95  !   0.99  !   0.    !
      !XBAR CLL     !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.95  !   0.50  !   0.    !
      !XBAR         !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   2.02  !   1.10  !   0.    !
      !XBAR CLU     !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !  12.09  !   8.26  !   0.    !
------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56  0 !N            !   0     !   1     !   0     !   1     !   1     !   1     !   4     !   0     !   0     !
      !P CLL        !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.06  !   0.    !   0.    !
      !P            !   0.    !   0.    !   0.    !   1.00  !   1.00  !   0.    !   0.50  !   0.    !   0.    !
      !P CLU        !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.94  !   0.    !   0.    !
      !XBAR CLL     !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
      !XBAR         !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
      !XBAR CLU     !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !   0.    !
------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
```

		LONGITUDE								
LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
55 50	N	0	0	0	1	3	8	1	2	0
	P CLL	0.	0.	0.	0.	0.30	0.15	0.	0.	0.
	P	0.	0.	0.	1.00	1.00	0.50	0.	0.	0.
	P CLU	0.	0.	0.	0.	1.00	0.85	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.87	0.75	0.	0.	0.
	XBAR	0.	0.	0.	0.	1.82	1.51	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	9.49	6.91	0.	0.	0.
55 40	N	0	0	1	8	7	2	0	1	2
	P CLL	0.	0.	0.	0.24	0.10	0.	0.	0.	0.
	P	0.	0.	1.00	0.63	0.43	0.50	0.	0.	0.
	P CLU	0.	0.	0.	0.93	0.83	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.99	0.75	0.	0.	0.	0.
	XBAR	0.	0.	0.	1.77	1.88	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	5.13	48.92	0.	0.	0.	0.
55 30	N	3	10	5	5	2	0	0	0	2
	P CLL	0.	0.18	0.05	0.	0.	0.	0.	0.	0.
	P	0.	0.50	0.40	0.	0.	0.	0.	0.	1.00
	P CLU	0.70	0.82	0.86	0.50	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.66	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	1.13	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	2.83	0.	0.	0.	0.	0.	0.	0.

LONGITUDE

LAT		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
58 50	N	0	0	4	4	3	2	3	4	2
	P CLL	0.	0.	0.06	0.01	0.30	0.	0.01	0.06	0.
	P	0.	0.	0.50	0.25	1.00	0.50	0.33	0.50	1.00
	P CLU	0.	0.	0.94	0.82	1.00	0.	0.92	0.94	0.
	XBAR CLL	0.	0.	0.	0.	0.57	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	1.04	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	3.18	0.	0.	0.	0.
58 40	N	0	4	3	2	0	0	0	1	2
	P CLL	0.	0.	0.01	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.33	1.00	0.	0.	0.	1.00	0.
	P CLU	0.	0.60	0.92	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 30	N	2	1	1	0	1	0	3	0	2
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.50	1.00	1.00	0.	1.00	0.	0.	0.	0.50
	P CLU	0.	0.	0.	0.	0.	0.	0.70	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 20	N	2	3	2	0	0	1	1	0	1
	P CLL	0.	0.08	0.	0.	0.	0.	0.	0.	0.
	P	0.50	0.67	0.50	0.	0.	1.00	0.	0.	1.00
	P CLU	0.	0.99	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 10	N	1	1	0	0	0	4	4	1	4
	P CLL	0.	0.	0.	0.	0.	0.06	0.06	0.	0.18
	P	0.	0.	0.	0.	0.	0.50	0.50	1.00	0.75
	P CLU	0.	0.	0.	0.	0.	0.94	0.94	0.	0.99
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.84
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	1.85
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	14.00
58 0	N	0	0	0	0	0	1	3	2	3
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.08
	P	0.	0.	0.	0.	0.	1.00	0.	1.00	0.67
	P CLU	0.	0.	0.	0.	0.	0.	0.70	0.	0.99
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

LONGITUDE

LAT		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
57 50	N	0	0	0	0	0	11	11	4	2
	P CLL	0.	0.	0.	0.	0.	0.16	0.06	0.01	0.
	P	0.	0.	0.	0.	0.	0.45	0.27	0.25	0.
	P CLU	0.	0.	0.	0.	0.	0.78	0.62	0.82	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.86	0.51	0.	0.
	XBAR	0.	0.	0.	0.	0.	1.23	0.74	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	2.01	1.27	0.	0.
57 40	N	0	0	0	0	1	20	2	5	4
	P CLL	0.	0.	0.	0.	0.	0.46	0.	0.	0.01
	P	0.	0.	0.	0.	1.00	0.70	0.50	0.	0.25
	P CLU	0.	0.	0.	0.	0.	0.88	0.	0.50	0.82
	XBAR CLL	0.	0.	0.	0.	0.	1.88	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	2.60	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	3.98	0.	0.	0.
57 30	N	0	0	0	0	0	10	0	1	1
	P CLL	0.	0.	0.	0.	0.	0.06	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.30	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.66	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.51	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.76	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	1.33	0.	0.	0.
57 20	N	0	0	0	2	2	4	1	0	1
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.50	0.50	0.	1.00	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.60	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 10	N	0	0	1	5	2	0	1	0	0
	P CLL	0.	0.	0.	0.50	0.	0.	0.	0.	0.
	P	0.	0.	1.00	1.00	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	1.00	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	1.52	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	2.44	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	5.13	0.	0.	0.	0.	0.
57 0	N	0	9	4	10	0	2	1	1	0
	P CLL	0.	0.40	0.06	0.00	0.	0.	0.	0.	0.
	P	0.	0.78	0.50	0.10	0.	0.50	1.00	0.	0.
	P CLU	0.	0.98	0.94	0.46	0.	0.	0.	0.	0.
	XBAR CLL	0.	1.63	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	2.94	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	8.65	0.	0.	0.	0.	0.	0.	0.

L O N G I T U D E

LAT		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
56 50	N	0	4	7	3	0	4	1	1	0
	P CLL	0.	0.01	0.17	0.01	0.	0.40	0.	0.	0.
	P	0.	0.25	0.57	0.33	0.	1.00	0.	1.00	0.
	P CLU	0.	0.82	0.90	0.92	0.	1.00	0.	0.	0.
	XBAR CLL	0.	0.	0.75	0.	0.	0.85	0.	0.	0.
	XBAR	0.	0.	1.13	0.	0.	1.54	0.	0.	0.
	XBAR CLU	0.	0.	2.02	0.	0.	4.68	0.	0.	0.
56 40	N	3	3	2	0	1	1	0	0	0
	P CLL	0.01	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.33	0.	0.50	0.	1.00	1.00	0.	0.	0.
	P CLU	0.92	0.70	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 30	N	2	2	1	0	2	1	1	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.50	1.00	1.00	0.	1.00	1.00	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 20	N	5	0	0	0	1	1	1	0	2
	P CLL	0.01	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.20	0.	0.	0.	1.00	0.	1.00	0.	0.
	P CLU	0.73	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 10	N	0	2	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	1.00	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 0	N	3	1	2	1	0	0	0	0	1
	P CLL	0.01	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.33	0.	0.50	1.00	0.	0.	0.	0.	0.
	P CLU	0.92	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
55 50	N	2	0	0	1	0	0	0	1	2
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 40	N	2	2	0	0	0	0	1	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.50	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 30	N	1	0	0	0	1	2	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

LAT		L O N G I T U D E								
		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
58 50	N	3	3	1	0	0	2	2	1	0
	P CLL	0.01	0.01	0.	0.	0.	0.	0.	0.	0.
	P	0.33	0.33	1.00	0.	0.	0.	0.50	1.00	0.
	P CLU	0.92	0.92	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 40	N	0	1	3	1	3	0	2	6	0
	P CLL	0.	0.	0.01	0.	0.	0.	0.	0.00	0.
	P	0.	0.	0.33	1.00	0.	0.	0.	0.17	0.
	P CLU	0.	0.	0.92	0.	0.70	0.	0.	0.65	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 30	N	2	0	2	2	2	0	3	6	2
	P CLL	0.	0.	0.	0.	0.	0.	0.01	0.11	0.
	P	0.	0.	0.50	0.	0.	0.	0.33	0.50	1.00
	P CLU	0.	0.	0.	0.	0.	0.	0.92	0.89	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	1.81	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	4.51	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	112.38	0.
58 20	N	4	4	0	0	0	0	0	2	3
	P CLL	0.06	0.18	0.	0.	0.	0.	0.	0.	0.08
	P	0.50	0.75	0.	0.	0.	0.	0.	0.	0.67
	P CLU	0.94	0.99	0.	0.	0.	0.	0.	0.	0.99
	XBAR CLL	0.	1.74	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	4.93	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	5884.39	0.	0.	0.	0.	0.	0.	0.
58 10	N	5	3	4	0	0	2	0	0	0
	P CLL	0.14	0.01	0.01	0.	0.	0.	0.	0.	0.
	P	0.60	0.33	0.25	0.	0.	1.00	0.	0.	0.
	P CLU	0.95	0.92	0.82	0.	0.	0.	0.	0.	0.
	XBAR CLL	1.70	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	4.80	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	793.58	0.	0.	0.	0.	0.	0.	0.	0.
58 0	N	3	2	6	0	2	0	0	0	1
	P CLL	0.	0.	0.21	0.	0.	0.	0.	0.	0.
	P	0.	0.50	0.67	0.	1.00	0.	0.	0.	1.00
	P CLU	0.70	0.	0.97	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	1.94	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	4.05	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	21.09	0.	0.	0.	0.	0.	0.

LONGITUDE

LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
57 50	N	0	1	3	3	2	1	2	3	1
	P CLL	0.	0.	0.01	0.	0.	0.	0.	0.08	0.
	P	0.	1.00	0.33	0.	0.50	1.00	0.	0.67	1.00
	P CLU	0.	0.	0.92	0.70	0.	0.	0.	0.99	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 40	N	4	3	1	0	4	0	0	0	0
	P CLL	0.01	0.08	0.	0.	0.01	0.	0.	0.	0.
	P	0.25	0.67	1.00	0.	0.25	0.	0.	0.	0.
	P CLU	0.82	0.99	0.	0.	0.82	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 30	N	2	1	0	1	0	4	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.01	0.	0.	0.
	P	0.50	0.	0.	1.00	0.	0.25	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.82	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 20	N	5	3	0	1	0	0	8	1	0
	P CLL	0.14	0.	0.	0.	0.	0.	0.00	0.	0.
	P	0.60	0.	0.	0.	0.	0.	0.13	0.	0.
	P CLU	0.95	0.70	0.	0.	0.	0.	0.54	0.	0.
	XBAR CLL	3.24	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	7.94	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	176.15	0.	0.	0.	0.	0.	0.	0.	0.
57 10	N	1	1	2	1	0	1	0	5	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	1.00	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.50	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 0	N	0	0	0	0	2	3	2	0	6
	P CLL	0.	0.	0.	0.	0.	0.01	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.33	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.92	0.	0.	0.40
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
56 50	N	0	0	0	0	0	0	3	1	2
	P CLL	0.	0.	0.	0.	0.	0.	0.01	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.33	1.00	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.92	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 40	N	0	0	0	0	0	0	1	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 30	N	0	0	0	1	1	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	1.00	1.00	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 20	N	0	0	0	1	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	1.00	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 10	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 0	N	1	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
55 50	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 40	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 30	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table 5. Confidence limits on the density of murres by 20-km blocks in the vicinity of Kodiak. See Table 3 for definitions of symbols.

MOR

LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
		L O N G I T U D E								
58 50	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 40	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 30	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 20	N	0	0	0	0	0	0	0	0	2
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.50
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 10	N	0	0	0	0	0	0	0	0	2
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	1.00
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 0	N	0	0	0	0	0	0	0	1	4
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.06
	P	0.	0.	0.	0.	0.	0.	0.	1.00	0.50
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.94
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

LAT		LONGITUDE 156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
57 50	N	0	0	0	0	0	0	2	4	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.18	0.
	P	0.	0.	0.	0.	0.	0.	1.00	0.75	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.99	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.32	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.61	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	2.09	0.
57 40	N	0	0	0	0	0	2	5	1	0
	P CLL	0.	0.	0.	0.	0.	0.	0.14	0.	0.
	P	0.	0.	0.	0.	0.	0.50	0.60	1.00	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.95	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	5.02	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	7.68	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	14.35	0.	0.
57 30	N	0	0	0	2	2	5	2	0	0
	P CLL	0.	0.	0.	0.	0.	0.27	0.	0.	0.
	P	0.	0.	0.	1.00	1.00	0.80	0.50	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.99	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	1.35	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	3.11	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	30.53	0.	0.	0.
57 20	N	1	0	0	2	2	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.50	0.50	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 10	N	0	0	0	5	0	0	0	0	0
	P CLL	0.	0.	0.	0.14	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.60	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.95	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	2.58	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	4.65	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	13.60	0.	0.	0.	0.	0.
57 0	N	0	0	3	5	0	1	0	0	0
	P CLL	0.	0.	0.30	0.14	0.	0.	0.	0.	0.
	P	0.	0.	1.00	0.60	0.	0.	0.	0.	0.
	P CLU	0.	0.	1.00	0.95	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.68	1.16	0.	0.	0.	0.	0.
	XBAR	0.	0.	1.49	3.11	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	10.34	260.89	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
56 50	N	0	0	3	3	0	2	1	0	0
	P CLL	0.	0.	0.30	0.08	0.	0.	0.	0.	0.
	P	0.	0.	1.00	0.67	0.	1.00	1.00	0.	0.
	P CLU	0.	0.	1.00	0.99	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.74	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	1.89	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	58.79	0.	0.	0.	0.	0.	0.
56 40	N	1	1	0	0	2	1	2	0	6
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.21
	P	0.	1.00	0.	0.	1.00	1.00	1.00	0.	0.67
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.97
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	1.86
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	4.00
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	26.70
56 30	N	2	0	0	0	1	1	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	1.00	0.	0.	0.	1.00	1.00	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 20	N	1	0	0	0	1	0	0	0	6
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.21
	P	1.00	0.	0.	0.	1.00	0.	0.	0.	0.67
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.97
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	2.84
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	7.31
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	229.63
56 10	N	1	0	0	1	0	1	5	4	0
	P CLL	0.	0.	0.	0.	0.	0.	0.05	0.18	0.
	P	1.00	0.	0.	1.00	0.	1.00	0.40	0.75	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.86	0.99	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	5.72	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	7.14	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	9.33	0.
56 0	N	0	1	0	1	1	1	4	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.01	0.	0.
	P	0.	1.00	0.	1.00	1.00	0.	0.25	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.82	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

LAT		LONGITUDE								
		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
55 50	N	0	0	0	1	3	8	1	2	0
	P CLL	0.	0.	0.	0.	0.30	0.35	0.	0.	0.
	P	0.	0.	0.	0.	1.00	0.75	0.	0.	0.
	P CLU	0.	0.	0.	0.	1.00	0.98	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	1.56	1.14	0.	0.	0.
	XBAR	0.	0.	0.	0.	3.85	1.63	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	91.77	2.65	0.	0.	0.
55 40	N	0	0	1	8	7	2	0	1	2
	P CLL	0.	0.	0.	0.35	0.28	0.	0.	0.	0.
	P	0.	0.	0.	0.75	0.71	0.50	0.	0.	0.
	P CLU	0.	0.	0.	0.98	0.97	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	2.38	0.98	0.	0.	0.	0.
	XBAR	0.	0.	0.	3.86	1.72	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	8.28	4.62	0.	0.	0.	0.
55 30	N	3	10	5	5	2	0	0	0	2
	P CLL	0.01	0.11	0.05	0.01	0.	0.	0.	0.	0.
	P	0.33	0.40	0.40	0.20	0.50	0.	0.	0.	1.00
	P CLU	0.92	0.74	0.86	0.73	0.	0.	0.	0.	0.
	XBAR CLL	0.	1.54	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	1.98	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	2.71	0.	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
58 50	N	0	0	4	4	3	2	3	4	2
	P CLL	0.	0.	0.06	0.40	0.08	0.	0.01	0.01	0.
	P	0.	0.	0.50	1.00	0.67	0.50	0.33	0.25	0.50
	P CLU	0.	0.	0.94	1.00	0.99	0.	0.92	0.82	0.
	XBAR CLL	0.	0.	0.	5.17	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	9.44	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	29.09	0.	0.	0.	0.	0.
58 40	N	0	4	3	2	0	0	0	1	2
	P CLL	0.	0.01	0.30	0.	0.	0.	0.	0.	0.
	P	0.	0.25	1.00	1.00	0.	0.	0.	1.00	1.00
	P CLU	0.	0.82	1.00	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	1.98	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	5.55	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	877.40	0.	0.	0.	0.	0.	0.
58 30	N	2	1	1	0	1	0	3	0	2
	P CLL	0.	0.	0.	0.	0.	0.	0.01	0.	0.
	P	1.00	0.	1.00	0.	0.	0.	0.33	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.92	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 20	N	2	3	2	0	0	1	1	0	1
	P CLL	0.	0.08	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.67	0.50	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.99	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 10	N	1	1	0	0	0	4	4	1	4
	P CLL	0.	0.	0.	0.	0.	0.01	0.18	0.	0.40
	P	1.00	1.00	0.	0.	0.	0.25	0.75	1.00	1.00
	P CLU	0.	0.	0.	0.	0.	0.82	0.99	0.	1.00
	XBAR CLL	0.	0.	0.	0.	0.	0.	2.28	0.	9.67
	XBAR	0.	0.	0.	0.	0.	0.	5.79	0.	22.43
	XBAR CLU	0.	0.	0.	0.	0.	0.	167.41	0.	244.89
58 0	N	0	0	0	0	0	1	3	2	3
	P CLL	0.	0.	0.	0.	0.	0.	0.30	0.	0.30
	P	0.	0.	0.	0.	0.	1.00	1.00	1.00	1.00
	P CLU	0.	0.	0.	0.	0.	0.	1.00	0.	1.00
	XBAR CLL	0.	0.	0.	0.	0.	0.	2.72	0.	2.63
	XBAR	0.	0.	0.	0.	0.	0.	7.68	0.	3.53
	XBAR CLU	0.	0.	0.	0.	0.	0.	2275.21	0.	5.16

LAT		LONGITUDE								
		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
57 50	N	0	0	0	0	0	11	11	4	2
	P CLL	0.	0.	0.	0.	0.	0.47	0.38	0.01	0.
	P	0.	0.	0.	0.	0.	0.82	0.73	0.25	0.
	P CLU	0.	0.	0.	0.	0.	0.98	0.94	0.82	0.
	XBAR CLL	0.	0.	0.	0.	0.	4.19	1.64	0.	0.
	XBAR	0.	0.	0.	0.	0.	6.18	2.54	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	10.69	4.89	0.	0.
57 40	N	0	0	0	0	1	20	2	5	4
	P CLL	0.	0.	0.	0.	0.	0.61	0.	0.14	0.18
	P	0.	0.	0.	0.	1.00	0.85	0.	0.60	0.75
	P CLU	0.	0.	0.	0.	0.	0.97	0.	0.95	0.99
	XBAR CLL	0.	0.	0.	0.	0.	0.84	0.	0.41	0.67
	XBAR	0.	0.	0.	0.	0.	2.98	0.	0.44	1.40
	XBAR CLU	0.	0.	0.	0.	0.	.7461E+71	0.	0.49	7.20
57 30	N	0	0	0	0	0	10	0	1	1
	P CLL	0.	0.	0.	0.	0.	0.26	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.60	0.	1.00	0.
	P CLU	0.	0.	0.	0.	0.	0.89	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	1.75	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	2.60	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	4.57	0.	0.	0.
57 20	N	0	0	0	2	2	4	1	0	1
	P CLL	0.	0.	0.	0.	0.	0.06	0.	0.	0.
	P	0.	0.	0.	0.	0.50	0.50	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.94	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 10	N	0	0	1	5	2	0	1	0	0
	P CLL	0.	0.	0.	0.27	0.	0.	0.	0.	0.
	P	0.	0.	1.00	0.80	0.50	0.	1.00	0.	0.
	P CLU	0.	0.	0.	0.99	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	13.15	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	27.69	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	154.66	0.	0.	0.	0.	0.
57 0	N	0	9	4	10	0	2	1	1	0
	P CLL	0.	0.40	0.18	0.34	0.	0.	0.	0.	0.
	P	0.	0.78	0.75	0.70	0.	0.50	0.	0.	0.
	P CLU	0.	0.98	0.99	0.94	0.	0.	0.	0.	0.
	XBAR CLL	0.	31.06	8.78	1.26	0.	0.	0.	0.	0.
	XBAR	0.	60.02	24.43	1.93	0.	0.	0.	0.	0.
	XBAR CLU	0.	221.47	3545.90	3.62	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
56 50	N	0	4	7	3	0	4	1	1	0
	P CLL	0.	0.40	0.60	0.01	0.	0.18	0.	0.	0.
	P	0.	1.00	1.00	0.33	0.	0.75	0.	0.	0.
	P CLU	0.	1.00	1.00	0.92	0.	0.99	0.	0.	0.
	XBAR CLL	0.	5.96	4.35	0.	0.	0.72	0.	0.	0.
	XBAR	0.	13.15	6.69	0.	0.	1.88	0.	0.	0.
	XBAR CLU	0.	100.97	12.67	0.	0.	104.13	0.	0.	0.
56 40	N	3	3	2	0	1	1	0	0	0
	P CLL	0.30	0.08	0.	0.	0.	0.	0.	0.	0.
	P	1.00	0.67	0.	0.	0.	1.00	0.	0.	0.
	P CLU	1.00	0.99	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	1.81	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	3.38	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	11.23	0.	0.	0.	0.	0.	0.	0.	0.
56 30	N	2	2	1	0	2	1	1	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	1.00	1.00	1.00	0.	0.	1.00	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 20	N	5	0	0	0	1	1	1	0	2
	P CLL	0.14	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.60	0.	0.	0.	0.	1.00	0.	0.	0.
	P CLU	0.95	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.98	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	2.17	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	17.32	0.	0.	0.	0.	0.	0.	0.	0.
56 10	N	0	2	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 0	N	3	1	2	1	0	0	0	0	1
	P CLL	0.01	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.33	0.	0.50	1.00	0.	0.	0.	0.	0.
	P CLU	0.92	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

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                                                    L O N G I T U D E
LAT   !            !    153 40 !    153 20 !    153  0 !    152 40 !    152 20 !    152  0 !    151 40 !    151 20 !    151  0 !
------+------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
55 50 !N           !       2   !       0   !       0   !       1   !       0   !       0   !       0   !       1   !       2   !
      !P CLL       !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P           !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P CLU       !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLL    !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR        !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLU    !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
------+------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
55 40 !N           !       2   !       2   !       0   !       0   !       0   !       0   !       1   !       0   !       0   !
      !P CLL       !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P           !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P CLU       !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLL    !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR        !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLU    !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
------+------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
55 30 !N           !       1   !       0   !       0   !       0   !       1   !       2   !       0   !       0   !       0   !
      !P CLL       !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P           !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P CLU       !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLL    !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR        !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLU    !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
------+------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
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		LONGITUDE								
LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
58 50	N	3	3	1	0	0	2	2	1	0
	P CLL	0.08	0.30	0.	0.	0.	0.	0.	0.	0.
	P	0.67	1.00	1.00	0.	0.	0.	0.50	0.	0.
	P CLU	0.99	1.00	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	1.77	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	5.13	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	65594.81	0.	0.	0.	0.	0.	0.	0.
58 40	N	0	1	3	1	3	0	2	6	0
	P CLL	0.	0.	0.01	0.	0.30	0.	0.	0.00	0.
	P	0.	1.00	0.33	1.00	1.00	0.	0.	0.17	0.
	P CLU	0.	0.	0.92	0.	1.00	0.	0.	0.65	0.
	XBAR CLL	0.	0.	0.	0.	0.58	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	1.41	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	27.15	0.	0.	0.	0.
58 30	N	2	0	2	2	2	0	3	6	2
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.03	0.
	P	0.50	0.	0.50	0.	0.50	0.	0.	0.33	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.70	0.79	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 20	N	4	4	0	0	0	0	0	2	3
	P CLL	0.06	0.40	0.	0.	0.	0.	0.	0.	0.
	P	0.50	1.00	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.94	1.00	0.	0.	0.	0.	0.	0.	0.70
	XBAR CLL	0.	0.73	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	1.07	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	1.85	0.	0.	0.	0.	0.	0.	0.
58 10	N	5	3	4	0	0	2	0	0	0
	P CLL	0.14	0.08	0.01	0.	0.	0.	0.	0.	0.
	P	0.60	0.67	0.25	0.	0.	1.00	0.	0.	0.
	P CLU	0.95	0.99	0.82	0.	0.	0.	0.	0.	0.
	XBAR CLL	3.41	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	10.13	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	224177.12	0.	0.	0.	0.	0.	0.	0.	0.
58 0	N	3	2	6	0	2	0	0	0	1
	P CLL	0.30	0.	0.11	0.	0.	0.	0.	0.	0.
	P	1.00	1.00	0.50	0.	0.50	0.	0.	0.	0.
	P CLU	1.00	0.	0.89	0.	0.	0.	0.	0.	0.
	XBAR CLL	7.30	0.	2.53	0.	0.	0.	0.	0.	0.
	XBAR	20.49	0.	7.19	0.	0.	0.	0.	0.	0.
	XBAR CLU	3275.80	0.	25660.77	0.	0.	0.	0.	0.	0.

LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
		LONGITUDE								
57 50	N	0	1	3	3	2	1	2	3	1
	P CLL	0.	0.	0.08	0.08	0.	0.	0.	0.	0.
	P	0.	1.00	0.67	0.67	0.50	0.	1.00	0.	1.00
	P CLU	0.	0.	0.99	0.99	0.	0.	0.	0.70	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 40	N	4	3	1	0	4	0	0	0	0
	P CLL	0.18	0.08	0.	0.	0.	0.	0.	0.	0.
	P	0.75	0.67	1.00	0.	0.	0.	0.	0.	0.
	P CLU	0.99	0.99	0.	0.	0.60	0.	0.	0.	0.
	XBAR CLL	6.24	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	11.63	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	38.45	0.	0.	0.	0.	0.	0.	0.	0.
57 30	N	2	1	0	1	0	4	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.60	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 20	N	5	3	0	1	0	0	8	1	0
	P CLL	0.	0.01	0.	0.	0.	0.	0.00	0.	0.
	P	0.	0.33	0.	0.	0.	0.	0.13	0.	0.
	P CLU	0.50	0.92	0.	0.	0.	0.	0.54	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 10	N	1	1	2	1	0	1	0	5	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.50	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 0	N	0	0	0	0	2	3	2	0	6
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.70	0.	0.	0.40
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

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                                                  L O N G I T U D E
LAT     !             !  150 40 !  150 20 !  150  0 !  149 40 !  149 20 !  149  0 !  148 40 !  148 20 !  148  0 !
--------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 50   !N            !    0    !    0    !    0    !    0    !    0    !    0    !    3    !    1    !    2    !
        !P CLL        !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !P            !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !P CLU        !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.70 !    0.   !    0.   !
        !XBAR CLL     !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR         !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR CLU     !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
--------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 40   !N            !    0    !    0    !    0    !    0    !    0    !    0    !    1    !    0    !    0    !
        !P CLL        !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !P            !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !P CLU        !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR CLL     !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR         !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR CLU     !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
--------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 30   !N            !    0    !    0    !    0    !    1    !    1    !    0    !    0    !    0    !    0    !
        !P CLL        !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !P            !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !P CLU        !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR CLL     !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR         !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR CLU     !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
--------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 20   !N            !    0    !    0    !    0    !    1    !    0    !    0    !    0    !    0    !    0    !
        !P CLL        !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !P            !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !P CLU        !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR CLL     !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR         !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR CLU     !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
--------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56 10   !N            !    0    !    0    !    0    !    0    !    0    !    0    !    0    !    0    !    0    !
        !P CLL        !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !P            !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !P CLU        !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR CLL     !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR         !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR CLU     !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
--------+-------------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
56  0   !N            !    1    !    0    !    0    !    0    !    0    !    0    !    0    !    0    !    0    !
        !P CLL        !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !P            !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !P CLU        !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR CLL     !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR         !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
        !XBAR CLU     !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !    0.   !
========+=============+=========+=========+=========+=========+=========+=========+=========+=========+=========+
```

L O N G I T U D E

LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
55 50	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 40	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 30	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table 6. Confidence limits on the density of Tufted Puffins by 20-km blocks in the vicinity of Kodiak. See Table 3 for definitions of symbols.

```
                                                      L O N G I T U D E
L/T    :             :    156 40 :    156 20 :    156  0 :    155 40 :    155 20 :    155  0 :    154 40 :    154 20 :    154  0 :
-------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
58 50  :N            :     0     :     0     :     0     :     0     :     0     :     0     :     0     :     0     :     0     :
       :P CLL        :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :P            :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :P CLU        :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR CLL     :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR         :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR CLU     :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
-------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
58 40  :N            :     0     :     0     :     0     :     0     :     0     :     0     :     0     :     0     :     0     :
       :P CLL        :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :P            :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :P CLU        :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR CLL     :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR         :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR CLU     :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
-------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
58 30  :N            :     0     :     0     :     0     :     0     :     0     :     0     :     0     :     0     :     0     :
       :P CLL        :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :P            :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :P CLU        :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR CLL     :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR         :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR CLU     :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
-------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
58 20  :N            :     0     :     0     :     0     :     0     :     0     :     0     :     0     :     0     :     2     :
       :P CLL        :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :P            :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.50  :
       :P CLU        :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR CLL     :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR         :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR CLU     :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
-------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
58 10  :N            :     0     :     0     :     0     :     0     :     0     :     0     :     0     :     0     :     2     :
       :P CLL        :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :P            :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.50  :
       :P CLU        :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR CLL     :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR         :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR CLU     :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
-------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
58  0  :N            :     0     :     0     :     0     :     0     :     0     :     0     :     0     :     1     :     4     :
       :P CLL        :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.01  :
       :P            :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.25  :
       :P CLU        :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.82  :
       :XBAR CLL     :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR         :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
       :XBAR CLU     :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :     0.    :
-------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
```

		LONGITUDE								
LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
57 50	N	0	0	0	0	0	0	2	4	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.06	0.
	P	0.	0.	0.	0.	0.	0.	1.00	0.50	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.94	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 40	N	0	0	0	0	0	2	5	1	0
	P CLL	0.	0.	0.	0.	0.	0.	0.05	0.	0.
	P	0.	0.	0.	0.	0.	0.50	0.40	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.86	0.	0.
	XBAR CLL	0.	0.	0	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 30	N	0	0	0	2	2	5	2	0	0
	P CLL	0.	0.	0.	0.	0.	0.01	0.	0.	0.
	P	0.	0.	0.	0.	1.00	0.20	0.50	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.73	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 20	N	1	0	0	2	2	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	1.00	0.	0.	0.	0.50	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 10	N	0	0	0	5	0	0	0	0	0
	P CLL	0.	0.	0.	0.14	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.60	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.95	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.44	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.94	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	6.13	0.	0.	0.	0.	0.
57 0	N	0	0	3	5	0	1	0	0	0
	P CLL	0.	0.	0.01	0.01	0.	0.	0.	0.	0.
	P	0.	0.	0.33	0.20	0.	1.00	0.	0.	0.
	P CLU	0.	0.	0.92	0.73	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
56 50	N	0	0	3	3	0	2	1	0	0
	P CLL	0.	0.	0.01	0.01	0.	0.	0.	0.	0.
	P	0.	0.	0.33	0.33	0.	0.50	1.00	0.	0.
	P CLU	0.	0.	0.92	0.92	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 40	N	1	1	0	0	2	1	2	0	6
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.60
	P	1.00	1.00	0.	0.	0.50	1.00	1.00	0.	1.00
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	1.00
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	3.13
	XBAR	0.	0.	0	0.	0.	0.	0.	0.	4.89
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	9.67
56 30	N	2	0	0	0	1	1	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	1.00	0.	0.	0.	1.00	1.00	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 20	N	1	0	0	0	1	0	0	0	6
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.21
	P	1.00	0.	0.	0.	0.	0.	0.	0.	0.67
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.97
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	2.64
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	5.17
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	20.16
56 10	N	1	0	0	1	0	1	5	4	0
	P CLL	0.	0.	0.	0.	0.	0.	0.14	0.18	0.
	P	1.00	0.	0.	1.00	0.	0.	0.60	0.75	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.95	0.99	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	1.61	3.52	0.
	XBAR	0.	0.	0.	0.	0.	0.	4.27	7.54	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	265.71	47.65	0.
56 0	N	0	1	0	1	1	1	4	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.06	0.	0.
	P	0.	1.00	0.	1.00	0.	1.00	0.50	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.94	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

```
                                                   L O N G I T U D E
LAT    :               :   156 40 :   156 20 :   156  0 :   155 40 :   155 20 :   155  0 :   154 40 :   154 20 :   154  0 :
-------+---------------+----------+----------+----------+----------+----------+----------+----------+----------+----------+
55 50  :N              :   0      :   0      :   0      :   1      :   3      :   8      :   1      :   2      :   0      :
       :P CLL          :   0.     :   0.     :   0.     :   0.     :    0.30  :    0.24  :   0.     :   0.     :   0.     :
       :P              :   0.     :   0.     :   0.     :   0.     :    1.00  :    0.63  :   1.00   :   1.00   :   0.     :
       :P CLU          :   0.     :   0.     :   0.     :   0.     :    1.00  :    0.93  :   0.     :   0.     :   0.     :
       :XBAR CLL       :   0.     :   0.     :   0.     :   0.     :    1.60  :    4.23  :   0.     :   0.     :   0.     :
       :XBAR           :   0.     :   0.     :   0.     :   0.     :    3.29  :    7.42  :   0.     :   0.     :   0.     :
       :XBAR CLU       :   0.     :   0.     :   0.     :   0.     :   16.05  :   19.68  :   0.     :   0.     :   0.     :
-------+---------------+----------+----------+----------+----------+----------+----------+----------+----------+----------+
55 40  :N              :   0      :   0      :   1      :   8      :   7      :   2      :   0      :   1      :   2      :
       :P CLL          :   0.     :   0.     :   0.     :    0.35  :    0.28  :   0.     :   0.     :   0.     :   0.     :
       :P              :   0.     :   0.     :   0.     :    0.75  :    0.71  :   1.00   :   0.     :   0.     :   0.50   :
       :P CLU          :   0.     :   0.     :   0.     :    0.98  :    0.97  :   0.     :   0.     :   0.     :   0.     :
       :XBAR CLL       :   0.     :   0.     :   0.     :    2.65  :    2.22  :   0.     :   0.     :   0.     :   0.     :
       :XBAR           :   0.     :   0.     :   0.     :    4.81  :    4.55  :   0.     :   0.     :   0.     :   0.     :
       :XBAR CLU       :   0.     :   0.     :   0.     :   14.40  :   22.16  :   0.     :   0.     :   0.     :   0.     :
-------+---------------+----------+----------+----------+----------+----------+----------+----------+----------+----------+
55 30  :N              :   3      :  10      :   5      :   5      :   2      :   0      :   0      :   0      :   2      :
       :P CLL          :   0.08   :    0.43  :    0.14  :    0.14  :   0.     :   0.     :   0.     :   0.     :   0.     :
       :P              :   0.67   :    0.80  :    0.60  :    0.60  :   1.00   :   0.     :   0.     :   0.     :   0.50   :
       :P CLU          :   0.99   :    0.98  :    0.95  :    0.95  :   0.     :   0.     :   0.     :   0.     :   0.     :
       :XBAR CLL       :   0.     :    2.02  :    3.33  :    4.81  :   0.     :   0.     :   0.     :   0.     :   0.     :
       :XBAR           :   0.     :    2.85  :    7.46  :   13.70  :   0.     :   0.     :   0.     :   0.     :   0.     :
       :XBAR CLU       :   0.     :    4.54  :   62.35  : 57104.64 :   0.     :   0.     :   0.     :   0.     :   0.     :
-------+---------------+----------+----------+----------+----------+----------+----------+----------+----------+----------+
```

```
                                                   L O N G I T U D E
LAT    !             !  153 40 !   153 20 !  153  0 !  152 40 !   152 20 !     152  0 !  151 40 !  151 20 !  151  0 !
-------+-------------+---------+----------+---------+---------+----------+------------+---------+---------+---------+
58 50  !N            !    0    !    0     !    4    !    4    !     3    !       2    !    3    !    4    !    2    !
       !P CLL        !    0.   !    0.    !    0.   !    0.40 !     0.30 !       0.   !    0.01 !    0.06 !    0.   !
       !P            !    0.   !    0.    !    0.   !    1.00 !     1.00 !       1.00 !    0.33 !    0.50 !    0.   !
       !P CLU        !    0.   !    0.    !    0.60 !    1.00 !     1.00 !       0.   !    0.92 !    0.94 !    0.   !
       !XBAR CLL     !    0.   !    0.    !    0.   !    1.66 !     2.69 !       0.   !    0.   !    0.   !    0.   !
       !XBAR         !    0.   !    0.    !    0.   !    3.24 !     7.66 !       0.   !    0.   !    0.   !    0.   !
       !XBAR CLU     !    0.   !    0.    !    0.   !   12.58 ! 24527.21 !       0.   !    0.   !    0.   !    0.   !
-------+-------------+---------+----------+---------+---------+----------+------------+---------+---------+---------+
58 40  !N            !    0    !    4     !    3    !    2    !     0    !       0    !    0    !    1    !    2    !
       !P CLL        !    0.   !    0.    !    0.08 !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
       !P            !    0.   !    0.    !    0.67 !    0.50 !     0.   !       0.   !    0.   !    1.00 !    1.00 !
       !P CLU        !    0.   !    0.60  !    0.99 !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
       !XBAR CLL     !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
       !XBAR         !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
       !XBAR CLU     !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
-------+-------------+---------+----------+---------+---------+----------+------------+---------+---------+---------+
58 30  !N            !    2    !    1     !    1    !    0    !     1    !       0    !    3    !    0    !    2    !
       !P CLL        !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    0.01 !    0.   !    0.   !
       !P            !    1.00 !    1.00  !    0.   !    0.   !     0.   !       0.   !    0.33 !    0.   !    1.00 !
       !P CLU        !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    0.92 !    0.   !    0.   !
       !XBAR CLL     !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
       !XBAR         !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
       !XBAR CLU     !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
-------+-------------+---------+----------+---------+---------+----------+------------+---------+---------+---------+
58 20  !N            !    2    !    3     !    2    !    0    !     0    !       1    !    1    !    0    !    1    !
       !P CLL        !    0.   !    0.01  !    0.   !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
       !P            !    0.   !    0.33  !    0.   !    0.   !     0.   !       1.00 !    0.   !    0.   !    0.   !
       !P CLU        !    0.   !    0.92  !    0.   !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
       !XBAR CLL     !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
       !XBAR         !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
       !XBAR CLU     !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    0.   !    0.   !    0.   !
-------+-------------+---------+----------+---------+---------+----------+------------+---------+---------+---------+
58 10  !N            !    1    !    1     !    0    !    0    !     0    !       4    !    4    !    1    !    4    !
       !P CLL        !    0.   !    0.    !    0.   !    0.   !     0.   !       0.18 !    0.01 !    0.   !    0.18 !
       !P            !    1.00 !    0.    !    0.   !    0.   !     0.   !       0.75 !    0.25 !    1.00 !    0.75 !
       !P CLU        !    0.   !    0.    !    0.   !    0.   !     0.   !       0.99 !    0.82 !    0.   !    0.99 !
       !XBAR CLL     !    0.   !    0.    !    0.   !    0.   !     0.   !       5.97 !    0.   !    0.   !    1.74 !
       !XBAR         !    0.   !    0.    !    0.   !    0.   !     0.   !      17.10 !    0.   !    0.   !    4.66 !
       !XBAR CLU     !    0.   !    0.    !    0.   !    0.   !     0.   ! 107933.50  !    0.   !    0.   !  373.14 !
-------+-------------+---------+----------+---------+---------+----------+------------+---------+---------+---------+
58  0  !N            !    0    !    0     !    0    !    0    !     0    !       1    !    3    !    2    !    3    !
       !P CLL        !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    0.30 !    0.   !    0.30 !
       !P            !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    1.00 !    1.00 !    1.00 !
       !P CLU        !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    1.00 !    0.   !    1.00 !
       !XBAR CLL     !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !    7.31 !    0.   !    2.71 !
       !XBAR         !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !   13.32 !    0.   !    4.51 !
       !XBAR CLU     !    0.   !    0.    !    0.   !    0.   !     0.   !       0.   !   40.67 !    0.   !   10.32 !
-------+-------------+---------+----------+---------+---------+----------+------------+---------+---------+---------+
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LAT		LONGITUDE								
		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
57 50	N	0	0	0	0	0	11	11	4	2
	P CLL	0.	0.	0.	0.	0.	0.10	0.38	0.01	0.
	P	0.	0.	0.	0.	0.	0.36	0.73	0.25	0.50
	P CLU	0.	0.	0.	0.	0.	0.70	0.94	0.82	0.
	XBAR CLL	0.	0.	0.	0.	0.	7.15	3.08	0.	0.
	XBAR	0.	0.	0.	0.	0.	11.44	5.28	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	23.86	13.16	0.	0.
57 40	N	0	0	0	0	1	20	2	5	4
	P CLL	0.	0.	0.	0.	0.	0.31	0.	0.50	0.01
	P	0.	0.	0.	0.	0.	0.55	1.00	1.00	0.25
	P CLU	0.	0.	0.	0.	0.	0.77	0.	1.00	0.82
	XBAR CLL	0.	0.	0.	0.	0.	12.18	0.	2.68	0.
	XBAR	0.	0.	0.	0.	0.	21.48	0.	5.06	0.
	XBAR CLU	0.	0.	0.	0.	0.	57.85	0.	17.52	0.
57 30	N	0	0	0	0	0	10	0	1	1
	P CLL	0.	0.	0.	0.	0.	0.70	0.	0.	0.
	P	0.	0.	0.	0.	0.	1.00	0.	0.	1.00
	P CLU	0.	0.	0.	0.	0.	1.00	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	7.09	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	11.30	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	23.40	0.	0.	0.
57 20	N	0	0	0	2	2	4	1	0	1
	P CLL	0.	0.	0.	0.	0.	0.40	0.	0.	0.
	P	0.	0.	0.	0.50	0.50	1.00	1.00	0.	1.00
	P CLU	0.	0.	0.	0.	0.	1.00	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	3.55	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	8.95	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	246.12	0.	0.	0.
57 10	N	0	0	1	5	2	0	1	0	0
	P CLL	0.	0.	0.	0.27	0.	0.	0.	0.	0.
	P	0.	0.	1.00	0.80	0.50	0.	1.00	0.	0.
	P CLU	0.	0.	0.	0.99	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	3.24	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	4.83	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	8.55	0.	0.	0.	0.	0.
57 0	N	0	9	4	10	0	2	1	1	0
	P CLL	0.	0.70	0.40	0.26	0.	0.	0.	0.	0.
	P	0.	1.00	1.00	0.60	0.	1.00	0.	1.00	0.
	P CLU	0.	1.00	1.00	0.89	0.	0.	0.	0.	0.
	XBAR CLL	0.	5.21	3.02	2.52	0.	0.	0.	0.	0.
	XBAR	0.	8.58	7.09	3.89	0.	0.	0.	0.	0.
	XBAR CLU	0.	19.17	93.65	7.42	0.	0.	0.	0.	0.

		LONGITUDE								
LAT.		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
56 50	N	0	4	7	3	0	4	1	1	0
	P CLL	0.	0.40	0.17	0.08	0.	0.18	0.	0.	0.
	P	0.	1.00	0.57	0.67	0.	0.75	1.00	1.00	0.
	P CLU	0.	1.00	0.90	0.99	0.	0.99	0.	0.	0.
	XBAR CLL	0.	3.03	2.46	0.	0.	1.51	0.	0.	0.
	XBAR	0.	6.19	3.62	0.	0.	4.35	0.	0.	0.
	XBAR CLU	0.	29.24	6.27	0.	0.	32519.90	0.	0.	0.
56 40	N	3	3	2	0	1	1	0	0	0
	P CLL	0.30	0.30	0.	0.	0.	0.	0.	0.	0.
	P	1.00	1.00	0.50	0.	1.00	1.00	0.	0.	0.
	P CLU	1.00	1.00	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	1.63	6.55	0.	0.	0.	0.	0.	0.	0.
	XBAR	4.26	17.96	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	182.16	2164.59	0.	0.	0.	0.	0.	0.	0.
56 30	N	2	2	1	0	2	1	1	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	1.00	1.00	1.00	0.	0.50	1.00	1.00	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 20	N	5	0	0	0	1	1	1	0	2
	P CLL	0.50	0.	0.	0.	0.	0.	0.	0.	0.
	P	1.00	0.	0.	0.	1.00	0.	0.	0.	0.
	P CLU	1.00	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	2.07	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	3.17	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	5.98	0.	0.	0.	0.	0.	0.	0.	0.
56 10	N	0	2	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.50	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 0	N	3	1	2	1	0	0	0	0	1
	P CLL	0.08	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.67	0.	1.00	0.	0.	0.	0.	0.	0.
	P CLU	0.99	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
55 50	N	2	0	0	1	0	0	0	1	2
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.50	0.	0.	1.00	0.	0.	0.	0.	0.50
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 40	N	2	2	0	0	0	0	1	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	1.00	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 30	N	1	0	0	0	1	2	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	1.00	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
58 50	N	3	3	1	0	0	2	2	1	0
	P CLL	0.	0.01	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.33	0.	0.	0.	0.50	0.	0.	0.
	P CLU	0.70	0.92	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 40	N	0	1	3	1	3	0	2	6	0
	P CLL	0.	0.	0.01	0.	0.	0.	0.	0.00	0.
	P	0.	1.00	0.33	0.	0.	0.	0.	0.17	0.
	P CLU	0.	0.	0.92	0.	0.70	0.	0.	0.65	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 30	N	2	0	2	2	2	0	3	6	2
	P CLL	0.	0.	0.	0.	0.	0.	0.01	0.00	0.
	P	1.00	0.	1.00	1.00	1.00	0.	0.33	0.17	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.92	0.65	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 20	N	4	4	0	0	0	0	0	2	3
	P CLL	0.01	0.40	0.	0.	0.	0.	0.	0.	0.01
	P	0.25	1.00	0.	0.	0.	0.	0.	0.	0.33
	P CLU	0.82	1.00	0.	0.	0.	0.	0.	0.	0.92
	XBAR CLL	0.	5.98	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	13.38	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	110.21	0.	0.	0.	0.	0.	0.	0.
58 10	N	5	3	4	0	0	2	0	0	0
	P CLL	0.14	0.01	0.18	0.	0.	0.	0.	0.	0.
	P	0.60	0.33	0.75	0.	0.	1.00	0.	0.	0.
	P CLU	0.95	0.92	0.99	0.	0.	0.	0.	0.	0.
	XBAR CLL	6.89	0.	2.58	0.	0.	0.	0.	0.	0.
	XBAR	10.06	0.	5.96	0.	0.	0.	0.	0.	0.
	XBAR CLU	17.09	0.	59.34	0.	0.	0.	0.	0.	0.
58 0	N	3	2	6	0	2	0	0	0	1
	P CLL	0.30	0.	0.35	0.	0.	0.	0.	0.	0.
	P	1.00	0.50	0.83	0.	1.00	0.	0.	0.	0.
	P CLU	1.00	0.	1.00	0.	0.	0.	0.	0.	0.
	XBAR CLL	3.39	0.	1.14	0.	0.	0.	0.	0.	0.
	XBAR	9.16	0.	1.84	0.	0.	0.	0.	0.	0.
	XBAR CLU	894.10	0.	3.94	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
57 50	N	0	1	3	3	2	1	2	3	1
	P CLL	0.	0.	0.01	0.01	0.	0.	0.	0.01	0.
	P	0.	0.	0.33	0.33	0.	0.	0.	0.33	0.
	P CLU	0.	0.	0.92	0.92	0.	0.	0.	0.92	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 40	N	4	3	1	0	4	0	0	0	0
	P CLL	0.	0.01	0.	0.	0.06	0.	0.	0.	0.
	P	0.	0.33	0.	0.	0.50	0.	0.	0.	0.
	P CLU	0.60	0.92	0.	0.	0.94	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 30	N	2	1	0	1	0	4	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.06	0.	0.	0.
	P	1.00	1.00	0.	0.	0.	0.50	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.94	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 20	N	5	3	0	1	0	0	8	1	0
	P CLL	0.	0.08	0.	0.	0.	0.	0.07	0.	0.
	P	0.	0.67	0.	0.	0.	0.	0.38	0.	0.
	P CLU	0.50	0.99	0.	0.	0.	0.	0.76	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.47	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.92	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	3.48	0.	0.
57 10	N	1	1	2	1	0	1	0	5	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.01	0.
	P	1.00	1.00	0.50	1.00	0.	0.	0.	0.20	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.73	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 0	N	0	0	0	0	2	3	2	0	6
	P CLL	0.	0.	0.	0.	0.	0.01	0.	0.	0.
	P	0.	0.	0.	0.	0.50	0.33	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.92	0.	0.	0.40
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

LONGITUDE

LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
56 50	N	0	0	0	0	0	0	3	1	2
	P CLL	0.	0.	0.	0.	0.	0.	0.01	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.33	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.92	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 40	N	0	0	0	0	0	0	1	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	1.00	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 30	N	0	0	0	1	1	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	1.00	1.00	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 20	N	0	0	0	1	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	1.00	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 10	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 0	N	1	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
55 50	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 40	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 30	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

Table 7. Confidence limits on the density of shearwaters by 20-km blocks in the vicinity of Kodiak. See Table 3 for definitions of symbols.

```
                                                   L O N G I T U D E
LAT   :          :  156 40  :  156 20  :  156  0  :  155 40  :  155 20  :  155  0  :  154 40  :  154 20  :  154  0  :
------+----------+----------+----------+----------+----------+----------+----------+----------+----------+----------+
58 50 :N         :    0     :    0     :    0     :    0     :    0     :    0     :    0     :    0     :    0     :
      :P CLL     :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :P         :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :P CLU     :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR CLL  :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR      :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR CLU  :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
------+----------+----------+----------+----------+----------+----------+----------+----------+----------+----------+
58 40 :N         :    0     :    0     :    0     :    0     :    0     :    0     :    0     :    0     :    0     :
      :P CLL     :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :P         :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :P CLU     :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR CLL  :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR      :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR CLU  :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
------+----------+----------+----------+----------+----------+----------+----------+----------+----------+----------+
58 30 :N         :    0     :    0     :    0     :    0     :    0     :    0     :    0     :    0     :    0     :
      :P CLL     :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :P         :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :P CLU     :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR CLL  :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR      :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR CLU  :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
------+----------+----------+----------+----------+----------+----------+----------+----------+----------+----------+
58 20 :N         :    0     :    0     :    0     :    0     :    0     :    0     :    0     :    0     :    2     :
      :P CLL     :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :P         :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :P CLU     :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR CLL  :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR      :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR CLU  :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
------+----------+----------+----------+----------+----------+----------+----------+----------+----------+----------+
58 10 :N         :    0     :    0     :    0     :    0     :    0     :    0     :    0     :    0     :    2     :
      :P CLL     :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :P         :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    1.00  :
      :P CLU     :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR CLL  :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR      :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR CLU  :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
------+----------+----------+----------+----------+----------+----------+----------+----------+----------+----------+
58  0 :N         :    0     :    0     :    0     :    0     :    0     :    0     :    0     :    1     :    4     :
      :P CLL     :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :P         :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    1.00  :    0.    :
      :P CLU     :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.60  :
      :XBAR CLL  :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR      :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
      :XBAR CLU  :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :    0.    :
------+----------+----------+----------+----------+----------+----------+----------+----------+----------+----------+
```

		L O N G I T U D E								
LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
57 50	N	0	0	0	0	0	0	2	4	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.01	0.
	P	0.	0.	0.	0.	0.	0.	0.50	0.25	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.82	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 40	N	0	0	0	0	0	2	5	1	0
	P CLL	0.	0.	0.	0.	0.	0.	0.05	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.40	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.86	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 30	N	0	0	0	2	2	5	2	0	0
	P CLL	0.	0.	0.	0.	0.	0.01	0.	0.	0.
	P	0.	0.	0.	0.50	0.	0.20	0.50	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.73	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 20	N	1	0	0	2	2	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.50	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 10	N	0	0	0	5	0	0	0	0	0
	P CLL	0.	0.	0.	0.05	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.40	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.86	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 0	N	0	0	3	5	0	1	0	0	0
	P CLL	0.	0.	0.01	0.01	0.	0.	0.	0.	0.
	P	0.	0.	0.33	0.20	0.	1.00	0.	0.	0.
	P CLU	0.	0.	0.92	0.73	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

LONGITUDE

LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
56 50	N	0	0	3	3	0	2	1	0	0
	P CLL	0.	0.	0.01	0.08	0.	0.	0.	0.	0.
	P	0.	0.	0.33	0.67	0.	0.	1.00	0.	0.
	P CLU	0.	0.	0.92	0.99	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 40	N	1	1	0	0	2	1	2	0	6
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.35
	P	1.00	0.	0.	0.	0.50	0.	0.50	0.	0.83
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	1.00
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	49.42
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	119.75
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	2356.96
56 30	N	2	0	0	0	1	1	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	1.00	1.00	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 20	N	1	0	0	0	1	0	0	0	6
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.35
	P	1.00	0.	0.	0.	1.00	0.	0.	0.	0.83
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	1.00
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	111.26
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	281.26
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	7833.88
56 10	N	1	0	0	1	0	1	5	4	0
	P CLL	0.	0.	0.	0.	0.	0.	0.14	0.18	0.
	P	0.	0.	0.	0.	0.	1.00	0.60	0.75	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.95	0.99	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	1.40	20.17	0.
	XBAR	0.	0.	0.	0.	0.	0.	2.70	59.45	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	9.95	.1149E+07	0.
56 0	N	0	1	0	1	1	1	4	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.18	0.	0.
	P	0.	0.	0.	1.00	1.00	1.00	0.75	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.99	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	2.96	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	6.57	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	51.61	0.	0.

LONGITUDE

LAT		156 40	156 20	156 0	155 40	155 20	155 0	154 40	154 20	154 0
55 50	N	0	0	0	1	3	8	1	2	0
	P CLL	0.	0.	0.	0.	0.30	0.15	0.	0.	0.
	P	0.	0.	0.	0.	1.00	0.50	1.00	0.	0.
	P CLU	0.	0.	0.	0.	1.00	0.85	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	602.62	12.42	0.	0.	0.
	XBAR	0.	0.	0.	0.	1674.43	26.43	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	.1843E+13	160.18	0.	0.	0.
55 40	N	0	0	1	8	7	2	0	1	2
	P CLL	0.	0.	0.	0.35	0.17	0.	0.	0.	0.
	P	0.	0.	0.	0.75	0.57	0.50	0.	0.	1.00
	P CLU	0.	0.	0.	0.98	0.90	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	13.71	14.47	0.	0.	0.	0.
	XBAR	0.	0.	0.	27.78	26.90	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	127.23	88.07	0.	0.	0.	0.
55 30	N	3	10	5	5	2	0	0	0	2
	P CLL	0.08	0.34	0.14	0.05	0.	0.	0.	0.	0.
	P	0.67	0.70	0.60	0.40	0.	0.	0.	0.	1.00
	P CLU	0.99	0.94	0.95	0.86	0.	0.	0.	0.	0.
	XBAR CLL	0.	2.30	0.94	0.	0.	0.	0.	0.	0.
	XBAR	0.	4.11	2.46	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	11.60	93.95	0.	0.	0.	0.	0.	0.

LAT		LONGITUDE								
		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
58 50	N	0	0	4	4	3	2	3	4	2
	P CLL	0.	0.	0.01	0.40	0.30	0.	0.01	0.18	0.
	P	0.	0.	0.25	1.00	1.00	0.50	0.33	0.75	0.
	P CLU	0.	0.	0.82	1.00	1.00	0.	0.92	0.99	0.
	XBAR CLL	0.	0.	0.	55.54	7.11	0.	0.	1.72	0.
	XBAR	0.	0.	0.	154.53	20.43	0.	0.	3.88	0.
	XBAR CLU	0.	0.	0.	22448.68	166820.62	0.	0.	33.16	0.
58 40	N	0	4	3	2	0	0	0	1	2
	P CLL	0.	0.01	0.08	0.	0.	0.	0.	0.	0.
	P	0.	0.25	0.67	1.00	0.	0.	0.	1.00	1.00
	P CLU	0.	0.82	0.99	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 30	N	2	1	1	0	1	0	3	0	2
	P CLL	0.	0.	0.	0.	0.	0.	0.30	0.	0.
	P	0.	0.	1.00	0.	0.	0.	1.00	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	1.00	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	83.76	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	240.81	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	.1932E+07	0.	0.
58 20	N	2	3	2	0	0	1	1	0	1
	P CLL	0.	0.01	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.33	1.00	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.92	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 10	N	1	1	0	0	0	4	4	1	4
	P CLL	0.	0.	0.	0.	0.	0.01	0.01	0.	0.18
	P	1.00	0.	0.	0.	0.	0.25	0.25	1.00	0.75
	P CLU	0.	0.	0.	0.	0.	0.82	0.82	0.	0.99
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	9.43
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	28.06
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	664485.31
58 0	N	0	0	0	0	0	1	3	2	3
	P CLL	0.	0.	0.	0.	0.	0.	0.30	0.	0.08
	P	0.	0.	0.	0.	0.	0.	1.00	1.00	0.67
	P CLU	0.	0.	0.	0.	0.	0.	1.00	0.	0.99
	XBAR CLL	0.	0.	0.	0.	0.	0.	9.89	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	21.08	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	129.32	0.	0.

LAT		LONGITUDE								
		153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
57 50	N	0	0	0	0	0	11	11	4	2
	P CLL	0.	0.	0.	0.	0.	0.02	0.38	0.01	0.
	P	0.	0.	0.	0.	0.	0.18	0.73	0.25	1.00
	P CLU	0.	0.	0.	0.	0.	0.53	0.94	0.82	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	13.12	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	27.42	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	143.79	0.	0.
57 40	N	0	0	0	0	1	20	2	5	4
	P CLL	0.	0.	0.	0.	0.	0.31	0.	0.50	0.
	P	0.	0.	0.	0.	0.	0.55	1.00	1.00	0.
	P CLU	0.	0.	0.	0.	0.	0.77	0.	1.00	0.60
	XBAR CLL	0.	0.	0.	0.	0.	82.35	0.	7.51	0.
	XBAR	0.	0.	0.	0.	0.	168.07	0.	11.41	0.
	XBAR CLU	0.	0.	0.	0.	0.	793.41	0.	21.04	0.
57 30	N	0	0	0	0	0	10	0	1	1
	P CLL	0.	0.	0.	0.	0.	0.26	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.60	0.	1.00	0.
	P CLU	0.	0.	0.	0.	0.	0.89	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	43.38	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	100.51	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	1075.23	0.	0.	0.
57 20	N	0	0	0	2	2	4	1	0	1
	P CLL	0.	0.	0.	0.	0.	0.40	0.	0.	0.
	P	0.	0.	0.	0.	0.50	1.00	1.00	0.	1.00
	P CLU	0.	0.	0.	0.	0.	1.00	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	48.14	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	115.16	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	1975.47	0.	0.	0.
57 10	N	0	0	1	5	2	0	1	0	0
	P CLL	0.	0.	0.	0.01	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.20	1.00	0.	1.00	0.	0.
	P CLU	0.	0.	0.	0.73	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 0	N	0	9	4	10	0	2	1	1	0
	P CLL	0.	0.00	0.18	0.43	0.	0.	0.	0.	0.
	P	0.	0.11	0.75	0.80	0.	1.00	0.	1.00	0.
	P CLU	0.	0.49	0.99	0.98	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	492.72	974.21	0.	0.	0.	0.	0.
	XBAR	0.	0.	1341.40	2624.00	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	.1850E+13	240961.00	0.	0.	0.	0.	0.

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                                              LONGITUDE
LAT   !             !    153 40 !    153 20 !    153  0 !    152 40 !    152 20 !    152  0 !    151 40 !    151 20 !    151  0 !
------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
56 50 !N            !        0  !        4  !        7  !        3  !        0  !        4  !        1  !        1  !        0  !
      !P CLL        !       0.  !     0.06  !     0.41  !     0.30  !       0.  !     0.01  !       0.  !       0.  !       0.  !
      !P            !       0.  !     0.50  !     0.86  !     1.00  !       0.  !     0.25  !       0.  !     1.00  !       0.  !
      !P CLU        !       0.  !     0.94  !     1.00  !     1.00  !       0.  !     0.82  !       0.  !       0.  !       0.  !
      !XBAR CLL     !       0.  !       0.  !   242.16  !    17.26  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR         !       0.  !       0.  !   607.36  !    47.86  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLU     !       0.  !       0.  ! 16011.05  !  6665.89  !       0.  !       0.  !       0.  !       0.  !       0.  !
------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
56 40 !N            !        3  !        3  !        2  !        0  !        1  !        1  !        0  !        0  !        0  !
      !P CLL        !     0.08  !     0.30  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P            !     0.67  !     1.00  !     1.00  !       0.  !     1.00  !       0.  !       0.  !       0.  !       0.  !
      !P CLU        !     0.99  !     1.00  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLL     !       0.  !    34.09  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR         !       0.  !   101.50  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLU     !       0.  ! .2414E+07 !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
56 30 !N            !        2  !        2  !        1  !        0  !        2  !        1  !        1  !        0  !        0  !
      !P CLL        !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P            !     1.00  !       0.  !     1.00  !       0.  !     0.50  !       0.  !       0.  !       0.  !       0.  !
      !P CLU        !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLL     !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR         !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLU     !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
56 20 !N            !        5  !        0  !        0  !        0  !        1  !        1  !        1  !        0  !        2  !
      !P CLL        !     0.01  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P            !     0.20  !       0.  !       0.  !       0.  !     1.00  !     1.00  !     1.00  !       0.  !     1.00  !
      !P CLU        !     0.73  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLL     !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR         !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLU     !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
56 10 !N            !        0  !        2  !        0  !        0  !        0  !        0  !        0  !        0  !        0  !
      !P CLL        !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P            !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P CLU        !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLL     !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR         !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLU     !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
56  0 !N            !        3  !        1  !        2  !        1  !        0  !        0  !        0  !        0  !        1  !
      !P CLL        !     0.30  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P            !     1.00  !       0.  !     0.50  !     1.00  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !P CLU        !     1.00  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLL     !     4.98  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR         !    14.80  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
      !XBAR CLU     ! 331023.19 !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !       0.  !
------+-------------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+-----------+
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LAT		LONGITUDE 153 40	153 20	153 0	152 40	152 20	152 0	151 40	151 20	151 0
55 50	N	2	0	0	1	0	0	0	1	2
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.50	0.	0.	1.00	0.	0.	0.	1.00	0.50
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 40	N	2	2	0	0	0	0	1	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	1.00	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 30	N	1	0	0	0	1	2	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	1.00	0.	0.	0.	1.00	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
		LONGITUDE								
58 50	N	3	3	1	0	0	2	2	1	0
	P CLL	0.	0.08	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.67	0.	0.	0.	0.	0.50	0.	0.
	P CLU	0.70	0.99	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 40	N	0	1	3	1	3	0	2	6	0
	P CLL	0.	0.	0.	0.	0.08	0.	0.	0.03	0.
	P	0.	1.00	0.	0.	0.67	0.	0.	0.33	0.
	P CLU	0.	0.	0.70	0.	0.99	0.	0.	0.79	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 30	N	2	0	2	2	2	0	3	6	2
	P CLL	0.	0.	0.	0.	0.	0.	0.01	0.00	0.
	P	0.50	0.	0.50	0.50	0.50	0.	0.33	0.17	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.92	0.65	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
58 20	N	4	4	0	0	0	0	0	2	3
	P CLL	0.18	0.40	0.	0.	0.	0.	0.	0.	0.
	P	0.75	1.00	0.	0.	0.	0.	0.	1.00	0.
	P CLU	0.99	1.00	0.	0.	0.	0.	0.	0.	0.70
	XBAR CLL	110.41	4.98	0.	0.	0.	0.	0.	0.	0.
	XBAR	311.54	10.61	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	.2789E+12	64.63	0.	0.	0.	0.	0.	0.	0.
58 10	N	5	3	4	0	0	2	0	0	0
	P CLL	0.14	0.08	0.18	0.	0.	0.	0.	0.	0.
	P	0.60	0.67	0.75	0.	0.	0.	0.	0.	0.
	P CLU	0.95	0.99	0.99	0.	0.	0.	0.	0.	0.
	XBAR CLL	17.64	0.	3.66	0.	0.	0.	0.	0.	0.
	XBAR	27.00	0.	10.98	0.	0.	0.	0.	0.	0.
	XBAR CLU	50.56	0.	296058.00	0.	0.	0.	0.	0.	0.
58 0	N	3	2	6	0	2	0	0	0	1
	P CLL	0.30	0.	0.00	0.	0.	0.	0.	0.	0.
	P	1.00	0.	0.17	0.	0.	0.	0.	0.	0.
	P CLU	1.00	0.	0.65	0.	0.	0.	0.	0.	0.
	XBAR CLL	2158.03	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	5893.21	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	.2056E+20	0.	0.	0.	0.	0.	0.	0.	0.

LONGITUDE

LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
57 50	N	0	1	3	3	2	1	2	3	1
	P CLL	0.	0.	0.	0.01	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.33	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.70	0.92	0.	0.	0.	0.70	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 40	N	4	3	1	0	4	0	0	0	0
	P CLL	0.	0.	0.	0.	0.18	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.75	0.	0.	0.	0.
	P CLU	0.60	0.70	0.	0.	0.99	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.66	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	1.57	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	24.74	0.	0.	0.	0.
57 30	N	2	1	0	1	0	4	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	1.00	1.00	0.	1.00	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.60	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 20	N	5	3	0	1	0	0	8	1	0
	P CLL	0.	0.30	0.	0.	0.	0.	0.02	0.	0.
	P	0.	1.00	0.	1.00	0.	0.	0.25	0.	0.
	P CLU	0.50	1.00	0.	0.	0.	0.	0.65	0.	0.
	XBAR CLL	0.	5.02	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	13.98	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	2062.86	0.	0.	0.	0.	0.	0.	0.
57 10	N	1	1	2	1	0	1	0	5	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.50	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.50	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
57 0	N	0	0	0	0	2	3	2	0	6
	P CLL	0.	0.	0.	0.	0.	0.01	0.	0.	0.00
	P	0.	0.	0.	0.	0.	0.33	0.	0.	0.17
	P CLU	0.	0.	0.	0.	0.	0.92	0.	0.	0.65
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

		L O N G I T U D E								
LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
56 50	N	0	0	0	0	0	0	3	1	2
	P CLL	0.	0.	0.	0.	0.	0.	0.01	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.33	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.92	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 40	N	0	0	0	0	0	0	1	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	1.00	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 30	N	0	0	0	1	1	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	1.00	1.00	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 20	N	0	0	0	1	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	1.00	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 10	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
56 0	N	1	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

		LONGITUDE								
LAT		150 40	150 20	150 0	149 40	149 20	149 0	148 40	148 20	148 0
55 50	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 40	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
55 30	N	0	0	0	0	0	0	0	0	0
	P CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P	0.	0.	0.	0.	0.	0.	0.	0.	0.
	P CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLL	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR	0.	0.	0.	0.	0.	0.	0.	0.	0.
	XBAR CLU	0.	0.	0.	0.	0.	0.	0.	0.	0.

IX. LITERATURE CITED

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Shorebird Dependence on Arctic Littoral Habitats

Annual Report, R.U. 172

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I. Summary of Objectives, Conclusions and Implications

Shorebirds (sandpipers, plovers, and their relatives) are a major and important component of the Alaskan arctic avifauna. Prior to 1975, shorebird work in the Arctic had concentrated on events on the tundra, where these birds nest, and had largely been confined to the brief breeding period. In this study we have documented seasonal, and occasionally very heavy, use of littoral (shoreline) habitats by shorebirds and other birds in the Arctic.

The ultimate objective of Research Unit #172 is the assessment of the degree and nature of dependence of shorebird species on arctic habitats which are potentially susceptible to perturbation from offshore oil development activities. Within this objective, we have identified critical habitats, critical trophic processes, and critical areas of the Beaufort and Chukchi coasts, and we are estimating the relative susceptibilities of each shorebird species to potential disturbances. Efforts in 1979 focused primarily on this last objective and on final analysis of previous years' data.

For most topics, covered in previous annual reports, the final round of synthesis is not ready for inclusion here. Late notification of contract renewal and time-consuming problems with data entry equipment and software have delayed these efforts. Results for 1979 include brief observations of a markedly different distribution of littoral zone shorebird activity at Barrow compared with the four preceding years. Juvenile phalaropes, and to some extent other shorebirds, gulls, and terns, were less common along gravel shorelines in 1979. Instead, phalaropes were more common in Middle Salt Lagoon than in previous years, an apparent shift to exploit the high densities of small calanoid copepods in that lagoon. Along outer shores, marine zooplankton appeared to be relatively scarce, although no quantitative data are available. Thus, 1979 extended our appreciation of the variability in this system between years, and provided a good example of the flexibility of phalaropes under altered resource conditions.

For many bird species in some coastal areas we can now predict (for a hypothetical oil spill) the rate of encounter, on an area basis, of birds and oil. However, this is only part of the answer needed, since birds may affect the consequences of encounters by their subsequent behavior. A limited series of choice experiments, using shallow pans containing brine shrimp in water, suggested that naive juvenile Red Phalaropes did not distinguish between oiled and clear surfaces for foraging before they had any experience with the oil. However, upon contact they have a fairly consistent and very quick response to avoid the oil, and subsequently within the same trial period they can and do distinguish between oiled and clear surfaces, selecting clear surfaces. This suggests that through behavioral responses, Red Phalaropes may reduce the impact of small coastal oil spills. However, the outcome of even this brief learning exposure on survival will depend on the type and thickness of the oil film, the degree of contact, the accompanying stress due to environmental factors, and the physiological state of the bird. Effects of these factors are unknown.

II. Introduction

Shorebirds (Charadriiformes: Charadrii; Sandpipers, plovers and their close relatives) constitute a major and prominent segment of the avifauna of the Beaufort and Chukchi coasts of arctic Alaska (Bailey 1948; Gabrielson and Lincoln 1959; Pitelka 1974; Table 1). All of these 27 species, which occur regularly in the Arctic during summer months, spend their winters in temperate and tropical regions of both northern and southern hemispheres. As a group, they are an international resource, with individual species dependent in varying degrees on summer conditions along the Alaskan arctic coast.

Prior to 1975, considerable effort had been expended on studies of the ecology of tundra nesting shorebirds near Barrow, Alaska (see Connors and Risebrough 1977 for references). These studies dealt almost exclusively with conditions on the upland tundra, primarily during the short arctic breeding season. It had been noted, at Barrow and elsewhere in the Arctic, that densities of several species of shorebirds increase near the shoreline as the summer progresses, resulting in a net increase in use of littoral habitats (Holmes 1966; Bengtson 1970). This movement begins with non-breeders and is augmented progressively by a shoreward movement of local and also inland birds, especially after the young have fledged. However, the importance of this habitat shift in the breeding cycle of arctic shorebirds had not been adequately evaluated.

This study is attempting to provide the detailed and quantitative information necessary to assess the dependence of shorebirds and other species on littoral habitats along the Alaskan arctic coast. We wish to determine the relative susceptibilities of different species to potential impacts of oil development, and to identify sensitive species, habitats, areas, and periods to aid in OCSEAP development decisions. We are addressing several aspects of shorebird ecology essential to evaluating the significance of the littoral zone for shorebirds, gulls, and terns: seasonal occurrence of these birds by species, age, and sex, in different habitats; trophic relationships of shorebirds and other birds feeding in littoral habitas, and variability in foraging habitat preferences; and behavioral patterns and other aspects of littoral zone use by shorebirds, gulls, and terns. Further, we are using habitats already subjected to development alterations, chiefly at Prudhoe Bay, to assess the probable effects of disturbances associated with the development of offshore oilfields.

The relevance of this investigation to problems of coastal petroleum development is clear. To the extent that shorebirds and other birds utilize and depend upon shore and nearshore habitats, any perturbation of these habitats can affect them. Use of littoral habitats in the Arctic appears to be heaviest by juveniles moving from inland nesting areas to the coast in late summer, prior to their long-distance migrations. Since post-fledging mortality of juveniles is a significant factor in determining reproductive success, alteration of required habitat conditions for these birds could affect population levels over wide areas.

Table 1. Shorebird species occurring regularly along the Beaufort and Chukchi coasts of Alaska (from Connors *et al*., 1979).

Regular Breeders

Semipalmated Plover, *Charadrius semipalmatus*
American Golden Plover, *Pluvialis dominica*
Black-bellied Plover, *Pluvialis squatarola*
Ruddy Turnstone, *Arenaria interpres*
Black Turnstone, *Arenaria malanocephala*
Common Snipe, *Capella gallinago*
Whimbrel, *Numenius phaeopus*
Red Knot, *Calidris canutus*
Pectoral Sandpiper, *Calidris melanotos*
White-rumped Sandpiper, *Calidris fuscicollis*
Baird's Sandpiper, *Calidris bairdii*
Dunlin, *Calidris alpina*
Semipalmated Sandpiper, *Calidris pusilla*
Western Sandpiper, *Calidris mauri*
Stilt Sandpiper, *Micropalama himantopus*
Buff-breasted Sandpiper, *Tryngites subruficollis*
Long-billed Dowitcher, *Limnodromus scolopaceus*
Bar-tailed Godwit, *Limosa lapponica*
Red Phalarope, *Phalaropus fulicarius*
Northern Phalarope, *Lobipes lobatus*

Additional Migrants

Killdeer, *Charadrius vociferus*
Sharp-tailed Sandpiper, *Calidris acuminata*
Least Sandpiper, *Calidris minutilla*
Rufous-necked Sandpiper, *Calidris ruficollis*
Curlew Sandpiper, *Calidris ferruginea*
Sanderling, *Calidris alba*
Hudsonian Godwit, *Limosa haemastica*

Most of the efforts within this project have contributed to predicting the incidence of encounters by shorebirds with a hypothetical oil spill in a particular habitat at arctic coastal sites. This is only the first order answer to the question of effects of the spill. Second order effects, mainly through trophic dependencies, are also being addressed, and sublethal effects must be considered, since these may affect fitness and eventual reproduction. In addition, the severity of the first order effect (oil contact) may be altered by the behavior of individual birds confronted by the oil spill. For example, waterfowl may be attracted to an oil spill on the ice, increasing the frequency of contact over that which would be calculated based on the area of the oil spill and the density and distribution of birds. Alternatively, birds may avoid spilled oil, thereby decreasing their susceptibility in the presence of a spill. In 1979 we began experiments to determine the responses of juvenile Red Phalaropes to the presence of oil on water.

III. Current State of Knowledge

Available background information prior to RU #172 is referred to in the introductory paragraphs. Conclusions of previous seasons of field work by this RU are reported in earlier annual reports. Briefly: we now have a good understanding of many shorebird habitat use patterns, seasonal movements, distributions, and relative susceptibilities near Prudhoe Bay, Barrow, the northern Chukchi and parts of Hope Basin. Our appreciation of trophic relationships in these areas has improved, but significant questions remain. And we now have estimates of the magnitude of effects of some habitat disturbances associated with development, but lack the information necessary to estimate the effects of spilled oil disturbances.

IV. Study Area

Field activities in 1979 were conducted briefly at the Naval Arctic Research Laboratory, Barrow, Alaska (71°17'N, 156°46'W) from 3-30 August.

V. Methods

Much of our recent effort has been devoted to data entry with the new Texas Instruments terminal. Several problems have been overcome, but other analysis has stalled awaiting these solutions.

While at Barrow observing the distribution of shorebirds on shoreline transects established during previous summers, we performed two experiments with juvenile Red Phalaropes. We wished to test whether phalaropes can distinguish between oiled and clear water surfaces on potential foraging sites, and what their responses will be if they can distinguish oil on water.

We constructed a cylindrical pen of hardware cloth (1.9 cm mesh), 1.5 meter diameter, 1.4 meter height, wrapped with black plastic to a height of .6 meters to isolate birds from visual distractions. Within this pen, we placed a continuous ring of 8 identical shallow galvanized metal pans, each 40 cm inner diameter, 9 cm depth. A central plywood disc or table (80 cm in diameter) rested on all 8 pans, but left most of each pan uncovered. A bird standing on the center table has a choice of entering any of the pans which form a symmetrical ring around the circumference of the table.

During the experiments, all pans contained seawater to a depth of 7 cm, and equal densities of live brine shrimp, Artemia franciscana, (1.3 ml drained brine shrimp per pan, equal to approximately 150 prey items).

Juvenile Red Phalaropes were acclimated to the experimental setup for 2 to 3 hours with water containing prey, but with no oil. This acclimation period was necessary because the initial response of wild birds introduced to the cage often entailed fluttering escape attempts which resulted in the birds falling into pans. We wished to observe choices by the birds, not accidents.

For choice experiments, we placed a thin film of oil on 4 pans alternating with 4 clear pans around the circumference of the table. All pans contained equal amounts of water and prey. Oiled pans contained 10 ml of a 1:1 mixture of Prudhoe crude oil and diesel fuel (JPR-5). This formed an irregular surface film of small patches and spots of a medium brown semitransparent film, covering approximately 60% of the surface. To our eyes, the oiled and clear pans appeared distinctly different. Many of the moving prey could be readily seen in both clear and oiled pans. However, prey were more easily seen by us in clear pans.

To initiate an experiment, the bird was placed under a small box in the center of the table. The box was hoisted smoothly to the top of the cage by remote control, releasing the bird in the center of the table to choose a foraging pan. Two observers sat inside a nearby laboratory above the cage, recording movements, behavior, and sequence and duration of choices for a trial period of 15 minutes per bird. The behavior of most birds, entailing a period of inspection of several pans from the table edge before entering any pan, leads us to conclude that the birds were in some way choosing foraging pans based on the results of that initial inspection. The inspection period often lasted several minutes and included visual inspection of many or all pans. Choices were scored when a bird entered a pan directly from the table, and duration of foraging periods was timed until the bird left the pan. Until the end of the 15 minute trial period, subsequent entries were scored as sequential choices.

In a second experiment, phalaropes previously acclimated to swimming and foraging in a 15 gallon glass aquarium (rectangular, 30 cm x 60 cm x 8 cm depth of seawater) were placed singly in the aquarium containing .9 ml of drained brine shrimp (approximately 100 prey).

Behavior of each bird was timed for 60 seconds, in the absence of oil and in the presence of very thin films (1.1 μm and 2.8 μm) of the 1:1 mixture of crude oil and diesel fuel.

VI and VII. Results and Discussion

The initial results of the choice experiment are presented in Figure 1, comparing the number of choices made for clean pans and for oiled pans as a function of the sequence number of the choice. Of 12 birds making choices, all 12 made a first choice, 6 of them for oiled pans and 6 of them for clear pans. Only 10 of them made a second choice, 8 made third choices, and so forth, with only one bird making a twelfth choice. There is no suggestion of any discrimination in that first choice; birds were as likely to choose oiled as clear pans. Bur on subsequent choices, behavior changed. After the second round of choices, birds were able to make a distinction and were opting for clear pans rather than oiled. Of the last 33 choices, only 2 were for oiled pans. The birds seem to have learned something of the effects of the oil very quickly. They apparently can make the distinction and do learn to avoid the oil.

Figure 2 addresses a possible alternative explanation for these results: that any birds entering the oil on the first or second choice might be so damaged by the oil that they failed to make any subsequent choices, and that all later choices were made by birds who chose clear pans consistently. This explanation does not apply. Figure 2 is a comparison of the total number of choices made by all of the 12 individuals split up into two groups depending on whether they chose oil or clear on the first choice. It demonstrates that birds choosing oil initially did continue to make subsequent choices; most of these choices were for clear pans.

The duration of foraging periods also differed between oiled and clear pans, as indicated in Figure 3. The frequency histograms contrast markedly. A Mann-Whitney comparison of the duration of foraging periods on oiled vs. clear is significant ($p < .01$). The median duration on clear pans was 33 seconds, compared with a median time of only 5 seconds on oiled pans, an indication that once the birds get on the oil, they quickly respond to something and on average get out early.

The aquarium experiments support this conclusion. Phalarope behavior was recorded as foraging, resting, and escape behavior. This latter category includes swimming hard against the side of the aquarium, swimming rapidly from one side of the aquarium to the other, and occasionally attempting to fly. The percent of time spent by phalaropes in these escape behaviors varied widely, but increased strongly with increasing oil film thickness (Figure 4). In the presence of even these extremely thin oil films, the birds quickly sensed the difference and responded by trying to avoid the oil.

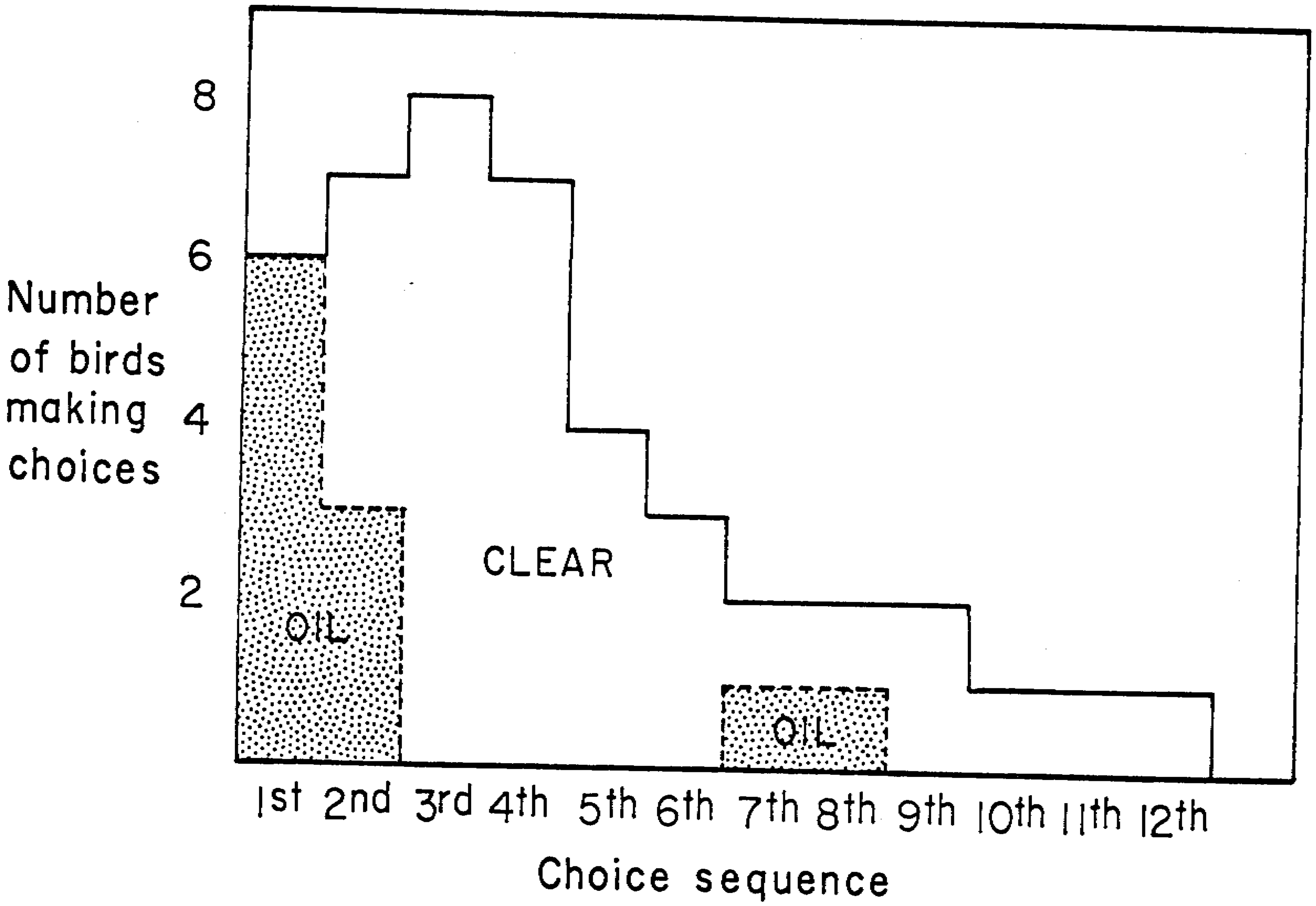

Figure 1. COMPARISON OF BIRDS CHOOSING OILED VERSUS CLEAR SURFACES

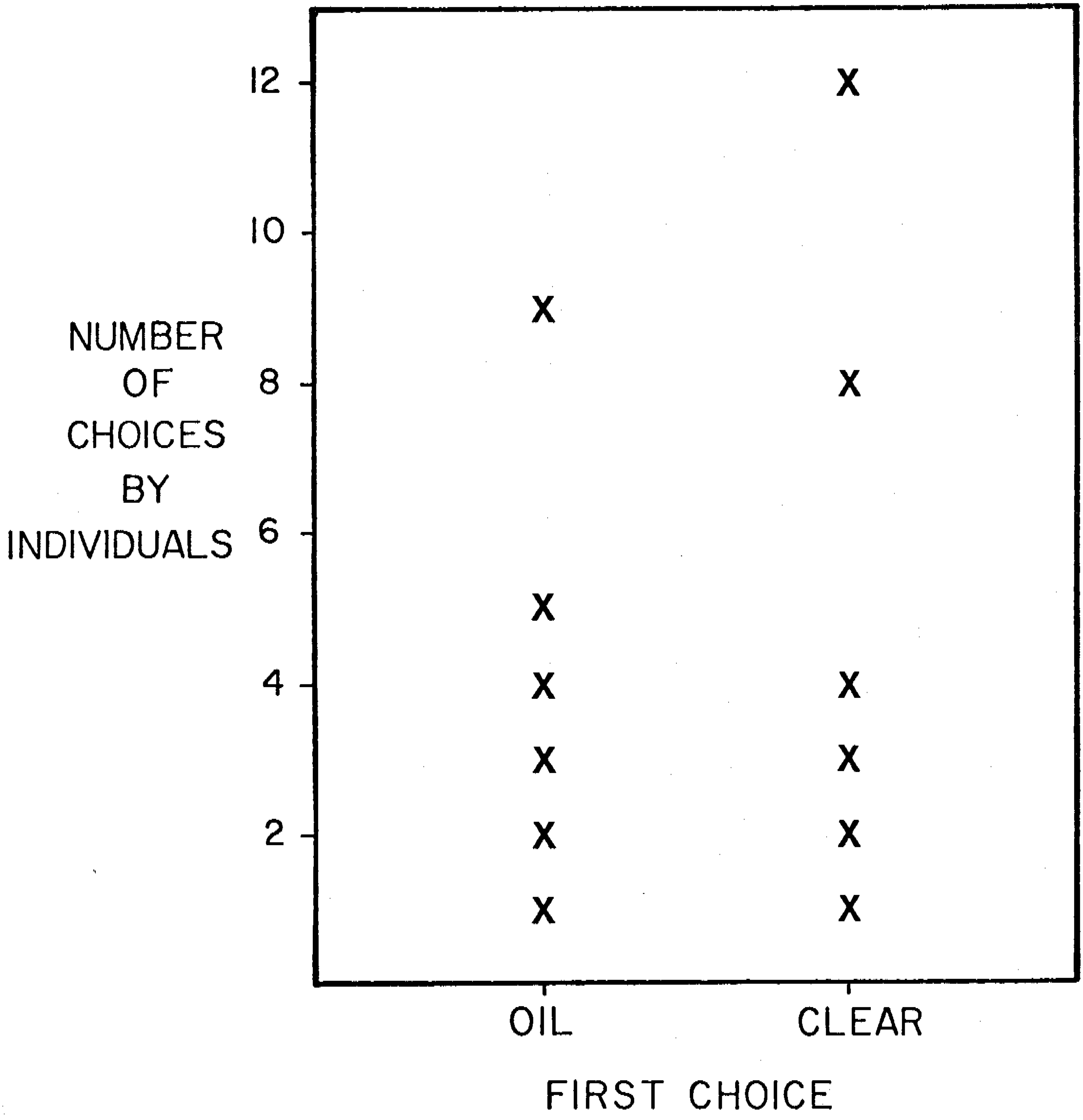

Figure 2. Number of total choices made by phalaropes after initial choices for oiled or clear pans.

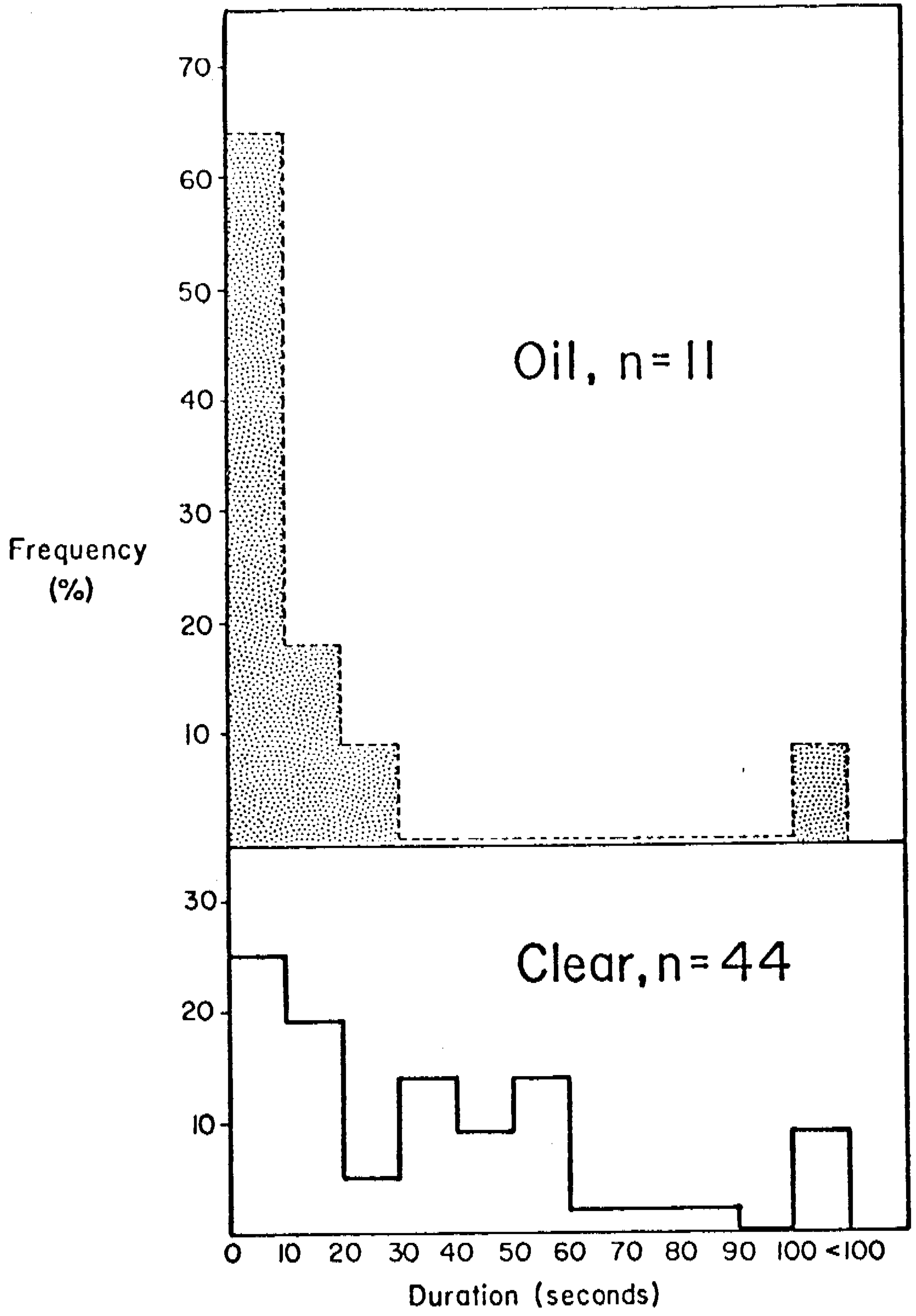

Figure 3. FREQUENCY OF SWIMMING PERIODS OF DIFFERENT DURATIONS, OILED VERSUS CLEAR SURFACES

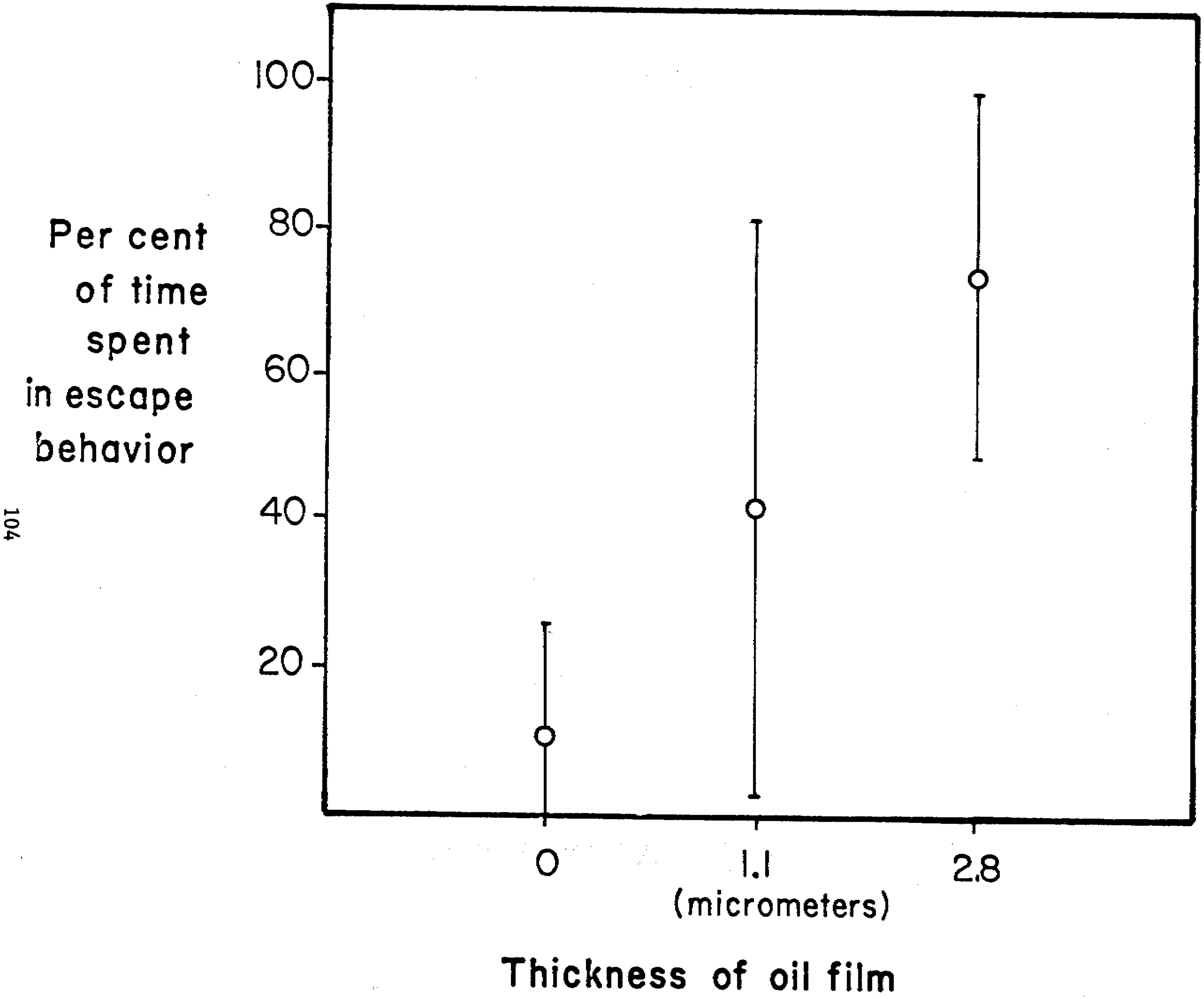

Figure 4. Escape response of Red Phalaropes in the presence of thin oil films.

What is the relevance of these results to OCSEAP? Admittedly these experiments present artificial situations and small sample sizes. Nevertheless, the statistical tests take into account the small sample sizes and judge the results significant. Naive juvenile Red Phalaropes apparently do not distinguish between oiled and clear surfaces for foraging before they have any experience with the oil. However, upon contact they have a fairly consistent and very quick response to try to get away from the oil, and subsequently they can and do distinguish between clear and oiled surfaces, and they avoid the oiled surfaces. This suggests that phalaropes may reduce the impact of an oil spill by behavioral adjustments after a brief learning period, but some questions remain.

For one thing, the bird can only avoid the oil if it has some alternative. In a very large, widespread, thick spill, the birds may not have nearby alternate choices of clean water. We have not tested whether they will fly long distances along the coast to avoid an extensive continuous spill. We suspect, however, that they will try to avoid small slicks if they have a clean nearby alternative, as might be the case in a small or patchy, broken-up oil slick.

The other critical question which remains is whether a bird after contact with oil for 5 seconds can be saved by subsequent behavior. Is that already too late? Within our experiment, we cleaned most of the birds after oil contact. Five seconds on one of the small pans was enough time to pick up a considerable amount of oil. On three of the individuals who had been in very briefly we did not do any cleaning. We merely returned them to their wire holding cage, outside at Barrow. They had plenty of food but may well have been under other stresses due to captivity. In each case these birds had, within a matter of a few hours, reworked all their plumage and had changed from wet, sticky smears on their underparts to a dry and very uniform buffy color on all the plumage. The feathers were in good fluffy condition so the birds were probably able to control their temperature while out of the water. In experiments within the next few days these birds appeared able to swim reasonably well, so they had their plumage back in apparently functional shape, although the buffy color betrayed the lingering presence of oil residue on the feathers.

Whether a bird in the wild after this kind of brief exposure to a thin film could regain a healthy condition will depend on a wide variety of factors. Survival will depend on the type and thickness of the oil film, degree of contact, stress due to environmental factors - weather and foraging conditions - and the physiological state of the bird. We are presently unable to assess this. However, our guess now is that in many circumstances, phalaropes with this brief exposure (5 seconds or less to a thin film) would have a good chance of recovery and survival. We are gathering information from other researchers and observers which may shed light on this question.

VIII. Conclusions

1. The general pattern of seasonal habitat use entailing a late summer shift to littoral zone habitats exhibited by most shorebird species at Barrow in previous years of this study were seen in 1979, but to a lesser degree for several important species. In particular, Red Phalaropes, Arctic Terns, Sabine's Gulls, and Sanderlings occurred in much lower densities along Barrow Spit in August. This may have been a response to low zooplankton densities. During a very local die-off of euphausiids at one site, densities of shorebirds were temporarily elevated. Densities of phalaropes were higher than normal in Middle Salt Lagoon, where copepod densities were high in 1979. The birds exhibited a flexible, opportunistic response to variable prey conditions.

2. From juvenile Red Phalarope responses to thin oil films in foraging experiments, we conclude that these birds probably will not avoid oil slicks in their initial encounters with oil on water, but that they will respond quickly after contact to attempt to escape and avoid the oil. We do not know how long this rapid learning will persist, nor how severe the effects of the initial contact will be.

IX. Needs for Further Study

After five seasons of OCS work, we now have a substantial outline of the seasonality of shorebird events in the littoral zone of much of the Beaufort and Chukchi coasts. Geographically, areas in the eastern Beaufort and parts of Kotzebue Sound retain the largest question marks. Trophically, we have only a rough understanding of the dependencies of different species in different regions. We know that some species are quite flexible in their responses to changing prey conditions; a better appreciation of this flexibility for key species is required if we are to predict any indirect effects of oil pollution through changes in prey conditions.

For some species and locations we can now make valuable estimates of the probabilities of encounters between birds and a hypothetical oil spill. In most cases, however, we cannot predict the behavior of birds confronted by the oil spill, and this step is critical to evaluating the eventual impact. Our experiments with Red Phalaropes have provided a first step for one important species, but many relevant questions remain.

X. Summary of January-March Quarter

1. Field Schedule.

No field activities during this quarter.

2. Scientific party.

Peter G. Connors, University of California, Bodega Marine Laboratory, research coordinator.

Kimberly Smith, Bodega Marine Laboratory, postdoctoral research ecologist.

Carolyn S. Connors, Bodega Marine Laboratory, research assistant.

3. Methods.

Laboratory analysis:

(1) Checking of all 1976 and 1977 digitized data

(2) Partial coding and entry of 1978 data

(3) Preparation of habitat data for analysis

(4) Continued analysis of 1978 and 1979 data. See this Annual Report.

4. Sample localities.

None

5. Data analyzed

1979 experimental results and field observations

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A. References

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2. Connors, P.G., K. Hirsch, and C. Hohenberger. 1978. Effects of coastal oil development on shorebirds in arctic Alaska (Abstract). Pacific Seabird Group Bulletin 5(2):85.

3. Connors, P.G. and C.S. Connors, 1978. Wet coastal tundra I (breeding bird census). American Birds 32:118.

4. Hirsch, K., D. Woodby, and C. Connors. 1978. Wet coastal tundra II (breeding bird census). American Birds 32:118-119.

5. Connors, P.G., D. Woodby, and C. Connors. Wet coastal tundra I (breeding bird census). Submitted to American Birds for 1979.

6. Myers, J.P. and F.A. Pitelka. 1979. Variations in summer temperature patterns near Barrow, Alaska: analysis and ecological interpretations. Arc. and Alp. Res. 12(2).

7. Connors, P.G. and S. Gellman. Red Phalarope responses to thin oil films in foraging experiments. In preparation.

C. Oral presentations

Connors, P.G., J.P. Myers, and F.A. Pitelka. Seasonality in a shorebird fauna of a high arctic Alaskan locality. Presented at Pacific Seabird Group Meeting, 6 January 1977.

Connors, P.G., K. Hirsch, and C. Hohenberger. Effects of coastal oil development on shorebirds in arctic Alaska. Presented at Pacific Seabird Group Meeting, 15 December 1978.

Connors, P.G. Alaskan coastal oil development: impacts on arctic shorebird populations. Presented at Northern Chapter, Cooper Ornithological Society Meeting, 11 January 1979.

Connors, P.G. and S. Gellman. Red Phalarope responses to thin oil films in foraging experiments. Presented at Pacific Seabird Group Meeting, 25 January 1980.

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The distribution, abundance and feeding ecology of birds associated with pack ice

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1 April 1980

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I. Summary of objectives, conclusions and implications with regard to OCS oil and gas development

As part of the environmental assessment of the outer continental shelf of Alaska the distribution, abundance and feeding ecology of seabirds associated with pack ice are being studied. An attempt is being made to determine the critical species and habitats associated with the pack ice.

Limited fieldwork was conducted in the past year from June to September at Cooper Island in the western Beaufort Sea. Analysis of Beaufort Sea data gathered in past years was the primary office activity. This report includes preliminary findings of the 1979 field season on Cooper Island and a preliminary analysis of Norton Sound coastal bird habitiats.

Observations on Cooper Island showed that 1979 was a year when early ice breakup meant that no ice associated zooplankton was present near the island during the late summer migration. In previous years a pagophilic or other type of zooplankton buildup in the littoral zone was a major food source for migrating seabirds. Certain species were able to utilize patchy, short-lived food sources and remained in the Cooper Island area spending much of their time roosting. Other species were not seen in their usual numbers and they apparently were feeding in other areas. Birds in the western Beaufort will be more sensitive to human disturbance in a year like 1979 than in years of abundant prey, such as 1976. Because food was not evenly distributed in 1979 birds had to concentrate in areas where prey was present. The areas where the food is present thus becomes a critical habitat where human disturbance could impact large numbers of birds. Unfortunately the appearance of the food patches in time and space is not predictable. 1979 observations also showed that the PLover Islands are important roosting areas even when birds are not attracted by abundant prey in the littoral zone. Thus human activity on the islands could negatively impact birds even if no disturbance to the marine system takes place.

A preliminary breakdown of Norton Sound coastal habitats indicates that a great diversity is present with little of the homogeneity present in the arctic. This indicates that a given section of coast will contain a variety of habitats that will vary greatly in the number of birds they support. This diversity should facilitate the determination of critcal habitats based on 1980 fieldwork.

II. Introduction

A. General nature and scope of bird/ice studies

Sea ice represents a unique marine habitat. Acting as a barrier between the air and water, it has a wide range of effects on seabirds. Sea ice creates a dynamic environment that can both increase and decrease bird numbers. Ways in which sea ice decreases seabird numbers include:

1. Decreasing the amount of open water available for feeding and roosting.
2. Lowering primary productivity in the water column by decreasing the depth of the euphotic zone and preventing wind mixing.
3. Reducing benthic prey by scouring the bottom in shallow water.

Ways in which sea ice can enhance bird numbers include:

1. Providing a roosting space for species that normally roost on solid substrates.
2. Providing a matrix for an in-ice phytoplankton bloom.
3. In areas of multi-year ice, providing a substrate for an under-ice community of zooplankton and fish.
4. Decreasing wind speeds and sea surface disturbances in the immediate vicinity of ice.

B. Specific objectives

The specific objectives of this study are:

1. To determine the distribution and abundance of seabirds found in the open water south of the pack ice, at the ice edge and in the pack ice. Densities in the pack ice are analysed with regard to ice type, ice cover and distance from ice edge.

2. To determine the role that pack ice plays in the yearly cycles of seabirds and identify those species that are most dependent on the pack ice environment.

3. To determine the primary prey species consumed by seabirds associated with the pack ice.

C. Relevance to problems of petroleum development

The ice environment of the Bering, Chukchi and Beaufort Seas will present unique problems to those involved in the exploitation of oil and gas reserves. The dynamic aspects of pack ice and the severe temperatures associated with it increase the chances of mechanical and human error causing incidents which could prove harmful to biological systems. In the pack ice the biological systems that will be impacted by such incidents could be expected to be less resilient than those in areas further south. This is due both to the slow rate of biodegration of oil in Arctic waters and the low species diversity of biological systems in the Arctic.

Birds found in and next to the pack ice can be expected to be severely impacted by oil spills and other perturbations associated with oil and gas exploitation. Birds are typically one of the most obvious and immediate victims of oil spills. Direct mortality is caused by oil fouling feathers, resulting in loss of insulation, stress and possible ingestion of oil. More subtle effects are caused by the impacts of oil on the lower levels of trophic webs. Seabirds are at the terminal end of the marine food chain and thus are sensitive to any changes that occur at lower levels. Oil spilled in the pack ice will spread out in areas of open water such as leads and polynas. Because these are the areas where birds are concentrated in the ice, the chances of birds coming in contact with spilled oil are greater in the ice than in open water.

The data obtained through this research unit are applicable to problems of petroleum development in a number of ways. Areas that support high densities of birds can be designated as critical areas so that little or no human disturbance will occur in the area. Alternatively, human activity can be planned so that it occurs at a time when bird use of the area is low. Because of the dynamic nature of the pack ice, critical areas and the times when they are critical vary greatly. Unlike delineating critical areas on or near the mainland where specific geographical areas can be described, critical areas in the pack ice are frequently defined in terms of ice cover, distance to shelfbreak, water temperature, etc. These factors are constantly changing during ice formation and deformation. Thus the designation of critical areas and species has to develop slowly and requires a large data base.

This project will provide a pre-development data base on bird distribution and abundance in relation to these parameters. Thus specific questions that government or industry seeks to address can be answered by using the data set. Ultimately it is hoped that future studies will be able to compare their data with that of this research unit so that the effects of petroleum development can be quantified.

D. General nature and scope of Norton Sound habitat study

In addition to the primary work on bird-ice relationships, a coastal habitat survey is being conducted in the spring, summer and fall of 1980. This will consist of a systematic survey of coastal migratory bird habitats in Norton Sound with special emphasis on critical, sensitive and/or susceptible biological habitats. A preliminary presentation of habitats based on physiographic features is included in this report.

III. Current state of knowledge

Previous studies that attempted to correlate ice with bird distribution are few. Frame (1973) reported on bird observations in the Beaufort Sea in summer. He only counted followers, however. Because followers in the Beaufort are directly related to the type of ice-breaking being done, his observations do not provide accurate estimates of densities. Watson and Divoky (1972) present information on birds next to and south of the pack ice in the Chukchi Sea in September and October. Irving et al. (1970) presented general information on birds at the Bering Sea ice edge in March.

Published accounts of pelagic observations in and next to the ice that do not deal specifically with ice in relation to bird distribution include Watson and Divoky's (1974) observations in the Beaufort and Jacque's (1930), Nelson's (1883) and Swartz's (1967) observations in the Chukchi. Unpublished pelagic observations deep in the Bering Sea pack ice were made by Divoky in March 1973.

The feeding habits of birds in and next to the pack ice are poorly known. The only applicable studies are those of Watson and Divoky (1972) and Divoky (1976) who report on prey items and feeding behavior of birds at the Chukchi ice edge in September.

IV. Study areas

The three seas covered by this project differ greatly in their amount and type of ice cover and their importance to seabirds. The following is a discussion of the marine and ice environment in each of these areas.

Bering Sea. Ice begins to cover the northern Bering Sea in late November. Ice coverage is at a maximum in February and March when the southern edge of the ice is usually found near the edge of the continental shelf. Decomposition of the pack ice begins in late April and continues until mid-June. This period (approximately six months) of ice cover is quite short compared to the Chukchi and Beaufort seas where some ice is present throughout the year. Because almost all of the ice in the Bering Sea is first year ice, it lacks the extensive keels and pressure ridges found on ice in the Arctic. While the Bering Sea ice supports an in-ice phytoplankton bloom (McRoy and Goering 1974), it is not known to have an under-ice fauna associated with its underside as does the ice in the northern Chukchi and Beaufort.

The Bering Sea ice "front" refers to the area of loose ice south of the more consolidated pack. It is composed primarily of bands of ice pans. Large floes are prevented from forming by swells on the open water to the south. When the wind is from the south the front is compacted against the main pack ice in a narrow band. When the wind is from the north the front becomes wider and more diffuse. In spring primary productivity is high in the water column under the ice front. At the same time productivity in the water column under the consolidated pack and south of the ice front is low (McRoy and Goering 1974). For this reason the ice front is an important biological area supporting large numbers of birds and mammals (Fay 1974).

Another feature of the Bering Sea ice pack of importance to birds is the open water associated with the islands found in the pack ice. These areas of open water (polynyi) are formed by the northerly winds which concentrate ice on the north side of islands and move ice away from the southern sides. These polynyi act as refugia deep in the pack ice.

The Bering Sea differs from the two Arctic seas studied by this project in that it has a high level of biological productivity. This is demonstrated by the large fishery the Bering Sea supports and by the large number of breeding and non-breeding birds present in summer.

Chukchi Sea. Ice covers the Chukchi Sea from November to May and coverage is almost complete during this period. Exceptions are the area of broken ice in the Bering Strait, a polynya associated with the shoreline northwest of Point Barrow. In late May the ice in the southern Chukchi Sea begins to decompose and most of the area south of Cape Lisburne is ice-free by July. The edge of the Arctic pack ice is present in the northern Chukchi throughout the summer, occurring anywhere between 70° and 72° N.

The ice in the Chukchi Sea apparently supports an in-ice algae bloom similar to those found in the Bering and Beaufort seas. The multi-year ice in the Chukchi is known to support an under-ice fauna of zooplankton and arctic cod. The underside of multi-year ice has numerous keels and pockets which create a large surface area. Amphipods are known to concentrate on the ice underside, presumably obtaining food from the plankton blooms occurring in and on the underside of ice (Mohr and Geiger 1968; MacGintie 1955). Arctic cod prey on the amphipods and other zooplankton found next to the ice. The underside of multi-year ice is thus similar to a reef in that it has fish and invertebrate populations associated with a substrate. Little is known about this community. It is present in the spring and summer but little is known about the winter situation. This will no longer be the case after OCSEAP's winter studies in the Beaufort Sea.

The water flowing north through the Bering Strait is a major influence on the Chukchi Sea. The water is warmer than Arctic waters and is the main reason for the rapid decomposition of ice in the southern Chukchi Sea. This water also supports high levels of primary productivity in summer (McRoy et al. 1972) and makes the southern portion on the Chukchi Sea the most biologically productive waters in the Arctic Ocean off Alaska.

Beaufort Sea. Ice covers much of the Beaufort Sea for almost twelve months of the year. The amount of open water present in the summer is dependent on wind and weather conditions. Adjacent to the coast strips of open water are present from approximately June to October; their width is dependent on the wind, with south winds moving the ice offshore and north winds pushing the ice inshore. The pack ice present in the northern Chukchi and Beaufort seas in summer contains much open water between ice floes. Thus even in areas deep in the permanent pack ice there is open water available to birds in summer.

The Beaufort Sea supports an in-ice plankton bloom followed by a bloom in the open water. The Beaufort Sea is characteristic of arctic waters with productivity being reduced due to the lack of upwelling or mixing. Because of this the Beaufort is the least biologically productive of the three seas studied by this project.

V. Sources, methods and rationale of data collection

Field work during the last year was limited to a summer field camp on Cooper Island (30 km east of Pt. Barrow) in the Beaufort Sea. The following data gathering methods were used.

A. Breeding birds

The chronology, hatching success, fledging success and growth rates of Arctic Terns (Sterna paradisaea) and Black Guillemots (Cepphus grylle) breeding on Cooper Island were studied in order to compare 1979 with previous years and examine how ice conditions affect these parameters. Chicks were weighed and measured every other day after hatching until fledging. All tern chicks were banded with USFWS bands. Guillemot chicks were color banded in addition to the USFWS band. Adult Black Guillemots were captured at the nest and banded with USFWS bands and color bands in order to allow recognition of individual birds.

Nest watches were conducted at Black Guillemot and Arctic Tern sites from a blind in the breeding colony. Information recorded included time of departure and arrival at nest sites and type and size of prey returned to nests. Blind watches lasted from 2 to 8 hours/day.

B. Shoreline transects

The north and south shores of Cooper Island were divided into six transects. These transects were walked every other day. The species, number, age, sex, plumage, behavior, flight direction and habitat of all birds were recorded. The number of birds sighted by species per km walked was computed. Environmental data collected during each transect included weather and ice conditions.

C. Plankton tows

Plankton tows were conducted every other day at six locations around the island;surface and bottom tows were taken at each site. Zooplankton organisms were identified and measured. Numbers of individuals by species per m^3 of water were computed.

Whenever feeding birds were observed an attempt was made to locate and identify prey organisms.

VI. Results

A. Beaufort Sea

The Beaufort Sea Final Report is due at the end of the 1980 calendar year. All Beaufort Sea data files gathered by R.U. 196 and R.U. 3/4 will be included in the report. Validation of all Beaufort Sea data files is currently being completed using the Texas Instrument 771 and programs prepared by the Data Projects Group of the University of

Rhode Island (R.U. 527). Once validation is complete R.U. 527 will run a series of programs on the data, which will allow the determination of which oceanographic and habitat features are most important in determining the distribution and abundance of Beaufort Sea seabirds. The final report will include sections on:

1. Mainland habitats adjacent to marine waters
2. Littoral and inshore habitats
3. Offshore distribution
4. Migration
5. Trophic relationships

Because of the preparation for the final report no data is being presented in this report, except for some preliminary statements on the 1979 Cooper Island work.

B. Cooper Island

1. Breeding chronology

The four species that nested on Cooper Island in 1979 were Arctic Tern (Sterna paradisaea), Black Guillemot (Cepphus grylle), Oldsquaw (Clangula hyemalis), and Snow Bunting (Plectrophenax nivalis).

All species began breeding activities in June. Egg-laying commenced in mid- to late June. Most breeding acitvity was completed in August but late Arctic Tern and Black Guillemot chicks did not fledge until early to mid-September.

The bulk of Arctic Tern egg laying in 1978 and 1979 occurred in late June and early July similar to previous years. In 1979, however, Arctic Fox (Alopex lagopus) consumed a total of 20 Arctic Tern eggs (26 percent of all eggs) from 14 nests (34 percent of all nests) from 29 June to 11 July. Fox predation appeared responsible for the much longer laying period of 1979 with the last egg laid on 23 July. This is the latest tern laying date for Cooper Island. Apparent relaying by Arctic Tern adults caused a greatly staggered breeding season with a second and smaller peak later in each of the three activities, laying, hatching and fledging (Fig. 2). There was, therefore, much overlap in time within laying, hatching, and fledging unlike any of the previous years (1975-78); 43 percent of surviving chicks had fledged by the last hatching date in 1979. In 1978 there was no arctic fox predation and the chronology of breeding was earlier than past years with well-defined peaks in laying, hatching and fledging.

Eight Black Guillemot nests had been dug out prior to our arrival in 1979, also apparently the work of arctic fox. No predation of Black Guillemot nests was observed after our arrival in 1979 nor any time in 1978. Breeding data of the Black Guillemot colony for all years 1975-79 will be presented in the Beaufort Sea Final Report. Banding activities in 1979 allowed color-marking of all breeding Black Guillemots on Cooper Island.

There was one Snow Bunting nest in 1978 and three Snow Bunting nests in 1979 with fledging of young completed by late August in both years.

2. Breeding success

Arctic Tern breeding success was good in 1978 and fair in 1979 (Table 4). Mortality of young chicks $<$ 1 week old was similar in 1978 and 1979 (Table 5); however the majority of young chick mortality occurred during mid- to late July in 1978 and from early August on in 1979. This difference is partially explained by the extended laying period in 1979 causing young chicks to hatch during an open water period when ice-associated prey is less available. 1978 and 1979 were both light ice years, expecially compared to 1976 (Fig. 3). Causes of chick mortality in 1978 have not fully been examined, but it appears that lack of prey organisms resulted in death of older chicks during open water. Severe drops in chick growth rates in 1979 after strong winds blew the ice far offshore indicated Arctic Tern reliance on ice associated prey for successful breeding. Mortality would probably have been much more severe if a zooplankton washup of euphausiids (*Thysanoessa raschii*) had not occurred in early August which Arctic Tern parents fed to chicks.

Black Guillemot breeding success for the years 1975-79 will be presented in the Final Report.

3. Habitat use

Shoreline transects on Cooper Island in 1979 provided interesting comparisons with data from previous years. Complete presentation and analysis of this data will appear in the R. U. 196 Beaufort Sea Final Report. The principal findings of our 1979 Cooper Island work are summarized here.

In 1979 shorefast ice breakup and drifting pack ice periods began near the same time as 1977 and 1978. The 1976 dates of breakup and drifting ice were much later due to the heavy ice winter of 1975. The drifting ice period of 1979 was characterized by very little multi-year ice and the earliest removal of all ice from the island and nearshore waters.

Densities and activities of all plankton-eating species were affected by the lack of a major drifting ice period. The ice-associated zooplankton usually provides an important food source for migrating phalaropes, tern and other species. The lack of pagophilic zooplankters or an open water substitute (such as *Sagitta*) was reflected in a number of ways. There were virtually no feeding flocks near the island except during an euphausiid (Thysanoessa raschii) washup on the south shore 7-10 August. An average of 300 birds/km were present during this time, comprising the only significant flocks of feeding birds in 1979. Bird use of the habitat during peak migration was chiefly as a roosting area as opposed to feeding. A summary of how the ice conditions affected the numerically important species of Cooper Island is presented below.

1) Oldsquaw: Oldsquaw densities were high in late July when flocks of males are present in the moats and leads around the island. In the third week of July Oldsquaw densities were the highest of any of the past four years for the period of ice breakup. This early peak may be correlated with high concentrations of mysids (Mysis sp.) which were more abundant during the 1979 breakup period than in previous years. Oldsquaw numbers remained high for the rest of the summer with totals usually higher than previous years.

2) Red Phalaropes (Phalaropus fulicarus): No large shoreline flocks of phalaropes were seen at Cooper. Such flocks are usually found at Cooper with as many as 1000 birds per km being present. In 1979 densities were rarely over 100 birds per km, and phalaropes were seen feeding on copepods in ponds on the island rather than in the littoral zone. This was also observed by Peter Connors at Barrow (R.U. 172). During a mild storm dead juvenile phalaropes were found at a number of points on the island. Examination indicated that the mortality was due to starvaton. Only during the euphausiid wash up were actively feeding flocks of phalaropes seen in the littoral zone.

3) Arctic Terns: Arctic Terns at Cooper Island usually feed predominantly on Arctic cod (Boreogadus saida) with zooplankton constituting a smaller but sometimes substantial part of the diet. In 1979, however, invertebrates constituted less than 1 per cent of all food items brought to chicks. In addition no zooplankton feeding flocks of parent terns were observed during the breakup period. In past years feeding flocks are frequently seen during breakup feeding on amphipods. The relatively high breeding success of terns in 1979 does not demonstrate that a lack of zooplankton hurt breeding success. However, the euphausiid washup played a major role in providing food when tern chicks were dropping in weight. It appears that even though terns were affected by low zooplankton densities around the island, their ability to obtain arctic cod on a regular basis kept their breeding success high.

The early part of the Arctic Tern migration was characterized by their non-stop movement past the island. During the euphausiid washup densities of terns reached 40 birds/km as compared to 160/km during the same time in 1976. 250 Arctic Terns were observed in a mixed feeding flock which included Glaucous Gulls (Larus hyperboreus) and Sabine's Gulls (Xema sabinii) on 12 August behind Sanigurak Island, 9 km east of Cooper. The source of prey was a large school of arctic cod, which has not previously been observed behind the barrier islands. This occurrence seemed similar to the large movement of cod through Simpson Lagoon in 1978. East-west movement of Arctic Terns on Cooper Island was observed during this time indicating breeding bird and migrant utilization of zooplankton patches. From 18 August to 25 August numbers of Arctic Terns on the island built up to 10,000 birds, the largest concentration of terns observed in any year. The major activity was roosting, predominantly on the south side with very little feeding observed. These large numbers occurred during a time when the building up of fat reserves for the long distance migrants can be of critical importance.

The lack of a food resource in inshore waters was further illustrated by the very low numbers of Black-legged Kittiwakes (Rissa tridactyla) near the island. The Kittiwake is an offshore species which typically comes inshore to feed only when nearshore zooplankton densities are at a peak.

4) Black Guillemots: Black Guillemots at Cooper Island feed almost entirely on fish and thus the low zooplankton densities did not directly affect them. The lack of ice, however, meant that their usual prey item, arctic cod, was not as available as in years with more ice.

In previous years prey brought to chicks by parent Black Guillemots consisted almost entirely of arctic cod. In 1979, however, much of the prey brought to chicks consisted of sculpin (Myoxocephalus sp.) and other benthic fish. This indicates that the guillemots turned to a benthic food source when their usual under-ice or mid-water prey was not present. Analysis of data on food brought to chicks and chick growth rates will reveal how this shift affected the birds.

5) Sabine's Gull: Sabine's Gulls were present in very low numbers through the summer. In previous years densities reached 80 birds/km in 1976 and 1978 during the peak migration (mid to late August). The highest densities for 1979 (7 birds/km) occurred only during the euphausiid washup and on 26 August. 75 Sabine's Gulls were observed in the feeding flock behind Sanigurak Island.

C. Norton Sound Habitat Mapping

Significant operations during the first quarter of 1980:

I. Designing the sampling scheme
II. Logistical planning
III. Hiring of field personnel
IV. Preliminary habitat mapping

I. Sampling Scheme

Our sampling intent is to describe the magnitude and variation of coastal habitat use by birds during the 1980 season. The main approach is to select six representative sites from Wales to the Yukon delta and census portions of these on foot at least once per month from late May through October. A preliminary choice of sites is shown in Figure 1. These censuses will allow a comparison of abundance and variation between habitats, coastal sections, and sampling periods.

We will make similar surveys on Safety Sound, 25 km east of Nome, on a twice weekly basis. This will enable us to evaluate short term variability that will go undetected at the less frequently visited sites. We will also use a small boat (Zodiac raft) in Safety Sound and other protected waters to survey areas inaccessible on foot.

Aerial surveys will be flown once to twice per month. These will cover most of the coast and selected open water areas (lease tracts) to monitor large scale variations in bird use of habitats not encountered on the foot surveys.

Offshore zones will be surveyed via research vessels when available and appropriate. Currently, we plan to census transects from the USCG ice breaker Polar Star in May and June. Ship helicopters may be used to visit the isolated shorelines of St. Lawrence and Stuart Islands.

II. Logistical Planning

Olson's Air Service in Golovin and Munz Commercial from Nome will be used extensively for survey flights and personnel transport, respectively. A vehicle has been requested for use in Nome and a search is underway for housing there.

III. Hiring of Field Personnel

A maximum of seven biologists will be employed from mid May to early October.

IV. Preliminary Habitat Mapping

A. Shoreline habitats- lengths and percent frequencies.

Eleven different habitat types were identified using physiographic data from the USGS 15 minute topographic map series and using vegetation information from the Northwest Regional Profile atlas (AEIDC, Anchorage). These are:

1) Sea beach backed by high ground or cliffs
2) Sea beach backed by marsh/wet tundra
3) Sea beach backed by upland tundra, brush, or forest
4) Seaward beach on a spit
5) Lagoon or bay beach on a spit (facing the protected water)
6) Mainland beach on a lagoon or bay, backed by high ground
7) Mainland beach on a lagoon or bay, backed by marsh/wet tundra
8) Mainland beach on a lagoon or bay, backed by upland tundra, brush, or forest
9) Spits or bars in protected waters
10) River delta
11) River mouth

Shoreline lengths of these were measured and are summarized in Table 1. These are grouped into eight coastal sections as shown in Figure 1. With the exception of the Yukon delta, all of these sections will be visited on foot to allow elaboration and refinement of the habitat classifications.

B. Significant wetland habitats.

Table 2 lists surface areas of habitats that are considered to be of particular importance to coastal birds. These are marsh/wet tundra, river deltas, lagoons and bays, and mud flats. Upland sites are generally less useful to water oriented birds for nesting, feeding and roosting.

C. Seabird colonies.

A few large and many small seabird colonies occurring in Norton Sound have been studied by the OCSEAP program during the past four years. Table 3 summarizes known breeding populations for those with more than 100 birds (source: Catalog of Alaskan Seabird Colonies, U.S. Fish and Wildlife Service, Anchorage, 1978).

D. Predicted and known bird use of habitats, discussed by section.

The following narrative is due in large part to input provided by William Drury, College of the Atlantic.

<u>Section A</u>- Cape Prince of Wales to Cape Douglas

Steep shores dominate the open coast offering a few nesting sites for cormorants, gulls, and puffins. On the east end of this section there is a tiered system of shallow protected waters including Brevig Lagoon, Port Clarence, Grantley Harbor, and Imuruk Basin. Large areas of marsh-like wet tundra border the northern end of Imuruk Basin and the south side of Port Clarence. These may serve as waterfowl nesting and/or migration stopover sites. Cape Riley has nesting cormorants, gulls, and puffins while Pt. Spencer is a concentration site for shorebirds, gulls, and ducks.

Section B- Cape Douglas to Cape Nome

This shore offers small protected lagoons and areas of upland tundra dotted with lakes and drained by numerous small streams. Many loons, pintails, geese, swans, and shorebirds nest here, while migrants probably use the enclosed waters immediately behind the beach. Coastal outcrops in this area are frequented by eiders and other sea ducks feeding near shore.

Offshore, King and Sledge Islands support major seabird colonies with approximately 250,000 and 5,000 birds each, respectively.

Section C- Cape Nome to Rocky Point

Safety Sound is the dominant feature of the east end of this section with marsh areas on the north side and islets behind the barrier beach strip with Aleutian and Arctic Tern colonies. The steep ground from Topkok Head to Rocky Point has seabird cliffs at Topkok, Bluff, Square Rock, and a few sites on the Rocky Point peninsula.

Section D- Golovin Bay and Lagoon

Golovin Lagoon has extensive mud flats and delta on the northwest end with prime waterfowl nesting habitat; also a likely place for seasonal shorebird concentrations.

Section E- Cape Darby to Cape Denbeigh

Norton Bay is bordered by steep slopes with seabird cliffs on the two capes. There are extensive marshes, deltas, and tidal flats at the mouths of several rivers, including the Kwik, Koyuk, and Inglutalik. These are productive for waterfowl and shorebirds.

Section F- Cape Denbeigh to Stebbins including Stuart Island

The wet tundra behind Cape Denbeigh was found to have remarkably low populations of waterfowl (Drury). The Unalakleet delta is potentially productive while the beach to the south and west is narrow and backed by slumping bluffs, tree bordered streams, and occassional cliff outcrops. These small points of land often have minor colonies of cormorants, gulls, and puffins. Besboro Island has nesting puffins and cormorants, Egg Island has murres, kittiwakes, puffins, and Parakeet Auklets, while the islands near St. Michael have mostly puffins.

Stuart Island offers some waterfowl and crane habitat plus some puffin occupied outcrops on the west end.

Section G- Stebbins to Apoon Mouth (Pastol Bay)

The extensive wet tundra to the southwest of Stebbins is likely to support large populations of nesting waterfowl and shorebirds.

Section H- Yukon delta

The Clarence Rhode National Wildlife Refuge is a major waterfowl and shorebird nesting area with more than 3,000 square kilometers of prime habitat. The coast of the delta is relatively inaccessible and outside of this project's realm.

0 - Planned Completion Date
X - Actual Completion Date
(to be used for updates)

RU # 196 PI: George J. Divoky

Major Milestones: Reporting, data management and other significant contractual requirements; periods of field work; workshops; etc.

Norton Sound	1979			1980											
MAJOR MILESTONES	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Preliminary habitat mapping				--	--	O									
Habitat censusing								--	--	--	--	--	O		
POLAR STAR pelagic censusing								--	O						
Preliminary synthesis meeting													O		
Data analysis													--	--	O

VII. Discussion

The 1979 field season on Cooper Island was perhaps the most valuable, since it demonstrated how a severe food shortage can affect bird densities and behavior. We now know that when the typical littoral zooplankters are found in low numbers some shoreline migrants still gather in the Plover Islands in large numbers and move both east and west searching for food. Past studies by R.U. 196 and R.U. 314 have shown the Plovers to be an important area of concentration for a number of species prior to their southward migration. The die-off of phalaropes due to starvation and the fact that terns roosted rather than fed around the island indicates that these species were unable to find prey. This could have major implications in migration energy budgets, since these species typically put on weight prior to migration. The occurrence of patchy food sources, such as the euphausiid washup and large arctic cod school in Elson Lagoon, provided major but short-lived feeding opportunities. We do not yet know what causes the die-offs of euphausiids at Pt. Barrow and the Plover Islands. We have observed them in 1976 and 1979, and both times they were completely consumed by migrant birds in a few days. Further information on euphausiids in the western Beaufort Sea would prove valuable.

Unfortunately no Beaufort Sea cruise was conducted in 1979. In past years bird densities in the offshore Beaufort have been found to be extremely low and densities in nearshore waters moderate to high. In 1979 the lack of zooplankton in nearshore waters may have meant that densities offshore were higher. An example of a pelagic species that typically moves to the nearshore Beaufort to feed on zooplankton is the Black-legged Kittiwake. In 1979 the species apparently stayed offshore, since only scattered individuals were seen at Cooper.

VIII. Conclusions

Only very tentative conclusions can be drawn from the preliminary analysis of 1979 Cooper Island data. Perhaps the most important observation is that in years when zooplankton are not evenly distributed in the littoral zone, birds must turn to food sources that are patchy in nature. This means that the sensitivity of the food source to impacts from man's activities is increased due to their short duration and limited geographic distribution. Thus an oil spill or similar occurrence in a year similar to 1979 could have a much greater impact than in other years.

IX. Summary of Fourth Quarter Operations

A. Work completed

Office work was conducted on data gathered in previous years. The TI 777 was delivered from Bodega Bay and validation of R.U. 196 data began. Divoky traveled to the University of Rhode Island to discuss data outputs with personnel of R.U. 527. The visit resulted in a listing of analyses that will be done by URI as soon as validation is complete.

B. Meetings attended

Pacific Seabird Group	23-26 January 1980
Data Processing Meeting	28-30 January 1980

C. Papers or lectures presented

Pacific Seabird Group Meeting:

Murres and prey patches in the Bering Sea by Doug Woodby.

Organochlorine residues in eggs of Alaskan seabirds by Harry Ohlendorf, James C. Bartonek, George J. Divoky and Erwin E. Klass.

Post-breeding migration of Arctic Terns in Northwestern Alaska by Robert Boekelheide and George J. Divoky.

University of California at Santa Cruz - Marine Studies Seminar:

Birds of the Arctic pack ice by George J. Divoky.

D. Papers submitted for publication

Horned Puffins associated with Black Guillemot breeding colonies in northern Alaska by G.J. Divoky and T.L. McElroy.

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Table 1. Shoreline lengths (km) and percent frequencies of 11 coastal habitats in Norton Sound.

Habitat Type	Coastal Section A. Wales to Cape Douglas	B. Cape Douglas to Cape Nome	C. Cape Nome to Rocky Point	D. Golovin Bay/ Lagoon	E. Cape Darby to Cape Denbeigh	F. Cape Denbeigh to Stebbins	G. Stebbins to Apoon Mouth	H. Yukon Delta	Total	%
1. Sea beach with high ground/cliffs.	62		56	23	87	54	3		285	17
2. Sea beach backed by marsh/wet tundra	10	34	3		79	31	38		195	12
3. Sea beach backed by upland tundra, brush or forest		49	9	32	8	182	24		304	18
4. Seaward beach on a spit	49	24	41			26			140	8
5. Lagoon/bay beach on a spit	47	16	41			31			135	8
6. Mainland beach on a lagoon/bay backed by high ground/cliffs	29	2							31	2
7. Mainland beach on a lagoon/bay backed by marsh/wet tundra	66	39	34			38			177	11
8. Mainland beach on a lagoon/bay w/ upland tundra, brush, or for.	104	6	10	33					153	9
9. Spits or bars in protected waters	38								38	2
10. River delta	6		6	21	20			153	206	12
11. River mouth		3			1	2	2		8	1
Total=	411	171	202	109	195	364	67	153	1672	100%

Table 2. Surface areas (km^2) of significant coastal habitats in Norton Sound.

	Habitat Type			
Coastal Section	Marsh/wet tundra and deltas	Spits and bars	Lagoons and bays	Mud flats
A. Wales to Cape Douglas	352	15	676	
B. Cape Douglas to Cape Nome	46	2	14	
C. Cape Nome to Rocky Point	142		54	
D. Golovin Bay/ Lagoon	124		133	37
E. Cape Darby to Cape Denbeigh	360	3	28	8
F. Cape Denbeigh to Stebbins	456	7	28	14
G. Stebbins to Apoon Mouth	271			
H. Yukon Delta	3000+			

Table 3. Seabird colonies in Norton Sound and adjacent waters (only those with more than 100 birds per site are listed; in clockwise order around the sound beginning at Wales).

Colony Name	Coastal Section	Number of Birds
King Is.	A	246,000
Cape Riley	A	200
Cape Douglas	A	160
Sledge Is.	B	4,800
Safety Lagoon	C	160
Topkok Head	C	470
Topkok East	C	150
Bluff	C	50,000
Square Rock	C	4,000
Little Rocky Point	C	160
Rocky Point	C	600
Cape Darby	E	1,400
Cape Denbeigh North	F	7,250
Cape Denbeigh South	F	5,200
Besboro Is.	F	370
Tolstoi Point	F	120
Black Cove Island	F	106
Egg Is.	F	2,800
St. Michael Is.	F	200
		Total= 324,000+

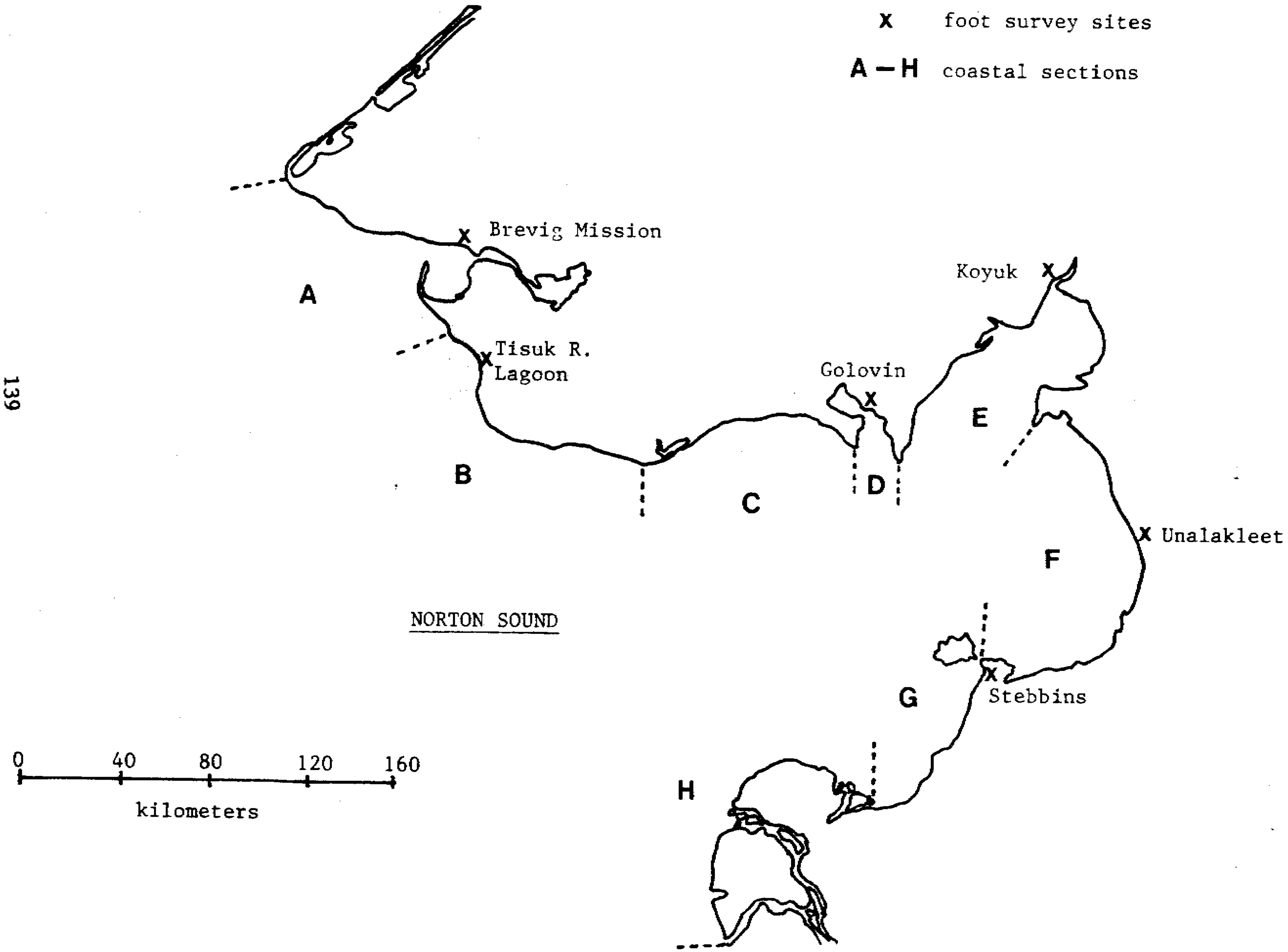
Year	1975	1976	1977	1978	1979
Number of Eggs	97	94	91	60	78
Number of Nests	51	58	61	38	49
Average Clutch Size	1.9	1.8	1.5	1.6	1.6
% Hatching Success	86	21	79	87	66
% Eggs Taken by Arctic Fox	0	53	5	0	26
Number of Eggs Hatched/Nest	1.6	0.4	1.1	1.4	1.0
% Fledging Success	79	33	57	69	71
Number of Chicks Fledged/Nest	1.3	0.1	0.7	0.9	0.8
% Breeding Success	68	7	46	60	47

Table 4. Arctic Tern breeding success on Cooper Island 1975-1979.

	1975	1976	1977	1978	1979
% Chicks dead < 1 week old	19	52	4	19	17
% Chicks dead 1-2 weeks old	0	10	6	2	12
% Chicks dead > 2 weeks old	1	5	33	10	0
% Fledging success	79	33	57	69	71

Table 5. Age of Arctic Tern chicks at death, Cooper Island 1975-1979.

Figure 1. Foot survey sites and coastal sections, Norton Sound coastal bird habitat project.



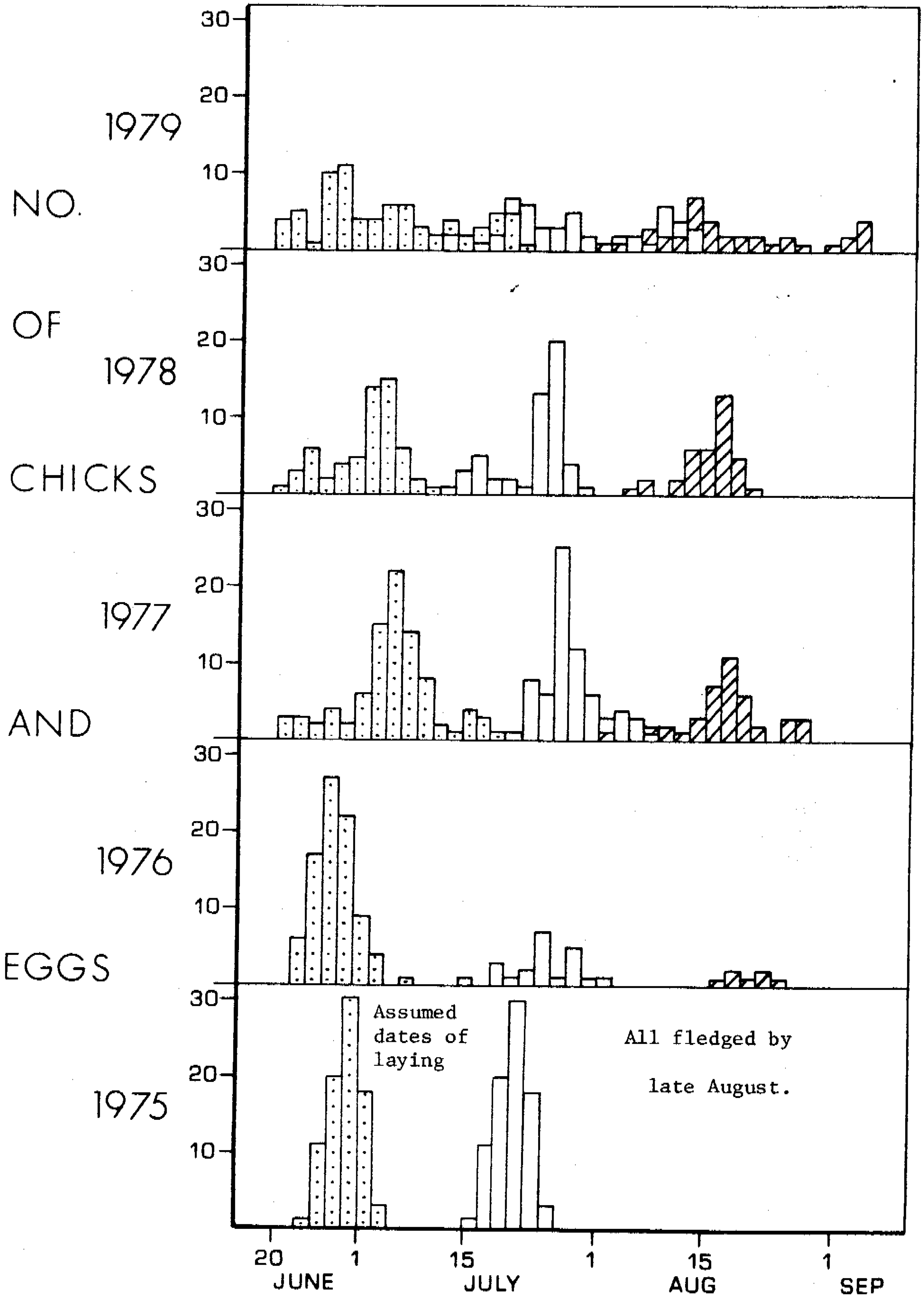


Figure 2. Breeding chronology of Arctic Terns on Cooper Island 1975-1979. Laying =⊡, hatching =☐, fledging =▨.

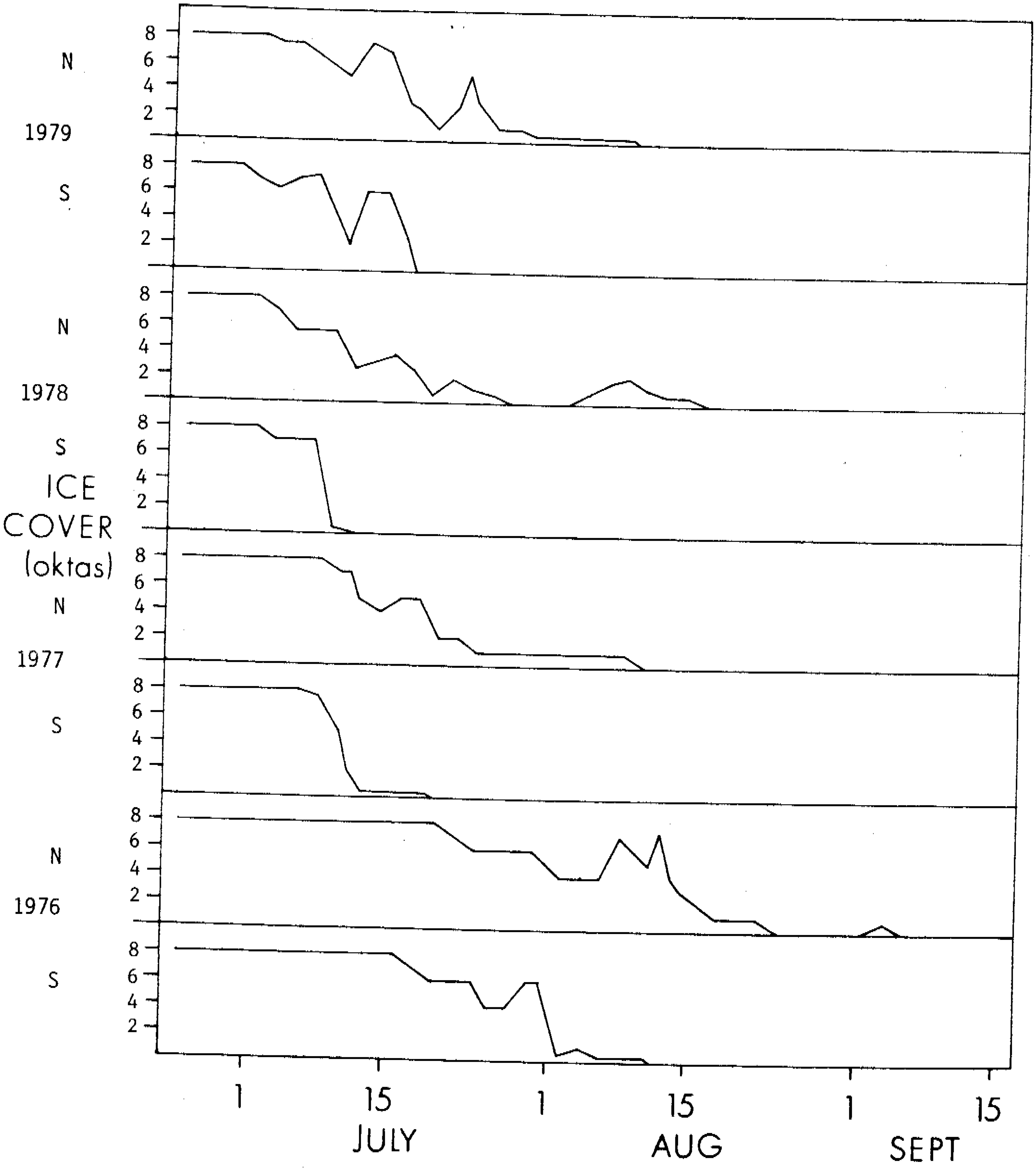


Figure 3. Ice coverage in oktas (eighths) on north and south sides of Cooper Island 1976-1979.

ANNUAL REPORT

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MONITORING POPULATION NUMBERS AND PRODUCTIVITY OF COLONIAL SEABIRDS

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I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

A. Objectives

The primary objective of this study is to use the census data for colonial seabirds breeding at Cape Thompson, Alaska, in evaluating the suitability of various census techniques in effectively tracking numeric changes in seabird populations. Secondly we will examine the historical data for trends in population numbers of murres (*Uria aalge* and *U. lomvia*) and Black-legged Kittiwakes (*Rissa tridactyla*) at the Cape Thompson colonies. Concommitently, we will analyze sources of variation in the census results, including diurnal, daily, and seasonal variation in attendance patterns of the birds at the colonies, and observer variability in the census estimates. Finally we present data on productivity of murres and kittiwakes and examine the relationships between annual variations in numbers and productivity.

B. Conclusions

Considerable diurnal, daily and seasonal variability in the attendance patterns of murres dictates repeated counts at selected areas if long-term changes in numbers are to be tracked effectively. Because the long-term changes in murre population numbers at Cape Thompson have varied spatially in magnitude, both within and among colonies, the most effective sampling designs will be those which insure broad coverage of different cliff types and exposures. At Cape Thompson systematic sampling of the larger colonies and complete censuses of the smaller colonies will be appropriate. Counts should be made on several days during the chick period, and successive counts should be conducted at approximately the same time of day as earlier counts. Two or more observers should conduct the counts independently. At selected areas photographs taken simultaneously with the counts will permit evaluation of observer bias in comparing results among years. These conclusions also apply to kittiwakes, but the observer source of variability is of lesser magnitude.

At Cape Thompson murre numbers have declined markedly since 1960 and the decline has continued in recent years. The magnitude of the decline has varied both within and among colonies, being greatest at Colony 5, the largest colony in 1960. Kittiwake numbers have also varied considerably but, in contrast, demonstrate no trend. Numbers in 1960 and 1979 were much higher than in 1976 or 1977.

Kittiwake productivity was high in 1979 at Cape Thompson. Data from Cape Lisburne and Bluff indicate that productivity has varied greatly in recent years but in parallel at all three locations. Productivity has fluctuated in parallel with numbers. Fewer kittiwakes occupy sites at the colony and attendance is more sporadic in years of low productivity than in years when conditions are especially conducive for reproduction.

C. Implications with Respect to OCS Oil and Gas Development

Murres and kittiwakes can be viewed as integrators of marine food webs because they occupy top trophic positions. Differences among Thick-billed Murres (*Uria lomvia*), Common Murres (*U. aalge*), and Black-legged kittiwakes in foraging techniques reflect different methods and capabilities of exploiting major food sources, e.g. Sand Launce (*Ammodytes hexapterus*). Such exploitation represents a sampling of lower trophic levels which has defied scientific sampling methodologies.

Availability of prey species within foraging range of the breeding colonies is reflected in population parameters of the seabirds that can be measured with relative ease. Kittiwakes feed at the water surface. They are buoyant but slow-speed flyers and thus must forage in the vicinity of the breeding colony if they are to maintain a site there. Consequently numbers and productivity of kittiwakes reflect near-surface foraging conditions nearby the colony. Murres, in contrast, are high-speed flyers, foraging at great distances from the colonies, and feed at considerable depths in the water column. Thus, they have a far greater three-dimensional foraging range than do kittiwakes. The number of murres occupying sites at the colonies may be less dependent on foraging conditions, but productivity does appear dependent on the timely appearance of a suite of invertebrate and fish prey as the breeding season progresses.

Studies of changes in numbers and productivity of easily studied, piscivorous seabirds will provide the most suitable window into the ecosystems-wide consequences of petroleum-related and other human activities.

II. INTRODUCTION

A. General Nature and Scope of Study

In the past several years enumeration of breeding seabird populations has been an important focus of studies in the Outer Continental Shelf Environmental Assessment Program (OCSEAP). Because of their sheer abundance, seabirds must certainly play a vital role in the marine ecosystems they inhabit. They are particularly vulnerable to oil pollution (e.g. Bourne 1976). Exploration and development of oil reserves are planned in many regions of seabird abundance. If the effect of oil-related activities is to be adequately assessed, it is important not only to enumerate breeding populations but also to quantify annual and long-term variability in population numbers to establish an adequate baseline for those populations prior to oil exploration and development.

Before OCSEAP, few seabird colonies in Alaska had been studied even cursorially and only those at Cape Thompson had been studied in detail. Swartz's (1966) studies at Cape Thompson from 1959-1961 and OCSEAP studies from 1976 to present (Springer and Roseneau 1977, 1978, Springer *et al.* 1979, present study) provide the most extensive data base for quantifying and evaluating annual and longer-term variations in numbers of murres and kittiwakes, two of the most abundant seabird taxa in Alaska (see Sowls *et al.* 1978) and the world. In the present study we exploit and extend the historical data base in evaluating census results and in delineating field routines which will be most effective in tracking future population changes. Supplementary studies at the Cape Lisburne and Bluff colonies provide a comparative but shorter-term data base.

In recent years there have been numerous studies of murre numbers (e.g. Nettleship 1976, Lloyd 1975, Birkhead and Ashcroft 1975, Birkhead 1978a) and kittiwake numbers (e.g. Hodges 1977). Yet despite the proliferation of such studies there is still little information on the accuracy with which fluctuations on small areas within colonies reflect colony-wide fluctuations in numbers. Such information is necessary in designing effective sampling routines for large colonies where entire censuses are impractical, if not impossible. In the present study we focus on spatial variation in the degree of numeric change in the murre populations at the Cape Thompson colonies.

Our studies of the reproductive success of murres and kittiwakes augment the census efforts and considerably increase our ability to view these taxa as indicators of short-term and long-term variability in marine ecosystems.

B. Specific Objectives

1. To census the murres and kittiwakes at the Cape Thompson and Bluff colonies.

2. To quantify diurnal, daily, and seasonal variability in attendance patterns of murres and kittiwakes at the Cape Thompson and Bluff colonies.

3. To examine the historical data base at Cape Thompson for spatial variation in the degree of numeric change of murres and kittiwakes.

4. To recommend a sampling design to effectively track annual and longer-term variations in numbers of murres and kittiwakes.

5. To determine breeding phenology and quantify productivity of kittiwakes at Cape Thompson, Cape Lisburne and Bluff.

6. To examine the relationships of numbers and productivity of kittiwakes at Cape Thompson, Cape Lisburne and Bluff.

C. Relevance to the Problems of Oil Development

This study is an extension of the OCSEAP baseline natural history studies of seabirds as it evaluates the suitability of the present data base in the assessment of long-term population trends. It thus provides a measure of the adequacy of the data base being generated within OCSEAP in assessing the effects of oil exploration and development.

Together with previous studies at Cape Thompson and Cape Lisburne (Springer and Roseneau 1977, 1978, Springer *et al.* 1979) and Bluff (Drury 1977, 1978, Ramsdell and Drury 1979), the present study permits quantification of annual variation in numbers and productivity of murres and kittiwakes. Unless such pre-development variation is quantified, there will be no basis for testing the effects of oil development on these abundant, and ecologically important, species.

Seabirds occupy top positions in marine food webs and thus integrate many components of the systems in the northern Bering Sea and Chukchi Sea ecosystem that have not been studied and indeed defy known sampling techniques. Thus the seabirds provide a finger on the pulse of ecosystem function and would indicate alteration of that function by oil-related activities.

Each of the three colonies we have studied is near a proposed lease area. Springer *et al.* (1979) and Ramsdell and Drury (1979) further elaborate on the relevance of the studies of seabirds at Cape Thompson, Cape Lisburne and Bluff to plans for oil development in the Hope Basin, Chukchi Sea, and Norton Sound, respectively.

III. CURRENT STATE OF KNOWLEDGE

Field efforts in this study from 1976 through 1979 have extended and amplified the data base established in previous studies at Cape Thompson (Swartz 1966, Springer and Roseneau 1977, 1978, Springer *et al.* 1979), Cape Lisburne (Springer and Roseneau 1977, 1978, Springer *et al.* 1979), and Bluff (Drury 1977, 1978, Ramsdell and Drury 1979). Other studies of seabirds in OCSEAP (e.g., Searing 1977, Hunt 1978) are also relevant.

Studies of small colonies of Common Murres (e.g. Birkhead and Ashcroft 1975, Birkhead 1978a, Lloyd 1975) and Black-legged Kittiwakes (e.g. Coulson 1968, Hodges 1977) in the British Isles have provided considerable insight on numbers and productivity of these two species. Other relevant studies are cited throughout the report as appropriate and are listed in Section XI, Part A.

IV. STUDY AREA

The five distinct seabird colonies in the vicinity of Cape Thompson, Alaska, comprise about 6.8 km of the 11.4 km of coastline between the north end of Imnakpak Cliff and Crowbill Point (Figure 1). Colony designations in the text correspond with those shown on Figure 1. Detailed environmental information for the Cape Thompson region can be found in Wilimovsky and Wolfe (1966). Swartz (1966) and Springer and Roseneau (1977, 1978) have discussed the seabird habitat.

Here we provide additional detail about the characteristics of the cliffs utilized by seabirds. The five colonies occur on the higher, more stable cliffs and are separated from each other by topographic discontinuities of low relief and softer rock. Heights of the colonies vary considerably. Virtually all of Colony 5 rises to heights of about 200 m asl as does Agate Rock, part of Colony 3. The maximum elevations elsewhere are rarely more than 100 m asl.

Campbell (1966) reviewed the complex geological history of the Cape Thompson vicinity. The cliffs are of marine sedimentary origin and Mississippian Age. There has been extensive folding as well as thrusting. Colonies 1 and 2 are exposures of a thick gray, fine to medium crystalline dolomitic sequence of late Mississippian Age, which has a very blocky appearance (Campbell 1966:65). Many surface cracks are nearly vertical on Colony 1, where "ledges that will safely accomodate an egg are relatively scarce" (Swartz 1966:663). Surface cracks at Colony 2 are often nearly horizontal. The blocky nature of the rock at Colony 2 provides occasional wide, as well as numerous narrow, ledges for breeding murres and kittiwakes.

Colonies 3, 4 and 5 are generally composed of older and more loosely bedded limestones and shales of Early to Late Mississippian Age. Portions of Colony 3 and all of Colony 5 are exposures of the upper portion of

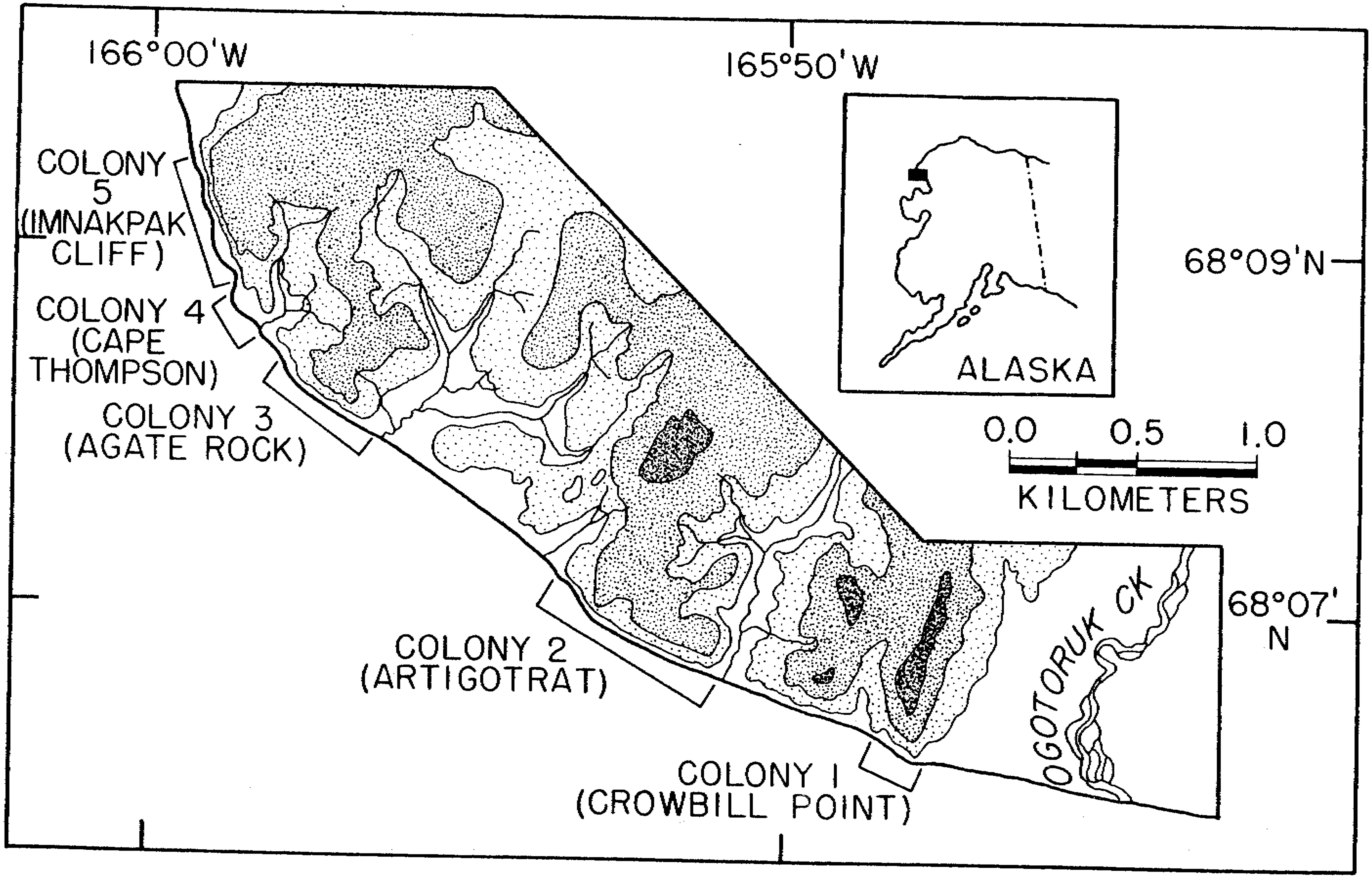

FIGURE 1. Seabird colonies in the vicinity of Cape Thompson, Alaska. Contour interval = 250 ft. No stippling, less than 250 ft.; light stippling, between 250 and 500 ft.; moderate stippling, between 500 and 750 ft.; heavy stippling, greater than 750 ft.

the formation and consist of thin- to medium-bedded limestones and thin-bedded silty shales (Campbell 1966). Thus, these cliffs are softer and more complexly fragmented than those of Colonies 1 and 2, providing a variety of small ledges for breeding seabirds.

The western portion of Colony 3 and much of Colony 4 consist of an 80 m thick layer of light gray, thickly-bedded limestone (Campbell 1966:63) that offers to breeding seabirds ledge configurations that are similar to those in Colony 2. Underlying silty clay shales which form a series of narrow horizontal breeding ledges characterize the eastern portion of Colony 4.

Here we also report data collected on the seabird colonies at Cape Lisburne and Bluff, Alaska. These colonies have been described by Springer and Roseneau (1978) and Drury (1977), respectively.

V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

A. Data Collection

Field efforts during 1979 began on 1 July and continued until 21 August at Cape Thompson. Two members of the field crew visited Cape Lisburne between 18 and 24 July and again between 14 and 20 August. The field effort at Bluff started on 19 July and continued through 10 August.

Murres and kittiwakes were collected at varying intervals during the summer at Cape Thompson and during the two visits to Cape Lisburne. Data on weights, breeding condition and fat condition were obtained at the time of collection and the stomach contents were preserved in 70% ethanol. These samples are now being analyzed and will be discussed in the Final Report.

In 1979 we conducted a complete census of murres and kittiwakes at Cape Thompson. Comparisons of the 1979 census data with those collected previously are the focus of this report. We obtained the 1960, 1976, and 1977 census data for both murres and kittiwakes from the original field notes. Counts of portions of the colonies were made in 1961 for murres and kittiwakes, and in 1978 for kittiwakes only. Although Thick-billed Murres and Common Murres inhabit the cliff faces in varying proportions throughout the colonies (Swartz 1966), differentiation to the species level has not been possible during the censuses and the two species have been counted together.

In conducting their counts of murres and kittiwakes in 1960 and 1961, Swartz and his assistants subdivided the 5 colonies into plots to facilitate counting. They generally defined plot boundaries by geomorphic features, such as cracks and deep ravines, and recorded the boundaries on photographs (Swartz, unpublished data). In subsequent censuses the field crews, aided by these photographs, were generally able to record numbers in accord with Swartz's plot designations. However, several minor and two major discrepancies did occur during subsequent counts. The two principal deviations from the original system were (1) the 1976 census of both murres and kittiwakes at Colony 5, and (2) the 1977 census of kittiwakes at Colonies 2, 3, and 4, when field crews used new boundaries. In addition, in those instances where boundaries were difficult to discern from photographs, adjacent plots were counted as a single unit.

In 1977 and 1979 we counted murres at Colony 5 so that these counts could be compared to both the 1960 and 1976 counts on a plot-by-plot basis. The 1976 and 1960 plots at Colony 5 lacked common boundaries. Consequently, it is possible to compare the counts of murres on a plot-by-plot basis in those 2 years for Colonies 1 through 4 only.

Many plot boundaries delineated in the 1977 kittiwake counts at Colonies 1 through 4 were identical to those defined in 1960. Consequently adjacent plots were amalgamated until a common boundary was reached, permitting intracolony comparisons of counts. Due to such amalgamations of adjacent plots, and because plot notations varied among years in several instances, plot designations have been standardized in this report. For those plots with variable notation, equivalencies and the notations used here are listed in the Appendix.

The method of censusing kittiwakes varied among years. In 1960 and 1961 Swartz (1966) counted the number of nests and then doubled the results to obtain an estimate of the size of the breeding population. In 1976 most kittiwakes failed to breed (Springer and Roseneau 1977). Consequently, counts made in that year, and also those made in 1977, were of individuals in adult plumage on the cliffs at the time of the count. Because of the variable presence of off-duty mates and nonbreeders on the cliffs there is no suitable way to compare the 1976 and 1977 data with those of 1960 and 1961. In 1979 we counted both individuals and nests to permit comparisons with all other years.

The actual techniques of counting murres and kittiwakes were similar but not identical among the censuses. Typically 2 or 3 observers counted with the aid of binoculars from a small boat anchored offshore. However, in 1960 the field crew counted many of the plots at higher elevations in Colony 5 from land, looking down at the ledges from the top of the colony. In 1976 and 1977 these, like all other plots, were counted from a boat anchored offshore. In 1979 we counted some of these plots from both perspectives to assess similarity of the 2 methods.

Usually observers have estimated numbers by tens, intermittently actually counting 10 individuals (or nests) to maintain accuracy and precision. In 1960 and 1976, however, all boat-based counts of murres at Colony 5 were in increments of 100 rather than 10. The available data do not permit evaluation of the accuracy of estimating by hundreds rather than tens. If the simultaneous counts by two or three observers are considered as independent estimates of numbers, then the variability between or among the counts is a measure of the precision of those counts. We examine the relative precision of the two counting techniques by comparisons of the coefficients of variation associated with each plot count (see below).

We also conducted counts at 2 hour intervals through a 24-hour period on several occasions at selected areas of Colonies 2, 4 and 5 during 1979. These data are used in this report to examine patterns of diurnal changes in numbers and spatial synchrony in such changes. Two such counts also coincide with the actual census counts so that the effect of diurnal variation in attendance patterns could be addressed in examining the census results.

In 1979 we counted murres on several plots throughout the colonies several times during the breeding season. We counted murres on all plots in Colony 1 on 6 occasions, including the date when Colonies 3, 4 and 5 were censused. We censused murres at Colony 4 a second time several days after the complete census of the colonies. These data permit evaluation of daily (day-to-day) and seasonal changes in numbers of murres on the cliffs.

In 1979 we examined kittiwake nests at varying intervals at Cape Thompson. For each nest we recorded dimensions and weights of the eggs, clutch size, hatching success, weights of nestling and fledging success as possible. The visits to Bluff and Cape Lisburne were timed to provide data on brood sizes, growth rates of nestlings, and fledging success only. At all 3 localities we visited the nests and weighed the nestlings several times to provide estimates of growth rates.

The field crew at Cape Lisburne counted murres on 15 August on 10 of the 75 plots. Counting techniques there were comparable to those at Cape Thompson.

At Bluff two observers censused the entire colony on three occasions. One observer counted murres and the other counted kittiwakes. Thus, no measure of observer variability is available from these counts. Also, observers counted from a boat moving slowly past the cliffs rather than anchoring at each plot. In previous years, field crews estimated the numbers of murres flushing in response to the passing boat (Ramsdell and Drury 1979). In 1979 we attempted to minimize this effect by passing very slowly below the cliffs, and relatively few murres flushed. Numbers flushing were estimated and are included in the census totals. In contrast field crews at Cape Thompson and Cape Lisburne have simply waited to start counting at a particular plot until murres that flush have returned to the cliffs. This procedure has typically necessitated a wait of several minutes only.

B. Data Analysis

Census

We first computed basic statistics, including the mean and coefficient of variation, of the counts on each plot in each year. Using the mean as a summary statistic of the counts of two to several observers implies that each observer's count is an equally valid estimate of actual numbers. We made no formulation of personal handicaps, having no basis for determining which observers were estimating numbers most accurately. Photodocumentation of actual numbers, which we lack, would be necessary for the evaluation of discrepancies among observers in their counts and the subsequent assignment of handicaps. Except on small, easily viewed plots, the numbers obtained by each observer should be considered estimates of actual numbers, rather than true counts. In the context of this report, and in most reported censuses, the term count is used loosely, synonymously with estimate. The coefficient of variation is a direct measure of the agreement between (among) observers simultaneously counting a particular plot and is thus indicative of the difficulty experienced in counting that plot in those conditions.

We next evaluated numeric change among years by ranking the means in each of the years (treatments) on each plot (block) and then conducting a Friedman's Test (e.g. Conover 1971) for each colony. This analysis represents a statistical comparison of the census results among years for each colony and provides an initial evaluation of the similarity among colonies in relative numbers.

We also examined spatial patterns of yearly variation in numbers of murres and kittiwakes using correlation analysis. First, data from each census plot were expressed as points on a bivariate scatter diagram, the mean number counted in one year being the first variable, that in a subsequent year being the second variable. A bivariate diagram was generated for each possible pair-wise combination of years.

Then we conducted correlation analyses for each pair-wise comparison, computing the correlation coefficient, the first eigenvector (the slope of the principal axis), 95 percent confidence limits for the first eigenvector, and the equation for the principal axis (see Sokal and Rohlf 1969:526-532). The procedure for calculating the principal axis of the correlation equation is similar to that in linear regression, but it minimizes the sum of squares of deviations from the principal axis rather than independent variable. It is appropriate for establishing the degree and nature of association between 2 variables (Sokal and Rohlf 1969:495-498).

The slope of the principal axis describes the trend in numbers between years. For example, if relative numbers in year 2 were 75 percent of those in year 1, the slope should equal 0.75. Thus, in this report, the slope is an expression of relative numbers in the 2 years, expressed as a proportion of the number in the earlier year.

Inserting the observed total of numbers of adults (or nests) counted in the earlier year into the correlation equation produces a mean estimate of total numbers in the later year. The 95 percent confidence boundaries for the slope can be used in the equation to bracket the mean estimate. If changes on individual plots reflect the overall changes, these estimates will bracket the observed change.

As a further test of how well the correlation equation reflected the observed overall change in numbers, we also computed correlation statistics for the relationship between numbers in the later year, expressed as a proportion of numbers in the earlier year, and the mean number in the earlier year for all plots. A significant correlation would show that the degree of numeric change was nonrandomly related to initial numbers, e.g. greater declines on plots with high numbers than on plots with low numbers in the earlier year would result in a negative correlation in this analysis. This analysis provides further insight into how well numeric changes on plots reflect the overall observed changes in numbers in the Cape Thompson colonies.

To test overall differences in numeric change among colonies at Cape Thompson, we first transformed averaged totals in 1976, 1977 and 1979 into percentages of the averaged 1960 total for each colony. For each of those three years we ranked the percentage values among colonies and conducted a Friedman Test, considering years as blocks and colonies as treatments. This procedure allowed a test of the null hypothesis that overall changes since 1960 were similar among colonies.

To analyze the effect of intracolony variation on the degree of numeric change at Cape Thompson, we first standardized the 1976, 1977 and 1979 counts among plots by dividing each averaged count by the 1960 averaged count for each plot. We defined peripheral plots as those plots either on the geographic edge of a colony or not contiguous with any other plot on that colony. We tallied the values for peripheral plots by quartile in relation to the distribution of values for all plots in each colony and then combined the tallies for the three years, 1976, 1977 and 1979. We then analyzed how accurately (Quartile Test, Median Test) and how precisely (Extreme vs. Central Quartiles) changes on peripheral plots reflected the overall changes within colonies. We also conducted a Chi Square Goodness of Fit Test to examine any differences among colonies.

To examine differences in relative numbers at high elevation plots and low elevation plots at Colony 5 we compared the 1979 counts, standardized in relation to the 1960 counts, on the two sets of plots. For this analysis we defined upper plots as those with the upper boundary at the top of the cliff and the lower boundary at or above the altitudinal midpoint of the cliff. Lower plots are those with the lower boundary at the base of the cliffs. We computed the Mann-Whitney Test Statistic, testing the null hypothesis that the standardized means for upper and lower plots were equivalent.

As noted earlier, we interpret the variation between observers counting simultaneously as a measure of the difficulty in counting a particular plot under those conditions. We therefore evaluated the null hypothesis that boat-based counts of upper plots were made with the same degree of precision as those of lower plots by comparing the distribution of the coefficients of variation for the two sets of plots. We used the data from 1977 and 1979 to make two independent tests of this hypothesis using the Mann-Whitney Test.

At Colony 5 some of the upper plots on the main cliff face have been counted from a boat in 1960 as well as in later years. Those upper plots on invaginations of the cliff face and visible from prominences at the top of the colony were counted from land in 1960, and some of these were counted from land in 1979. Comparing 1979 numbers, expressed as percentages of the 1960 numbers, on plots counted from land in both years and on plots counted from the sea in both years permits evaluation of the null hypothesis that the degree of change in murre numbers between 1960 and 1979 on the main cliff face and in the ravines was equivalent. We used a Mann-Whitney Test of this hypothesis.

Birkhead and Ashcroft (1975) computed the correlation between annual variation in murre numbers on selected areas at Skomer Island and overall variation there. They found significant positive correlations and concluded that annual variation on each area they selected did accurately reflect variation on the entire island. However, the correlation coefficient itself is only a measure of association, and it is the slope of the correlation equation that provides a measure of similarity in trends. We have extended Birkhead and Ashcroft's approach by computing the slope of the correlation equation, as well as the correlation coefficient, in our analyses of daily synchrony in numbers within the Cape Thompson colonies in 1979 (see Sokal and Rohlf 1969).

To analyze the data from the 24-hour counts at Cape Thompson we first rounded the starting time of each count to the nearest hour and then computed a correlation matrix among areas of counts during the same 24-hour period. Since the counts were conducted every 2 hours, there should have been 12 simultaneous counts at each area. However, we frequently were unable to count some of the areas at the appropriate time, e.g. because of dense fog, and consequently there are a number of gaps in the data base. We have included correlation coefficients for particular pair-wise comparisons of areas only if a minimum of 6 counts were made simultaneously. During the actual census, on 7-8 August, the counts were made hourly while the census was being conducted, resulting in more than 12 simultaneous counts at several plots on those dates. We tallied the number of significant correlation coefficients and compared the result to the number expected by chance if the null hypothesis of a no correlation were always true.

At Bluff we counted two portions of the colony repeatedly from 21 July to 6 August, including 3 periods of counts every 2 hours lasting 26, 34 and 26 hours. We counted at 1500 h on 12 of those days and 1700 h on 15 days during that period. The counts provide a data base for assessing daily and diurnal variation in numbers of murres and kittiwakes at Bluff. These and all other times in this report are Bering Daylight Time (BDT). We made these counts from Stakes 10 and 15 (see ramsdell Drury 1979), dividing those portions of the cliff face into 3 and 2 areas, respectively. As the two observers (F and J) synchronized their efforts, the counts were simultaneous at the 5 areas, permitting assessment of spatio-temporal variation in numbers on the cliffs.

In evaluating observer differences in counts of murres we have adhered to, and extended, the notation for observers used in earlier annual reports. As used in this report and applied to the field crews in 1979, the notations are

CODE	Name
B	D. Johnson
C	A.M. Springer
E	D.G. Roseneau
F	E.C. Murphy
H	M.I. (Johnson) Springer
I	W. Walker
J	A. Watson

Productivity

The data on kittiwake breeding phenology were tabulated and compared to those in earlier years. In addition to reporting earliest hatching dates for each locality-year sample we estimated the distribution of hatching dates for nestlings weighed in each sample. We used the following equations to derive the estimate for each nestling:

(1) Age (in days) $= \text{Weight}_1 - 35\text{ g})/\left[(\text{Weight}_2 - \text{Weight}_1)/(\text{Date}_2 - \text{Date}_1)\right]$

(2) Hatching Date $= \text{Date}_1 - \text{Age}$ where

Weight$_1$ was the weight on the day, Date$_1$ when the nestling was first measured, and

Weight$_2$ was the weight on the day, Date$_2$, when the nestling was measured the second time.

We have used 35 g as the estimate of hatching weight and have assumed in the calculation that the growth rate between the first two measurements was equal to that between hatching and the first measurement. Maunder and Threlfall's (1972) detailed studies of growth rates and our own data indicate that this assumption is appropriate until nestlings are about three weeks old, as growth rates are nearly linear from hatching to that age. We performed the calculation only for nestlings which were alive at the end of our observations and only if two measurements were made within 20 days of the estimated hatching date.

In 1978 Drury (Ramsdell and Drury 1979) recorded actual hatching dates during detailed observations of nests and also weighed a small sample of nestlings. We have compared the distribution of estimated hatching dates of those nestlings with the observed distribution at the kittiwake stakes (see Ramsdell and Drury 1979) as a check on the validity of this technique.

The data on kittiwake productivity were tabulated and compared to those in other years. In 1977 and again in 1979 we checked kittiwake nests at Cape Thompson in 3 areas, using a 5 m ladder for access from the beach below. In addition to gathering data on the nests within reach from the ladder ("Lower" nests), we visually examined nests up to several meters above the reach of the ladder ("Upper" nests) using a convex mirror on a 3 m pole. As upper nests were somewhat more centrally located than lower nests, we compared reproductive output in upper and lower nests to investigate any differences in reproductive output in central vs. peripheral nests as reported by Coulson (1968) at a colony in the British Isles.

At the time of hatching we were often unable to distinguish between egg and nestling loss if any reduction in nest contents occurred, e.g. if we found a clutch of 2 eggs on 1 visit and a single nestling on the next visit there was no way to determine the fate of the second individual. We frequently found unhatched eggs in nests long after hatching should have occurred and only rarely found dead nestlings. We have assumed in our calculations of hatching success that any change in nest contents from 2 eggs to 1 nestling or 1 egg, or from 1 egg to zero nestlings or zero eggs between our visits during the hatching period represented successful hatching but subsequent nestling death.

At all 3 localities we completed the field work before fledging of kittiwakes actually started and have assumed in our estimates of fledging success that any nestlings weighing 300 g or more on the last visit, or in plumage class 3 or 4 (see Ramsdell and Drury 1979), did eventually fledge. We calculated average daily weight gains for nestlings weighed two or more times between hatching and 300 g, using only the two extreme measurements within that range to make the calculation.

Preliminary analysis indicated that growth rates of most nestlings remained linear through 350 g. If a nestling was weighed only once when less than 300 g but was also weighed when between 300 g and 350 g we computed average daily weight gain. We included this value in the analysis only if data were unavailable for that nestling in the hatching to 300 g range and only if this weight gain exceeded the weight gain of the slowest growing nestling in the hatching to 300 g range. At Cape Lisburne in 1979, no nestlings were weighed twice when less than 350 g. On the first visit in late July many eggs were pipping; on the return visit in mid-August most nestlings weighed were over 350 g. We computed daily growth rates for Cape Lisburne in 1979 by (1) assuming the egg hatched the day after it was found pipping (see Maunder and Threlfall 1972:804), (2) assigning a weight of 35 g for hatching weight and (3) computing the daily weight gain between the presumed hatching day and the day the nestling was first measured about 3 weeks later. Our preliminary analyses and other accounts (e.g. Maunder and Threlfall 1972) of weight gains suggest that daily weight gains typically decline soon after nestlings reach 350 g; therefore, the 1979 Cape Lisburne data on average weight gains are not truly comparable with those from the other samples analyzed here.

VI. RESULTS

A. Murres

Censuses at Cape Thompson

Table 1 summarizes the census results for the 4 years when complete censuses were conducted. The census totals indicate a decline in numbers from 1960 to 1979, particularly at Colony 5, where numbers declined in each successive census. Although fewer murres have been counted at Colonies 1 through 4 in recent years than in 1960, there has been no trend among recent years. The 1977 figures are greater than either the 1976 or 1979 totals at those colonies. The continued significant decline at Colony 5 and the less marked declines at the other colonies suggest that factors responsible for changes in numbers either differ among colonies or have simply resulted in spatial consolidation of the murres at Colonies 1-4 as overall numbers have declined.

The census results suggest that total numbers of murres have declined at an annual rate of about 5% from 1976 to 1979. The average annual rate of decline between 1960 and 1976 was 3% (see Figure 2), suggesting that the rate of decline has increased over the past several years. While we recognize that there are several major sources of variability in the number of murres on the cliff faces within a breeding season, as will be discussed below, such variability is typically random and equally implicated in every census. Thus, the statement that murre numbers have apparently declined at a rate of several percent each year and that the rate of decline may have accelerated in recent years, is the best working hypothesis at the present time.

As noted earlier, 18 of the upper plots at Colony 5 were counted from the top of the colony in 1960, but from a boat at sea in later years. In 1979 we evaluated the possible bias induced by these different

TABLE 1. Murres: Summary of census results at Cape Thompson, Alaska[1].

	Year				
Colony	1960	1976	1977	1979	Spearman's rho[3]
1	4,187	2,090(50)[3]	2,471(59)	1,955(47)	-0.8
2	76,249	46,722(61)	52,320(69)	50,034(66)	-0.4
3	26,814	19,098(71)	21,282(79)	15,822(59)	-0.8
4	8,726	6,894(79)	7,621(87)	5,472(63)	-0.8
5	134,532	79,650(59)[4]	58,995(44)[4]	39,756(30)[4] 45,161(34)[5]	-1.0*
Total	250,508	154,454(62)[4]	142,689(57)[4]	113,039(45)[4] 118,444(47)[5]	-1.0*

*$p<0.05$

[1] Totals computed by summing values of average number/plot.

[2] Values are from the complete census, 7-8 August, only (see text).

[3] Row percent of 1960 value listed in paraentheses.

[4] All plots counted from boat at sea (see text).

[5] Land counts at 9 of the 18 plots counted from land in 1960, all other plots counted from boat at sea (see text).

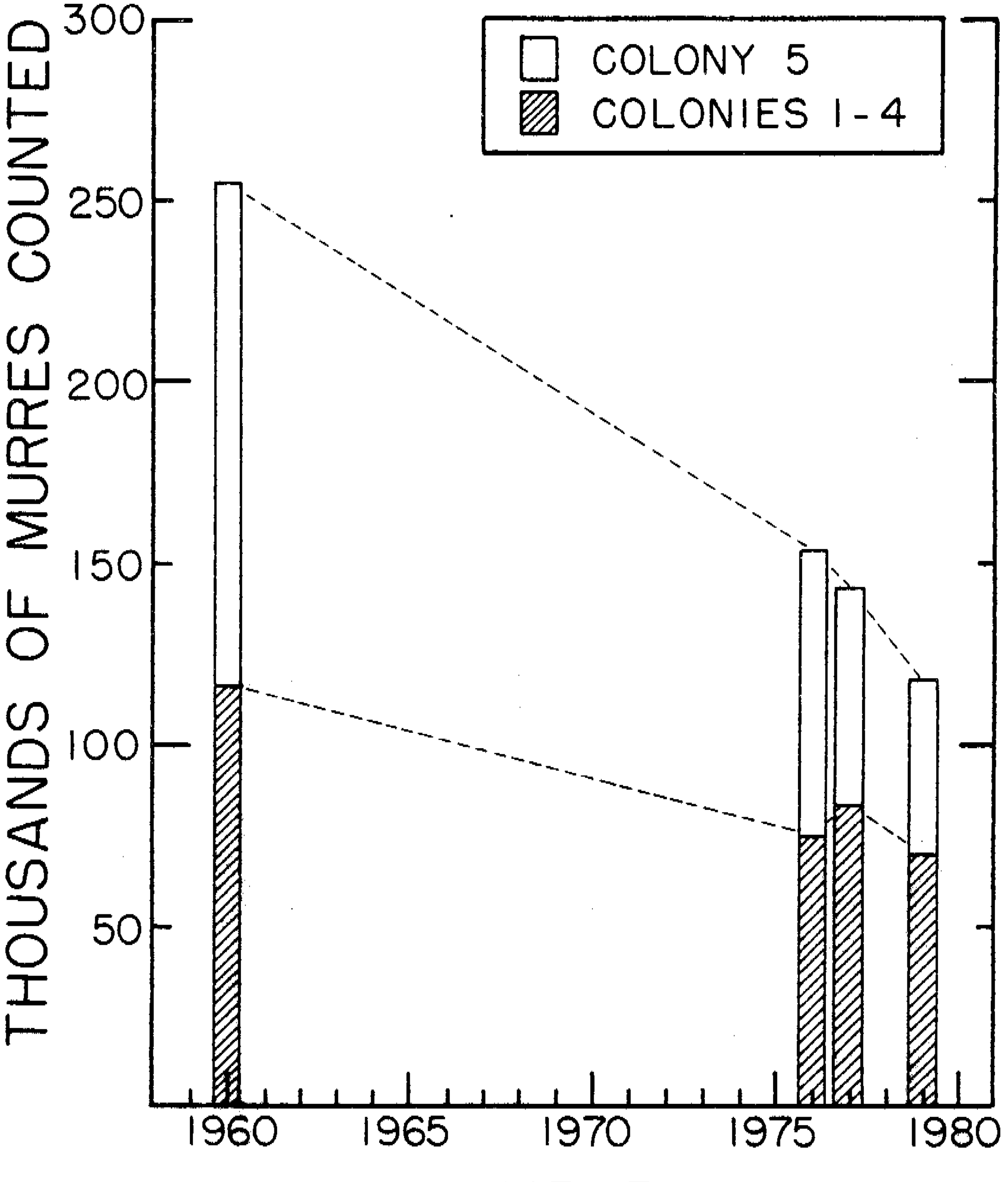

FIGURE 2. Murres: Numbers counted at Cape Thompson in years when complete censuses have been conducted.

techniques by simultaneous counts by boat-based and land-based observers at 8 of these plots. On all 8 plots, land-based counts were higher than boat-based counts, a highly unlikely result if the two techniques were comparable (Binomial Test, $n=8$, $y=0$, $p^*=0.5$, $p=0.0078$). Summing the counts, averaged among observers for each plot, results in totals of 8355 murres counted from above and 4379 murres counted from the boat. Thus, the boat-based counts totalled only 52% of the land-based counts. These plots are about 150-200 m above sea level. Clearly counts from a boat underestimate the numbers of murres on high elevation plots. Apparently substantial numbers of murres are obscured from view, even though the cliff faces appear quite visible to boat-based observers. As there are differences in the effectiveness of the two counting techniques, only those counts using the same technique will be compared in the following analyses.

The difference in effectiveness of the two techniques indicates that census results for Colony 5 in the different years are not strictly comparable. Table 2 shows relative numbers on those plots counted in the same manner. Again these figures substantiate those shown in Table 1.

We used a Friedman's Test to evaluate the null hypothesis that rankings of the plot counts did not vary among years, i.e. that there are no year to year differences in numbers of murres counted when censuses are compared on a plot-by-plot basis. At all colonies except Colony 4 the test statistic was highly significant (Table 3), indicating significant difference among years. Table 3 also shows that on most plots numbers were highest in 1960, as shown by the sums of ranks and the average rankings. At Colonies 1 and 5 numbers on every plot were higher in 1960 than in any other year. Thus, the changes analyzed on a plot-by-plot basis qualitatively reflect the overall change for each colony.

Correlation analysis provided a quantitative measure of the consistency with which changes on individual plots reflected overall changes between years. Table 4 summarizes all pair-wise comparisons. Figure 3 depicts

TABLE 2. Murres: Relative numbers (percentages) counted at Colony 5 on plots using the same techniques.

Previous Year	Number of Plots[1]	Subsequent Year 1976	1977	1979
1960	37	NA[2]	44(19)[3]	33(28)
1976	11	--	74(11)	50(11)
1977[4]	37	--	--	68(36)

[1] Plot designations differed in 1960 and 1976 (see text). In 1960, counts on 18 of the 37 plots were made from land at the top of the colony, none and 9 of these plots were counted from land in 1977 and 1979, respectively. Entire 1976 and 1977 censuses were conducted from a boat; only boat-based counts in 1979 are used in comparisons with those years.

[2] Not applicable: 1976 plots include a combination of areas counted from the top of the colony and from a boat in 1960.

[3] Number of plots counted using the same technique is listed in parentheses.

[4] 1960, rather than 1976, plot designations are used in comparisons of 1977 and 1979 counts in this report.

TABLE 3. Murres: Summary of the Friedman's Test results evaluating differences among years.

		SUM OF RANKS				
		Year				
Colony	Number of Plots	1960	1976	1977	1979	Test Statistic[1]
1	6	24.0(4.0)[2]	11(1.8)	16.5(2.8)	8.5(1.4)	14.150(3)**
2	34	125.0(3.7)	62.0(1.8)	72.0(2.1)	81.0(2.4)	40.835(3)**
3	13	43.0(3.3)	32.0(2.5)	37.0(2.8)	18.0(1.4)	15.738(3)**
4	17	51.0(3.0)	42.0(2.4)	45.0(2.6)	33.0(1.9)	6.035(3)
5	19[3]	57.0(3.0)	--	35.0(1.8)	22.0(1.2)	32.947(2)**
	11[4]	--	30.0(2.7)	22.0(2.0)	14.0(1.3)	11.636(2)**

** P<0.005

[1] Chi Square test statistic (degrees of freedom in parentheses).

[2] Average ranking (sum of ranks/number of plots).

[3] 1960 plot designations, counts from boat only (see text).

[4] 1976 plot designations (see text).

TABLE 4. Murres: Results of the correlation analyses comparing census data, based on plot counts.

A. Correlation coefficients (sample size - number of plots - in parentheses).[1]

	COLONY					
	1	2	3	4	5	ALL
1976 vs. 1960	0.99(6)	0.81(34)	0.93(13)	0.87(17)	--	0.89(70)
1977 vs. 1960	0.99(6)	0.89(34)	0.99(13)	0.88(17)	0.81(19)	0.89(89)
1979 vs. 1960	0.99(6)	0.83(34)	0.99(13)	0.75(17)	0.72(28)	0.75(98)
1977 vs. 1976	1.00(6)	0.84(34)	0.97(13)	0.91(18)	0.91(11)	0.94(82)
1979 vs. 1976	0.99(6)	0.94(34)	0.95(13)	0.67(18)	0.95(11)	0.90(82)
1979 vs. 1977	1.00(6)	0.86(34)	0.98(13)	0.80(18)	0.83(19)	0.88(107)

TABLE 4 (cont.).

B. Relative numbers, expressed as percentages.[2]

	COLONY					
	1	2	3	4	5	ALL
1976 vs. 1960	46(40-52)	69(53-87)	74(59-91)	71(53-93)	--	69(61-77)
1977 vs. 1960	56(50-63)	67(56-79)	76(69-83)	72(56-92)	42(29-56)	52(47-58)*
1979 vs. 1960	45(39-52)	73(57-90)	53(48-58)*	44(26-64)	21(14-29)*	36(30-42)*
1977 vs. 1976	122(117-126)	94(75-117)	101(88-116)	102(82-126)	60(45-78)	71(65-76)*
1979 vs. 1976	99(87-112)	104(92-118)	70(57-83)	61(33-97)	33(27-40)*	47(42-53)*
1979 vs. 1977	81(74-89)	111(91-136)	70(63-77)	64(43-89)	52(37-68)	78(70-86)

[1] All correlation coefficients are significant $P < 0.01$ (see text).

[2] Slope of the principal axis time 100 (95% confidence interval in parentheses) (see text).

*Underestimate of actual value, based on summed total for all plots counted by the same techniques in the year being compared.

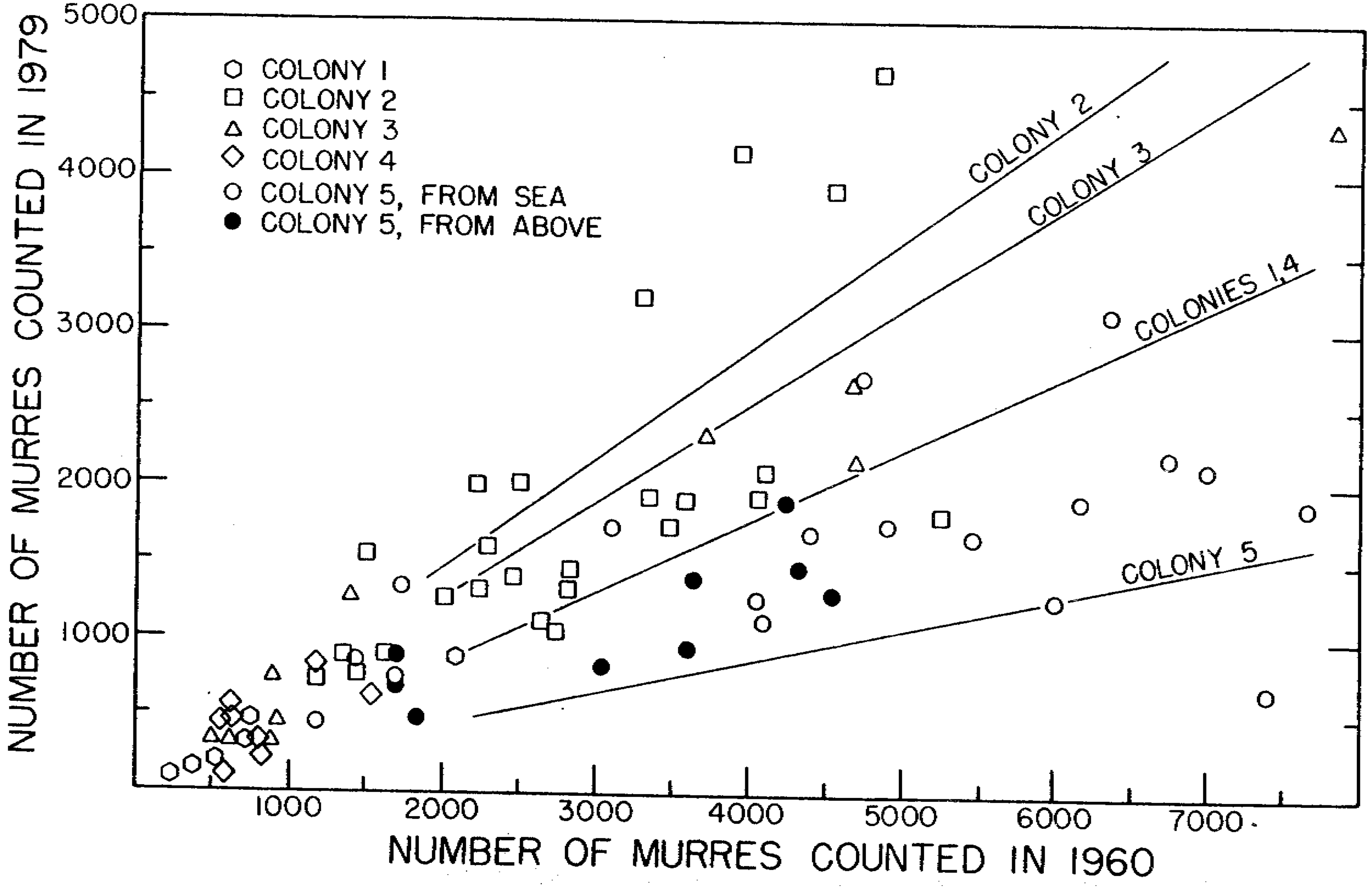

FIGURE 3. Murres: Comparisons of numbers counted in 1960 and 1979 at the 5 Cape Thompson colonies. Each symbol represents a plot within the appropriate colony.

the relationships between numbers in 1960 and 1979 for the 98 plots counted by the same technique in both years. In general, the slope of the correlation equation does reflect the relative total numbers within colonies. However, the correlation equation underestimated the 1979 numbers relative to the 1960 numbers at both Colonies 3 and 5, and relative to the 1976 numbers at Colony 5 (Figure 4). Combining all colonies in the analysis generally resulted in an underestimate of numbers. For example, on the 98 plots counted by the same technique in 1960 and 1979, the field crews counted 242,285 murres in 1960 and 114,542 murres in 1979. The 1979 total was thus 47% of the 1960 total. Yet the percentage predicted by the correlation equation, i.e. the slope of the principal axis, was only 36% and the 95% confidence limits for the slope did not bracket the observed total (Table 4, Figure 4).

For both Colonies 3 and 5 Figure 3 suggests that relative numbers of murres in 1979 were higher on plots where comparatively few murres were counted in 1960 than on plots where high numbers were counted in 1960, i.e. declines on some of the plots where high counts were made in 1960 were perhaps disproportionately great. To quantify any trend between initial numbers and relative numbers in later years we again computed correlation statistics, in this instance using (1) actual numbers counted in the earlier year and (2) relative numbers in the later year as the two variables in the analysis.

The results of these correlation analyses are listed in Table 5. All the correlation coefficients at Colonies 2 and 4 were negative; three were significantly so. Four of the five correlations for Colony 5 were significantly negative, indicating that the declines there have been most marked on plots where high numbers were counted initially.

Although the correlation coefficients themselves were often negative and sometimes significant, there was very little apparent slope to the correlation line and the 95% confidence limits for the slope usually

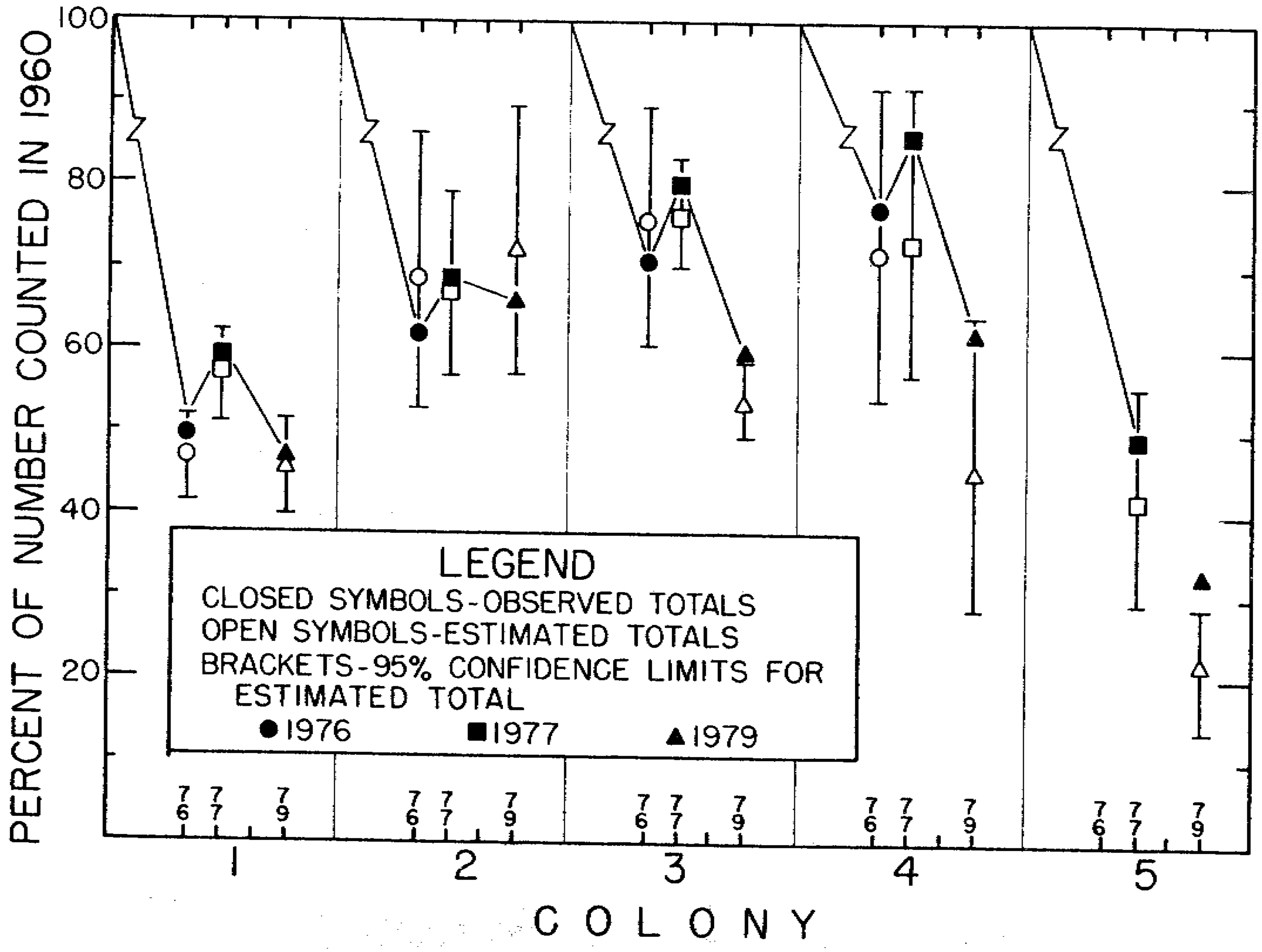

FIGURE 4. Murres: Numbers in recent years relative to those in 1960, based on correlation analyses of plot counts (see text).

TABLE 5. Murres: Results of the correlation analyses of initial numbers/plot and subsequent relative numbers/plot.[1]

A. Correlation Coefficients (sample size - number of plots - in parentheses).

	Colony					
Comparison	1	2	3	4	5	ALL
1976 vs. 1960	0.38(6)	-0.13(34)	-0.36(13)	-0.19(17)	--	-0.20(70)
1977 vs. 1960	0.45(6)	-0.19(34)	-0.37(13)	-0.47(17)	-0.58(19)*	-0.34(89)*
1979 vs. 1960	0.61(6)	-0.25(34)	-0.37(13)	-0.51(17)*	-0.53(28)*	-0.38(98)*
1977 vs. 1976	0.48(6)	-0.37(34)*	0.02(13)	-0.42(18)	-0.62(11)*	-0.29(82)*
1979 vs. 1976	0.75(6)	-0.34(34)	0.06(13)	-0.50(18)*	-0.87(11)*	-0.31(82)*
1979 vs. 1977	0.64(5)	-0.27(34)	-0.00(13)	-0.34(18)	-0.37(36)	-0.16(106)

B. Slope of the Principal Axis (95% confidence limits in parentheses).

	Colony					
Comparison	1	2	3	4	5	ALL
1976 vs. 1960	0.01(-0.01-0.02)	0.00(-0.01-0.00)	-0.02(-0.05-0.01)	-0.02(-0.05-0.02)	--	-0.01(-0.02-0.00)
1977 vs. 1960	0.02(-0.01-0.04)	0.00(-0.01-0.00)	-0.02(-0.04-0.00)	-0.06(-0.11-(-0.01))	0.00(-0.01-0.00)	-0.01(-0.01-0.00)
1979 vs. 1960	0.02(0.00-0.04)	-0.01(-0.01-0.00)	-0.01(-0.03-0.00)	-0.05(-0.10-(-0.01))	0.00(0.00-0.00)	-0.01(-0.01-0.00)
1977 vs. 1976	0.07(-0.03-0.17)	-0.02(0.04-0.00)	0.00(-0.01-0.01)	-0.14(-0.28-0.00)	0.00(0.00-0.00)	-0.01(-0.01-0.00)
1979 vs. 1976	0.11(0.03-0.19)	-0.02(-0.03-0.00)	0.00(-0.01-0.01)	-0.14(-0.25-(-0.03))	0.00(-0.01-0.00)	-0.01(-0.01-0.00)
1979 vs. 1977	0.06(0.00-0.12)	-0.01(-0.02-0.00)	0.00(0.00-0.00)	-0.03(-0.07-(-0.01))	-0.01(-0.02-0.00)	0.00(-0.01-0.00)

* $P<0.05$

[1] Relative numbers/plot = (number in 2nd year/number in 1st year) times 100.

bracketed zero (see Table 5). These results suggest that although declines on plots where numbers were initially great were in some instances particularly marked, these influenced the correlation equation surprisingly little. Thus, these analyses do not fully account for the discrepancies between predicted totals and actual counts in Table 4.

The results of the correlation analyses suggested that there might be a curvilinear relationship between initial numbers of murres and subsequent numbers, such that changes (declines) were comparatively great on those areas where numbers were initially highest. Sokal and Rohlf (1969) suggest methods of testing for curvilinearity and transforming curvilinear relationships into linear ones. We attempted a series of transformations, including power and logarithmic transformations of numbers counted in the first year of each comparison, but found no procedure which increased the proportion of the variance of the counts in the second year explained by the correlation model, i.e. no transformation resulted in a better model than the linear model.

There are several possible explanations as to why the correlation equations sometimes underestimate observed numbers in the later year. Figure 3 demonstrates that the variance of the counts in the second year increases with the magnitude of the counts in the first year--a violation of an underlying assumption in the correlation model (see Sokal and Rohlf 1969:410). We are presently conducting these correlation anaylses on logarithmically transformed data to negate this effect. The results of these analyses will be incorporated in the Final Report.

Secondly, inserting the observed total count from the first year in the correlation equation to estimate the total number of murres in the second year involves extending the line of the correlation equation well beyond the range of values on which it is based. Furthermore, the confidence limits for the slope are only approximate unless the sample size is large (Sokal and Rohlf 1969:532). All of these effects suggest that the actual confidence limits for the slope are likely much wider than indicated here.

Spatial Variation in Numeric Change at the Cape Thompson Colonies

As noted in the previous section, numbers of murres have declined more markedly at Colony 5 than at the other four colonies since 1960. Colony 5 is the only colony where numbers have been lower on each successive census. Figures 2 and 4 graphically indicate that numeric changes have varied considerably among colonies. This conclusion is apparently substantiated by the Friedman's Test (Table 6) which indicates significant differences among colonies in numbers of murres counted in recent years relative to the 1960 totals for each colony. However, in this analysis, all 3 blocks (years) are partially dependent on the 1960 data and are thus not truly independent.

For all pairwise comparisons between years Table 7 summarizes the data on relative numbers on peripheral plots in comparison to the distribution of values for all plots at each colony. Overall, the Goodness of Fit tests indicated that the trends in numbers on peripheral plots reflected the overall pattern of numeric change within colonies but were more likely to be towards one extreme or the other of the distribution of values. Thus, peripheral plots apparently provided an accurate (unbiased) but imprecise measure of numeric change.

Yet comparing the numbers of values above and below the median for each colony in Table 7 indicates significant variation among colonies (X^2=15.758, v=4, $P < 0.005$). For example, at Colony 1, relative numbers on 10 of the 11 peripheral plots fell below the median value for all plots at that colony, while only 2 of the 12 values for peripheral plots at Colony 4 were below that colony's median. Numbers on the two peripheral plots at Colony 1 were low in 1960 and no murres were seen on those plots in the 1979 census. On the other hand, numbers increased threefold between 1960 and 1979 at one of the Colony 3 peripheral plots. Thus,

TABLE 6. Murres: Friedman's Test of colony differences in numeric change. [1]

	PERCENT OF 1960 TOTAL[2]				
	Colony				
Year	1	2	3	4	5
1976	50(1)[3]	61(3)	71(4)	77(5)	59(2)
1977	59(2)	69(3)	79(4)	86(5)	49(1)
1979	47(2)	66(5)	59(3)	62(4)	25(1)
Sum of Ranks	5	11	11	14	4

Test Statistic = 9.867, v = 4, P>0.05

[1] Null Hypothesis: numbers relative to 1960 are similar among colonies for the three subsequent years counts have been made (see text).

[2] Values are based on totals for plots counted in the same manner as in 1960 except that the Colony 5 total in 1976 as reported in Table 1 is used.

[3] Rank relative to values for other colonies.

TABLE 7. Murres: Relative numbers of peripheral plots[1], tallied by quartiles for each colony (see text).

	Quartile				
Colony	1	2	3	4	Total
1	6	4	0	1	11
2	5	6	3	4	18
3	9	1	6	8	24
4	1	1	4	6	12
5	1	2	2	5	10
Total	22	14	15	24	75

Quartile Test: $X^2 = 3.987$, $v = 3$, n.s.

Median Goodness of Fit Test: $X^2 = 0.120$, $v = 1$, n.s.

Extreme Quartiles vs. Central Quartiles: $X^2 = 3.853$, $v = 1$, $P<0.05$.

[1] Any plot either on the geographic edge of a colony or not contiguous with any other plots on that colony. Plots so defined are 1A, 1H, 2A1, 2A2, 2HI, 3A-3C, 3S, 4A, 4R, 5AX, 5RR, 5XA, and 5XL (notation here corresponds to that in the Appendix).

numbers on peripheral plots not only fluctuated more markedly than on central plots, but, at a particular colony, they may have fluctuated in a different pattern than did overall numbers. Qualitatively, peripheral plots at Cape Thompson are typically small in area and contain relatively few murres in comparison with centrally located plots within colonies.

The counts at Colony 5, as percentages of the counts in 1960, in 1979, were similar on upper and lower plots (Mann-Whitney Test, n=13, m=15, T=67, P > 0.10). We also conducted the Siegel-Tukey Test for inequality of variance (see Conover 1971: 230) and found no evidence that variance of the 1979:1960 ratios differed between upper and lower plots (n=13, m=15, T=113, P > 0.20). Therefore, numeric change within Colony 5 showed no pattern in relation to elevation.

We utilized the coefficient of variation values to compare the precision of boat-based counts of upper and lower plots. The Mann-Whitney Tests using the 1977 and 1979 samples independently provided no evidence that upper plots were counted with less precision (n=13, m=24, T=154.5, P > 0.20; n=13, m=23, T=143, P > 0.20, respectively). Although boat-based observers underestimated numbers of murres on upper plots, as previously discussed, the precision of their estimates on upper and lower plots was comparable. Thus, the boat-based counts of upper plots are inaccurate (biased) but no less precise than counts of lower plots.

Because the decline in numbers counted at Colony 5 has been dramatic and has continued over the past several years we further examined spatial variation in degree of the numeric change within Colony 5. Figure 5 shows numbers in 1979, expressed as percentages of numbers in 1960, in relation to location within the colony. While the decline in numbers was greatest at plot JJ, a central plot, and least at RR, a peripheral plot, there is no distinct trend to the pattern of change from one end of the colony to the other or from the periphery to the center. In addition, we calculated a Spearman's rank correlation coefficient, pairing each lower plot with the corresponding upper plot(s); the

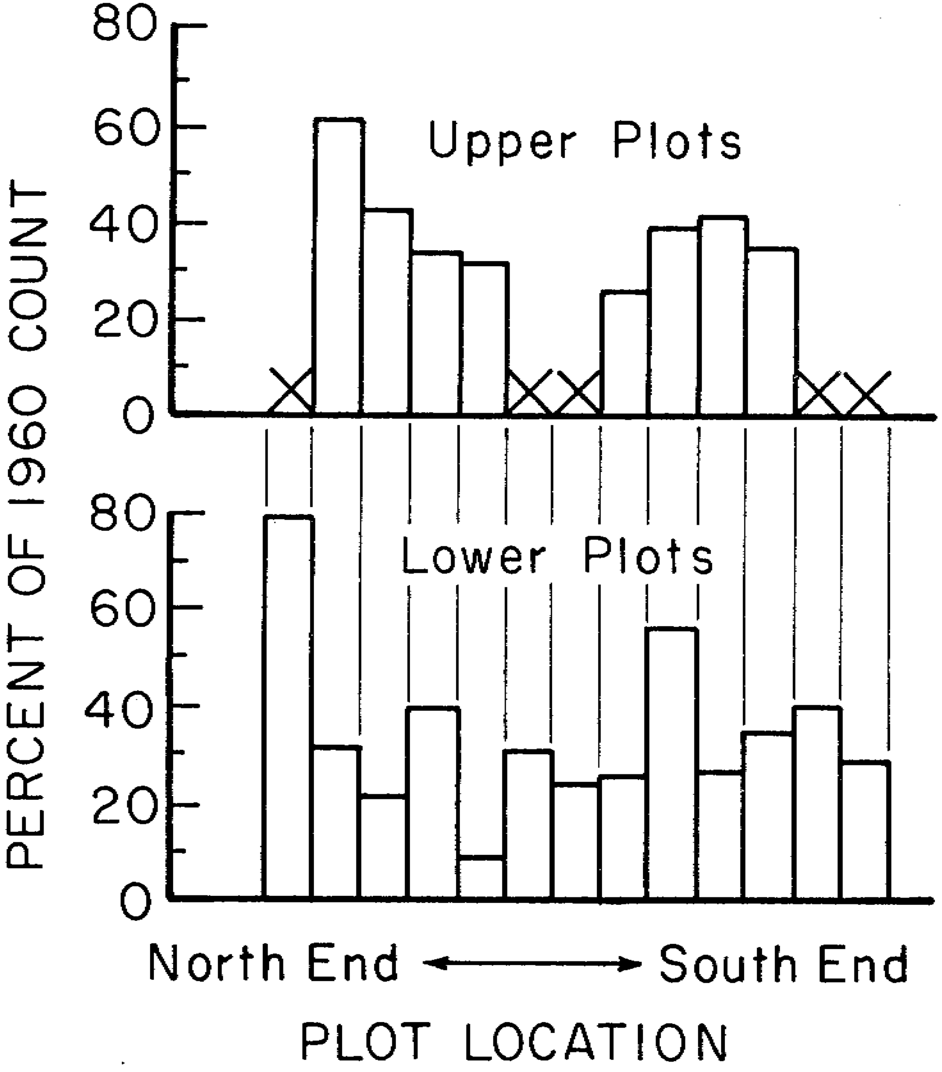

FIGURE 5. Murres: Numbers in 1979 relative to those in 1960 at Colony 5, Cape Thompson. An "X" denotes a region of the colony where a plot encompasses the entire vertical extent of the cliffs.

correlation was not significant ($n=8$, $r=0.143$, $P > 0.10$).

Comparing the degree of numeric change on the main cliff face and in the ravines of the upper portion of Colony 5 revealed that declines between 1960 and 1979 were more dramatic in the ravines (Mann-Whitney Test, $n=6$, $m=9$, $P < 0.05$). Thus the magnitude of the decline at Colony 5 did not vary with elevation or in relation to location, but did apparently vary in relation to some detail in the cliff structure.

At the other four colonies, plots typically spanned the vertical extent of the cliffs, precluding any evaluation of the relationship between numeric change and elevation. We did examine effects of location, tallying the number of plots on which percentage declines were greater than the median decline between 1960 and 1979. On the upcoast and downcoast halves of each colony we found a location effect at Colony 2 only (Median Test, $T=9.529$, $v=1$, $P < 0.005$). On plots A1 through Q, the 1979 counts totalled 51.6% of the 1960 counts; on plots R through HI the 1979 counts totalled 77.5% of the 1960 counts. Thus the declines were greater on the downcoast half than on the upcoast half of Colony 2.

Seasonal Variation in Attendance Patterns at the Cape Thompson Colonies

Several studies, e.g. Lloyd (1975) and Birkhead (1978a), have addressed daily and seasonal variation in attendance patterns of murres at breeding colonies. Nettleship (1976:20) recommended that censuses of murres be conducted during the last half of the incubation period. His recommendation agrees with Birkhead's (1978a) findings that numbers of Common Murres on Skomer Island in the British Isles were highest and varied least from day to day late in the incubation period (from the day the first eggs were laid to the day the first eggs hatched) and then declined through the chick period. However, Lloyd (1975) documented the highest numbers and least daily variability during the chick period (day first eggs hatched to the day first chicks left the cliffs) at another small Common Murre colony, Handa Island, in the British Isles. Although these studies both indicate synchony between the seasonal peak in numbers and the least daily variability, the timing of the peak in relation to breeding phenology varies between the studies. Nevertheless, these studies do demonstrate that daily and seasonal variation in attendance patterns must be considered in conducting counts and evaluating census results.

Table 8 shows the timing of the census in relation to breeding phenology at Cape Thompson during each year when a complete census has been conducted. All counts have been made between mid-incubation and the first sea-going. Although one chick was seen on the water during the 7 August census in 1979, that was the only chick seen by either team during the entire 11-hour period each team was anchored at various points along the colonies that day. As no additional chicks were seen on the water until 11 August, we have reported 11 August as the date of first sea-going. In 1960, most plots were counted during the incubation period; only Colony 5 was counted completely during the chick period. Thus, the 1960 census dates do contrast with those in later years at the first four colonies, but not at Colony 5. Thus, the seasonal discrepancies among censuses were least at Colony 5, where the greatest changes in numbers have been noted.

In 1979 we counted all the plots at Colony 1 four times in addition to the census on 7 August. We also counted various other areas in the other four colonies one or more additional times. We have used the repeated counts to examine daily and seasonal variation in murre numbers. Table 9 shows all counts of Colony 1 that have been made since 1960. Swartz (1966) commented on the great variation between counts taken on different days at this colony. Discrepancies between counts in 1961 were extreme: the average of the two counts on 3 August was 227% of the count on 25 July. Similarly in 1979, the high count (15 August) was 190% of the low count (7 July). The 1979 counts were not significantly lower than the 1961 counts (Mann-Whitney two-tailed test, $n=3$, $m=5$, $T=14$, $P=0.10$), but none of the 1979 counts approach the 1960 count of

TABLE 8. Murres: Dates of censuses in relation to breeding phenology.

	YEAR			
	1960	1976	1977	1979
First Hatching	30 Jul	9 Aug	1 Aug	26 Jul
First Sea-Going	18 Aug	(23 Aug)[1]	23 Aug	11 Aug[2]
Census Dates				
Colony 1	17 Jul	6 Aug	11 Aug	8 Aug
Colony 2	27,29,31 Jul 3 Aug	18 Aug	9 Aug	
Colony 3	21-23 Jul	23 Jul	10,12 Aug	7 Aug
Colony 4	15-17 Jul	9 Aug	12 Aug	7 Aug
Colony 5	1,2,4,12 Aug	19 Aug	13,14,17 Aug	7 Aug
Number of Census Days				
Incubation Period	8	1	0	0
Chick Period	6	4	7	2
Total	14	5	7	2

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[1] No murre chicks had left cliffs when field crews left the study site on 23 August.

[2] One murre chick seen on water on 7 August, none were seen again until 11 August; when many were on the water.

TABLE 9. Murres: Counts[1] at Colony 1, 1960-1979.

YEAR and DATE	PLOT						TOTAL	Time at Start[2]
	A	BC	D	E	FG	H		
1960								
17 Jul	34	533	721	2,090	774	36	4,187	13.33
1961								
25 Jul	8	509	244	1,104	624	0	2,489	23.17
3 Aug	23	816	697	2,923	980	43	5,482	14.08
3 Aug	15	815	959	2,857	1,101	49	5,796	16.42
1976								
20 Jul	12	340	240	1,006	550	55	2,203	18.50
6 Aug	6	325	325	955	466	13	2,090	10.00
1977								
11 Aug	0	343	390	1,153	570	16	2,471	20.51
1979								
7 Jul	0	220	265	560	320	1	1,366	22.25
20 Jul	0	440	558	1,270		0	2,268	21.67
7 Aug	0	205	354	913	483	0	1,955	21.75
15 Aug	0	320	330	1,333	620	0	2,600	21.00
18 Aug	0	320	333	1,158	575	0	2,386	19.25

---

[1] Values averaged among observers and rounded to the nearest whole number for each plot.

[2] Hours and hundredths of hours (Bering Daylight Time).

Colony 1.

Swartz (1966) suggested that Colony 1 "is composed to a large extent of non-incubating birds" (p. 663), noting that there are relatively few ledges that will safely accommodate an egg. Therefore, there may be relatively high numbers of non-breeding birds at this colony in comparison to the other colonies.

In addition to the census results shown in Table 1, Colony 4 was censused completely in 1961, and we conducted a second complete census there in 1979. On 22 July 1961, two observers estimated that 6,445 murres were present there (Swartz, unpublished data). On 14 August 1979, the average total obtained by 3 observers was 6,841 murres, 25% more than on 7 August 1979. The 1961 total was lower than either the 1976 or the 1977 totals (see Table 1) and only 4.7% higher than the average of the 7 August and 14 August 1979 counts. The 1960 census total for Colony 4 was 59% higher than the 7 August 1979 census and 35% higher than the 1961 count. Although numbers in recent years at Colony 4 have been lower than in 1960, the 1979 counts bracketed the 1961 count, indicating that there have been no distinct long-term trends in numbers there.

Our repeated counts on selected areas in 1979 also show the magnitude of daily variation in numbers (see Table 10). On the three plots at Colony 2 that we counted on six other occasions, the census total was lower than four of those counts. The totals on the two counts during the incubation period (10 and 18 July) were comparable to the census count. Although the two counts during the chick period bracketed the census count, they demonstrate that the range of daily variation was great: the count on 1 August totalled 50% more than that on 5 August. This range is comparable to that reported by Lloyd (1975:509) for Common Murres. The counts made on these plots after the first chicks left the ledges indicate that numbers were higher on some days during the chick-jumping period than earlier in the season.

TABLE 10. Murres: Comparisons of counts at selected plots, 1960-1979.

Colony	Plot	Census Total	1960	1976	1977	Percent of 1979 Census Total							
						July		August					
						10	18	1	5	11	15	16	17
2	C,O,BB	3,138	190	119	110	96	103	125	83	--	127	121	--
2	T,V,BB EE,HI	11,216	119	93	77	--	--	--	--	--	--	--	67
3	S	290	155	192	228	118	209	231	141	--	175	206	--
3	B,E,F, GK(part)	1,507	161	143	149	--	--	--	--	115	--	--	--
4	E.G.M.P	2,253	187	127	139	--	--	--	--	126	--	--	--
5	AX(part) AA,JJ,LL	4,071	358	--	171	--	--	--	--	154	--	--	--

At plot 3-S numbers were lower on the census day than on six other days that plot was counted in 1979. Also daily variation was greater on this plot than on the three plots on Colony 2 just discussed: the high count on 1 August was more than double the count during the census. This plot forms the northwest end of Colony 3. Like Colony 1, perhaps it is used by non-breeding birds to a greater extent than more centrally located plots within the colony, resulting in greater daily variation in numbers.

At Colony 4 both the total recount and recounts on selected plots were about 25% higher than the census results; both of these estimates were made once sea-going of chicks began. The recount of four plots on Colony 5 on 11 August, when sea-going began, was 54% higher than the census total for those plots.

Except at Colony 2, which was censused one day after the other colonies, the census results were lower than counts on other days from late incubation through the first several days of sea-going. The discrepancy between the census results and recounts of the four plots at Colony 5 was higher than for central plots on other colonies. Yet comparing 1979 recounts to the 1960 census results on the same areas, recount totals on the four Colony 5 plots were only 43% of 1960 totals on those plots. This figure is lower than those for all other recounted areas. Additionally, only on plot 3-S did any 1979 count exceed the 1960 result. This plot is one of the few plots where numbers increased between 1960 and 1976 and again in 1977. Thus, the recounts support the conclusion based on the census results that numbers have declined on all colonies since 1960 and the decline has been most marked at Colony 5, even though the census of Colonies 1, 3, 4 and 5 was conducted on a day of relatively low numbers during the 1979 season.

In addition to the recounts of various census plots we examined the counts on the census dates at 24-hour counting areas in relation to counts made at those same areas earlier in 1979 (Table 11). Dates of

TABLE 11. Murres: Counts on 24-hour Count Areas in 1979[1].

Colony	Area	4-5 July	12-13 July	22-23 July	Census (7 Aug)
4	1A	206(77)[2]	234(87)	237(88)	268
	1B	370(89)	392(95)	400(97)	414
	2	400(90)	378(85)	467(105)	446
5	1A	229(82)		294(105)	279
	1B	381(81)		510(108)	472
	1C	346(78)		442(100)	443
	2	172(86)		218(108)	201

---

[1] Maximum counts reported here.

[2] Row percent of census value.

the previous counts correspond to early, mid- and late incubation, just prior to hatching. The counts of these areas during the census were comparable to those made just before hatching and were higher than those made earlier during incubation.

The 24-hour counting areas are upper portions of Colonies 4 and 5. These results suggest that numbers there may not have followed the same day-to-day trends as numbers on the census plots, i.e. daily variation in numbers may not be synchronous among areas within and among colonies.

Lack of daily synchrony among areas within a colony is reflected in the Colony 5 recounts. For example, numbers relative to the census counts ranged from 97% to 206% of the census results among the four plots. Lack of daily synchrony among plots in attendance patterns of murres has an important implication in evaluating census results: the greater the heterogeneity among plots in relative numbers between counts, the greater the masking of daily variability when counts are conducted over large portions of the colonies.

To further examine spatial synchrony in daily variation in murre numbers at Cape Thompson in 1979, we used correlation analysis on two sets of repeated counts: the Colony 1 counts (Table 9) and the counts of the seven randomly selected plots (see Table 12). Table 13 shows that numbers on particular plots have been positively and sometimes significantly correlated with the total numbers. Yet the slope of the relationship has varied among plots, and, on some plots, changes have not closely reflected the overall changes, i.e. the slope of the correlation equation differs significantly from a value of one. These correlation analyses further demonstrate that (1) there was lack of tight synchrony in daily fluctuations of numbers among plots, as evidenced by insignificant correlation coefficients, and (2) the daily fluctuations in numbers were of considerably different magnitude on different plots.

Due to the magnitude of the daily variation within a season, we considered the likelihood that counts in 1960 were made on days when

TABLE 12. Murres: Counts at randomly selected plots at colonies 2 through 5 in 1979.

Colony	Plot	Date 10 Jul	18 Jul	1 Aug	5 Aug	Census	15 Aug	16 Aug
2	C	648(73)[1]	684(77)	886(100)	615(69)	788(89)	805(91)	758(86)
	O	1,310(87)	1,313(87)	1,504(100	853(57)	1,065(71)	1,865(124)	1,768(118)
	BB	1,043(68)	1,230(80)	1,544(100)	1,163(75)	1,285(83)	1,323(86)	1,275(83)
3	MN[2]	742(58)	722(56)	1,282(100)	838(65)	--	1,070(83)	1,320(103)
	S	342(51)	607(90)	671(100)	410(61)	290(43)	507(76)	598(89)
5	AA[2]	798(81)	622(63)	990(100)	943(95)	--	1,150(116)	1,240(125)
	GG[2]	647(72)	848(95)	896(100)	635(71)	--	852(95)	793(89)
TOTAL		5,530(71)	6,026(78)	7,773(100)	5,457(70)	--	7,572(97)	7,752(100)
Starting Time of Counts		20.45	18.58	18.53	18.75	--	18.67	19.50

---

[1] Percent of the 1 August count.

[2] Lower portion of plot only.

TABLE 13. Murres: Correlation between numbers/plots and total numbers on plots counted repeatedly in 1979.[1]

A. Colony 1.

Plot	Sample Size	Correlation Coefficient	Slope of Principal Axis
BC	5	0.615	2.606[2]
D	5	0.372	1.914
E	4	0.999*	1.327[2]
FG	4	0.997*	0.987

B. Randomly Selected Plots.

Colony	Plot	Sample Size	Correlation Coeffecient	Slope of Principal Axis
2	C	6	0.922*	0.795
	O	6	0.849*	1.819[2]
	BB	6	0.820*	0.702
3	MN[3]	6	0.919*	1.482[2]
	S	6	0.746	1.408
5	AA[3]	6	0.720	1.822
	GG[3]	6	0.786	0.825

* $P<0.05$

[1] Prior to analyses numbers were translated to percentages of the 7 August count (Colony 1) or 1 August count (Randomly Selected Plots) to provide standardization among plots.

[2] 95% Confidence boundaries do not bracket 1.0, which reflects equal magnitude of change on the plot and of overall change.

[3] Lower portion of plot only.

murre cliff attendance was at the upper extreme of the range of daily variability. Because it took field crews three or four days in 1960 to complete the census of each colony, except Colony 1, we considered it unlikely that each of those days coincided with a peak in attendance. Each colony was censused completely during a single day in 1979. We could thus test the null hypothesis that relative numbers (percentage values) on the plots in 1979 were unrelated to the day of the count in 1960. We used a Kruskal-Wallis Test (e.g. Conover 1971:257) and found no significant differences in the percentage values in relation to the day of the 1960 count (Colony 2: $T=6.455$, $v=3$, $0.1 > P > 0.05$; Colony 3: $T=0.104$, $v=2$, $P > 0.25$; Colony 4: $T=0.214$, $v=2$, $P > 0.25$; Colony 5: $T=1.349$, $v=3$, $P > 0.25$). In addition, because all colonies except Colony 3 were counted on the same date in 1979, it is highly unlikely that daily or seasonal variation is implicated in the among-colony differences in the magnitude of the decline in murre numbers between 1960 and 1979.

Diurnal Variation in the Attendance Patterns at the Cape Thompson Colonies

Several studies (e.g. Swartz 1966, Lloyd 1975, Birkhead 1978a) have documented marked diurnal fluctuations in numbers of murres on the cliffs by periodic counts of selected ledges throughout a 24-hour period. Lloyd (1975) found a single late morning peak in attendance at Skokholm Island in the British Isles. Birkhead (1978a) documented relatively low numbers early and late in the day and high, fairly constant, numbers throughout the middle of the day at Skomer Island. Studies elsewhere in Alaska (e.g. Drury 1978) suggest that there are two peaks in attendance each day, generally at about 0800 and 2000 hours. Swartz (1966:659-660) found a similar pattern at Cape Thompson. Diurnal variability in attendance is clearly of sufficient magnitude that it should be considered in detail in evaluating the census results.

Figure 6 shows the time of day each census was conducted at Cape Thompson. There was no overlap in the timing of censuses at Colony 1 among years. Counts of other colonies were typically in mid-afternoon through early evening, and the timing of those in recent years generally

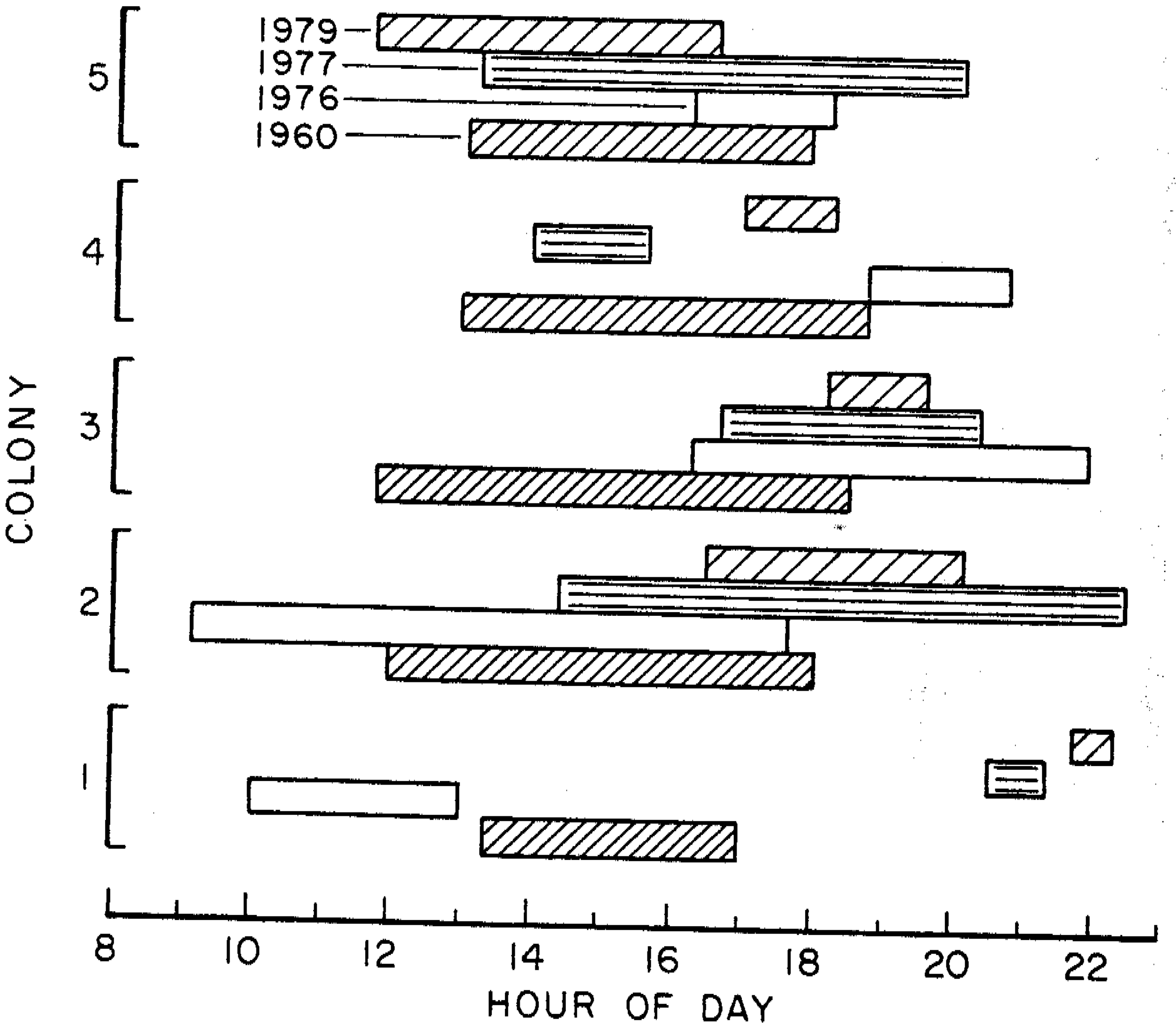

FIGURE 6. Murres: Time of day of census (Bering Daylight Time).

overlapped the 1960 counts to some extent.

In 1979 we conducted counts on selected areas to determine patterns of diurnal fluctuation in attendance not only during the census but also during three 24-hour periods during the incubation period (see Figure 7). The fluctuations in numbers tended to follow the general pattern found in previous years at Cape Thompson (Swartz 1966, Springer and Roseneau 1977, 1978), showing a morning and evening peak. However, there was considerable variation and departures from the general pattern were frequent. Most notably, numbers peaked during the afternoon and evening, while the census counts were being conducted, on the day of the census of Colonies 1, 3, 4 and 5 (see Figure 8). The census of Colony 2 also coincided with a diurnal peak in numbers on the following day (Figure 9).

Correlations between counts of different areas during the same period are listed in Table 14. In addition to these counts, two areas were counted at Colony 2 on 8 and 9 August in conjunction with the census there ($n=12$, $r=0.80$, $P < 0.05$). Twenty-four of the 81 total bivariate correlations were positive and significantly ($P < 0.05$) different from zero. By chance only 4 (5%) of the 81 correlations would be significant. This number of significant correlations is highly unlikely if the null hypothesis of zero correlation were always true (Goodness of Fit $X^2=103.44$, $v=1$, $P < 0.001$). Thus, there was some degree of synchrony among areas in diurnal fluctuations in numbers, yet the large number of insignificant correlations demonstrates that the synchrony was not very tight. While none of the correlations between areas at Colony 2 and Colony 4 were highly positive and significant, there was not a clear pattern of increasing synchrony with increased proximity: of the 57 correlations between areas of the same colony 15 (26%) were significant; 9 of the 24 (37.5%) correlations between areas of different colonies were significant.

Lack of diurnal synchrony among areas even within colonies has two implications in evaluation of the census results because diurnal trends

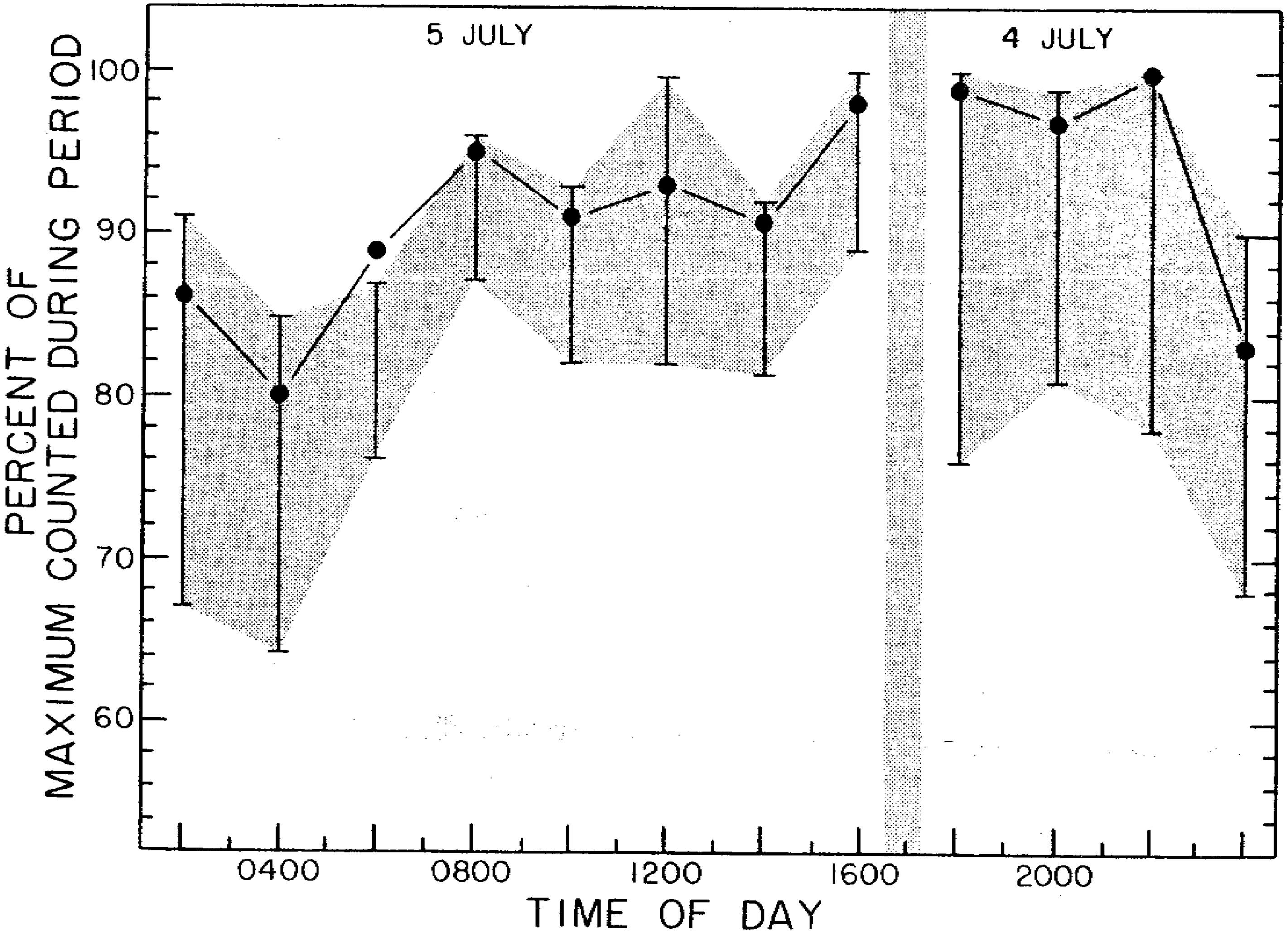

FIGURE 7. Murres: Diurnal variation in numbers at selected areas of the Cape Thompson Colonies. A, early

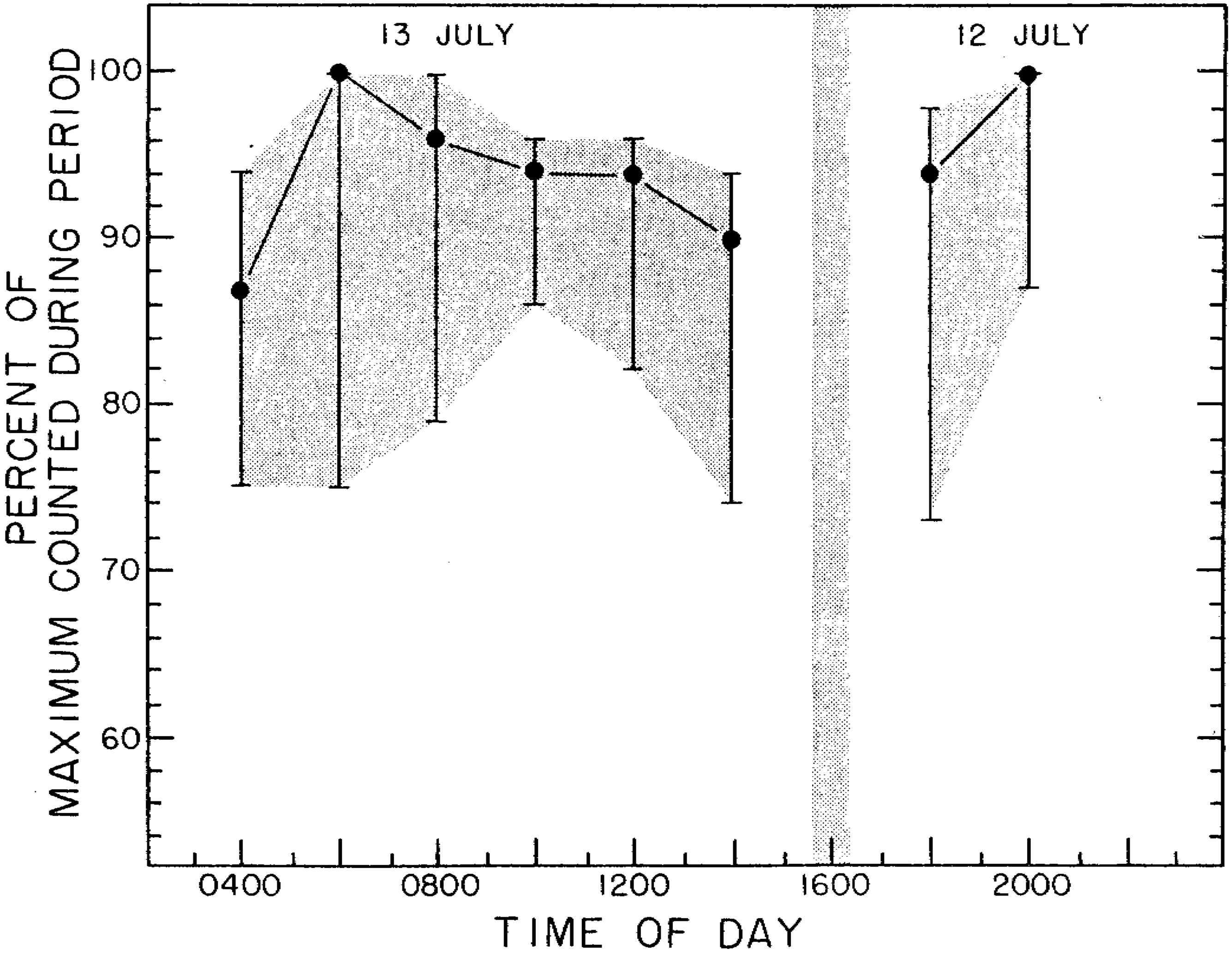

FIGURE 7. Continued. B. Mid-incubation.

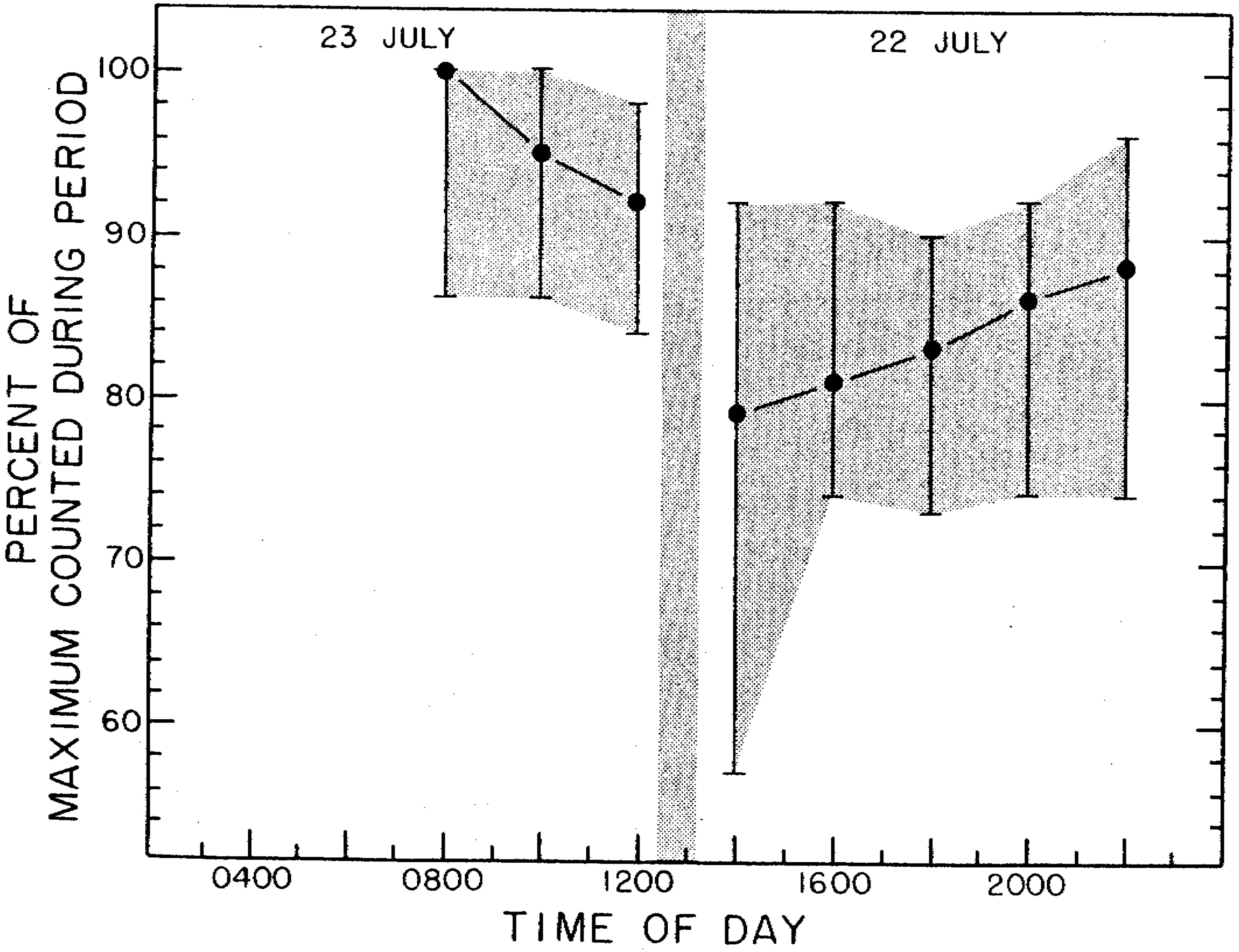

FIGURE 7. Continued. C. Late incubation.

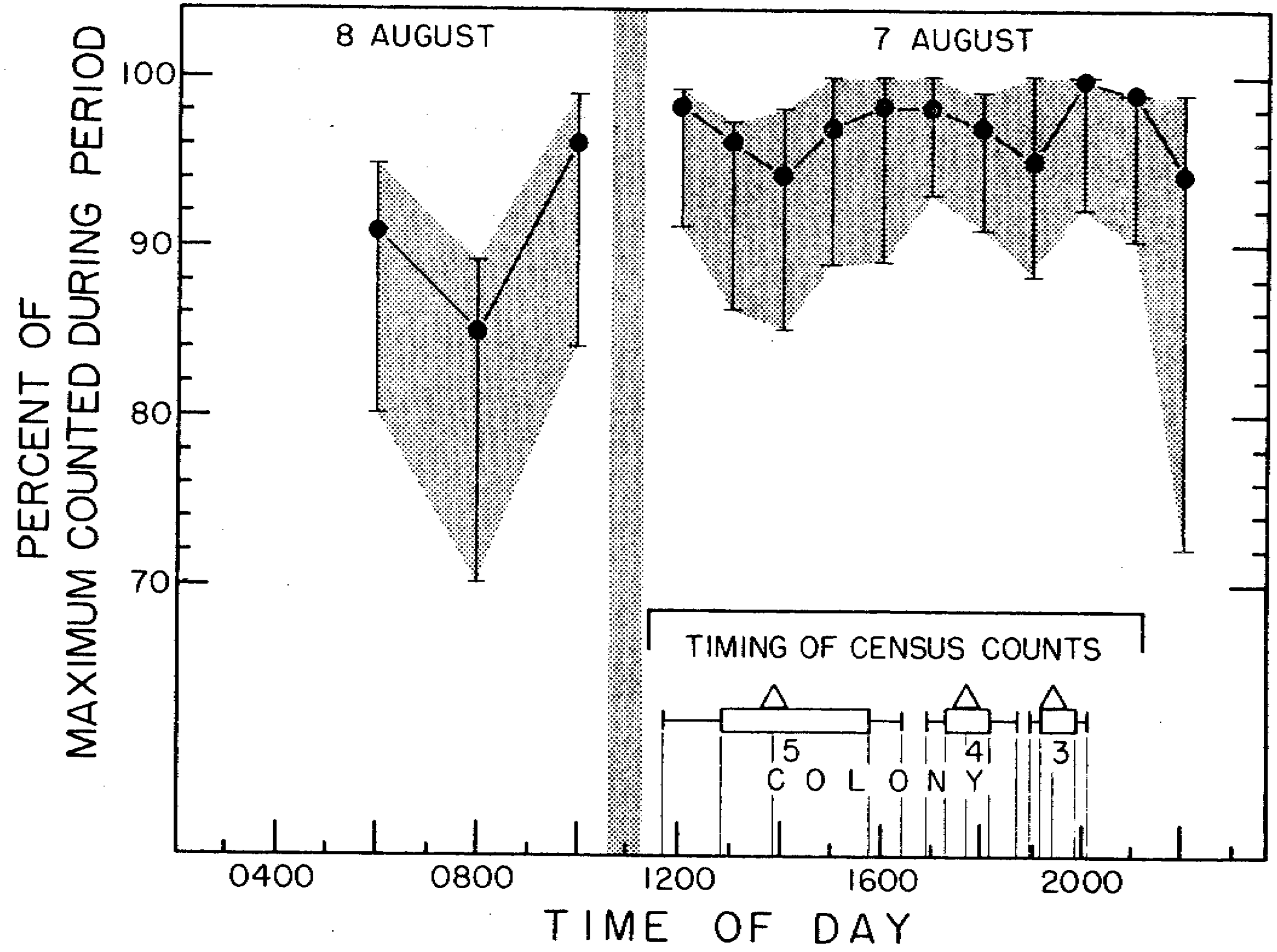

FIGURE 8. Murres: Diurnal variation in numbers at selected areas at Colonies 4 and 5, Cape Thompson, during the census of colonies 1, 3, 4 and 5. Inset: Mean (triangle), one standard deviation (bar) and range (bracket) of the census times for colonies 3, 4 and 5, based on data for each plot.

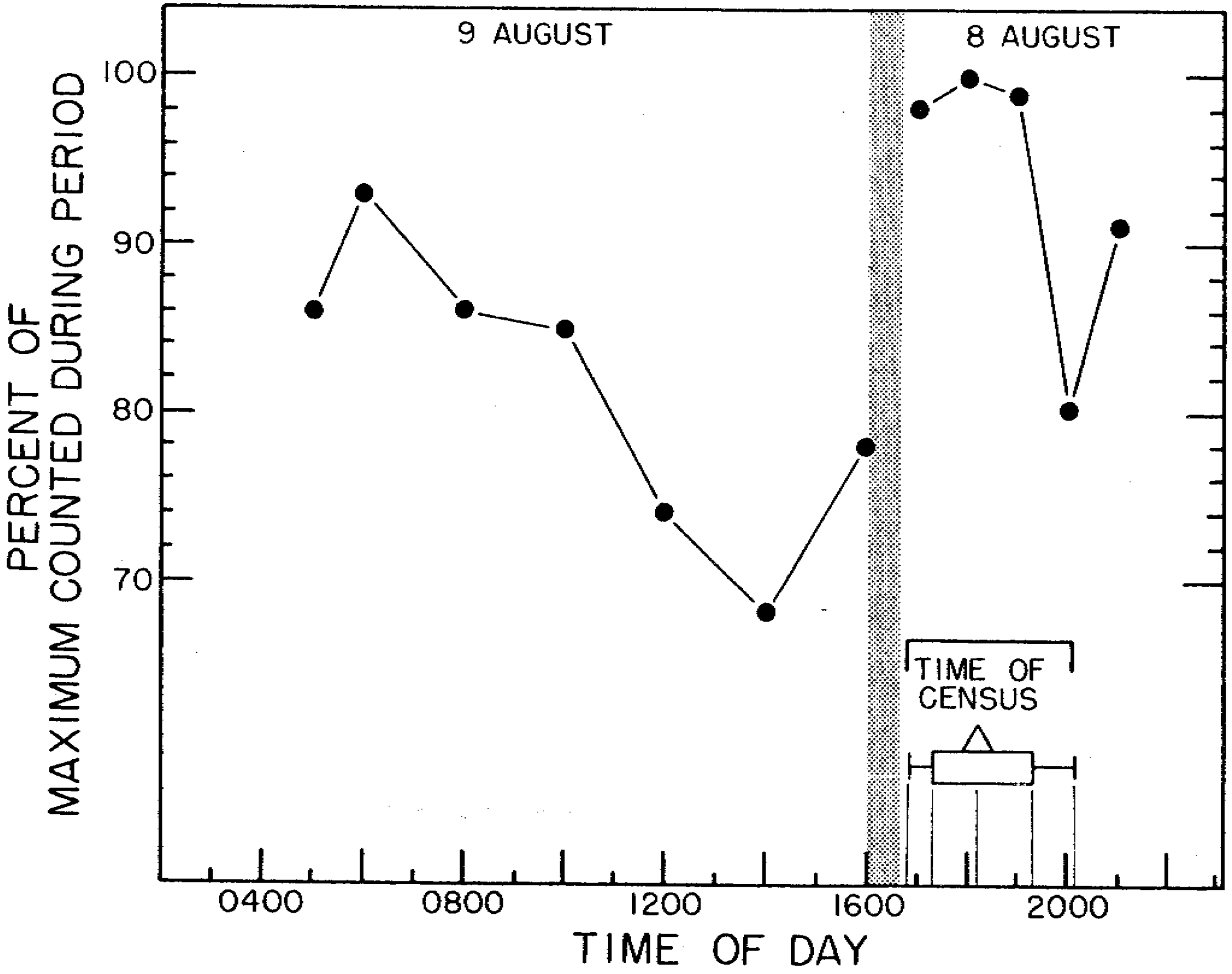

FIGURE 9. Murres: Diurnal variation in numbers at selected areas at Colony 2, Cape Thompson, during the census of that colony. Inset: Mean (triangle), one standard deviation (bar) and range (bracket) of the census times, based on data for each plot.

TABLE 14. Murres: Correlation matrices for diurnal attendance patterns at Cape Thompson in 1979.

A. 4-5 July (above diagonal) and 22-23 July (below diagonal)

	AREA[1]								
AREA	4-1A	4-1B	4-2	5-1A	5-1B	5-1C	5-2	5-3	5-4
4-1A	1.0	0.58(8)	-.35(8)	--	--	--	--	--	--
4-1B	0.87(8)*	1.0	-0.46(6)	--	--	--	--	--	--
4-2	0.58(7)	0.72(7)	1.0	--	--	--	--	--	--
5-1A	0.51(7)	0.78(7)*	0.75(9)*	1.0	0.28(12)	0.08(12)	0.15(12)	0.36(10)	-0.23(8)
5-1B	0.76(7)*	0.91(7)*	0.78(9)*	0.83(10)*	1.0	0.63(12)*	0.57(12)	0.68(10)*	0.08(8)
5-1C	0.84(7)*	0.95(7)*	0.58(9)	0.57(10)	0.48(10)	1.0	0.72(12)*	0.73(10)*	0.09(8)
5-2	0.30(7)	0.47(7)	0.35(8)	0.76(9)*	0.62(9)	0.54(9)	1.0	0.35(10)	0.04(8)
5-3	0.74(7)	0.80(7)*	0.81(8)*	0.79(9)*	0.88(9)*	0.82(9)*	0.60(9)	1.0	-0.06(10)
5-4	--	--	0.23(6)	0.14(6)	-0.06(6)	-0.27(6)	-0.61(7)	-0.61(7)	1.0

* $P < 0.05$

[1] Area notation: First number denotes Colony, second number denotes stake (observation site) location, and letter denotes counting areas if more than one area is counted from that stake.

TABLE 14 (cont.)

B. 12-13 July

AREA	AREA[1]						
	4-1A	4-1B	4-2	2-1	2-2	2-3	2-4
4-1A	1.0	0.44(9)	-0.20(8)	-0.13(7)	0.45(7)	-0.21(7)	--
4-1B	--	1.0	0.26(8)	0.02(7)	0.39(7)	-0.63(7)	--
4-2	--	--	1.0	-0.05(7)	-0.03(7)	-0.34(7)	--
2-1	--	--	--	1.0	0.29(10)	0.48(10)	0.93(7)*
2-2	--	--	--	--	1.0	0.06(10)	0.24(7)
2-3	--	--	--	--	--	1.0	0.82(7)*
2-4	--	--	--	--	--	--	1.0

* $P < 0.05$

[1] Area notation: First number denotes Colony, second number denotes stake (observation site) location, and letter denotes counting areas if more than one area is counted from that stake.

TABLE 14 (cont.)

C. 7-8 August (census)

	AREA[1]				
AREA	4-2	5-1A	5-1B	5-1C	5-2
4-2	1.0	-0.31(14)	0.02(14)	0.33(14)	0.44(14)
5-1A	--	1.0	0.77(14)*	0.39(14)	0.29(14)
5-1B	--	--	1.0	0.53(14)	0.37(14)
5-1C	--	--	--	1.0	0.62(14)*
5-2	--	--	--	--	1.0

* $P < 0.05$

[1] Area notation: First number denotes Colony, second number denotes stake (observation site) location, and letter denotes countaing areas if more than one area is counted from that stake.

in numbers are frequently out of phase among areas. First, colony-wide counts will mask diurnal variations to the extent fluctuations on different areas are out of phase. Secondly, counts on selected areas may be unrepresentative of overall trends on the plots being censused. Consequently, compensating overall numbers on the basis of trends on such areas to mitigate the effects of diurnal variation (e.g. Swartz 1966) may be inappropropriate. The best way to minimize the effect of diurnal variation in attendance patterns is to conduct censuses at the same time of day that previous counts have been made.

Observer Variability in Counts at the Cape Thompson Colonies

Swartz (1966) noted that discrepancies between the counts of experienced observers tend to be low: e.g. total counts of two observers in 1960 deviated only 0.5% from the mean of their counts. However, Swartz also suggested that, "the seeming objectivity of such analyses may be in some measure illusory in that subtle adjustments certainly take place through conversations between observers living and working together" (p. 661).

In censuses at Cape Thompson in recent years, counts of observers have also shown close agreement. In 1976, counts of various observers deviated between 1.7% and 7.2% from the mean of the counts. In 1977, two observers (E and F) counted all of the colonies together and their total counts deviated only 0.4% from the mean of their totals. In 1979, two teams of two observers each counted different portions of each colony, except Colony 1, which was counted repeatedly by various teams of observers. Within each team, observer counts were equivalent; total counts of observers in Team A (Observers C and H) and Team B (Observers E and I) deviated 1.2% and 0.3% from the respective means of their counts. Thus, the variation between (among) observers counting as a team has been low in recent years as well as during Swartz's (1966) field studies.

During all censuses at Cape Thompson observers have typically compared their results after completing the count of each plot as a check to insure that each observer scanned the cliffs effectively, covering all of the ledges but not duplicating areas already covered. The problem of an effective counting pattern is particularly acute on the larger plots but is lessened with experience. With practice, observers improve their ability to determine an effective pattern of counting murres on plots viewed for the first time. In 1979 we conducted some recounts without comparing results after completion of each count. In the recount of Colony 4 the totals of the two observers of Team B deviated 6.6% from the mean of their counts compared to 2.4% during their census of the same plots. The total count of a third observer (F), who had not counted with Team B during the census, was 15% lower than the mean of their counts. In the two mid-August counts of Colony 1, Observer E and Observer F counted without comparing notes, and their counts deviated 3.9% and 2.5% from the mean of their counts. Observer F's total was lower than Observer E's total on 15 August and higher on 18 August. On the 16 August count of the Randomly Selected Plots, their individual totals deviated 1.4% from the mean. These results suggest that counts conducted by experienced observers without comparing notes are more variable but, overall, provide similar estimates of total numbers, as the tendency of one observer to count higher or lower than others was not consistent.

A more effective method of evaluating variability of independent counts and comparability of the counts of different observers would be to compare simultaneous counts of the same plots by observers of the two teams who had been counting different plots independently. We were unable to conduct extensive comparisons, but the two teams did count two plots simultaneously during the 7 August census and two others during recounts on 11 August (Table 15). The discrepancies on the two plots counted simultaneously on 7 August were between observers and within teams, but those for the two plots counted on 11 August were primarily between teams. Sunset on 11 August at Ogotoruk Creek is 2109 h (BDT) (Allen and Weedfall 1966:27); the recounts on that date were made after the sun had set. The large discrepancies among observers on those

TABLE 15. Murres: Comparisons of simultaneous counts of all observers who counted the 1979 census.

				Team A		Team B		
Colony	Plot	Date	Time	C	H	E	I	Mean
1	FG	7 Aug	21.75	515	420	545	450	483
4	L	7 Aug	18.28	300	310	290	280	295
Subtotal				815	730	835	730	778
2	BB	11 Aug	22.37[1]	1,015	960	1,530	1,360	1,216
2	Z	11 Aug	22.65[1]	560	545	813	780	675
Subtotal				1,575	1,505	2,343	2,140	1,891

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[1] Observers noted that it was hard to see as it was getting dark.

recounts may be due to the poor light conditions at the time of their counts.

Although the previous analyses on observer variability suggest that observer variability has not been a major factor in differences in counts of murres among years, the evaluation of observer variability could be improved considerably. Observers, once experienced, should not compare their counts during the census. Confidentiality of the results will increase the independence of the counts by different observers. In 1979 we would have been able to evaluate independence of counts and comparability of results far more effectively if both teams had counted several more plots simultaneously.

One final aspect of observer variation relates to the estimation technique itself. In 1976 observers estimated numbers of murres at Colony 5 in increments of 100, while in 1977 and 1979 estimates were made in increments of ten on the same plots. Variability among observers was much higher in 1976 than in 1977 and 1979 [Friedman's Test on Coefficients of Variation, $b=11$, $k=3$, $T=10.864$, $v=2$, $P < 0.005$; Multiple Comparison Procedure (see Hollander and Wolfe 1973), $R_{1976} = 33$, $R_{1977} = 14.5$, $R_{1979} = 18.5$, 1976 vs. 1977: $P < 0.008$, 1976: $P < 0.008$, 1977 vs. 1979: $P > 0.05$], suggesting that estimation by hundreds gives a more variable estimate of numbers of murres. Yet overall variation among observers was generally higher in 1976 than in other years, so that the above difference may simply mirror the higher variability within the field crew in that year. As in our evaluation of other aspects of observer differences, the available data do not readily permit evaluation of the effects of the technique in relation to the census results. Although we have not demonstrated and quantified such effects they may have influenced the census figures to some extent.

Counts of the Cape Lisburne Colony

In 1976 and 1977 complete censuses of murres were conducted at the Cape Lisburne Colony (Springer and Roseneau 1977, 1978). Partial counts in 1978 and 1979, together with comparable results in previous years, are shown in Table 15. Observer C has counted murres there in all 4 years. His lowest count (1978) was 89% of his highest count (1979). Overall, the discrepancies among years are slight in relation to the magnitude of variation in attendance patterns within years. There is no evidence of any trends in numbers over the four year period.

Counts of the Bluff Colony

Drury (1977, 1978) and Ramsdell and Drury (1979) have summarized the census efforts of Common Murres at Bluff in previous years. In 1979 one observer (Observer F) counted murres there on three occasions (Table 16). Two of these counts were during the chick period. The third count on 9 August occurred several days after the first sea-going of chicks (3 August). The averages of the 1979 counts and of those also conducted between mid-July and mid-August in previous years are listed in Table 17.

The counts at Bluff have been made from a boat moving slowly past the colony, and observers have typically counted murres flushed from the cliffs by the boat as well as murres remaining on the ledges. This procedure differs from that of the sea-based counts at Cape Thompson and Cape Lisburne, where observers anchored the boat offshore in front of each plot and waited for any birds that flushed to return to the ledges before starting the count. We cannot compare the effectiveness of the two procedures. Certainly estimates of numbers flushing are less precise than the counts of murres on the ledges, and estimates from a moving boat may be more variable than from a stationary boat.

Table 18 shows a decline in the average number of murres counted in successive years at Bluff. Comparison of the ranks of the average values in successive years demonstrates the negative trend (Spearman's Rank Correlation, n=5, r=1.0, $P < 0.01$). None of the three 1979 counts exceeded the 1975 or 1976 counts. We conducted an Analysis of Variance, grouping the counts by year, for years with two or more counts in mid-summer. The results of the ANOVA do not demonstrate any differences among the years 1976 to 1979 ($F_{3,6}=2.086$, P=0.204). Thus, while the

TABLE 16. Murres: Counts at the Cape Lisburne Colony, 1976-1979.

	1976 (25-28 Aug) Observer			1977 (21-26 July) Observer		
Plot	B	C	$\bar{X}$	C	E	$\bar{X}$
11	900	600	750	910	945	928
12	1,200	1,400	1,300	1,460	1,630	1,545
25	1,050	600	825	1,050	1,120	1,085
26	550	650	600	1,115	1,335	1,225
30	3,900	4,600	4,250	3,925	3,245	3,585
32	1,900	2,500	2,200	1,875	1,600	1,738
Sub-total	9,500	10,350	9,925	10,335	9,875	10,106
65	1,200	1,350	1,275	1,930	2,090	2,010
66	1,000	1,500	1,250	1,310	1,360	1,335
70	600	1,200	900	1,270	1,140	1,205
72	600	900	750	830	860	845
TOTAL	12,900	15,300	14,100	15,675	15,325	15,501
TOTAL FOR ENTIRE COLONY (Plots 1-75)	128,350	130,800	129,575	129,068	133,775	131,420

TABLE 16 (cont.).

Plot	1978 (3 Aug) Observer C	H	$\bar{X}$	1979 (15 Aug) Observer C	H	$\bar{X}$
11	788	770	779	950	870	910
12	1,350	1,270	1,310	1,550	1,410	1,480
25	930	1,100	1,015	850	730	790
26	1,100	1,450	1,275	1,160	1,120	1,140
30	3,400	2,900	3,150	4,330	3,800	4,065
32	2,200	1,790	1,995	2,160	1,850	2,005
Sub-total	9,768	9,280	9,524	11,000	9,780	10,390
65				1,780	2,050	1,915
66				1,525	1,610	1,568
70				1,370	1,210	1,290
72				1,030	890	960
TOTAL				16,705	15,540	16,123

TABLE 17. Murres: Counts of the Bluff Colony in 1979.

Section	20 July	31 July	7 August
A-C	5,690	8,265	6,680
C-D	10,190	16,900	12,740
D-E	2,300	4,620	3,070
E-F	3,830	6,260	4,720
F-G	1,435	1,820	1,430
G-H	1,420	1,810	1,450
H-I	3,289	2,770	3,140
I-J	130	830	140
Total	28,284	43,275	33,370
Time at A	14:23	19:00	13:25
J	11:30	23:00	11:00

Census Conditions:

20 July: Clear, light SE winds, seas: light chop (murre counting a bit difficult).

31 July: 100% overcast, calm, seas: light swells, counts between points F and J made in dim light.

7 August: 90-100% overcast, occasional showers, seas: choppy.

TABLE 18. Murres: Counts of the Bluff Colony between mid-July and mid-August, 1975-1979.

	Census[1]			
Year	1	2	3	Average
1975	69,900	--	--	69,900(100)
1976	45,175	55,390	--	50,283(72)
1977	39,250	36,100	--	37,675(54)
1978	33,520	46,560	32,080	37,387(53)
1979	28,284	43,275	33,370	34,976(50)

[1] Values reported here are the averages of observers' counts if two or more observers counted murres during a particular census.

general downward trend in average numbers has continued in recent years, variability among counts within each season has been sufficiently high to make that trend insignificant.

Although the repeated counts at Bluff permit statistical comparisons of total numbers among years, many more counts each year would be necessary to detect differences among annual means. Sokal and Rohlf (1969:247) provide a technique for determining the sample size needed to detect differences between means, but it is also appropriate to consider the ways in which variability of counts within a season can be reduced. Conducting successive counts at the same time of day and anchoring the boat offshore, at least when counting the more difficult plots, would probably reduce the variability considerably.

Combined counts from Stakes 10 and 15 on successive days in mid-afternoon throughout much of the chick period varied between 67% and 88% at 1500 h and between 70% and 95% at 1700 h of the maximum counts of 2639 murres recorded at 1900 h on 27 July. Thus, numbers during the chick period ranged as high as 31% at 1500 h and 37% at 1700 h greater than the minimum count at those hours. Figure 10 shows that numbers on the cliff in mid-afternoon rose to a peak on 25 July and then declined until after sea-going had already begun (see below).

We also combined the counts at Stakes 10 and 15 to assess diurnal patterns in cliff attendance at Bluff in 1979. Numbers typically peaked in the early morning and late evening (Figure 11), but, as at Cape Thompson, there was considerable variation on this theme. These data reinforce our contention that adequate monitoring of numbers entails repeated counts to quantify daily variation and standardization by time of day to minimize the influence of diurnal variation in census results.

At Bluff we cursorially examined the comparability of boat-based counts and those made from the top of the cliffs. During the boat-based census on 31 July, Observer F counted 1750 murres at Stakes 10 and 15 at

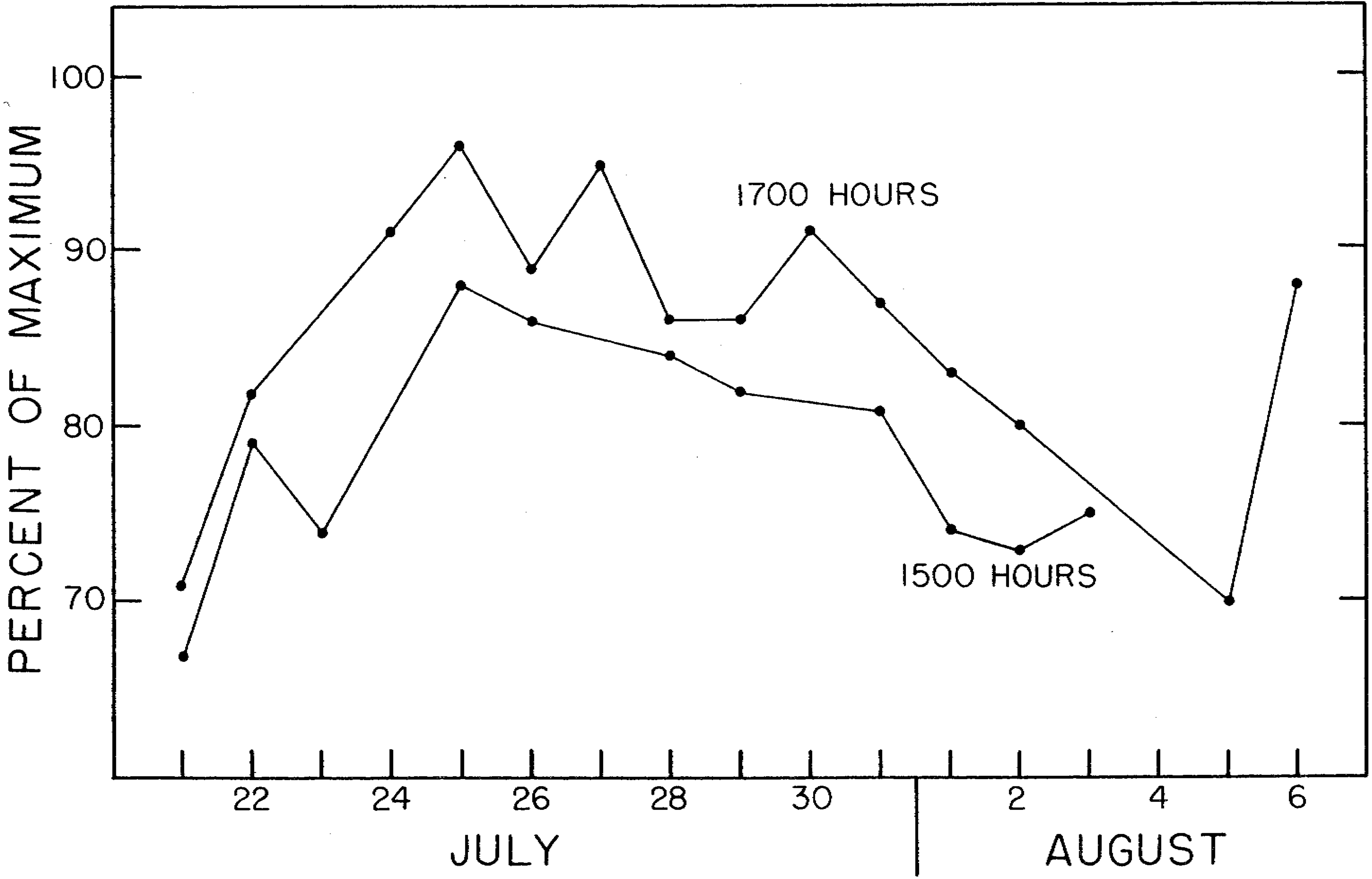

FIGURE 10. Murres: Daily variation in numbers at Bluff (data from Stakes 10 and 15 combined).

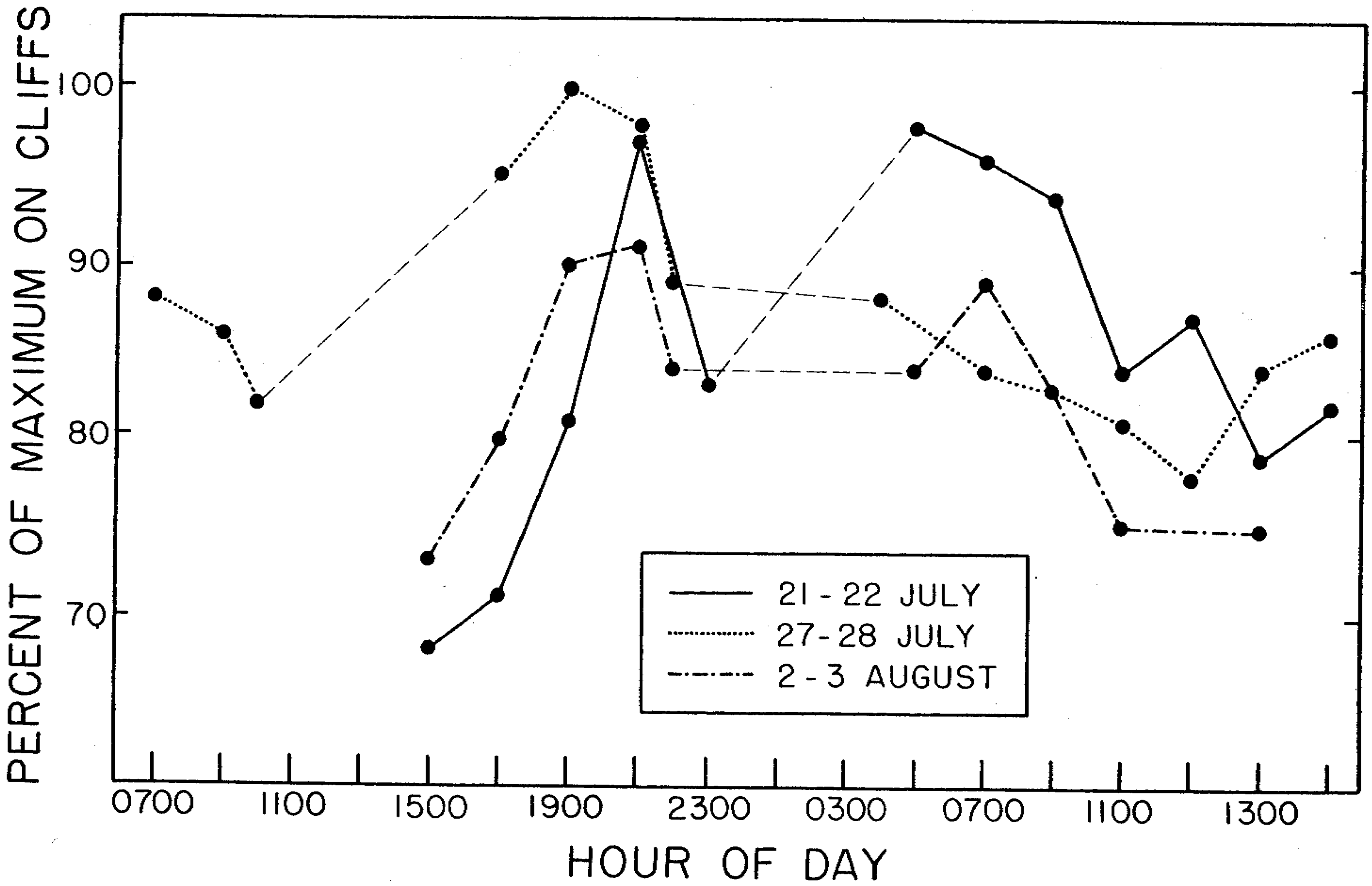

FIGURE 11. Murres: Diurnal variation in numbers at Bluff in 1979 (data from Stakes 10 and 15 combined).

1900 h. Two hours earlier on that day 2295 murres were counted from above at these 2 stakes. Although simultaneous land-based and boat-based counts were not made, such a decline in numbers during that period appears unlikely. Numbers actually increased between 1700 h and 1900 h during the 3 24-hour counts. During the boat-based census on 7 August, 1280 murres were recorded at these 2 stakes. This figure is only 72% of the lowest total recorded in the 60 land-based counts of Stakes 10 and 15 when 1970 murres were counted at 1500 h on 21 July. These data further demonstrate that observers counting from boats below a colony significantly underestimate actual numbers, even in areas where it appears that all of the murres are visible.

Reproductive Phenology

We have not made a detailed study of the reproductive phenology of murres at Cape Thompson, and here we simply summarize available information on dates the first chicks hatched and the first chicks went to sea. As these dates are extremes for each sample they are certainly less representative of the sample than modal dates, which are only available for a few of the locality-year samples.

Table 19 shows that phenology was advanced at Cape Thompson in 1979 relative to any other year and by more than two weeks compared to 1976. Phenology at both Cape Thompson and Cape Lisburne was similar in 1978 and 1979. At Bluff both hatching and sea-going in 1979 began a few days later than in 1978 and about two weeks earlier than in other previous years.

Reproductive Output

Few data on murre reproductive success have been collected at Cape Thompson and Cape Lisburne in recent years. At Bluff reproductive output has been studied intensively at several study areas since 1976. In 1979 we determined numbers of eggs and chicks at the same 7 areas studied in detail in 1978. Stake 10 has been the most intensively

TABLE 19. Murres: Summary of breeding phenology at Cape Thompson, Cape Lisburne and Bluff.

A. First Hatching

Year	Cape Thompson	Cape Lisburne	Bluff
1959	11 Aug	--	--
1960	30 Jul	--	--
1961	27 Jul	--	--
1976	9 Aug	--	27 Jul
1977	1 Aug	2 Aug	3 Aug
1978	--	24 Jul	16 Jul
1979	26 Jul	--	< 19 Jul

B. First Sea-Going

Year	Cape Thompson	Cape Lisburne	Bluff
1959	25 Aug	--	--
1960	18 Aug	--	--
1961	19 Aug	--	--
1976	> 25 Aug	27 Aug	17 Aug
1977	23 Aug	20 Aug	20 Aug
1978	13 Aug	11 Aug	31 Jul
1979	11 Aug	< 14 Aug	2 Aug

studied area since 1976. In 1976, only 5 chicks were successfully reared there (Drury 1977); in 1977, 71 chicks hatched and 58 left successfully (Drury 1978).

We found chicks on the study areas when we first arrived in 1979. Ramsdell and Drury (1979) found that 40% of chick loss occurred within five days of when they were first seen. Overall loss was 17% at Stake 10. In 1979, only 4 of the 97 (5%) chicks observed between 21 July and 9 August disappeared; 58 were alive but still on the cliffs when we left. Of these, 39 were at least two weeks old and only 6 had not been seen before 1 August. In Table 20 we have assumed that all chicks seen alive on the last visit to an area later jumped. This assumption is reasonable if chick mortality is confined primarily to the first few days after hatching, but results in an overestimate of numbers jumping to the extent that mortality of older chicks occurs on the ledges. As our values of hatching success probably underestimated actual success due to mortality of very young chicks before our observations began, hatching success in 1979 probably equalled or exceeded that in 1978. In comparison to 1978, murres also had equivalent or slightly better success in rearing chicks to jumping age in 1979. Over the past 4 years, the reproductive success of murres was poorest in 1976 and best in 1978 and 1979.

Numbers of Breeders and Nonbreeders

During the repeated counts of selected areas, adults on the stake 10 map area were counted on 49 occasions. Numbers ranged from 137 to 185, averaging 165 (standard deviation = 10.53). The total number of attended eggs and/or chicks was 93, which is a minimum estimate of the number of breeding pairs. Birkhead (1978a) and others have calculated the ratio of breeding pairs to the number of individuals. This ratio varied between 0.50 and 0.68, averaging 0.56, at stake 10 in 1979. To the extent that eggs were lost and were not replaced and chicks were

TABLE 20. Murres: Reproductive output at Bluff, 1978 and 1979.

	Number Hatching		Number Jumping	
Stake	1978[1]	1979[2]	1978[1]	1979[3]
8	26	24	21	23
10	89	87-88	74	83
12 inside	28	27	25	27
12 crack	29	28	24	28
13	44	45-47	36	45-47
14	73	66-67	65	66-67
15	30	31-38	27	31-38
Total	319	308-319	272	303-313

[1] From Drury (1979).

[2] Hatching had begun when we first visited the study sites

[3] Only 40 chicks had actually left the ledges as of the last visit before our departure on 10 August. We have assumed that any chicks alive on the last visit subsequently left successfully.

lost, this figure underestimates the number of breeding pairs. Drury (1978) estimated that egg loss was about 15% during incubation. Assuming no replacement of eggs lost before we started our field work at Bluff in 1979 and 15% loss during incubation, we can estimate that 109 breeding pairs were present at Stake 10. Thus, on the average, about one-third of the murres on Stake 10 were therefore nonbreeders or off-duty mates.

Hodges (1977) showed that kittiwake breeding pairs coordinate their attendance patterns at the cliffs, i.e. although one of the mates is in attendance constantly, rarely are both mates in attendance. Although comparative data are lacking for murres, it is likely that murre pairs similarly coordinate their attendance and foraging activities. Consequently, the degree to which the number of indidivuals exceeds the number of eggs laid is probably largely a measure of the number of nonbreeding murres. We do not know if nonbreeding site-holders are sexually immature birds in adult plumage or birds that failed in the very early stages of a breeding attempt.

Swartz (1966:660) found no physiological nonbreeders in his extensive collections of birds residing on the cliffs at Cape Thompson. Swartz's data are somewhat in variance with the findings of Birkhead and Hudson (1977) at Skomer. They found that three-year olds and four-year olds spent time on the breeding ledges as well as in clubs (loitering areas) at the base of the colonies. As few four-year olds and no three-year olds bred, physiological nonbreeders do occupy the breeding ledges at Skomer.

Some areas of the colony may contain greater proportions of nonbreeders than do others. Among the five areas counted extensively from Stakes 10 and 15, the maximum numbers ranged between 132% and 280% of the minimum numbers (see Table 21). As counts were always simultaneous (within 20 minutes) on all five areas, these differences reflect spatial variation only. The results certainly indicate that nonbreeders were far more abundant relative to breeders on the areas counted from Stake 15 than at

TABLE 21. Murres: Maximum and minimum counts of five frequently counted areas at Bluff, 1979.

Area	Number of Counts	Number of Murres		Ratio	Mean	Coeffecient of Variation
		Maximum	Minimum			
10-A	63	298	209	1.43	139	6.44
10-B	63	678	514	1.32	603	6.60
10-C	63	665	479	1.39	587	7.12
15-A	61	123	344	2.80	254	20.4
15-B	61	329	686	2.09	536	12.3

Stake 10. Although no studies have addressed spatial variation in proportions of breeders and nonbreeders actually on the breeding ledges in any detail, the variation appears to be high. Such variation will affect comparability of census results to the degree that relative numbers of breeders and nonbreeders vary diurnally, seasonally and annually as well. Changes in the proportion of younger, nonbreeding age classes would be reflected most dramatically on those areas of the breeding ledges where they aggregate in high numbers. Identification of such areas may provide a key technique for monitoring changes in recruitment over time.

Numbers and Productivity

At Bluff there are now several years of data for both numbers of murres and reproductive success. Comparing the number of chicks produced at Stake 10 to the number of murres counted at the entire colony provides an index of relationship between numbers and productivity. Comparing Tables 18 and 20 shows that there has been an inverse correlation: numbers were highest in 1976 when productivity was lowest, and lowest in 1979 when productivity was high.

We have considered two hypotheses to explain this relationship. First, productivity could be density-dependent. However, Birkhead (1977) showed convincingly that breeding success is higher where murres are tightly packed in breeding aggregations than where murres breed at lower densities; the likelihood of predation is lessened as density on the ledges increases.

Alternatively, numbers and productivity may be causally unrelated. Birkhead (1978a) documented very high site tenacity and seasonally prolonged occupation of breeding sites by Common Murres at Skomer. In conjunction with the data for Bluff, these findings suggest murre attendance at the cliffs does not drop in those years that breeding success is poor. Presumably foraging conditions within range of the colony are also poor in such years. Birkhead and Hudson (1977) showed that adult mortality is confined primarily to the winter months and is related primarily to foraging conditions as well as human activities. Thus, productivity is determined by foraging conditions during the breeding season, while numbers are determined primarily by conditions during the winter months. As murres inhabiting colonies in the northern Bering Sea and Chukchi Sea probably winter south of the seasonal pack ice, and in the ice front zone in the southern Bering Sea (see Shuntov 1974, Divoky 1979), natality and mortality factors are spatially, as well as temporally disjunct. We interpret the inverse correlation at Bluff as a short-term artifact of two independent events: numbers have declined in relation to possible directional changes in winter conditions (see below) while productivity has fluctuated in relation to summer foraging conditions, which have improved over the past several years.

Studies of numbers and productivity have not been of sufficient duration to examine the relationship between varying natality rates and subsequent recruitment into the adult population several years later. Yet, because adult survivorship is typically high (e.g. Birkhead and Hudson 1977) and maximum annual reproductive output of a breeding pair is only one chick, population numbers are likely more sensitive to changes in winter survivorship than to annual fluctuations in natality rates (see Mertz 1971).

B. Kittiwakes

Census Results at Cape Thompson

The complete and partial counts of kittiwake nests between 1960 and 1979 are listed in Table 22. The only complete counts of nests at the Cape Thompson colonies have been in 1960 and 1979. There have been no kittiwakes on the Colony 1 cliffs in any year studies have been conducted.

TABLE 22. Kittiwakes: Summary of nest counts at Cape Thompson, Alaska.[1]

A. Number of nests counted.

	Year			
Colony	1960	1961	1978	1979
2	5,173	-	-	4,558
3	2,598	-	-	3,674
4	3,132	2,996	1,630	2,790
5	3,191	-	-	2,489
Total	14,094			13,511

B. Percent of 1960 totals for plots counted in both years.

		Year		
Colony	Number of Plots	1961	1978	1979
2	31	93(17)[2]	77(2)	88(31)
3	23	147(14)	-	141(22)
4	17	96(17)	52(17)	90(16)
5	28	101(6)	-	78(28)

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[1] Totals computed by summing values of average number/plot.

[2] Number of plots counted in both years.

In 1979 we counted fewer nests at Colonies 2, 4 and 5 than were counted in 1960 but over a thousand more nests at Colony 3. Overall the total number of nests counted in 1979 was 89% of the 1960 total. These figures demonstrate high variability among the colonies in the relative numbers of nests found in different years.

By expressing the partial and complete counts as percentages of the 1960 counts (see Table 22), the great magnitude of variability between successive years becomes readily apparent. In 1961 the numbers of nests were similar to the numbers found in 1960 at Colonies 2, 4 and 5, but there were far more nests at Colony 3. The number of nests at Colony 4 increased by 71% between 1978 and 1979. In 1976 few nests were built (Springer and Roseneau 1977) and no attempts at counting nests were made in that year of in 1977.

In 1976 and 1977 observers counted individuals in adult plumage rather than nests. In 1979 observers counted both nests and individuals. At all four colonies more kittiwakes were counted in 1979 than in 1976 or 1977 (see Table 23). The ratio of adults to nests in 1979 was similar among the colonies (Colony 2, 1.32; Colony 3, 1.14; Colony 4, 1.30; Colony 5, 1.34). This ratio reflects the proportion of the adults that are off-duty mates, adults which have failed to build nests, and non-breeders of the cliffs, since active nests are always tended by one member of the breeding pair. It is difficult to differentiate among these three classes of adults in the counts however, because off-duty mates, as well as non-breeders, are found in club, or loitering areas (Hodges 1977:121). Yet the magnitude of the ratio, once corrected for temporal variation within seasons, possibly does provide a quick index of nest-building success of adults: it will be very high in years such as 1976 when moderate numbers of individuals were counted on the cliffs but few nests were completed. The ratio would be lowest in those years where all adults do successfully build nests. It is thus a potential indicator of foraging conditions at the time of nest building. We did

TABLE 23. Kittiwakes: Summary of censuses of adults at Cape Thompson, Alaska.[1]

	Year			
Colony	1976	1977	1978	1979
2	3,387	3,444(102)[2]	-	5,529(163)
3	3,068	2,655(87)	-	4,964(162)
4	1,649	2,459(149)	3,290(200)	3,178(193)
5	2,432	1,665(68)	-	3,146(129)
Total	10,536	10,223(97)		16,817(160)

[1] Totals computed by summing values of average number/plot.

[2] Row percent of 1976 value listed in parentheses.

not assess daily or diurnal variation in kittiwake numbers at Cape Thompson in 1979 and simply report the timing of the censuses of each colony here (Table 24). We collected appropriate data to assess the magnitude of such variation at Bluff only.

Numbers at Bluff

In 1979 three counts of individuals were conducted at Bluff. The totals were similar (Table 25), providing a mean estimate of 9020 for 1979. Counts reported for previous years and the 1979 counts are summarized in Table 26. Counts were also conducted by Drury's field crews in 1975 and 1976 but the actual totals have not been reported. Drury (1978) concluded that numbers in 1977 were comparable to those in 1975 and 1976.

We compared the 1977, 1978 and 1979 counts in an ANOVA, grouping the data by year. Although there is a significant difference among years ($f_{2,5}$=7.118, P=0.034), the variances are unequal ($F\ max_{3,7}$= 13.190, $P < 0.005$). The 1979 counts appeared higher and were less variable then the counts in either 1977 or 1978.

Drury (1978) documented substantial diurnal variation in numbers in 1977. In that year 24-hour counts during the nestling period demonstrated that numbers were low in the very late evening and then increased through the morning until peaking at about 2000 hour. In some instances the low counts were less than 10% of the diurnal maximum counts (Drury 1978:536-540). In contrast, Ramsdell and Drury (1979) documented low variability in diurnal attendance patterns during the nestling period in 1978.

In 1979 we conducted counts of kittiwakes on five areas within the Bluff Colony in conjunction with those of murres already discussed. Figure 12 and Table 27 show that day-to-day variation in numbers during the nestling period was very slight. Overall, numbers in mid-afternoon

TABLE 24. Kittiwakes: Date and hour of the Cape Thompson counts of individuals, 1976-1979.

A. Date

Colony	Year			
	1976	1977	1978	1979
2	18 Aug	17,18 Jul	--	17,18 Jul
3	23 Jul	24 Jul, 3 Aug	--	31 Jul, 1 Aug
4	9 Aug	18,19 Jul	14 Aug	10 Jul
5	19 Aug	19,20 Jul	--	5 Aug

B. Hour of Day (Bering Daylight Time), Start to Finish

Colony	Year			
	1976	1977	1978	1979
2	13.50-19.00	19.00-01.50	--	17.28-23.00
3	NA[1]	21.05-22.50	--	14.33-19.75
4	~ 20.75	22.00-01.50	14.17-16.87	21.17-23.50
5	NA	17.00-03.50	--	13.17-17.50

[1] Not available.

TABLE 25. Kittiwakes: Counts of individuals at Bluff in 1979.[1]

Section	Date 20 Jul	 31 Jul		 7 Aug
A-C	1,840	2,107		1,820
C-D	2,070	1,890		1,655
D-E	810	1,200		850
E-F	1,510	1,435		1,552
F-G	960	780	dim light	870
G-H	470	250		405
H-I	1,350	828		1,288
I-J	215	625		280
Total	9,225	9,115		8,270
Time at A	14:23	19:00		13:25
J	11:30	23:00		11:00

Census Conditions: See murre census summary. All counts were by Observer K.

TABLE 26. Kittiwakes: Counts of the Bluff Colony between mid-July and mid-August, 1977-1979.

	Year		
Census[1]	1977	1978	1979
1	6,706	7,760	9,225
2	8,070	6,360	9.115
3	--	5,825	8,720
Average (± 1 s.d.)			
	7,388 ± 964	6,648 ± 999	9,020 ± 266

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[1] Values reported here are means of observers' totals if two or more observers counted kittiwakes simultaneously.

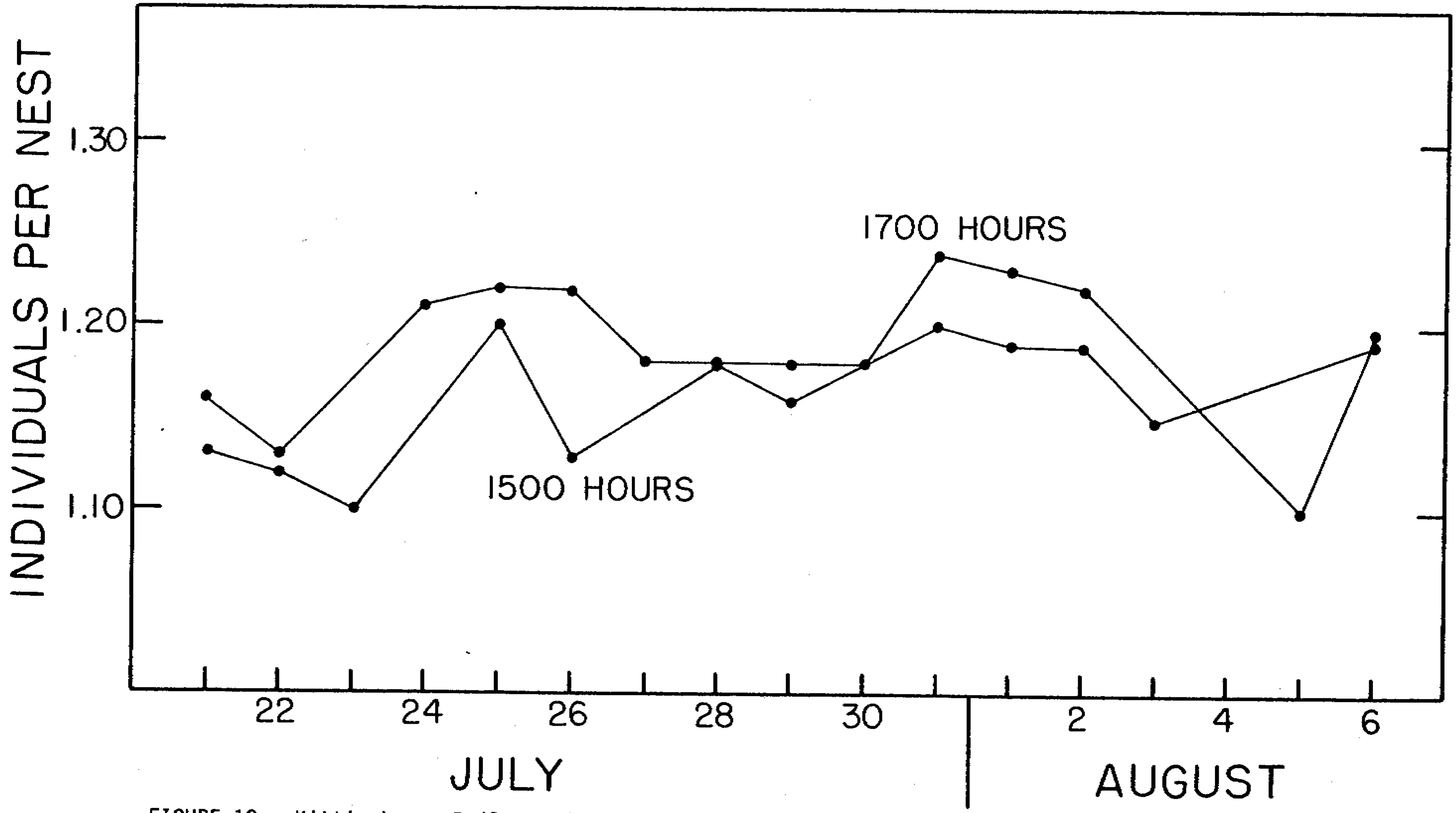

FIGURE 12. Kittiwakes: Daily variation in numbers during the nestling period at Bluff in 1979 (data from Stakes 10 and 15 combined).

TABLE 27. Kittiwakes: Daily variation in numbers on selected areas at Bluff during the nestling period, 1979.

Area	Hour		Number of Nests
	15.00	17.00	
10-A	114.9 ± 4.4(12)[1]	116.6 ± 5.3(15)	121
10-B	117.2 ± 5.3(12)	119.0 ± 4.9(15)	91
10-C	122.2 ± 6.5(12)	120.7 ± 6.8(15)	76
15-A	116.0 ± 7.2(12)	121.7 ± 4.9(14)	50
15-B	119.6 ± 4.2(12)	117.7 ± 5.1(14)	101
ALL	116.1 ± 3.5(12)	119.0 ± 3.8(14)	339

[1] Mean ± standard deviation (sample size). Numbers are expressed as percentages of the number of nests (100 times the number of individuals/number of nests).

fluctuated between 110 and 124 percent of the number of nests over the 17 day period.

Successive bi-hourly counts of kittiwakes for three periods are shown in Figure 13. Numbers consistently peaked in the late evening and were lower when light was sufficient to resume the counts the following morning. Numbers were typically lowest in mid-day. Numbers of individuals varied most at 0700 h, from 109 to 127 percent of the number of nests. Maximum numbers exceeded minimum numbers by 29 percent on 27 July, the greatest variation we observed in any 24-hour period. The kittiwake diurnal fluctuations in 1979 showed a distinct and predictable pattern of very small magnitude compared to those in 1976 and 1977 during the same phase of reproduction. Diurnal fluctuations in 1979 were similar to those reported by Ramsdell and Drury (1979) in 1978 during the nestling period.

Breeding Phenology

Table 28 lists the dates nestlings were first found at Cape Thompson, Cape Lisburne, and Bluff during Swartz's (1966) studies and in recent years. Comparing the past four years, phenology has advanced by several days in each successive year at all three localities. In 1979 hatching occurred two weeks or more earlier than in 1976. Earliest hatching dates for each colony may not reflect the pattern for the population simply because they represent one endpoint in a range of dates over which hatching occurred. We computed the estimated hatching dates for nestlings weighed at Bluff in 1978. The median estimated hatching date was 22 July, which corresponds to that which Ramsdell and Drury (1979) present on the basis of detailed nest observations. Thus, our method of estimating hatching dates provides a reliable means of reconstructing hatching phenology for the remaining samples where such dates are unknown, but where data on growth rates exist, e.g. the 1977 and 1979 Cape Thompson samples and the 1979 Bluff sample.

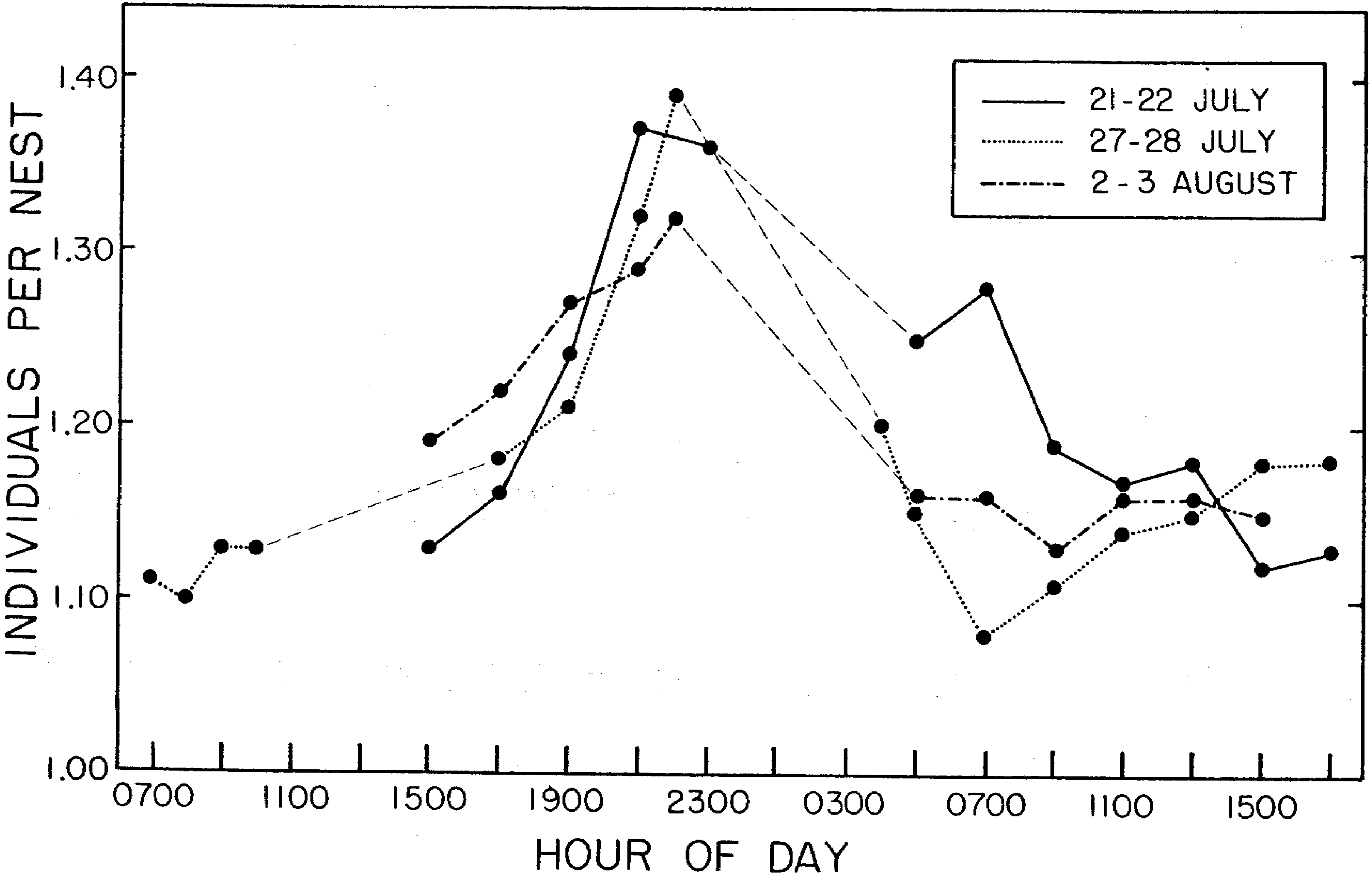

FIGURE 13. Kittiwakes: Diurnal variation in numbers at Bluff in 1979 (data from Stakes 10 and 15 combined).

TABLE 28. Kittiwakes: Breeding phenology, dates of first hatching.

	Locality		
Year	Cape Thompson	Cape Lisburne	Bluff
1959	20 July	--	--
1960	17 July	--	--
1961	22 July	--	--
1976	9 August	12 August[1]	22 July[2]
1977	29 July[3]	1-5 August	18 July
1978	25 July[3]	22 July[3]	10 July
1979	18 July[3]	14 July[3]	7 July[3]

[1] Estimate based on sizes of nestlings relative to those at Cape Thompson on same date. Hatching predated arrival of field crew, and no nestlings were weighed.

[2] Estimated from date first egg found and an incubation period of 28 days (see Swartz 1966).

[3] Extrapolated from weight of heaviest nestling when first found and its subsequent growth rate (see text).

At Cape Thompson the median hatching date was about 1 week earlier in 1979 than in 1977, and the hatching period lasted twice as long (4 weeks vs. 2 weeks, see Figure 14). At Bluff the median hatching date was 15 July, 1 week earlier than that in 1978 and more than 2 weeks earlier than in 1977 (see Drury 1978).

Although we lacked detailed data for hatching phenology at Cape Lisburne in 1979, 26 nestlings were found on 23 July and 15 of 24 eggs examined were pipped. Thus, that date represents a median value for hatching dates, and the duration of hatching was apparently short. In 1977 hatching occurred 3 weeks later: the estimated median date based on a sample of 20 nestlings was 15 August in that year.

Hatching has consistently occurred earlier at Bluff than at either Cape Thompson or Cape Lisburne (Table 28, Figure 14) but the difference appears to be less pronounced in years when phenology is advanced than in years when it is delayed. Hatching at Cape Lisburne has typically preceded that at Cape Thompson except in 1977, when median hatching dates were 15 August and 4 August, respectively.

Reproductive Success

At all 3 localities, kittiwake fledging success was higher in 1979 than in any of the 3 previous years in those instances for which comparable data are available (Table 29). At Cape Thompson, clutch sizes were somewhat lower than in 1960 or 1961 but fledging success was equivalent to that in 1960 and higher than in 1961.

Table 30 summarizes the data on reproductive output for the "upper" and "lower" nests at each of the three study areas at Cape Thompson. We tested for heterogeneity among the areas in the inter-relationships of the various measures of reproductive output, using a Chi Square test of row by column independence (see Conover 1971). The test statistic was

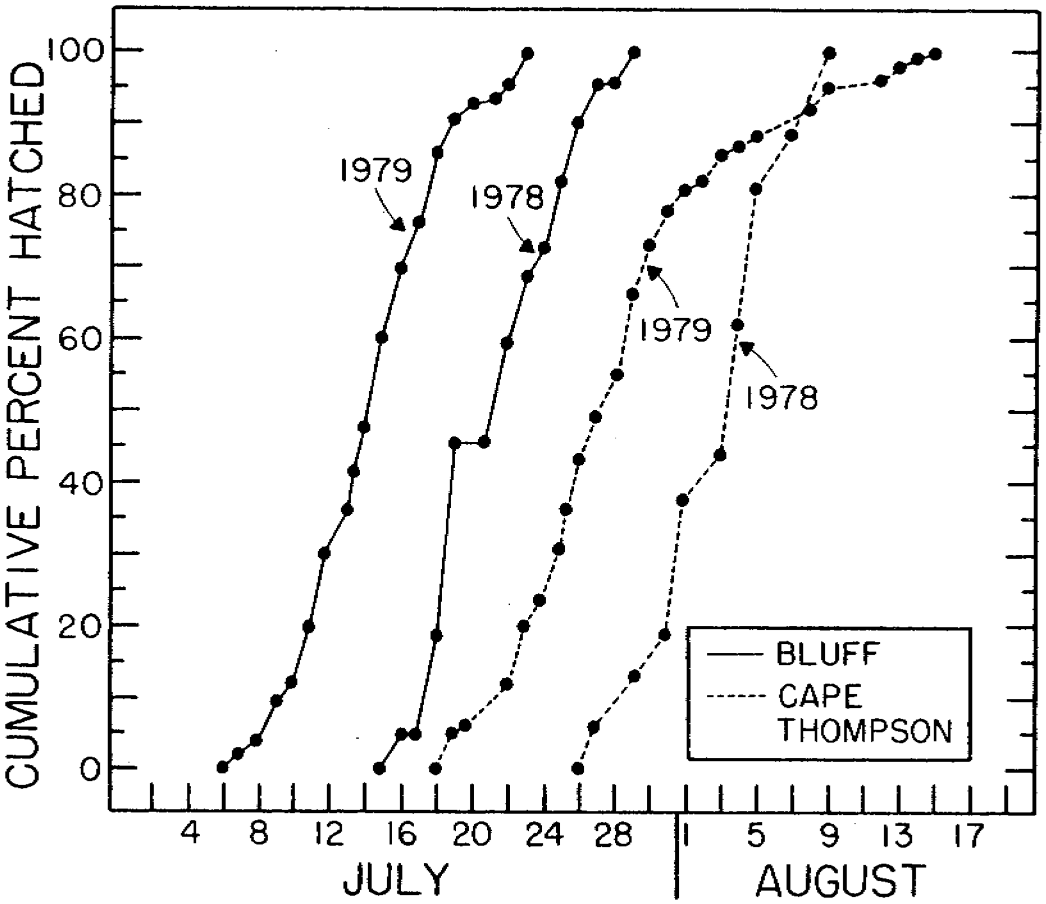

FIGURE 14. Kittiwakes: Hatching phenology at Bluff and Cape Thompson (see text).

TABLE 29. Kittiwakes: Reproductive Output.

A. Number per nest[1] built.

Year	Cape Thompson			Cape Lisburne			Bluff		
	n	eggs	fledglings	n	eggs	fledglings	n	eggs	fledglings
1976	200	0.05	0.00	132	NA	0.11	131	NA	0.04
1977	220	NA	0.48	146	NA	0.52	98	NA	0.11
1978	236	NA	0.42	113	NA	0.84	201	1.55	0.82
1979	381	1.48	1.12	84	1.63	1.28	207	--	1.05

B. Number per completed clutch.

Year	Cape Thompson			Cape Lisburne			Bluff		
	n	eggs	fledglings	n	eggs	fledglings	n	eggs	fledglings
1960	60	1.92	1.22	NA	--	--	NA	--	--
1961	29	1.88	0.72	NA	--	--	NA	--	--
1976	NA	--	--	NA	--	--	NA	--	--
1977	73	1.18	0.71	85	NA	0.89	NA	--	--
1978	NA	--	--	NA	--	--	183	1.70	0.90
1979	357	1.58	1.19	76	1.80	1.42	151[2]	NA	1.21

NA: not available.

[1] We define nest as a substantial mud platform with evidence of activity in the present season (Ramsdell and Drury 1979).

[2] Area viewed from Stake 17 (see Ramsdell and Drury 1979) not included.

TABLE 30. Kittiwakes: Reproductive output at selected areas at Cape Thompson, 1979.[1]

Area	Complete Nests	Nests with Eggs	Numbers of Eggs	Numbers of Nestlings	Numbers of Fledglings
2A Lower	42	40(95)[2]	53(126)	49(117)	45(107)
Upper	86	81(94)	119(138)	113(131)	88(102)
2C Lower	61	56(92)	91(149)	87(143)	68(111)
Upper	67	66(99)	101(151)	99(148)	86(128)
4A Lower	49	42(86)	69(141)	60(122)	53(108)
Upper	69	66(96)	102(148)	96(139)	73(106)
Total	374	351(94)	535(143)	504(135)	413(110)

---

[1] Data from nests of known clutch size only.

[2] Percent of number of complete nests shown in parentheses.

insignificant (T=3.373, v=20, P > 0.25), indicating that the pattern of reproductive output was similar for all 6 samples. Examining relative numbers of 1 and 2 egg clutches, we also found no evidence of variation among the 6 samples in clutch size only (T=7.686, v=5, P > 0.10).

There were no clutches of 3 eggs at Cape Thompson in 1979. Table 31 presents the data for 2 egg clutches, which comprised 53% of all completed clutches there. We calculated that 2 eggs hatched in 87% of those clutches, and both young fledged in 62% of the cases both eggs hatched. Nestling survival was thus considerably higher in broods of 2 in 1979 than in 1977 at Cape Thompson (see Springer and Roseneau 1978).

Nests were checked too infrequently at Cape Lisburne in 1979 for detailed evaluation of reproductive success. On 14 August, 18 nests examined on the west-facing portion of the colony contained 22 nestlings. On the north-facing portions, 48 nests were checked on 18 August, and there contained a total of 68 nestlings. Because most nestlings weighed more than 400 g, these figures suggest that 1.36 young fledged from nests which were still active late in the nestling period.

In 1979 hatching at the Bluff colony was nearly complete when the field crew arrived. On 19 July we counted 190 nestlings at Stakes 8, 10, 13 and 14, and only 9 additional nestlings were recorded on subsequent visits. Thus, the estimates of hatching success are biased downward to the extent eggs hatched but disappeared before 19 July. As we estimated a median hatching date of 15 July at Bluff in 1979 on the basis of nestling growth patterns and nestling disappearance typically occurs within several days of hatching (e.g. Ramsdell and Drury 1979), our estimates of hatching success are undoubtedly somewhat low. When we last checked nests to weigh nestlings on 6 August, 46 of 52 nestlings still alive weighed over 350 g and only 2 weighed less than 300 g. Therefore, although the field crew departed before fledging actually began, the last examination of nests provides a valid estimate of feldging success.

TABLE 31. Kittiwakes: Success of clutches of two eggs at Cape Thompson, 1979.

Area	Number of Clutches	Number of Nests					
		Nestlings			Fledglings		
		0	1	2	0	1	2
2A Lower	16	0	3	13	1	4	11
Upper	39	0	4	35	2	19	18
2C Lower	35	0	2	33	1	17	17
Upper	35	0	2	33	1	10	24
4A Lower	27	1	4	22	1	10	16
Upper	36	1	3	32	2	16	18
Total	188	2	18	168	8	76	104

Reproductive output at Bluff in 1979 is summarized in Table 32. In 1978 Ramsdell and Drury (1979) counted a total of 210 nests at the map areas of Stakes 8, 10, 13, 14 and 17, where we mapped 207 nests in 1979. Although the average of the three counts of kittiwakes at Bluff was 1.36 times the average of three counts during the same period in 1978 (see Table 26), few additional nests were counted on the map areas. Thus, the increase in the overall census figures was not mirrored by a comparable increase in numbers of nests in thoses areas sampled.

In 1978, 200 eggs hatched at Stakes 8, 10, 13 and 14; we estimated that 199 eggs hatched at those 4 stakes in 1979. In contrast to similarities between 1978 and 1979 in numbers of nests built and numbers of eggs hatching at these stakes, fledging success was considerably higher in 1979. A total of 217 nestlings apparently fledged from these 4 stakes and Stake 17 in 1979 (table 32), but only 164 nestlings fledged from the same areas in 1978.

In 1978 both nestlings in broods of 2 lived to fledging age in only 13 nests. In 1979 both nestlings lived to fledging age in 43 instances. Ramsdell and Drury (1979) showed that the probability of both nestlings in broods of 2 surviving to fledging age was inversely correlated to the interval between hatching of the eggs. Using the 1978 data, they calculated that the probability that both nestlings would survive in 2-nestling broods was 0.12 if the second egg hatched within 1 day of the first and declined as the interval increased. Since hatching was virtually completed by the time we arrived in 1979, we have no comparable data to evaluate the effect of this interval on ultimate fledging success in 1979. However, 2 nestlings fledged from 21% of the nests built in 1979--certainly the probability of success of 2 nestling broods was considerably greater than in 1978, even in comparison to success of broods where hatching spanned less than a day in that year. Therefore the higher success of 2-nestling broods in 1979 must have been related to factors other than the hatching interval.

TABLE 32. Kittiwakes: Reproductive output at selected areas at Bluff, 1979.

Area[1]	Numbers of Complete Nests	Nestlings	Fledglings
Stake 8	40	53(1.33)[2]	42(1.05)
10	51	60(1.18)	59(1.16)
13	45	50(1.11)	47(1.04)
14	32	36(1.13)	34(1.06)
17[3]	39	--	35(0.90)
Subtotal	207	--	217(1.05)
Castle	47	55(1.17)	48(1.02)
Thumb Stack	18	14(0.77)	12(0.67)
Golden Eagle Beach	15	20(1.33)	17(1.13)
Subtotal	80	89(1.11)	77(0.96)
Square Rock[3]	30	--	25(0.83)

[1] Notation corresponds to that of Drury (e.g., Ramsdell and Drury 1979).

[2] Proportion of complete nestsis shown in parentheses.

[3] Stake 17 and Square Rock visited once only, on 5 August 1979.

Kittiwakes: Growth Rates of Nestlings

Table 33 summarizes information gathered over the past 3 years at the study sites. At Cape Thompson nestlings were weighed in 1977 and 1979 only. The mean daily weight gain of nestlings was 13.1 g in 1977 and 19.7 g in 1979. Thus, not only was breeding success much higher in 1979, but also growth rates were much higher.

Growth rates at Cape Lisburne probably were comparable to those at Cape Thompson in 1979. Observers first visited nests on 23 July and returned a second time on 14 August. Twenty-three of the nestlings weighed on 14 August had not yet hatched on 23 July, 3 weeks earlier. All but 6 of those 23 nestlings weighed over 400 g on 14 August. Thus, nestlings attained peak weight levels in less than 3 weeks after hatching at Cape Lisburne in 1979.

Daily growth rates at Bluff were higher in 1979 than in 1978 and were comparable to those at Cape Thompson in 1979, averaging 20.2 g. However, there was greater variability among the areas within the Bluff Colony in 1979 than was evident there in 1978 or at Cape Thompson in 1979. Growth rates at Thumb Stack averaged only 17.5 g; in contrast those at Golden Eagle Beach averaged 24.3 g.

At both Bluff and Cape Thompson growth rates have paralleled other aspects of reproductive success of kittiwakes, i.e. in those years clutch sizes and fledging success have been high, growth rates have also been high. At Cape Lisburne growth rates have been comparatively high even in years of modest reproductive success.

Kittiwakes: Population Numbers and Reproductive Success

At Cape Thompson breeding success and nestling growth rates have been highest in those years numbers of individuals and/or nests have been greatest. Numbers were high and similar in 1960 and 1979 (Table 22); reproductive success was also comparatively high in those years

TABLE 33. Kittiwakes: Daily growth rates of nestlings.

Colony	Area	Year 1977	 1978	 1979
Cape Thompson	2A	11.2 ± 3.4(6)[1]	--	18.7 ± 3.6(33)
	2C	14.1 ± 3.5(10)	--	19.1 ± 4.3(58)
	4A	--	--	21.0 ± 3.9(49)
Cape Lisburne	West	19.7 ± 2.9(18)	18.7 ± 7.1(13)	--
	North		21.1 ± 6.1(16)	--
Bluff	Castle	--	17.4 ± 2.6(7)	19.3 ± 3.5(18)
	Thumb Stack	--	18.0 ± 5.5(6)	17.5 ± 2.3(12)
	Golden Eagle Beach	--	17.7 ± 3.2(10)	24.3 ± 3.7(12)

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[1] Mean ± Standard Deviation (Sample size). All values are in grams.

(Table 29). Numbers were relatively low in 1976 and 1977. Breeding success was virtually zero in 1976 and was lower in 1977 than in either 1960 or 1979. There are no data on nestling growth rates from Swartz's (1966) studies. Nestling growth rates were much greater in 1979 than in 1977 at Cape Thompson (Table 33). Thus, growth rates, as well as breeding success, have apparently fluctuated in parallel with numbers of kittiwakes at the Cape Thompson colonies.

At Bluff a similar pattern has occurred. Numbers, breeding success and nestling growth rates were higher in 1979 than in 1978. However, numbers were lower in 1978 than in 1977 (Table 26) while reproductive success was higher (Table 29). Thus, there is a generally positive, but variable, relationship between numbers and productivity of kittiwakes at Cape Thompson and Bluff.

Drury (1978) and Ramsdell and Drury (1979) noted that numbers of kittiwakes fluctuated dramatically, both diurnally and daily, in 1976 and 1977, years of low reproductive success and fluctuated little in 1978, a year of moderate reporductive success. In 1979, high reproductive success coincided with very low temporal variability in numbers (see Figures 12 and 13). Springer and Roseneau (1977) noted that daily variation in numbers of kittiwakes at the Cape Thompson colonies was extremely high in 1976, the year of the reproductive failure. Apparently fewer adults occupy breeding sites and those occupying sites do so more sporadically in years when reproductive success is low. Hodges (1977) has noted that successfully breeding kittiwakes coordinate their attendance with their mate so that eggs and nestlings are constantly attended by at least one member of the pair. Consequently, in those years when most pairs nest successfully, temporal variation in numbers will be comparatively low. As numbers are typically higher as well as less variable in years of high productivity, apparently more adults occupy sites more consistently at the colony such years than in years of low productivity.

VII. AND VIII. DISCUSSION AND CONCLUSIONS

A. Monitoring Changes in Numbers

Complete censuses at colonies as large as those of murres at Cape Thompson are time-consuming and may be an ineffective, if not impossible, method of continued tracking of changes in numbers. Yet any sampling design must either eliminate or at least quantify spatial, diurnal, daily, seasonal and observer sources of variability before hypotheses regarding changes in numbers can be tested effectively.

As the magnitude of the decline in murre numbers at Cape Thompson has been greater at Colony 5 than at the other 4 colonies, inter-colony variability must be addressed in any numeric monitoring. Sampling efficiency could be increased by a stratified sampling design, the choice of plots to be counted being random within each colony.

The magnitude of numeric change has also varied within the Cape Thompson colonies. First, changes have been more variable on peripheral than on central plots. Secondly, we have documented more substantial declines on invaginations of the cliff face than on the main cliff face along upper portions of Colony 5. Declines have also been greater on the east half of Colony 2 than on the west half. At Cape Thompson, systematic (e.g. every other plot) sampling within colonies would insure more complete coverage of all cliff types and areas than would random sampling within those colonies.

Although our highest counts of murres at selected sites at the Cape Thompson colonies in 1979 generally occurred once chicks had begun to jump from the cliffs, our counts were too infrequent to differentiate a seasonal pattern of cliff attendance from daily variability in attendance. Daily variability in attendance within any stage of reproduction, e.g. the chick period, appeared high, and such variability would obscure any seasonal trends. Any effects of seasonal variation could be minimized by timing counts similarly in relation to breeding phenology in each year. Since the counts at Cape Thompson usually have been conducted in the chick period, future counts there should be similarly timed to negate effects of seasonal variation in attendance patterns. Lloyd (1975) showed that daily variability in attendance of murres was lowest during the chick period in her studies of seasonal variation in attendance patterns.

Daily variability can be addressed only by repeated counts. At Cape Thompson daily variability in attendance patterns of murres is of sufficient magnitude that repeated counts of selected plots would be more efficient than a single count of all plots. For example, counting one-half or one-third of the plots at Colonies 2, 3 and 5 on two or three occasions, respectively, during the chick period would permit a better evaluation of numeric change at those colonies than would a single count of all plots. Small colonies, such as Colonies 1 and 4, could be counted completely on a comparable number of occasions.

Diurnal variability in attendance patterns, like seasonal variation, can be minimized by timing successive counts similarly in relation to time of day. If spatial variation within the colonies in diurnal patterns of attendance is high, as at Cape Thompson in 1979, any diurnal compensation of colony counts is precluded.

Observer variability may be high and can be addressed only if counts are made simultaneously and independently. Observers should not compare their results while the counts during any particular season are still in progress. Swartz (1966) commented on the subtle, unintentional adjustments observers may make following comparisons of their counts so that their estimates are more similar than might be expected if such estimates were truly independent.

Complete overlap of some counts by several different observers would provide several different, independent estimates of numbers and would allow computation of mean and variance in total numbers for comparisons among years. Photographs of selected areas taken at the time counts are made would permit evaluation of observer bias and comparisons of such bias among years.

At Cape Thompson we have not addressed the relationship of numbers of murres in adult plumage to the actual breeding population in any detail. The numbers of murres on the cliff face during a count include not only adults incubating their egg or attending their chick but also off-duty mates, adults which have failed to lay an egg or have lost their egg or chick, and sub-adults. Other studies (e.g. Birkhead 1978a) have addressed the census of these various classes of adult-plumage murres. Such detail requires frequent and careful observation of selected areas during egg-laying to map the position of each egg site and subsequent repetitive counts of birds in adult plumage on those areas, which has been beyond the scope of the studies at Cape Thompson.

Our data from both Cape Thompson and Bluff show that boat-based counts are not comparable to land-based counts from the top of the colonies. Although it may appear from the boat that all of the murres are visible, boat-based counts are considerably lower than land-based counts of the same areas. Consequently, observers should follow the techniques of previous field crews of insure that results are comparable.

In comparing boat-based counts of murres, we have not considered the effects of weather on attendance patterns (e.g. see Birkhead 1978a). There is a fairly narrow window of wind and sea conditions in which boat-based counts are even possible. Thus, by necessity, the weather conditions during all boat-based counts are similar.

As land-based counts can be conducted in a greater variety of weather conditions, weather must be considered as a source of variability in attendance patterns in comparisons of land-based counts. However, land-based counts are clearly more accurate, i.e. they provide a better estimate of actual numbers of the cliffs, than are boat-based counts. Consequently land-based counts from above the cliffs should be conducted wherever possible within the colonies. At Cape Thompson and Bluff we have delineated both the observation site by a permanent marker and the counting area by photographs for all land-based counting areas. Such documentation is necessary to permit comparable counts in future years.

Our counts of kittiwakes show that temporal (diurnal, daily and seasonal) variability in numbers varies in conjunction with productivity and is very low in years of high reproductive success. Yet Drury (1977) showed that diurnal variation in numbers may be extremely high in years of complete nesting failure or low success. Consequently repeated counts at the same time of day are necessary so that temporal variation in attendance patterns can be quantified and successfully addressed in comparison of census results.

Kittiwakes do not form such dense breeding aggregations on the broader ledges as do murres. Consequently counting is much easier and observer variability much lower. Complete censuses of kittiwakes at the Cape Thompson colonies require much less time than do those of murres. Therefore sampling, rather than repeated complete censuses, probably is not necessary if field efforts are modestly time-constrained. If field efforts are severely time-constrained a similar approach to a sampling design -- stratifying by colony and systematic sampling within the larger colonies -- would be appropriate as spatial variation in the magnitude of change in kittiwake numbers within the Cape Thompson colonies has been considerable.

Counts both of kittiwakes in adults plumage and of nests permit documentations of the number of kittiwakes at least visiting the breeding colony and of those actually intiating a breeding attempt each year, respectively. As such counts can be made simultaneously and provide different insight into the status of the kittiwake population, both should be made.

B. Annual Variation in Murre and Kittiwake Numbers

The results of the 1960, 1976, 1977 and 1979 censuses of murres at Cape Thompson indicate a marked and continued decline in numbers in the past 2 decades. At this time we can only speculate on the causes of the decline.

First, the decline has not occurred uniformly either within or among the 5 colonies, suggesting either (1) localized differences in natality and survivorship within and among the colonies or (2) a consolidation of the population in the most suitable breeding locations as the decline has progressed.

Perhaps one of the murre species has declined but the other has not. Swartz (1966) noted that Thick-billed Murres outnumbered Common Murres most markedly at Colonies 1 and 5, and least at Colonies 2 and 4 in 1960. Generally the decline has been greatest at those colonies predominated by thick-billed Murres, suggesting that perhaps numbers of Thick-billed Murres have declined more dramatically than those of Common Murres. We have not differentiated between the two species in subsequent censuses. We could test the hypothesis that the decline is related primarily to a reduction in Thick-billed Murre numbers by differentiating between the 2 species in future land-based counts of the upper plots of Colony 5 and comparing the results to Swartz's unpublished counts of each species on those same plots. We have attempted to differentiate between the 2 species during boat-based counts without success.

The censuses from Cape Lisburne and Bluff in recent years do not show the same downward trend. There is no eveidence that numbers have declined at Cape Lisburne between 1976 and 1979 where Thick-billed

Murres predominate. Numbers have apparently declined over the past several years at Bluff where Common Murres vastly outnumber Thick-billed Murres (e.g. see Drury 1977).

Considering the 2 species separately it appears unlikely that there have been localized differences in natality and survivorship within the Cape Thompson colonies. We have observed (unpublished data) that murres from various areas in the colonies flock together when flying out to foraging areas and that returning flocks are comprised of murres from different areas. Consequently, for either species, all of the murres at the Cape Thompson colonies are similarly affected by foraging conditions during the breeding season. As the murres migrate to wintering areas at least as far south as the ice front zone along the continental shelf break in the Bering Sea, it is improbable that murres within the Cape Thompson colonies could be differentially affected by winter conditions.

Although Birkhead (1976) showed that fidelity of murres to breeding sites was high at his study sites at Skomer Island in Wales, it is possible that consolidation of the population in the most suitable breeding locations has occurred as the decline has progressed at Cape Thompson. As we noted earlier, the cliff structure varies considerably among the colonies. Sites on the comparatively fragmented and softer rock of Colony 5 perhaps have been abandoned for more favorable sites at other colonies as the decline has progressed.

Documentation of the species-specific or spatial pattern of the decline would not necessarily provide insight into the factors actually responsible for the decline. Bailey and Davenport (1972) documented a substantial die-off of Common Murres following a severe storm along the Alaska Penninsula. Such natural catastrophic events could induce substantial fluctuations in numbers over time.

Also, human-related activities could be implicated in the declines. The murres breeding at Cape Thompson likely winter in the Southern Bering Sea. Data on food habits of murres in winter are sparse: only Divoky (1978) has provided limited information of food habits of murres in the southern Bering Sea. He found that Walleye Pollock (*Theragra chalcogramma*), was a ubiquitous item in the diet of both Thick-billed Murres and Common Murres. Pollock also constitute the most important single species fishery in the north Pacific (e.g. Low 1979). Consequently humans may be competing with murres for this and other fish species (see Bakkala *et al.* 1979) which are key prey of the murres.

Because the prey base of seabirds is an interactive predator-prey and competition system it is quite complex and thus defies attempts at predictive modelling (see May *et al.*). Only more detailed natural history and population data will provide further insight into such inter-actions and increase our ability to ascribe cause and effect relationships to ecological changes once oil exploration and development occurs in this region.

Unlike the murre populations at Cape Thompson, and perhaps Bluff, kittiwake population numbers have fluctuated with no apparent trend. Fluctuations between years have been sufficiently high that it is unlikely that they reflect actual changes in numbers of adults in the population. In conjunction with the data on productivity, our counts of kittiwakes suggest that relatively few adults occupy sites at the cliffs, do so more sporadically and have poor reproductive success if foraging conditions in the vicinity of the colony are poor.

In contrast, if foraging conditions in the vicinity of the colony are excellent, numbers, reproductive output and nestling growth rates are high. In 1978 and 1979 we sighted kittiwakes in immature plumage at Cape Thompson and Cape Lisburne, but we saw none at those colonies in 1976 and 1977 -- the younger age classes apparently remain pelagic in years of poor foraging conditions in the vicinity of the colony.

We speculate that the contrast between murres and kittiwakes is related to differences both in morphology and in life history attributes. Murres are high-speed flyers, achieving great thrust but little lift with their high-speed wings. In contrast, kittiwakes are buoyant flyers, achieving lift at the expense of thrust with their elliptical wings. Kittiwakes occupying sites at breeding colonies thus tend to forage relatively close to the colonies, while murres can, and typically do, fly long distances to foraging areas.

Kittiwakes dip or plunge for foods near the water surface and do not exploit foods more than about a meter deep in the water column (e.g. Ashmole 1971). Murres are wing-propelled divers and are capable of feeding at virtually any depth in the water column in the shallow continental shelf areas (see Spring 1971). They thus have a much greater 3 dimensional foraging range than do kittiwakes, enabling them to retain sites at colonies even if foraging conditions nearby are poor.

The life history of murres indicates the vulnerability of their populations to factors affecting adult survivorship. Murres are typically long-lived and do not become mature until 5 or 6 years of age (Birkhead and Hudson 1977). At best a breeding pair raises a single chick each year. Mertz (1971) has shown that population numbers of the California Condor (*Gymnogyps californianus*), which has similar life history attributes, are particularly sensitive to change in adult survivorship. Any factor, e.g. from commercial fisheries or oil development, which shifts ecosystem equilibria will have destabilizing and potentially severe effects on seabirds and marine mammals (May *et al.* 1979) and the consequence for long-lived, low fecundity species may be particularly severe.

Kittiwakes exploit many of the same prey species as do murres (e.g. Swartz 1966, Springer and Roseneau 1977, 1978), but have different life history attributes. They mature more rapidly, at 3 or 4 years of age, have relatively low adult survivorship (see Coulson and Wooler 1976), and variable, but potentially, high fecundity. Consequently their populations will likely show greater short-term sensitivity but long term resilience to environmental alterations caused by oil development than will murre populations.

IX. NEEDS FOR FURTHER STUDY

We have documented a decline in murre numbers at Cape Thompson since colonies there were first censused in 1960. Declines may have occurred elsewhere as well, e.g. Bluff and also St. Lawrence Island (See Searing 1977). Unfortunately the studies within OCSEAP have spanned several years at most, precluding any conclusions on the long-term, pre-development status of murre populations in Alaska.

There is a clear need for continued census efforts at Cape Thompson and Bluff and renewed efforts at St. Lawrence Island. Study of numeric trends at several geographically dispersed locations will permit evaluation of the geographic extent of any trends. As various localities differ in relative composition of Thick-billed Murres and Common Murres, attention can also be focused on numeric trends of each species. In conjunction with census efforts, we recommend establishment of permanent plots in mixed species colonies so that relative proportions of the 2 species can be monitored effectively over time. At Cape Thompson, the 2 species could be differentiated on the upper plots at Colony 5 and the ratios could then be compared to those found in 1960 (Swartz, unpublished data) to evaluate the relative changes in Thick-billed Murre and Common Murre numbers there.

Interdisciplinary studies designed to explain physical and biological oceanography from the perspective of seabirds would be highly productive. Such studies should be well integrated and should be conducted within regions which are reasonably self-contained ecologically. The northern Bering Sea and Chukchi Sea form such a unit. We suggest the next logical phase of OCSEAP would be to initiate such work in this region.

Unfortunately, winter studies of seabird trophic relationships have been neglected. Such studies would be logistically difficult but could contribute valuable information on the winter ecology of pelagic ecosystems. As we have discussed in the previous section, commercial fisheries activities could possibly be implicated in the decline of murre numbers at Cape Thompson. Without basic natural history data in winter we cannot assess the role of human activities in future development trends of seabirds.

Research on marine fishes in Alaska has centered on species of commercial importance. Very few data have been reported on the natural history of other species, e.g. Sand Lance, Arctic Cod (*Boregadus saida*), Saffron Cod (*Eleginus gracilis*) and sculpins (*Cottidae*), which play key roles in the trophic dynamics of the northern Bering Sea and Chukchi Sea. Our analyses of food habits of kittiwakes (Springer and Roseneau 1977, 1978, Springer *et al.* 1979, in progress) show that Sand Lance play a key role in the reproductive success of kittiwakes in Norton Sound and in the Chukchi Sea.

As we begin to integrate our studies of population numbers, productivity and trophic relationships of murres and kittiwakes we are becoming firmly convinced that seabirds are ideal indicators of variations in physical and biological processes in regional marine ecosystems. Seabirds are highly visible and thus easily studied. Because they typically occupy apex positions in marine food webs, they are highly sensitive to ecological changes. Their numbers, breeding phenology and reproductive success reflect seasonal and annual fluxes in community structure and stability. Their food habits and feeding areas serve to identify and describe the various communities in which they participate. No other marine studies can provide the details of marine systems as efficiently, economically and thoroughly as can those of seabirds.

X. SUMMARY OF JANUARY - MARCH QUARTER

The only time devoted to RU 460 during this quarter was in report preparation.

XI. AUXILIARY MATERIAL

A. References Used

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B. Papers in Preparation or Print

We are presently preparing summary papers of our studies of (1) murre numbers and (2) kittiwake numbers and productivity for publication in refereed journals.

C. Oral Presentations

Murphy, E.C. Numeric Changes in the Murre Populations at Cape Thompson, Alaska. Sixth Annual Pacific Seabird Group Meeting. Asilomar, Pacific Grove, CA. 23-26 January, 1980.

APPENDIX

Comparison of Plot notations used in various censuses and in this report.[1]

A. Murres.

	Year of Census				
	1960-61	1976	1977	1979	This Study
Colony 1.	B,C	B,C	B,C	BC	BC
	F,G	F,G	F,G	FG	FG
Colony 2.	K,L	K,L	K,L	KL	KL
	HH,II	HH,II	HH,II	HI	HI
Colony 3.	G-K	G-K	G-K	G-K	GK
	P	L	L	L	L
	L,M,N,O	M,N	M,N	MN	MN
	Q,R,S	O,P	O,P	OP	OP
	T,U	Q	Q	Q	Q
	V	R	R	R	R
	W	S	S	S	S
Colony 5 (1960 designations).					
	A-C,X	-	AX	AX	AX
	D,Y,Z	-	DZ	DZ	DZ
	E,F	-	EF	EF	EF
	G	-	G,113	G	G
	AA	-	111,112	AA	AA
	BB,DD	-	BB,DD	BD	BD
	HH	-	107,108	HH	HH
	JJ	-	105,106	JJ	JJ
	KK	-	103,104	KK	KK
	PP	-	PP,102	PP	PP

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[1] Listing is only of those plots or areas with variable notation among censuses.

Appendix (cont.).

	Year of Census				
	1960-61	1976	1977	1979	This Study
Colony 5 (1976 designations).					
	-	AA	AA	XA	XA
	-	BB	BB	XB	XB
	-	CC	CC	XC	XC
	-	DD	DD	XD	XD
	-	FF	FF	XF	XF
	-	HH	HH	XG	XG
	-	KK	KK	XH	XH
	-	LL	LL	XI	XI
	-	NN	NN	XJ	XJ
	-	QQ	QQ	XK	XK
	-	RR	RR	XL	XL

B. Kittiwakes, Counts of Individuals.

	Year of Census			
	1976	1977	1979	This Study
Colony 2.	D,E,F	combined	D,E,F	DF
	G-J	combined	G-J	GJ
	K-N	combined	K-N	KN
	O-R	combined	O-R	OR
	S,T	combined	S,T	ST
	V,W	combined	V,W	VW

Appendix (cont.).

	Year of Census			
	1976	1977	1979	This Study
Colony 2 (cont.).				
	X,Y	combined	X,Y	XY
	Z,AA	combined	Z,AA	ZA
	BB,CC	combined	BB,CC	BC
	DD-FF	combined	DD,FF	DF
	GG-II	combined	GG-II	GI
Colony 3.	B,C	combined	B,C	BC
	D-F	combined	D-F	DF
	G,I-L	combined	G-I-L	GL
	M,N	combined	M,N	MN
	O,P	combined	O,P	OP
Colony 4.	A,B	combined	A,B	AB
	D,E	combined	D,E	DE
	F-I	combined	F-I	FI
	J-L,O	combined	J-L,O	JO
	M,N,P-R	combined	M,N,P-R	MR
Colony 5 (1976 designations).				
	AA	AA	XA	XA
	BB	BB	XB	XB
	CC	CC	XC	XC
	DD,EE	DD	XD	XD
	FF	FF	XF	XF
	HH	HH	XG	XG
	KK	KK	XH	XH
	LL	LL	XI	XI
	NN,QQ,RR	NN,QQ,RR	XJ	XJ

Appendix (cont.).

C. Kittiwakes, Counts of Nests.

	Year of Census			
	1960,1961	1978	1979	This Study
Colony 2.	K,L	-	KL	KL
Colony 3.	A-W	-	A-W	A-W
Colony 4.	F,G	F,G	FG	FG
Colony 5 (1960 designations).				
	A-C,X	-	A-C,X	AX
	D,Y,Z	-	D,Y,Z	DZ
	E,F	-	E,F	E,F
	O,P	-	O-P	OP

RECEPTORS-PLANKTON

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ANNUAL REPORT

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Plankton Studies in the Bering Sea: CGC *Polar Sea*, 17 Apr - 6 May 1979

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The objective of this study was to determine the primary productivity, plant pigments, zooplankton standing stock and related hydrographic features in the northern Bering Sea at a time when conventional research vessels cannot penetrate the area because of ice conditions.

The ice edge in spring is a region of intense biological activity. Birds and mammals congregate there because of the availability of food. A phytoplankton bloom occurs that supplies food to the primary consumers.

Information concerning this critical habitat is important and necessary before industrial development occurs.

II. Introduction

A. General Nature and Scope of Study

The April-May 1979 cruise of CGC *Polar Sea* provided OCSEAP scientists the opportunity to study the hydrography, microbiology, plankton, and benthos in the Norton Sound lease area at a time when conventional research vessels cannot work the area because of ice conditions. OCSEAP studies emphasized the lower end of the marine food web, microbiology and plankton, with special attention being given to the ice edge area.

B. Specific Objectives

The specific objective of RU 359 was to determine the primary productivity, plant pigments, zooplankton standing stock, and related hydrographic features in the northern Bering Sea in April.

C. Relevance to Petroleum Development

The Draft Environmental Impact Statement for the Norton Basin is due in June 1981 (OCSEAP 1979). Little information is available concerning the planktonic community of this region at any season, but especially during the time when ice covers the area. The time in late April-early May when the ice is beginning to breakup is one of intense biological activity and is therefore critical to the overall ecology of the Bering Sea.

III. Current State of Knowledge

Cooney (1976 in 1978b) has provided an extensive bibliography concerning available information about the zooplankton community in the Bering Sea. Much of the information has been summarized in Hood and Kelley (1974) and Hood and Takenouti (1975). Japanese efforts during hydrographic and high sea fishery surveys from 1956 to 1970 have provided most of the recent descriptive information on the pelagic community.

Many references to Bering Sea plankton communities are concerned with the southern Bering Sea and especially the area along the shelfbreak (McRoy *et al.* 1972; McRoy and Goering 1974, 1976; Goering and Iverson 1978; Cooney *et al.* 1978; Alexander and Cooney 1979), although McRoy *et al.* (1972) included a few winter stations from the Navarin Basin area; McRoy and Goering (1974) show several winter stations near the eastern end of St. Lawrence Island, and Alexander and Cooney (1979) did a survey of chlorophyll *a* in ice algae in Norton Sound. Motoda and Minoda (1974) reviewed summer studies on phyto- and zooplankton species and standing stocks, primary productivity and plant pigments, and zooplankton biomass in the whole Bering Sea.

Taniguchi *et al.* (1976) described the vertical distribution of phytoplankton during May and June in the southern Bering Sea, while Saito and Taniguchi (1978) studied the phytoplankton community in the seasonally ice-covered areas from the northern Bering to the northern Chukchi seas.

Alexander and Cooney (1979) reviewed previous phytoplankton studies in the Bering Sea with regard to species present and their distribution. These authors applied numerical analysis techniques to their data, collected at discrete depths and at all seasons except mid-winter.

IV. Study Area

The study area and station locations are given in Fig. 1.

V. Sources, Methods, and Rationale of Data Collection

Water samples were collected with 5 ℓ Niskin bottles (General Oceanics Inc., Miami, FL.) equipped with reversing thermometers belonging to the U.S. Coast Guard. Samples were collected from 6 or 8 depths spaced throughout the water column with the bottom bottle placed as close to the sea bed as possible. Portions of each water sample were processed for salinity, nutrient concentrations, primary productivity, plant pigments, and phytoplankton standing stock.

Primary productivity experiments were run in 60 ml glass reagent bottles with 2 light and 1 dark bottle per depth. Each bottle was inoculated with 2 ml $NaH^{14}CO_3$. The dark bottle was wrapped in aluminum foil and all bottles were incubate for 3 to 4 hr under ambient light conditions in an incubator located on the fantail. Low temperature was maintained by constantly running seawater through the system. Light was measured at the beginning and end of incubation period with a Gossen Super Pilot photographic light meter. Following incubation, the samples were filtered onto 25 mm 0.45 μm Millipore filters, rinsed with a few ml 0.1 N HCl and a few ml of filtered seawater, and were placed in vials for return to Seattle. Radioactive uptake was measured using liquid scintillation techniques in a Packard Tri-Carb Scintillation spectrometer using Aquasol (New England Nuclear, Boston, MA.) as the scintillation cocktail.

Carbon uptake was calculated using the equation

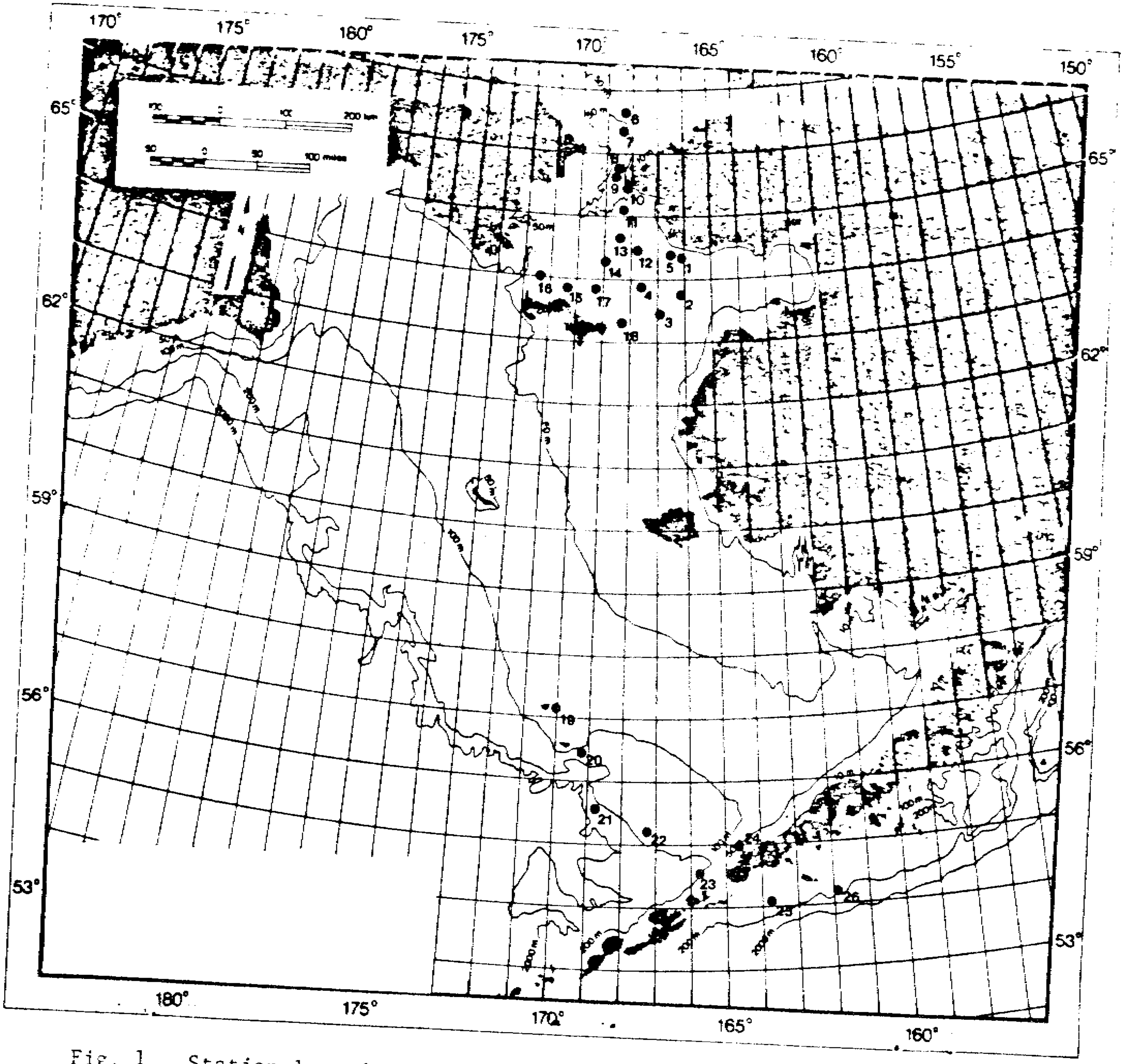

Fig. 1. Station locations, Bering and Chukchi seas, CGC *Polar Sea*, 17 Apr - 6 May 1979.

$$\text{Ps (mg C m}^{-3}\text{ hr}^{-1}) = \frac{(L - D) \times W \times 1.05}{R \times T}$$

where L = light bottle disintegrations per minute; D = dark bottle disintegration per minute; W = carbonate carbon present in the water; 1.05 = isotope factor for ^{14}C; R = activity of the ^{14}C added to each sample; T = incubation time (Strickland and Parsons 1968).

Plant pigment samples, usually 2 ℓ, were filtered through 47 mm 0.45 μm Millipore filters with a few drops of saturated $MgCO_3$ solution added near the end of the filtration. The filters and filter towers were rinsed with a few ml filtered seawater and the filters were folded into quarters, placed in glassine envelopes, and frozen.

Samples were analyzed by grinding the filters in 90% acetone with a Teflon tissue grinder. The samples were centrifuged *ca*. 30 min, and the extract was analyzed with a Turner Model 111 fluorometer.

Chlorophyll *a* and phaeopigments were calculated using the equations

$$\text{Chl } a \text{ (mg m}^{-3}) = \frac{\dfrac{F_o/F_{a_{max}}}{(F_o/F_{a_{max}}) - 1}\ (K_x)\ (F_o - F_a)}{\text{Vol filtered}}$$

$$\text{Phaeo (mg m}^{-3}) = \frac{\dfrac{F_o/F_{a_{max}}}{(F_o/F_{a_{max}}) - 1}\ (K_x)\ \ F_o\ (F_a/F_{o_{max}}) - F_a}{\text{Vol filtered}}$$

where F_o = fluorometer reading before acidification; F_a = fluorometer reading after acidification; K = fluorometer door calibration factor; $F_o/F_{a_{max}}$ = acid ration; Vol filtered = volume of sample filtered.

Nutrient samples were taken from the plant pigment filtrate. About 500 ml of the pigment sample were filtered to wash the Millipore filter and that water was thrown out. The nutrient sample was taken from the next quantity of water filtered and before the $MgCO_3$ was added. The nutrient samples were poured into 125 ml polyethylene bottles and frozen. Nitrate, nitrite, ammonia, phosphate, and silicate concentrations were determined at the Department of Oceanography, University of Washington, Chemistry Laboratory, using autoanalyzer techniques.

Most of the salinity samples were analyzed and the results calculated on board using a Bissett Berman induction salinometer and standard seawater. A few samples were analyzed by the Chemistry Laboratory in the Department of Oceanography.

Phytoplankton standing stock samples were preserved with 4 - 5 ml 4% formaldehyde buffered with sodium acetate. None of these samples has been analyzed.

Temperatures were taken with reversing thermometers attached to the Niskin bottles. Temperatures were sent to the Coast Guard Oceanographic Unit, Washington, D.C., for correction using Coast Guard-determined calibration factors for the thermometers.

Secchi disc depths were determined at all stations using a 30 cm diameter Secchi disc lowered on a hand line.

Zooplankton samples were collected with bongo or ring nets depending on ice conditions. When ice was present, a 0.75 m ring net with a mesh size of 308 μm, was lowered to the bottom and vertically hauled to the surface while the ship was stopped on station. The net was deployed at 50 m/min and retrieved at 20 m/min.

When enough open water was present, 60 cm diameter bongo nets with mesh sizes of 335 μm and 500 μm, were used to take oblique tows. Flow meters (TSK, Model 313, InterOcean System, Inc., San Diego, CA.) were mounted in the mouths of each net to determine the amount of water filtered. The nets were deployed at 50 m/min and retrieved at 20 m/min. Ship speed varied from 1.5 to 3 kt to maintain a 45° wire angle. At shallow stations the net was lowered to within 10 m of the bottom and at deep stations to 200 m.

All nets were washed down with seawater. The samples were concentrated in the net collection cup by gently swirling to remove excess water. The samples were put in labeled 250 ml or 500 ml jars and preserved with 37% formaldehyde buffered with sodium acetate and sodium borate.

Acoustic surveys were conducted using a Ross 200A Fine Line Echo-sounder system operating with a frequency of 105 kHz. A 10° transducer mounted in a 0.6 m V-Fin depressor was lowered to just beneath the water surface when the ship was stopped on station. The incoming signal was recorded on a paper chart and on magnetic tape for later analysis.

Zooplankton samples collected with the 0.75 m ring net and 500 μm mesh bongo net have been analyzed. Large and rare organisms were first sorted from the whole sample, counted and placed in vials by taxonomic category. The remaining sample was split in a Folsom plankton splitter until approximately 100 specimens of the most abundant taxonomic category remained. A few samples contained large number of several different taxonomic categories and these samples were split before any organisms were removed. The individual splits of the sample were then sorted and rough counted by taxonomic category until at least 100 of each category or the total number of organism in the whole sample was counted. A set of voucher specimens was made by the three sorters working on the samples.

The number of animals per 1000 m^3 was calculated using the equation

$$\text{No per } 1000\ m^3 = \frac{1000\ m^3}{\text{Vol water filtered}}\ (\text{no. organisms counted})$$

For the 0.75 m ring net the volume of water filtered is calculated from

$$\text{Vol water filtered } (m^3) = \pi r^2 \times D$$

where r = radius of the net ring; D = depth of the tow.

For the 60 cm bongo net, the volume of water filtered was calculated from

$$\text{Vol water filtered } (m^3) = \frac{\text{mouth area}}{\text{of frame}} \times \text{meters/revolution} \times \text{revolutions}$$

where meters/revolution is taken from the flowmeter calibration curve and revolutions is taken from the flowmeter.

VI. Results

Temperature, salinity, plant pigment concentrations, and primary productivity data are given in Table 1 and vertical profiles are shown in Fig. 2. Primary productivity ranged from 0.12 mg C m^{-3} hr^{-1} on the surface at station 2 to 17.16 mg C m^{-3} hr^{-1} at 12 m at station 12 in the northern Bering Sea. In the southern Bering Sea and south of the Alaska Peninsula, primary productivity ranged from 0.08 mg C m^{-3} hr^{-1} at station 26-60, to 14.05 mg C m^{-3} hr^{-1} at station 23-20. In Shelikof Strait, primary productivity ranged from 3.49 mg C m^{-3} hr^{-1} at station 27-50 to 22.33 mg C m^{-3} hr^{-1} at station 28-00.

Chlorophyll *a* ranged from 0.13 mg m^{-3} at station 15-00 to 12.00 mg m^{-3} at station 12-12 in the northern Bering Sea. In the southern Bering Sea south of the Pribilof Islands and south of the Alaska Peninsula, chlorophyll *a* ranged from 0.24 mg m^{-3} at station 20-40 and 50 m to 4.00 mg m^{-3} at station 23-00. At the Shelikof Strait stations, chlorophyll *a* ranged from 1.25 mg m^{-3} at 27-50 to 4.8 mg m^{-3} at station 28-20.

Nutrient concentrations (nitrate, nitrite, ammonia, phosphate, and silicate) are listed in Table 2.

Table 3 lists zooplankton taxa and numbers of animals per 1000 m^3 found in bongo and ring net hauls. One hundred forty-two (142) categories of organisms were identified. Of these, 75 were identified to species; the other 67 categories were identified to genus or other higher taxonomic rank and included larval stages and eggs.

Calanoid copepods, the chaetognath *Sagitta elegans*, and amphipods were present at all stations. The hydromedusa *Aglantha digitale*, and crustacean eggs were present in the majority of samples. Samples from stations 21 to 23, 25 and 26 contained *Eukrohnia hamata* and *Sagitta elegans*. *Clione limacina* was the most abundant pteropod from northern stations, while *Limacina helicina* was the most abundant pteropod from southern stations. The euphausid *Thysanoëssa raschii* was present only in samples from the northern stations, while *T. spinifera* and *Euphausia pacifica* were only collected from southern stations. *Thysanoëssa inermis* and *T. longipes* were present in samples from both areas. Euphausid larvae were present at stations 22 through 28. Crab larvae were present at all stations except 1, 5, 7, and 8, and were very abundant at station 19 near St Paul Island.

Table 1. Summary of station locations, hydrography, ice cover, chlorophyll *a* and phaeopigment concentrations, and primary productivity, CGC *Polar Sea* cruise, Bering Sea, 17 Apr - 6 May 1979.

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Secchi Depth (m)	Temp (°C)	$S^{\circ}/_{\circ\circ}$	Chl a	Phaeo	Prim Prod (mg C m^{-3} hr^{-1})
										(mg m^{-3})		
01	000	0644	19 Apr	64°15.5'	165°51.9'	8	2	*	31.842	1.68		8.23
	003							-1.67	31.845	1.92		7.29
	006							-1.69	31.887	2.32		9.82
	009							-1.68	31.886	1.28		7.00
	012							-1.68	31.877	1.36		7.25
	015							-1.69	31.800	1.36		8.26
	018							-1.71	31.820	2.72		10.31
	021							-1.72	31.929	2.64		11.82
02	000	1622	19 Apr	63°46.1'	166°03.2'	0	4	-1.51	31.675	4.48		0.12
	003							-1.52	31.652	5.76		3.67
	006							-1.52		Bottle didn't trip		
	009							-1.53	31.653	5.04		2.84
	012							-1.53	31.654	5.76		3.35
	015							-1.54	31.665	7.56	0.36	3.44
	018							-1.56	31.684	10.44	0.36	2.12
	021							-1.54	31.693	11.16		2.79
03	000	0612	20 Apr	63°32.95'	166°52.78'	0	4	-1.62	31.559	4.66		9.19
	004							-1.63	31.554	3.36	0.42	10.51
	008							-1.64	31.550	1.34	1.83	7.88
	012							-1.63	31.555	3.90	0.26	7.63
	016							-1.64	31.557	3.22	0.40	6.41
	020							-1.64	31.559	2.94	0.28	8.09
	024							-1.65	31.553	3.80	0.44	5.32
	028							-1.64	31.556	2.10	0.28	4.58

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* Where no temperature is present, both thermometers on the bottle malfunctioned.

Table 1. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Secchi Depth (m)	Temp (°C)	S°/°°	Chl a (mg m^{-3})	Phaeo	Prim Prod (mg C m^{-3} hr^{-1})
04	000	1237	20 Apr	63°56.7'	167°35.9'	5-6	4	-1.62	31.933	0.91		2.45
	004							-1.64	31.927	1.44		2.60
	008							-1.63	31.928	0.81	0.15	1.71
	012							-1.67	31.939	1.63	0.14	2.44
	016							-1.65	31.935	1.14	0.09	1.72
	020							-1.69	31.938	1.14	0.23	3.02
	024							-1.73	31.937	1.29	0.31	1.85
	028							-1.73	31.944	1.56	0.28	2.50
05	000	0537	21 Apr	64°30.3'	166°23.3'	6-7	4	-1.67	31.240	2.89		3.10
	003							-1.66	31.225	1.56		7.20
	006							-1.68	31.457	3.20	0.19	3.88
	009							-1.66	31.438	1.28		4.13
	012							-1.68	31.490	1.93		3.61
	015							-1.72	31.456	1.68	0.06	6.16
	018							-1.71	31.456	0.83		5.51
06	000	0956	22 Apr	66°36.26'	168°25.40'	7-8	4	-1.29	31.587	0.25	0.94	0.97
	005								31.689	0.26	0.99	1.30
	010							-1.66	31.715	0.14	0.95	0.84
	015							-1.70	31.716	1.17		1.25
	020								31.740	0.35	0.59	0.81
	025							-1.69	31.760	1.07	0.22	1.19
	030							-1.71	31.763	0.12	1.42	0.77
	035							-1.72	31.760	1.00	0.40	1.26

Table 1. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Secchi Depth (m)	Temp (°C)	S°/₀₀	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
09	000	1222	24 Apr	65°36.6'	168°35.6'	7-8	2	-1.64	31.684	0.35	1.40	1.59
	005							-1.69	31.726	0.98	0.14	1.60
	010							-1.70	31.723	0.94	0.08	1.33
	015							-1.72	31.714	0.82	0.18	1.27
	020							-1.70	31.723	0.91	0.27	1.56
	025							-1.71	31.723	0.93	0.21	1.21
	035							-1.73	31.722	1.16	0.27	1.01
	045							-1.72	31.719	1.16	0.38	1.07
10	000	1222	25 Apr	65°29.89'	168°06.11'	7-8	3	-1.30	31.437	0.62	0.08	8.66
	005							-1.39	31.432	0.52	0.07	11.24
	010							-1.63	31.442	0.53	0.09	5.93
	015							-1.37	31.444	0.41	0.03	10.42
	020							-1.39	31.443	0.48	0.09	6.84
	025								31.448	0.54	0.11	7.73
	030							-1.33	31.458	0.50	0.09	6.02
11	000	0625	26 Apr	65°01.8'	168°15.7'	7-8	3		32.312	0.49	0.42	0.53
	005							-1.38	32.308	0.39	0.27	0.52
	010							-1.49	32.308	0.26	0.33	0.33
	015							-1.44	32.311	0.26	0.23	0.42
	020								32.306	0.39	0.20	0.46
	025							-1.51	32.323	0.36	0.27	0.44
	030							-1.42	32.345	0.46	0.31	0.62
	040								32.359	0.40	0.40	0.60

Table 1. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Secchi Depth (m)	Temp (°C)	$S^{\circ}/_{\circ\circ}$	Chl *a*	Phaeo	Prim Prod (mg C m^{-3} hr^{-1})
										(mg m^{-3})		
12	000	0634	27 Apr	64°29'64'	167°40.10'	0	2	-1.11	31.568	10.00	2.00	12.27
	004							-1.18	31.569	8.50	2.00	15.94
	008							-1.21	31.572	10.00	1.50	15.07
	012							-1.21	31.569	12.00	0.50	17.05
	016							-1.22	31.573	3.50		13.24
	020							-1.21	31.571	9.50	2.00	14.75
	024							-1.23	31.568	9.00	2.00	8.63
	028							-1.23	31.563	4.60	4.40	17.16
13	000	1337	27 Apr	64°37.82'	168°25.67'	< 1	2	-1.49	32.191	1.00	0.50	0.94
	004							-1.57	32.189	0.80	0.40	1.60
	008							-1.58	32.191	0.50	0.30	1.06
	012							-1.60	32.195	0.60	0.30	1.70
	016							-1.60	32.192	0.70	0.30	1.15
	020							-1.61	32.193	0.70	0.35	1.14
	024							-1.63	32.196	0.70	0.40	1.12
	030							-1.63	32.200	0.55	0.40	1.19
14	000	0602	28 Apr	64°12.66'	168°57.44'	4-5	4	-1.69	32.371	0.17	0.14	0.23
	004							-1.73	32.376	0.17	0.14	0.30
	008							-1.75	32.368	0.17	0.16	0.29
	012							-1.76	32.368	0.16	0.15	0.28
	016							-1.74	32.377	0.17	0.17	0.31
	020							-1.77	32.406	0.16	0.14	0.26
	026							-1.77	32.433	0.15	0.19	0.33
	032							-1.78	32.499	0.14	0.20	0.21

Table 1. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Secchi Depth (m)	Temp (°C)	S°/oo	Chl *a* (mg m^{-3})	Phaeo	Prim Prod (mg C m^{-3} hr^{-1})
15	000	0611	29 Apr	63°50.91'	170°26.03'	0	3	-1.40	32.029	0.13	0.11	0.38
	004							-1.53	32.032	0.17	0.12	0.44
	008							-1.54	32.028	0.18	0.10	0.36
	012							-1.54	32.031	0.16	0.10	0.33
	016							-1.53	32.025	0.15	0.10	0.32
	020							-1.54	32.035	0.18	0.10	0.39
	024							-1.54	32.037	0.14	0.12	0.33
	030							-1.56	32.034	0.17	0.12	0.32
16	000	1307	29 Apr	64°00.6'	171°25.5'	1-3	4	-1.52	31.978	0.38	0.11	0.71
	004							-1.64	31.980	0.30	0.06	0.54
	008							-1.66	31.979	0.39	0.09	0.90
	012							-1.69	31.980	0.40	0.06	0.77
	016							-1.68	31.979	0.27	0.24	0.83
	020							-1.68	31.976	0.38	0.11	0.63
	024							-1.69	31.966	0.37	0.08	0.71
	028							-1.70	31.980	0.35	0.10	0.75
17	000	0600	30 Apr	63°44.83'	169°12.32'	0	5	-1.58	32.261	0.16	0.10	0.28
	002							-1.61	32.282	0.21		0.21
	006							-1.58	32.398	0.15	0.11	0.22
	010							-1.59	32.299	0.14	0.09	0.21
	014							-1.56	32.348	0.13	0.11	0.23
	018								32.316	0.12	0.10	0.18
	024							-1.63	32.346	0.11	0.11	0.22
	030							-1.68	32.434	0.12	0.13	0.16

Table 1. (continued)

Sta	Depth (m)	Time (Local	Date	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Secchi Depth (m)	Temp (°C)	S°/oo	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
18	000	1343	30 Apr	63°17.83'	168°20.07'	0	4	-1.16	31.449	1.40	0.25	2.02
	004							-1.19	31.450	1.20	0.30	2.02
	008							-1.20	31.456	1.35	0.30	2.04
	012							-1.23	31.455	1.30	0.30	2.70
	018							-1.27	31.457	1.35	0.30	1.76
	024							-1.32	31.461	1.80	0.35	2.38
	030							-1.34	31.459	1.40	0.30	3.44
	036							-1.33	31.462	1.80	0.40	3.67
19	000	0552	2 May	57°06.89'	170°00.7'	0	3-4	2.68	32.583	1.05	0.35	2.13
	005							1.56	32.542	1.35	0.50	2.19
	010							2.67	32.540	1.05	0.35	2.47
	015							2.64	32.538	1.65	0.60	3.20
	020							2.67	32.664	1.05	0.45	1.69
	025							2.67	32.585	0.95	0.40	2.53
	030							2.66	32.583	1.05	0.25	2.35
	042							2.66	34.977	0.85	0.70	3.58
20	000	1255	3 May	56°27.50'	169°25.06'	0	12	3.91	32.546	0.28	0.15	0.54
	010								32.514	0.28	0.11	0.81
	020							3.55	32.504	0.29	0.16	1.08
	030							3.49	32.485	0.24	0.11	1.07
	040							3.50	32.468	0.25	0.17	0.70
	050								32.444	0.25	0.17	0.85
	060							3.48	32.410	0.25	0.14	0.82
	080							3.48	32.379	0.28	0.14	0.93

Table 1. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Secchi Depth (m)	Temp (°C)	S°/∘∘	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
23	000	0657	3 May	54°34.07'	165°58.64'	0	∿ 7	4.49	32.808	4.00	0.80	6.18
	010							4.57	32.788	3.30	0.70	10.42
	020							4.57	32.785	2.80	0.70	14.05
	030							4.40	32.785	1.90	0.30	7.99
	045							4.40	32.800	1.70	0.45	5.90
	060							4.35	32.808	1.55	0.40	5.55
	075							4.32	32.829	1.60	0.55	8.74
	100							4.09	32.977	0.65	0.40	2.15
24	000	1423	3 May	54°58.7'	164°36.2'	0	∿ 7	4.81	32.240	1.15	0.35	5.18
	005							4.76	32.235	0.95	0.25	5.19
	010							4.74	32.239	1.10	0.20	5.75
	015							4.70	32.252	1.10	0.30	5.60
	020							4.72	32.303	1.25	0.45	2.58
	025							4.52	32.318	0.70	0.35	4.45
	035							4.44	32.380	0.85	0.30	2.42
	045							4.41	32.424	0.55	0.40	0.98
25	000	0658	4 May	54°10.36'	163°47.78'	0	8	4.72	31.704	0.85	0.20	2.71
	010							4.69	31.709	0.80	0.30	2.45
	020							4.70	31.718	0.90	0.25	2.74
	030							4.54	31.812	1.60	0.45	3.23
	040							4.53	31.875	1.25	0.35	3.10
	050							4.47	31.923	0.90	0.60	1.91
	060							4.21	31.974	0.55	0.50	0.71
	075							4.04	32.170	0.09	0.32	0.20

Table 1. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Ice Cover (oktas)	Secchi Depth (m)	Temp (°C)	S°/oo	Chl *a* (mg m^{-3})	Phaeo (mg m^{-3})	Prim Prod (mg C m^{-3} hr^{-1})
26	000	1605	4 May	54°14.7'	161°52.5'	0	> 12	4.62	31.789	0.45	0.30	1.34
	005							4.60	31.798	0.50	0.20	1.25
	010							4.59	31.794	0.75	0.20	1.33
	020							4.47	31.805	0.55	0.20	1.43
	030								31.822	0.45		0.59
	040							4.15	31.953	0.13	0.27	0.15
	050							3.97	32.138	0.14	0.10	0.12
	060							4.03	32.250	0.07	0.22	0.08
27	000	1506	5 May	56°21.44'	155°30.78'	0	> 10	5.07	32.194	3.60	0.60	15.14
	005							5.00	32.192	3.40	0.60	16.23
	010							4.77	32.192	3.90	0.50	14.25
	015							4.55	32.205	3.10	0.40	7.91
	020							4.53	32.194	3.30		8.94
	030							4.47	32.199	2.25	0.40	5.47
	040							4.49	32.230	1.85	0.50	3.73
	050							4.64	32.323	1.25	0.65	3.49
28	000	0659	6 May	59°07.07'	152°54.38'	0	> 10		32.099	3.40	0.60	22.33
	010							4.98	32.044	3.70	0.60	19.80
	020							4.89	32.100	4.80	0.80	18.78
	030							4.71	32.144	3.10	0.70	13.47
	040							4.72		2.80	0.80	10.66
	050							4.70	32.142	3.10	1.00	9.27
	060							4.69	32.136	2.30	0.70	8.53
	070							4.68	32.138	2.60	0.90	8.88

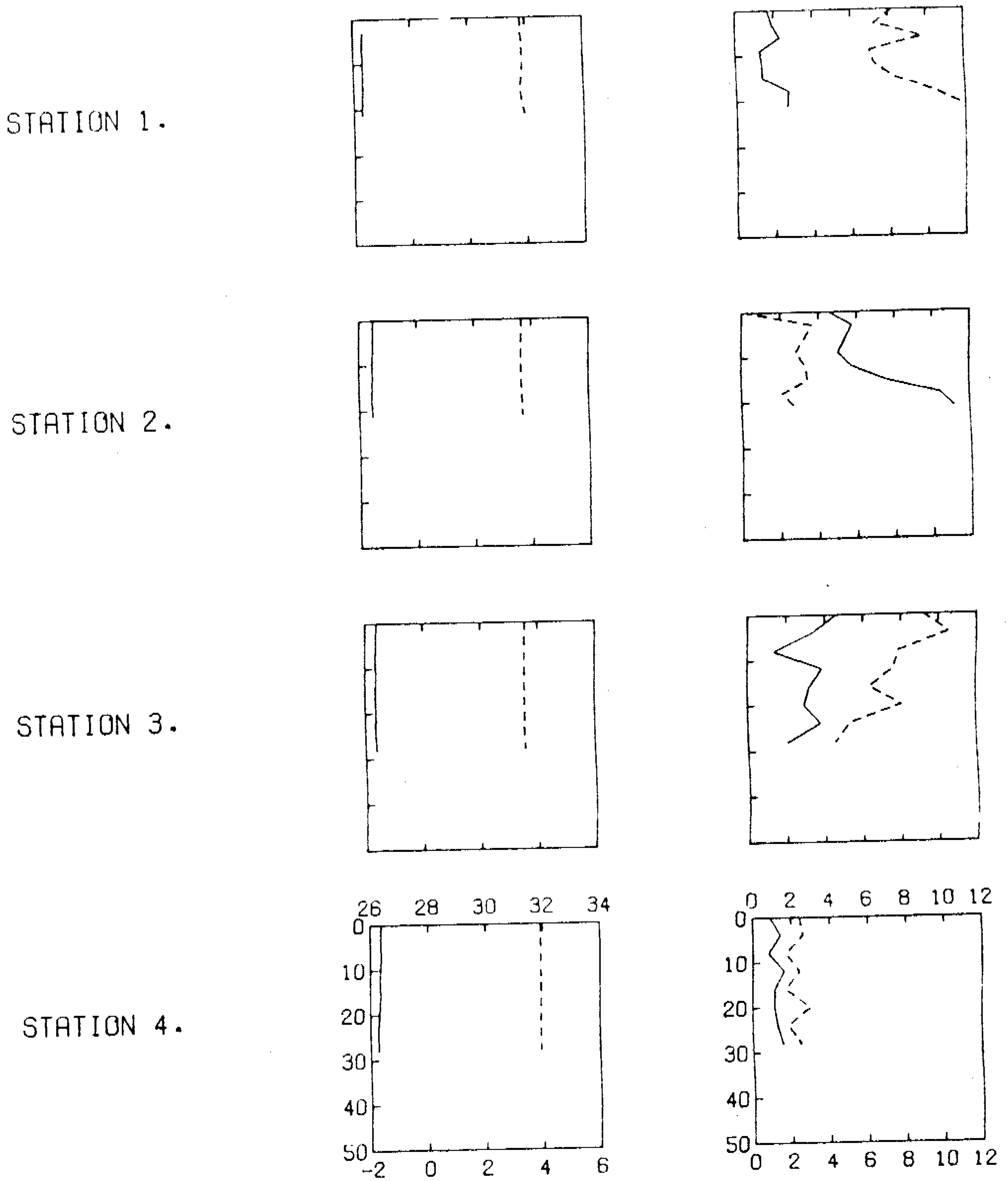

Fig. 2. Depth profiles of temperature-salinity and chlorophyll *a*-primary productivity in the Bering Sea and Shelikof Strait, 17 Apr-6 May 1979. Salinity (°/oo) ---; temperature (°C) ___; primary productivity (mg C m^{-3} hr^{-1}) ---; chlorophyll *a* (mg m^{-3}) ___.

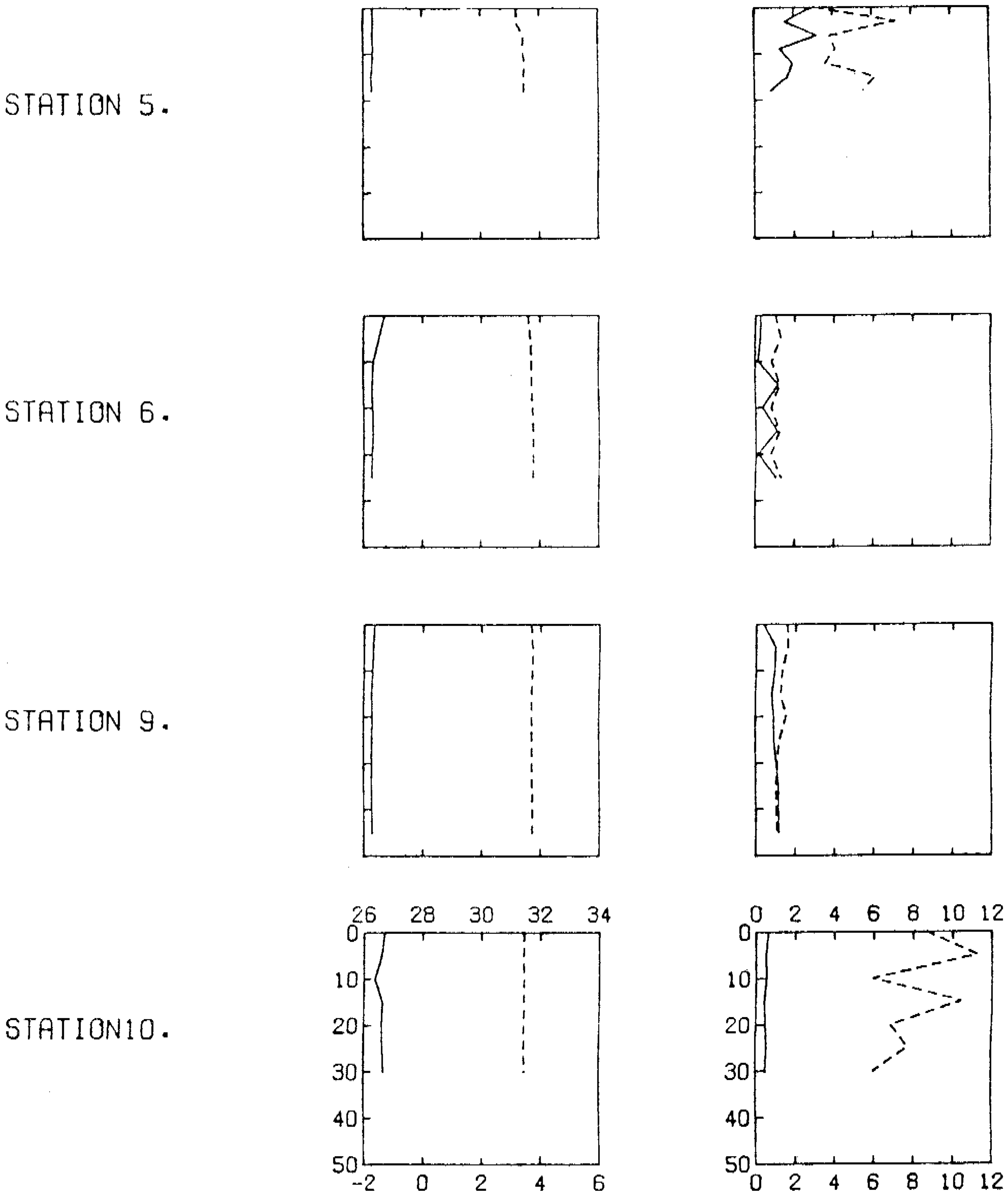

Fig. 2. (continued)

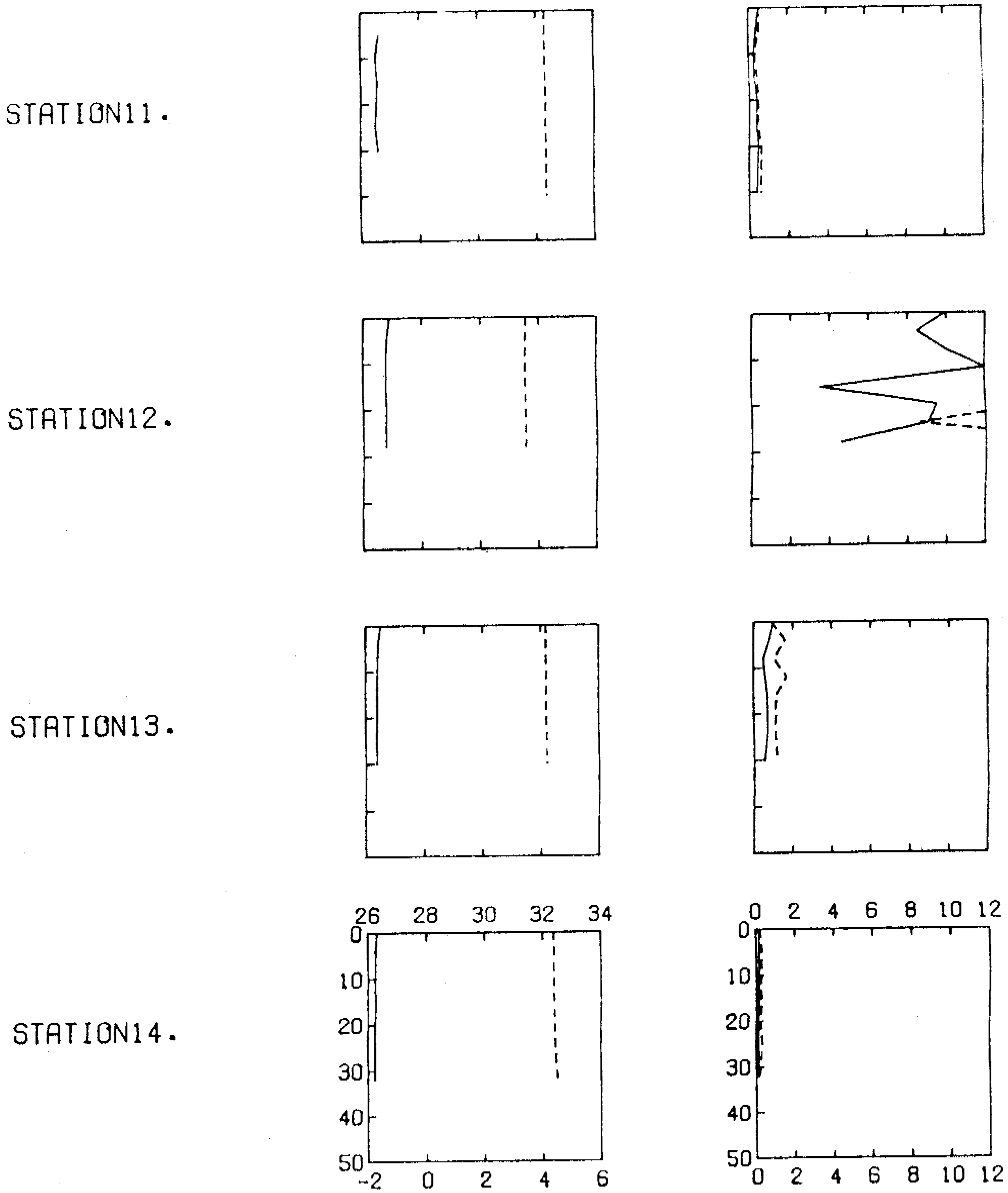

Fig. 2 (continued)

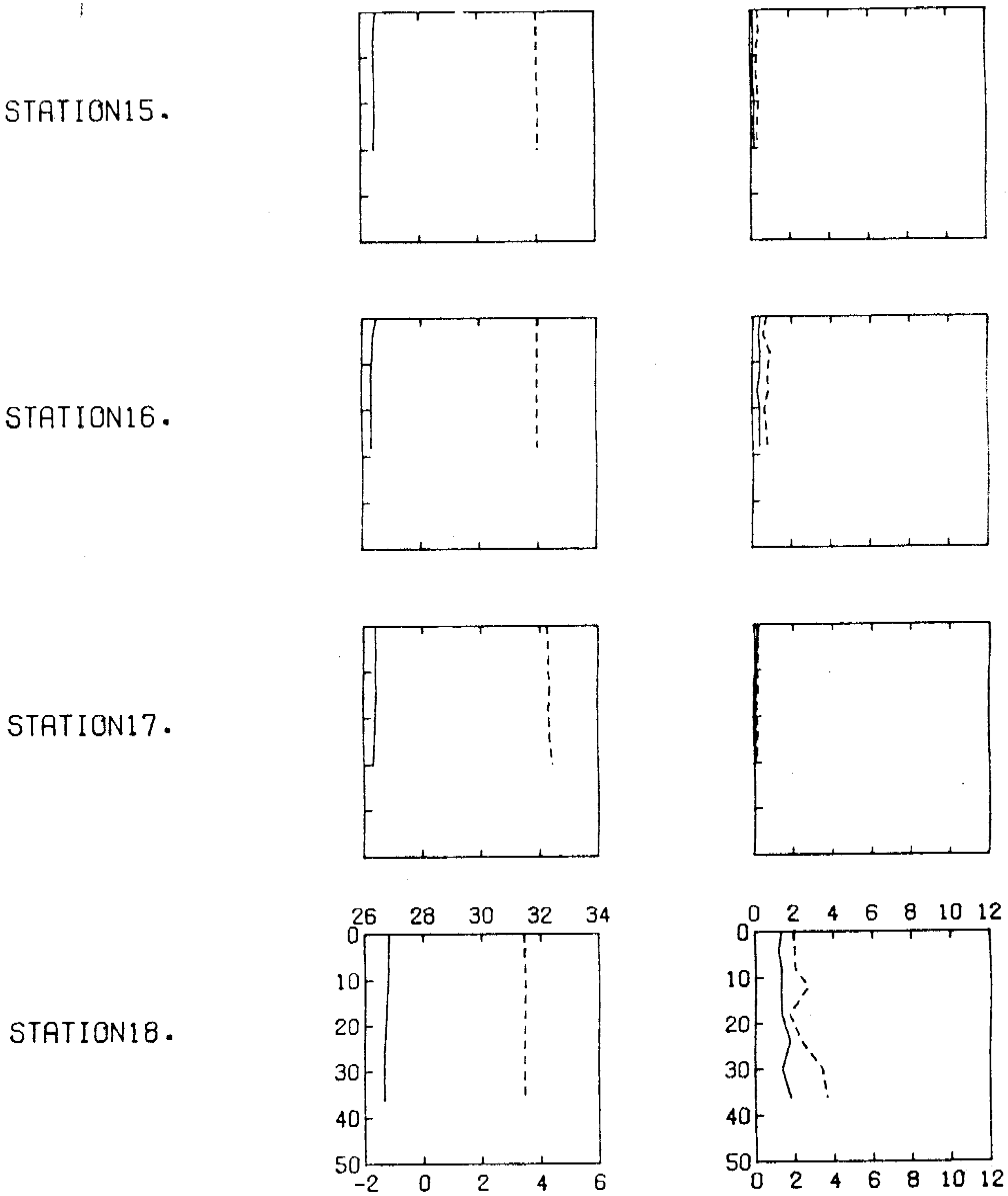

Fig. 2. (continued)

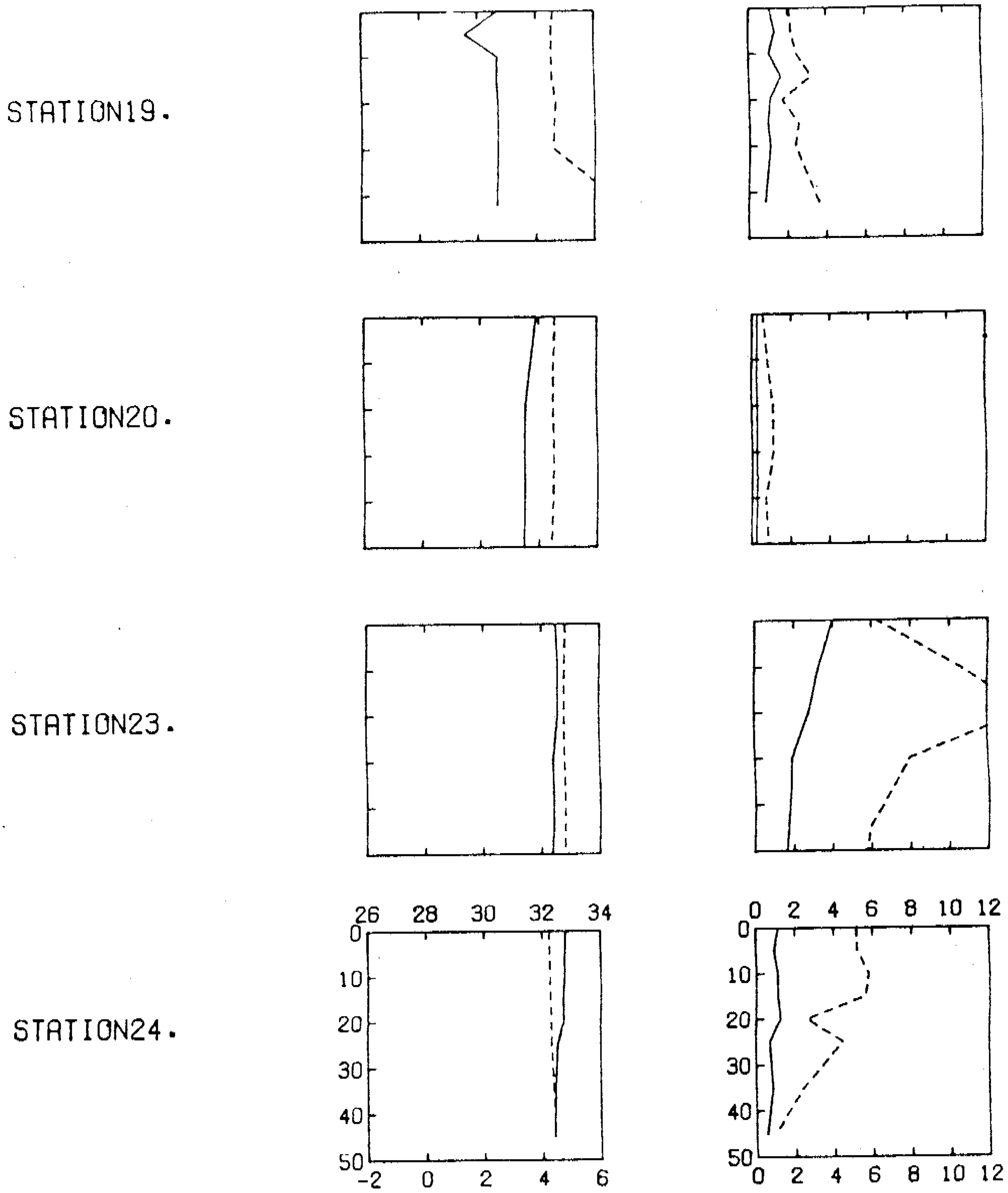

Fig. 2. (continued)

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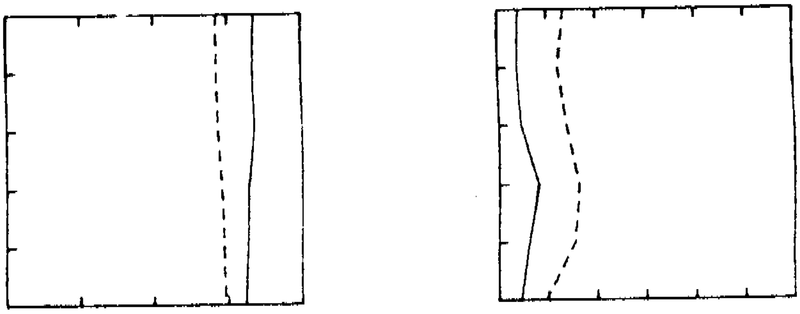

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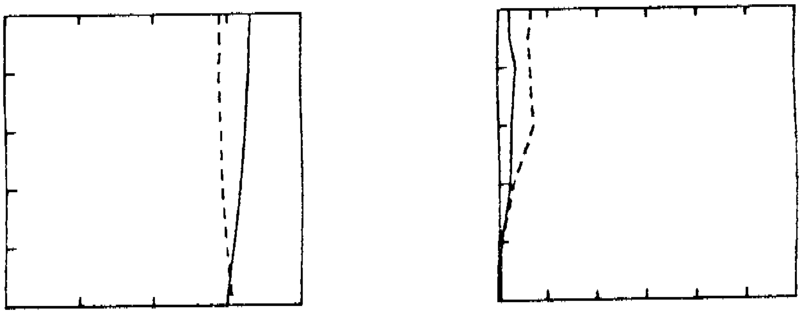

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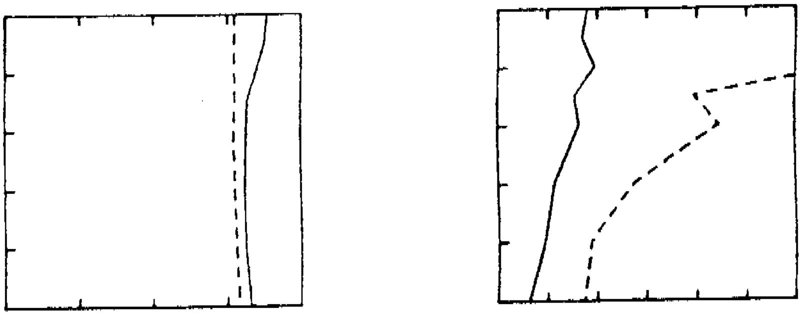

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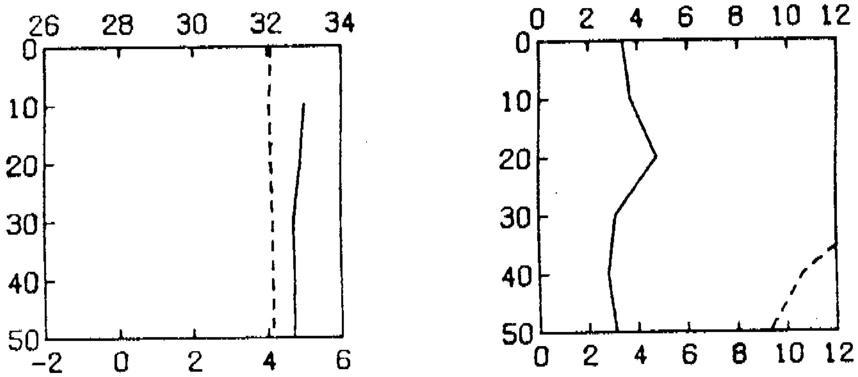

Fig. 2. (continued)

Table 2. Hydrographic data, CGC *Polar Sea* cruise, Bering Sea, 17 Apr - 6 May 1979.

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Secchi Depth (m)	Temp (°C)	S‰	PO_4	SiO_4	NO_3	NO_2	NH_3
											(µg at ℓ)			
01	000	0644	19 Apr	64°15.5'	165°51.9'	22	2	*	31.842	1.04	23.61	2.90	0.04	1.09
	003							-1.67	31.845	0.85	19.63	2.23	0.03	2.53
	006							-1.69	31.887	0.76	14.79	1.76	0.02	2.28
	009							-1.68	31.886	0.79	17.11	2.29	0.03	3.69
	012							-1.68	31.877	0.77	13.72	1.66	0.03	2.28
	015							-1.69	31.800	1.05	24.52	3.08	0.04	0.64
	018							-1.71	31.820	0.86	18.21	2.30	0.02	0.95
	021							-1.72	31.929	1.12	24.52	3.29	0.06	0.66
02	000	1622	19 Apr	63°46.1'	166°03.2'	26	4	-1.51	31.675	0.44	5.66	0.08	0.00	1.04
	003							-1.52	31.652	0.40	5.79	0.09	0.00	0.93
	006							-1.52		Bottle didn't trip				
	009							-1.53	31.653	0.51	6.94	0.12	0.00	0.65
	012							-1.53	31.654	0.44	7.18	0.21	0.00	1.60
	015							-1.54	31.665	0.35	4.97	0.09	0.00	1.07
	018							-1.56	31.684	0.52	7.93	0.09	0.00	0.50
	021							-1.54	31.693	0.43	6.64	0.09	0.00	0.79
03	000	0612	20 Apr	63°32.95'	166°52.78'	31	4	-1.62	31.559	1.15	16.69	5.06	0.22	1.24
	004							-1.63	31.554	1.12	16.70	5.17	0.23	1.23
	008							-1.64	31.550	1.13	16.32	5.17	0.19	1.08
	012							-1.63	31.555	1.13	16.32	5.11	0.19	1.12
	016							-1.64	31.557	1.15	16.71	5.08	0.21	1.07
	020							-1.64	31.559	1.11	16.33	5.11	0.24	1.19
	024							-1.65	31.553	1.11	16.41	5.17	0.20	1.11
	028							-1.64	31.556	1.12	16.41	5.08	0.19	0.99

* Where no temperature is present, both thermometers on the bottle malfunctioned.

Table 2. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Secchi Depth (m)	Temp (°C)	S°/oo	PO$_4$	SiO$_4$ (µg at ℓ)	NO$_3$	NO$_2$	NH$_3$
04	000	1237	20 Apr	63°56.7'	167°35.9'	32	4	-1.62	31.933	1.50	27.88	9.57	0.14	1.46
	004							-1.64	31.927	1.52	28.36	9.70	0.15	1.59
	008							-1.63	31.928	1.55	28.45	9.73	0.14	1.58
	012							-1.67	31.939	1.56	28.35	9.61	0.13	1.33
	016							-1.65	31.935	1.56	28.54	9.70	0.14	1.49
	020							-1.69	31.938	1.56	28.54	9.77	0.14	1.46
	024							-1.73	31.937	1.49	28.44	9.77	0.14	1.34
	028							-1.73	31.944	1.54	28.53	9.83	0.14	1.44
05	000	0537	21 Apr	64°30.3'	166°23.3'	22	4	-1.67	31.240	1.11	20.80	4.15	0.08	1.21
	003							-1.66	31.225	1.12	20.64	4.15	0.09	1.26
	006							-1.68	31.457	1.14	21.06	4.25	0.09	1.08
	009							-1.66	31.438	1.10	20.23	4.04	0.08	0.99
	012							-1.68	31.490	1.10	20.73	4.35	0.15	1.25
	015							-1.72	31.456	1.12	20.90	4.27	0.08	1.10
	018							-1.71	31.456	1.12	20.32	4.25	0.09	1.21
06	000	0956	22 Apr	66°36.26'	168°25.40'	40	4	-1.29	31.587	1.28	25.85	6.49	0.10	2.03
	005								31.689	1.29	26.22	6.54	0.11	2.32
	010							-1.66	31.715	1.26	26.12	6.57	0.11	2.41
	015							-1.70	31.716	1.07	20.75	5.23	0.07	2.29
	020								31.740	1.00	16.41	4.32	0.06	2.91
	025							-1.69	31.760	1.00	17.47	4.45	0.05	2.39
	030							-1.71	31.763	1.00	16.93	4.28	0.05	2.32
	035							-1.72	31.760	1.33	26.47	6.60	0.06	1.95

Table 2. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Secchi Depth (m)	Temp (°C)	S°/∘∘	PO$_4$	SiO$_4$	NO$_3$	NO$_2$	NH$_3$
											(μg at ℓ)			
09	000	1222	24 Apr	65°36.6'	168°35.6'	55	2	-1.64	31.684	1.49	26.09	8.71	0.14	1.97
	005							-1.69	31.726	1.50	26.55	8.72	0.21	1.90
	010							-1.70	31.723	1.55	26.45	9.24	0.38	2.19
	015							-1.72	31.714	1.54	26.08	8.72	0.12	2.10
	020							-1.70	31.723	1.54	26.35	9.01	0.11	2.26
	025							-1.71	31.723	1.46	24.06	8.03	0.09	2.25
	035							-1.73	31.722	1.54	25.97	8.75	0.10	2.16
	045							-1.72	31.719	1.55	26.43	8.73	0.10	2.07
10	000	1222	25 Apr	65°29.89'	168°06.11'	40	3	-1.30	31.437	0.89	14.58	0.82	0.05	0.98
	005							-1.39	31.432	0.91	14.93	0.90	0.05	0.70
	010							-1.63	31.442	0.90	15.44	1.38	0.18	1.25
	015							-1.37	31.444	0.91	14.78	1.06	0.06	0.70
	020							-1.39	31.443	0.90	15.44	1.30	0.05	0.84
	025								31.448	0.63	9.43	0.69	0.11	1.16
	030							-1.33	31.458	0.93	15.95	1.06	0.02	0.70
11	000	0625	26 Apr	65°01.8'	168°15.7'	44	3		32.312	1.49	30.00	10.90	0.17	2.10
	005							-1.38	32.308	1.86	38.08	13.52	0.20	1.82
	010							-1.49	32.308	1.48	28.44	9.93	0.15	2.38
	015							-1.44	32.311	1.54	31.35	11.25	0.13	2.38
	020								32.306	1.57	31.32	11.07	0.12	2.16
	025							-1.51	32.323	1.32	26.41	9.46	0.10	2.11
	030							-1.42	32.345	1.38	24.80	8.99	0.12	2.49
	040								32.359	1.39	28.17	10.08	0.11	2.41

Table 2. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Secchi Depth (m)	Temp (°C)	S°/₀₀	PO$_4$	SiO$_4$	NO$_3$	NO$_2$	NH$_3$
											(µg at ℓ)			
12	000	0634	27 Apr	64°29.64'	167°40.10'	36	2	-1.11	31.568	1.02	12.68	2.37	0.17	0.47
	004							-1.18	31.569	1.05	13.15	2.21	0.18	0.40
	008							-1.21	31.572	1.01	12.95	2.25	0.14	0.51
	012							-1.21	31.569	1.04	13.22	2.25	0.19	0.31
	016							-1.22	31.573	1.03	13.22	2.18	0.13	0.33
	020							-1.21	31.571	1.05	12.95	2.35	0.11	0.33
	024							-1.23	31.568	1.02	13.50	1.99	0.12	0.20
	028							-1.23	31.563	1.02	12.34	1.91	0.10	0.34
13	000	1337	27 Apr	64°37.82'	168°25.67'	35	2	-1.49	32.191	1.90	37.39	14.09	0.23	1.04
	004							-1.57	32.189	1.94	38.45	14.09	0.17	1.08
	008							-1.58	32.191	1.92	38.81	14.31	0.16	0.94
	012							-1.60	32.195	1.92	38.93	14.22	0.20	0.98
	016							-1.60	32.192	1.60	37.04	13.50	0.19	1.66
	020							-1.61	32.193	1.60	38.81	14.53	0.18	1.40
	024							-1.63	32.196	1.90	38.69	14.00	0.20	0.94
	030							-1.63	32.200	1.83	37.98	13.79	0.23	0.94
14	000	0602	28 Apr	64°12.66'	168°57.44'	36	4	-1.69	32.371	2.05	43.88	17.25	0.20	0.80
	004							-1.73	32.376	2.06	43.83	17.25	0.16	0.71
	008							-1.75	32.368	2.09	44.97	17.25	0.11	1.08
	012							-1.76	32.368	2.06	45.24	17.25	0.12	1.03
	016							-1.74	32.377	2.05	45.38	17.36	0.12	0.88
	020							-1.77	32.406	2.00	45.94	17.30	0.12	1.01
	026							-1.77	32.433	2.10	46.22	17.36	0.12	1.15
	032							-1.78	32.499	2.10	47.36	17.70	0.14	1.07

Table 2. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Secchi Depth (m)	Temp (°C)	S°/₀₀	PO$_4$	SiO$_4$	NO$_3$	NO$_2$	NH$_3$
											(µg at ℓ)			
15	000	0611	29 Apr	63°50.91'	170°26.03'	34	3	-1.48	32.029	2.04	44.01	16.76	0.17	0.87
	004							-1.53	32.032	2.05	45.24	16.98	0.14	0.78
	008							-1.54	32.028	2.04	45.24	16.92	0.13	0.80
	012							-1.54	32.031	2.05	44.97	17.03	0.20	0.82
	016							-1.53	32.025	2.05	44.69	16.71	0.12	0.72
	020							-1.54	32.035	2.04	45.24	17.03	0.11	0.86
	024							-1.54	32.037	2.04	45.24	17.08	0.12	0.82
	030							-1.56	32.034	2.05	44.56	16.92	0.13	1.26
16	000	1307	29 Apr	64°00.6'	171°25.5"	32	4	-1.52	31.978	1.95	42.63	16.28	0.11	0.43
	004							-1.64	31.980	1.99	43.43	16.48	0.12	0.45
	008							-1.66	31.979	2.03	44.10	16.74	0.13	0.63
	012							-1.69	31.980	2.00	43.31	16.43	0.10	0.40
	016							-1.68	31.979	2.00	43.32	16.42	0.10	0.34
	020							-1.68	31.976	1.99	43.46	16.47	0.09	0.40
	024							-1.69	31.966	1.99	44.01	16.57	0.10	0.34
	028							-1.70	31.980	2.00	44.15	16.68	0.10	0.53
17	000	0600	30 Apr	63°44.83'	169°12.32'	36	5	-1.58	32.261	2.08	44.71	17.26	0.20	0.74
	002							-1.61	32.282	2.09	46.24	17.26	0.15	0.75
	006							-1.58	32.298	2.09	46.82	17.42	0.14	0.79
	010							-1.59	32.299	2.10	46.68	17.59	0.18	0.73
	014							-1.56	32.348	2.09	46.84	17.31	0.14	0.71
	018								32.316	2.08	46.99	17.53	0.14	0.85
	024							-1.63	32.346	2.12	47.72	17.81	0.15	0.91
	030							-1.68	32.434	2.13	48.61	18.22	0.16	0.94

Table 2. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Secchi Depth (m)	Temp (°C)	S°/∘∘	PO_4	SiO_4	NO_3	NO_2	NH_3
										(µg at ℓ)				
18	000	1343	30 Apr	63°17.83'	168°20.07'	42	4	-1.16	31.449	1.41	25.26	7.86	0.13	2.19
	004							-1.19	31.450	1.66	29.35	9.88	0.13	1.78
	008							-1.20	31.456	1.53	26.57	9.60	0.11	1.51
	012							-1.23	31.455	1.53	25.17	9.47	0.17	1.52
	018							-1.27	31.457	1.48	25.95	9.44	0.13	1.57
	024							-1.32	31.461	1.48	28.10	9.98	0.11	1.39
	030							-1.34	31.459	1.55	28.13	9.95	0.10	1.32
	036							-1.33	31.462	1.44	24.80	8.92	0.10	1.63
19	000	0552	2 May	57°06.89'	170°00.7'	46	3-4	2.68	32.583	1.77	48.02	22.01	0.24	0.80
	005							1.56	32.542	1.77	48.91	22.00	0.21	0.78
	010							2.67	32.540	1.78	49.22	22.24	0.21	0.86
	015							2.64	32.538	1.77	48.94	22.08	0.21	0.89
	020							2.67	32.664	1.77	48.95	22.32	0.21	0.96
	025							2.67	32.585	1.80	49.71	22.32	0.21	0.97
	030							2.66	32.583	1.80	50.02	22.49	0.23	1.07
	042							2.66	34.977	1.79	49.88	22.40	0.21	1.03
20	000	1255	3 May	56°27.50	169°25.06'	93	12	3.91	32.546	1.75	48.20	22.58	0.24	0.68
	010								32.514	1.79	50.00	22.74	0.24	0.73
	020							3.55	32.504	1.82	50.31	23.17	0.23	0.82
	030							3.49	32.485	1.80	50.94	23.16	0.24	0.69
	040							3.50	32.468	1.79	51.26	23.51	0.24	0.77
	050								32.444	1.79	51.27	23.60	0.25	0.83
	060							3.48	32.410	1.82	51.91	23.51	0.24	0.82
	080							3.48	32.379	1.78	49.92	22.74	0.24	0.88

Table 2. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Secchi Depth (m)	Temp (°C)	S°/₀₀	PO$_4$	SiO$_4$	NO$_3$	NO$_2$	NH$_3$
											(µg at ℓ)			
23	000	0657	3 May	54°34.07'	165°58.64'	437	∿ 7	4.49	32.808	0.87	14.75	9.04	0.14	1.00
	010							4.57	32.788	1.29	28.22	16.54	0.29	0.47
	020							4.57	32.785	1.29	28.15	16.76	0.27	0.54
	030							4.40	32.785	1.49	32.50	18.41	0.24	1.06
	045							4.40	32.800	1.51	34.62	18.77	0.25	1.07
	060							4.35	32.808	1.54	35.09	19.35	0.25	1.13
	075							4.32	32.829	1.52	35.46	19.35	0.25	1.13
	100							4.09	32.977	1.78	43.94	23.68	0.29	1.03
24	000	1423	3 May	54°58.7'	164°36.2'	55	∿ 7	4.81	32.240	1.27	32.54	14.32	0.23	0.79
	005							4.76	32.235	1.32	34.87	14.63	0.23	0.86
	010							4.74	32.239	1.30	35.12	14.73	0.21	0.87
	015							4.70	32.252	1.33	35.83	14.96	0.21	0.87
	020							4.72	32.303	1.38	36.90	16.49	0.22	1.11
	025							4.52	32.318	1.38	37.27	17.03	0.22	1.17
	035							4.44	32.380	1.47	37.89	17.87	0.23	1.55
	045							4.41	32.424	1.50	38.39	18.35	0.21	1.51
25	000	0658	4 May	54°10.36'	163°47.78'	86	8	4.72	31.704	0.78	26.29	5.32	0.21	1.37
	010							4.69	31.709	0.78	27.18	5.27	0.17	1.32
	020							4.70	31.718	0.80	27.20	5.29	0.15	1.66
	030							4.54	31.812	0.91	28.19	6.71	0.16	1.66
	040							4.53	31.875	1.06	28.81	10.47	0.16	2.11
	050							4.47	31.923	1.12	30.04	10.64	0.15	2.08
	060							4.21	31.974	1.29	32.35	13.25	0.19	2.13
	075							4.04	32.170	1.50	36.36	17.45	0.26	2.61

Table 2. (continued)

Sta	Depth (m)	Time (Local)	Date	Latitude (N)	Longitude (W)	Sonic Depth (m)	Secchi Depth (m)	Temp (°C)	S°/oo	PO$_4$	SiO$_4$	NO$_3$	NO$_2$	NH$_3$
											(μg at ℓ)			
26	000	1605	4 May	54°14.7'	161°52.5'	71	> 12	4.62	31.789	0.65	14.33	3.78	0.08	2.89
	005							4.60	31.798	1.04	25.85	6.61	0.12	2.21
	010							4.59	31.794	1.03	25.95	6.71	0.10	2.26
	020							4.47	31.805	1.03	25.97	6.59	0.10	2.22
	030								31.822	1.03	25.89	6.71	0.11	2.20
	040							4.15	31.953	1.20	29.75	10.99	0.14	2.16
	050							3.97	32.138	1.42	34.81	15.78	0.19	0.95
	060							4.03	32.250	1.45	36.17	16.65	0.20	0.84
27	000	1506	5 May	56°21.44'	155°30.78'	60	> 10	5.07	32.194	0.92	21.53	10.27	0.17	0.43
	005							5.00	32.192	0.93	22.39	10.44	0.23	0.50
	010							4.77	32.192	0.94	22.58	10.44	0.15	0.67
	015							4.55	32.205	0.98	22.76	11.33	0.15	1.03
	020							4.53	32.194	0.93	22.00	11.16	0.14	0.82
	030							4.47	32.199	1.05	23.68	12.01	0.14	1.63
	040							4.49	32.230	1.13	25.38	12.47	0.15	1.97
	050							4.64	32.323	1.21	27.33	13.28	0.15	2.39
28	000	0659	6 May	59°07.07'	152°54.38'	81	> 10		32.099	0.82	19.80	9.24	0.16	0.44
	010							4.98	32.044	0.89	20.62	9.90	0.19	0.66
	020							4.89	32.100	0.96	21.87	10.83	0.15	0.76
	030							4.71	32.144	1.07	23.95	12.32	0.16	1.16
	040							4.72		1.08	24.48	12.52	0.15	1.21
	050							4.70	32.142	1.12	24.93	12.72	0.15	1.30
	060							4.69	32.136	1.12	24.93	12.73	0.15	1.28
	070							4.68	32.138	1.13	24.38	12.90	0.15	1.29

Table 3. Abundance (number per 1000 m^3) of zooplankton taxa found in net hauls from the Bering and Chukchi seas, north Pacific Ocean, and Shelikof Strait, CGC *Polar Sea*, 17 Apr - 6 May 1979. Samples were collected with bongo nets, mesh size 505 μm, except where indicated. Where no number is present, no animals were found.

	Station Number	1*	2	3	4	5*	6*	7*	8*
Taxon	Depth of Tow (m)	19	17	22	30	21	35	51	55
Annelida									
Polychaeta									
Unidentified spp.					34	2056	1039	312	
Unidentified trochophores		7416					844		
Spionidae - immature spp.		16986					519		124
Arthropoda									
Crustacea									
Unidentified eggs		x					x		x
Ostracoda									
Halocyprididae									
Conchoecia spp.									
Cytheridae - unidentified spp.		837							
Copepoda									
Unidentified nauplii									
Calanoida									
Unidentified adult °		104300	282	250	2547	332482	292964	328550	148091
Unidentified adult o					85		4156	15713	6611
Unidentified juveniles		34448			17	238971	124666	305694	149413
Harpacticoida - unidentified spp.									
Cirripedia									
Unidentified cypris larvae									
Unidentified nauplii		2392					779		
Malacostraca									
Mysidacea									
Unidentified adult sp.									
Unidentified immature spp.									

* samples taken with a 0.75 m ring net, mesh size 308 μm

x present in sample, but not counted

Table 3 (continued)

Taxon	Station Number Depth of Tow (m)	1* 19	2 17	3 22	4 30	5* 21	6* 35	7* 51	8* 55
Mysidae									
Acanthomysis nephrophthalma									
Acanthomysis pseudomacropsis									41
Neomysis rayii									
Pseudomma roseum									
Cumacea									
Lampropidae									
Lamprops fuscata									
Leuconidae									
Leucon nasicoides									
Leucon kobjakovae		239						45	
Leucon spp.		120							
Diastylidae									
Diastylis bidentata									
Diastylis paraspinulosa									
Pseudocumidae									
Petalosarsia declivis									
Campylaspidae									
Campylaspis crispa		120							
Isopoda									
Epicaridea microniscus stage							65		
Munnidae - unidentified sp.		239							
Amphipoda									
Unidentified immature spp.									
Hyperiidae									
Hyperia galba									
Parathemisto pacifica				23	68	108		45	
Phrosinidae									
Primno macropa									
Scinidae									
Scina rattrayi									

Table 3. (continued)

Taxon	Station Number	1*	2	3	4	5*	6*	7*	8*
	Depth of Tow (m)	19	17	22	30	21	35	51	55
Eusiridae									
Rhachotropis oculata									
Rhachotropis inflata									41
Isaeidae									
Protomedeia fasciata		837	43						
Ischyroceridae									
Jassa pulchella									
Lysianassidae									
Anonyx lilljeborgi									
Cyphocaris challengeri									
Oedicerotidae									
Unidentified immature sp.									41
Acanthostepheia incarinata									
Monoculodes packardi								45	
Monoculodes zernovi					17				
Monoculodes sp. #1									
Westwoodilla coecula				23		433			
Westwoodilla megalops									
Stenothoidae									
Unidentified immature spp.									41
Metopa alderi									
Synopiidae									
Syrrhoe crenulata									
Euphausiacea									
Euphausiidae									
Unidentified immature spp.									
Euphausia pacifica									
Thysanoëssa inermis				129					
Thysanoëssa longipes									
Thysanoëssa raschii				902			195		
Thysanoëssa spinifera									

Table 3. (continued)

	Station Number	1*	2	3	4	5*	6*	7*	8*
Taxon	Depth of Tow (m)	19	17	22	30	21	35	51	55
Decapoda									
Unidentified shrimp larvae									
Hippolytidae - unidentified spp.									
Pandalidae									
Pandalus borealis I									
Pandalus borealis II									
Pandalus borealis III									
Pandalus montagui tridens I									
Pandalus montagui tridens II									
Pandalus stenolepis I									
Pandalus stenolepis II									
Paguridae									
Unidentified zoea			43	99	51		65		
Lithodidae									
Unidentified zoea									
Paralithodes camtschatica I zoea									
Paralithodes camtschatica II zoea									
Paralithodes camtschatica III zoea									
Paralithodes platypus I zoea									
Majidae									
Unidentified zoea									
Oregoniinae spp. zoea									
Chionoecetes opilio I zoea									
Chionoecetes bairdi I zoea									
Chionoecetes bairdi megalopa									
Atelecyclidae									
Erimacrus isenbeckii I zoea									
Erimacrus isenbeckii II zoea									
Cancridae									
Cancer spp. I zoea									
Pinnotheridae - unidentified zoea									

Table 3. (continued)

Taxon	Station Number Depth of Tow (m)	1* 19	2 17	3 22	4 30	5* 21	6* 35	7* 51	8* 55
Chaetognatha									
Sagitta elegans		16268	7288	3957	4769	5087	16752	7633	11900
Eukrohnia hamata									
Cnidaria									
Hydrozoa									
Bougainvilliidae									
Perigonimus yoldia-arcticae									
Perigonimus spp.									
Rathkea octopunctata						108			
Bougainvillia superciliaris								45	
Tubulariidae									
Corymorpha flammea									
Tubularia prolifer									
Plotocnide borealis									
Corynidae									
Unidentified spp.									
Coryne principes									
Campanulinidae									
Aequorea forskalea									
Trachynemidae									
Aglantha digitale		359	694	197	376	866	519	446	578
Aeginidae									
Aeginopsis laurentii									
Diphyidae									
Dimophyes arctica									
Scyphozoa - unidentified ephyra									
Ctenophora									
Beroe cucumis		120	43		137	108	130		165
Beroe sp.			22						

Table 3. (continued)

	Station Number	1*	2	3	4	5*	6*	7*	8*
Taxon	Depth of Tow (m)	19	17	22	30	21	35	51	55
Echinodermata									
Ophiuroidea									
Unidentified ophiopluteus larvae		120					195		
Echinoidea									
Unidentified echinopluteus larvae									
Holothuroidea - unidentified sp.			22						
Mollusca									
Gastropoda									
Unidentified veliger larvae		239				108	195		83
Thecosomata									
Limacina helicina						216		89	41
Gymnosomata									
Clione limacina		239					65		207
Bivalvia - unidentified immature spp.		239	43	152			1299	2990	1611
Cephalopoda									
Coleoidea - unidentified immature sp.									
Theuthidida - unidentified sp.									
Octopodida - unidentified sp.									
Nematoda - unidentified spp.		239							41
Protozoa									
Actinopodea									
Radiolaria - unidentified sp.		x							x
Rhizopodea									
Foraminiferida - unidentified sp.							x		x

Table 3. (continued)

	Station Number	1*	2	3	4	5*	6*	7*	8*
Taxon	Depth of Tow (m)	19	17	22	30	21	35	51	55
Urochordata									
Larvacea - unidentified spp.									
Oikopleuridae									
Oikopleura spp.									
Fritillariidae									
Fritillaria borealis									
Chordata									
Unidentified fish eggs *ca.* 1 mm									
Unidentified fish eggs *ca.* 2 mm			43	8	34		130	89	83
Gnathostomata I									
Osmeridae									
Mallotus villosus larvae									
Myctophidae									
Stenobrachius leucopsarus juvenile									
Gadidae									
Unidentified larvae					51	108	195	89	83
Gadus macrocephalus larvae									
Theragra chalcogramma larvae									
Gnathostomata II - unidentified larvae									
Scorpeanidae									
Sebastes sp. larvae									
Hexagrammidae									
Hexagrammos stelleri larvae									
Cottidae									
Unidentified sp. larvae									
Artedius spp. larvae									
Myoxocephalus sp. larvae									
Triglops sp. larvae									
Agonidae - unidentified larvae									
Cyclopteridae - unidentified larvae			22						

Table 3. (continued)

	Station Number	1*	2	3	4	5*	6*	7*	8*
Taxon	Depth of Tow (m)	19	17	22	30	21	35	51	55
Bathymasteridae - unidentified larvae									
Stichaeidae									
Unidentified larvae									
Lumpenus sp. larvae									
Pholidae - unidentified larvae									
Ammodytidae									
Ammodytes hexapterus larvae									
Pleuronectidae									
Atheresthes sp. larvae									
Hippoglossoides sp. eggs									
Lepidopsetta bilineata larvae									
Reinhardtius hippoglossoides larvae									
Unidentified animals									
Unidentified sp. # 1		120							
Unidentified sp. # 2									

Table 3. (continued)

Taxon	Station Number Depth of Tow (m)	9^{*} 68	10^{*} 33	11^{*} 42	12 25	13 35	14 29	15 27	16 29
Annelida									
Polychaeta									
Unidentified spp.		368	4759		14		17		355
Unidentified trochophores		234	22069						
Spionidae - immature spp.		1605		162					
Arthropoda									
Crustacea									
Unidentified eggs		x	x	x	x	x		x	x
Ostracoda									
Halocyprididae									
Conchoecia spp.									
Cytheridae - unidentified spp.									
Copepoda									
Unidentified nauplii			1103						
Calanoida									
Unidentified adult ^{o}		363827	176552	243892	240	2532	4608	5947	10022
Unidentified adult o		17121	3310	17297			351	285	466
Unidentified juveniles		346706	253793	115892	1061	73	1185	20	89
Harpacticoida - unidentified spp.			1103						
Cirripedia									
Unidentified cypris larvae									
Unidentified nauplii		568	26483	541					
Malacostraca									
Mysidacea									
Unidentified adult sp.									
Unidentified immature spp.			69				17		

Table 3. (continued)

Taxon	Station Number Depth of Tow (m)	9* 68	10* 33	11* 42	12 25	13 35	14 29	15 27	16 29
Mysidae									
Acanthomysis nephrophthalma									
Acanthomysis pseudomacropsis					28				
Neomysis rayii									
Pseudomma roseum									
Cumacea									
Lampropidae									
Lamprops fuscata									
Leuconidae									
Leucon nasicoides									
Leucon kobjakovae									
Leucon spp.		67							
Diastylidae									
Diastylis bidentata		301			14				
Diastylis paraspinulosa									
Pseudocumidae									
Petalosarsia declivis									
Campylaspidae									
Campylaspis crispa									
Isopoda									
Epicaridea microniscus stage								63	
Munnidae - unidentified sp.									
Amphipoda									
Unidentified immature spp.					71				
Hyperiidae									
Hyperia galba								20	
Parathemisto pacifica		100	69	162	14	147	534	448	2439
Phrosinidae									
Primno macropa									
Scinidae									
Scina rattrayi									

Table 3. (continued)

	Station Number	9*	10*	11*	12	13	14	15	16
Taxon	Depth of Tow (m)	68	33	42	25	35	29	27	29
Eusiridae									
Rhachotropis oculata									
Rhachotropis inflata									
Isaeidae									
Protomedeia fasciata									
Ischyroceridae									
Jassa pulchella							17		
Lysianassidae									
Anonyx lilljeborgi									
Cyphocaris challengeri									
Oedicerotidae									
Unidentified immature sp.									
Acanthostepheia incarinata						18	33	20	
Monoculodes packardi									
Monoculodes zernovi		33				18			
Monoculodes sp. #1									
Westwoodilla coecula					509	18			
Westwoodilla megalops									
Stenothoidae									
Unidentified immature spp.		67				18		1344	
Metopa alderi					14			265	
Synopiidae									
Syrrhoe crenulata					14				
Euphausiacea									
Euphausiidae									
Unidentified immature spp.									
Euphausia pacifica									
Thysanoëssa inermis					156		33		89
Thysanoëssa longipes									
Thysanoëssa raschii		702			226				
Thysanoëssa spinifera									

Table 3. (continued)

	Station Number	9*	10*	11*	12	13	14	15	16
Taxon	Depth of Tow (m)	68	33	42	25	35	29	27	29
Decapoda									
Unidentified shrimp larvae									
Hippolytidae - unidentified spp.			69			18	17	265	89
Pandalidae									
Pandalus borealis I									
Pandalus borealis II									
Pandalus borealis II									
Pandalus montagui tridens I									
Pandalus montagui tridens II									
Pandalus stenolepis I									
Pandalus stenolepis II									
Paguridae									
Unidentified zoea		167		54	523	92	17	41	22
Lithodidae									
Unidentified zoea			69						
Paralithodes camtschatica I zoea									
Paralithodes camtschatica II zoea									
Paralithodes camtschatica III zoea									
Paralithodes platypus I zoea									
Majidae									
Unidentified zoea									
Oregoniinae spp. zoea									
Chionoecetes opilio I zoea									
Chionoecetes bairdi I zoea									
Chionoecetes bairdi megalopa									
Atelecyclidae									
Erimacrus isenbeckii I zoea									
Erimacrus isenbeckii II zoea									
Cancridae									
Cancer spp. I zoea									
Pinnotheridae - unidentified zoea									

Table 3. (continued)

Taxon	Station Number	9*	10*	11*	12	13	14	15	16
	Depth of Tow (m)	68	33	42	25	35	29	27	29
Chaetognatha									
Sagitta elegans		6655	5034	1676	31231	1284	12521	8676	13636
Eukrohnia hamata									
Cnidaria									
Hydrozoa									
Bougainvilliidae									
Perigonimus yoldia-arcticae					28				
Perigonimus spp.								20	
Rathkea octopunctata		33							
Bougainvillia superciliaris			138		42				
Tubulariidae									
Corymorpha flammea			69						
Tubularia prolifer									
Plotocnide borealis									
Corynidae									
Unidentified spp.									
Coryne principes									
Campanulinidae									
Aequorea forskalea									
Trachynemidae									
Aglantha digitale		67		54	184	165	1770		1530
Aeginidae									
Aeginopsis laurentii									
Diphyidae									
Dimophes arctica									
Scyphozoa - unidentified ephyra									
Ctenophora									
Beroë cucumis		100	69					61	22
Beroë sp.						18			

Table 3. (continued)

	Station Number	9*	10*	11*	12	13	14	15	16
Taxon	Depth of Tow (m)	68	33	42	25	35	29	27	29
Echinodermata									
Ophiuroidea									
Unidentified ophiopluteus larvae		33							
Echinoidea									
Unidentified echinopluteus larvae									
Holothuroidea - unidentified sp.									
Mollusca									
Gastropoda									
Unidentified veliger larvae		33		54					
Thecosomata									
Limacina helicina									
Gymnostomata									
Clione limacina		67		162		18	17		133
Bivalvia - unidentified immature spp.		3311	828	270		113			
Cephalopoda									
Coleoidea - unidentified immature sp.									
Theuthidida - unidentified sp.									
Octopodida - unidentified sp.									
Nematoda - unidentified spp.		33				18			
Protozoa									
Actinopodea									
Radiolaria - unidentified sp.		x							
Rhizopodea									
Formaniniferida - unidentified sp.			x						

Table 3. (continued)

Taxon	Station Number Depth of Tow (m)	9* 68	10* 33	11* 42	12 25	13 35	14 29	15 27	16 29
Urochordata									
Larvacea - unidentified spp.									
Oikopleuridae									
Oikopleura spp.									
Fritillariidae									
Fritillaria borealis									
Chordata									
Unidentified fish eggs *ca.* 1 mm		100							
Unidentified fish eggs *ca.* 2 mm		33		162		18			22
Gnathostomata I									
Osmeridae									
Mallotus villosus larvae					42				
Myctophidae									
Stenograchius leucopsarus juvenile									
Gadidae									
Unidentified larvae		468	276	270	14	275			44
Gadus macrocephalus larvae									
Theragra chalcogramma larvae									
Gnathostomata II - unidentified larvae									
Scorpeanidae									
Sebastes sp. larvae									
Hexagrammidae									
Hexagrammos stelleri larvae									
Cottidae									
Unidentified sp. larvae									
Artedius spp. larvae									
Myoxocephalus sp. larvae									
Triglops sp. larvae									
Agonidae - unidentified larvae									
Cyclopteridae - unidentified larvae		33		54	57	37			

Table 3. (continued)

Taxon	Station Number	9*	10*	11*	12	13	14	15	16
	Depth of Tow (m)	68	33	42	25	35	29	27	29
Bathymasteridae - unidentified larvae									
Stichaeidae									
Unidentified larvae									
Lumpenus sp. larvae					71				
Pholidae - unidentified larvae									
Ammodytidae									
Ammodytes hexapterus larvae								61	
Pleuronectidae									
Atheresthes sp. larvae									
Hippoglossoides sp. eggs									
Lepidopsetta bilineata larvae									
Reinhardtius hippoglossoides larvae									
Unidentified animals									
Unidentified sp. # 1									
Unidentified sp. # 2									

Table 3. (continued)

Taxon	Station Number Depth of Tow (m)	17* 36	18 41	19 30	20 49	21 200	22 130	23 200	24 46
Annelida									
Polychaeta									
Unidentified spp.				10		64	13	95	63
Unidentified trochophores								21	
Spionidae - immature spp.							4	101	
Arthropoda									
Crustacea									
Unidentified eggs		x	x	x	x	x	x	x	x
Ostracoda									
Halocyprididae									
Conchoecia spp.					5	1230		707	47
Cytheridae - unidentified spp.									
Copepoda									
Unidentified nauplii							2294		
Calanoida									
Unidentified adult ^{o}		141770	2204	26199	587755	9518	153681	54743	51473
Unidentified adult o		12152		1219	138449	1298	13762	4562	20186
Unidentified juveniles		76961	57	87432	902531	184737	444989	88957	56772
Harpacticoida - unidentified spp.									
Cirripedia									
Unidentified cypris larvae						78	13	53	1214
Unidentified nauplii					959	210	1738	588	4132
Malacostraca									
Mysidacea									
Unidentified adult sp.						3			
Unidentified immature spp.			46				188		

Table 3. (continued)

	Station Number	17*	18	19	20	21	22	23	24
Taxon	Depth of Tow (m)	36	41	30	49	200	130	200	46
Mysidacea									
Acanthomysis nephrophthalma							49		
Acanthomysis pseudomacropsis									
Neomysis rayii			11						
Pseudomma roseum			69						
Cumacea									
Lampropidae									
Lamprops fuscata				29					
Leuconidae									
Leucon nasicoides							4		
Leucon kobjakovae			11						
Leucon spp.									
Diastylidae									
Diastylis bidentata				29					
Diastylis paraspinulosa							4		
Pseudocumidae									
Petalosarsia declivis							4		
Campylaspidae									
Campylaspis crispa									
Isopoda									
Epicaridea microniscus stage				19	5	14		3	
Munnidae - unidentified sp.									
Amphipoda									
Unidentified immature spp.			11				9		
Hyperiidae									
Hyperia galba									
Parathemisto pacifica		253	114	1504	112282	3407	887	146	126
Phrosinidae									
Primno macropa						81		33	
Scinidae									
Scina rattrayi							27		

Table 3. (continued)

	Station Number	17*	18	19	20	21	22	23	24
Taxon	Depth of Tow (m)	36	41	30	49	200	130	200	46
Eusiridae									
Rhachotropis oculata							18		
Rhachotropis inflata									
Isaeidae									
Protomedeia fasciata									
Ischyroceridae									
Jassa pulchella									
Lysianassidae									
Anonyx lilljeborgi			23						
Cyphocaris challengeri						27		18	
Oedicerotidae									
Unidentified immature sp.									
Acanthostepheia incarinata									
Monoculodes packardi									
Monoculodes zernovi			365						
Monoculodes sp. #1							27		
Westwoodilla coecula			126						
Westwoodilla megalops							72		
Stenothoidae									
Unidentified immature spp.									
Metopa alderi			23						
Synopiidae									
Syrrhoe crenulata									
Euphausiacea									
Euphausiidae									
Unidentified immature spp.						6436	475	392	1877
Euphausia pacifica						14	18	56	
Thysanoëssa inermis				10		27	479	24	
Thysanoëssa longipes					5	159	59	249	
Thysanoëssa raschii		443	103						
Thysanoëssa spinifera							215	53	

Table 3. (continued)

Taxon	Station Number	17*	18	19	20	21	22	23	24
	Depth of Tow (m)	36	41	30	49	200	130	200	46
Decapoda									
Unidentified shrimp larvae						7	9	273	
Hippolytidae - unidentified spp.				143	1531	118	484	636	3516
Pandalidae									
Pandalus borealis I									
Pandalus borealis II							421		16
Pandalus borealis III									
Pandalus montagui tridens I					51	14		6	
Pandalus montagui tridens II									
Pandalus stenolepis I									32
Pandalus stenolepis									
Paguridae									
Unidentified zoea		63	80	3960	160	10	13	24	4794
Lithodidae									
Unidentified zoea				914	480			9	
Paralithodes camtschatica I zoea									16401
Paralithodes camtschatica II zoea									3785
Paralithodes camtschatica III zoea									
Paralithodes platypus I zoea				305					
Majidae									
Unidentified zoea									
Oregoniinae spp. zoea						98		3	
Chionoecetes opilio I zoea				81948	42776	41	224	15	252
Chionoecetes bairdi I zoea						54			
Chionoecetes bairdi megalopa								3	
Atelecyclidae									
Erimacrus isenbeckii I zoea				17974	480				
Erimacrus isenbeckii II zoea							4		
Cancridae									
Cancer spp. I zoea									
Pinnotheridae - unidentified zoea									

Table 3. (continued)

Taxon	Station Number	17*	18	19	20	21	22	23	24
	Depth of Tow (m)	36	41	30	49	200	130	200	46
Chaetognatha									
Sagitta elegans		3608	1633	13861	1204	379	744	1307	79
Eukrohnia hamata						7193	72	5845	
Cnidaria									
Hydrozoa									
Bougainvilliidae									
Perigonimus yoldia-arcticae									
Perigonimus spp.									189
Rathkea octopunctata									189
Bougainvillia superciliaris			11						47
Tubulariidae									
Corymorpha flammea					5	3	4	15	
Tubularia prolifer						20	76	21	331
Plotocnide borealis									
Corynidae									
Unidentified spp.							4		
Coryne principes				10		7			
Campanulinidae									
Aequorea forskalea			11						
Trachynemidae									
Aglantha digitale		506	11	438	418	152	345	365	63
Aeginidae									
Aeginopsis laurentii							4	9	
Diphyidae									
Dimophyes arctica						54		309	32
Scyphozoa - unidentified ephyra				10					
Ctenophora									
Beroe cucumis		190							
Beroe sp.									

Table 3. (continued)

Taxon	Station Number Depth of Tow (m)	17* 36	18 41	19 30	20 49	21 200	22 130	23 200	24 46
Echinodermata									
Ophiuroidea									
Unidentified ophiopluteus larvae						51	9	1319	284
Echinoidea									
Unidentified echinopluteus larvae						3			
Holothuroidea - unidentified sp.									
Mollusca									
Gastropoda									
Unidentified veliger larvae								570	
Thecosomata									
Limacina helicina				1752	1092	541	1649	270	262
Gymnosomata									
Clione limacina		316		19	10	169	99	33	
Bivalvia - unidentified immature spp.									
Cephalopoda									
Coleoidea - unidentified immature sp.						825	4	12	16
Theuthidida - unidentified sp.						7	18	68	
Octopodida - unidentified sp.								3	
Nematoda - unidentified spp.									
Protozoa									
Actinopodea									
Radiolaria - unidentified sp.						x		x	
Rhizopodea									
Foraminiferida - unidentified sp.									

Table 3. (continued)

	Station Number	17*	18	19	20	21	22	23	24
Taxon	Depth of Tow (m)	36	41	30	49	200	130	200	46
Urochordata									
Larvacea - unidentified spp.					153	2866	4157	1105	867
Oikopleuridae									
Oikopleura spp.						541	1290		
Fritillariidae									
Fritillaria borealis					148	4543	2150	214	442
Chordata									
Unidentified fish eggs *ca.* 1 mm									63
Unidentified fish eggs *ca.* 2 mm				219	31		27	3	32
Gnathostomata I									
Osmeridae									
Mallotus villosus larvae									
Myctophidae									
Stenobrachius leucopsarus juvenile								3	
Gadidae									
Unidentified larvae			34						
Gadus macrocephalus larvae									
Theragra chalcogramma larvae					61	61	596	152	32
Gnathostomata II - unidentified larvae									
Scorpeanidae									
Sebastes sp. larvae					15	3		6	
Hexagrammidae									
Hexagrammos stelleri larvae					5				
Cottidae									
Unidentified sp. larvae					107				16
Artedius spp. larvae									
Myoxocephalus sp. larvae									
Triglops sp. larvae									16
Agonidae - unidentified larvae			11	10					3
Cyclopteridae - unidentified larvae			11	190	31				

Table 3. (continued)

	Station Number	17*	18	19	20	21	22	23	24
Taxon	Depth of Tow (m)	36	41	30	49	200	130	200	46
Bathymasteridae - unidentified larvae					10				
Stichaeidae									
Unidentified larvae				19	31				
Lumpenus sp. larvae				19	5				
Pholidae - unidentified larvae									
Ammodytidae									
Ammodytes hexapterus larvae				29					95
Pleuronectidae									
Atheresthes sp. larvae						3		18	
Hippoglossoides sp. eggs							54		
Lepidopsetta bilineata larvae					15				457
Reinhardtius hippoglossoides larvae							4	6	
Unidentified animals									
Unidentified sp. # 1									
Unidentified sp. # 2								6	

Table 3. (continued)

Taxon	Station Number Depth of Tow (m)	25 74	26 58	27 50	28 78
Annelida					
Polychaeta					
Unidentified spp.		7	6	33	
Unidentified trochophores		20			
Spionidae - immature spp.		13	6		
Arthropoda					
Crustacea					
Unidentified eggs		x	x	x	x
Ostracoda					
Halocyprididae					
Conchoecia spp.					6
Cytheridae - unidentified spp.					
Copepoda					
Unidentified nauplii					
Calanoida					
Unidentified adult ^{o}		23088	35750	6290	979
Unidentified adult o		9360	10944		356
Unidentified juveniles		57616	95578	16118	8985
Harpacticoida - unidentified spp.					
Cirripedia					
Unidentified cypris larvae		13	114	262	
Unidentified nauplii			51	2293	4893
Malacostraca					
Mysidacea					
Unidentified adult sp.					
Unidentified immature spp.					

Table 3. (continued)

	Station Number	25	26	27	28
Taxon	Depth of Tow (m)	74	58	50	78
Mysidae					
Acanthomysis nephrophthalma					
Acanthomysis pseudomacropsis					
Neomysis rayii					
Pseudomma roseum					
Cumacea					
Lampropidae					
Lamprops fuscata		7			
Leuconidae					
Leucon nasicoides					
Leucon kobjakovae					
Leucon spp.					
Diastylidae					
Diastylis bidentata		7			
Diastylis paraspinulosa					
Pseudocumidae					
Petalosarsia declivis					
Campylaspidae					
Campylaspis crispa					
Isopoda					
Epicaridea microniscus stage					
Munnidae - unidentified sp.					
Amphipoda					
Unidentified immature spp.					
Hyperiidae					
Hyperia galba					
Parthemisto pacifica		72	314	2359	56
Phrosinidae					
Primno macropa					
Scinidae					
Scina rattrayi					

Table 3. (continued)

	Station Number	25	26	27	28
Taxon	Depth of Tow (m)	74	58	50	78
Eusiridae					
Rhachotropis oculata					
Rhachotropis inflata					
Isaeidae					
Protomedeia fasciata					
Ischyroceridae					
Jassa pulchella					
Lysianassidae					
Anonyx lilljeborgi					
Cyphocaris challengeri					
Oedicerotidae					
Unidentified immature sp.					
Acanthostepheia incarinata					
Monoculodes packardi					
Monculodes zernovi					
Monoculodes sp. #1					
Westwoodilla coecula					
Westwoodilla megalops					
Stenothoidae					
Unidentified immature spp.					
Metopa alderi					
Synopiidae					
Syrrhoe crenulata					
Euphausiacea					
Euphausiidae					
Unidentified immature spp.		8996	11309	311	83
Euphausia pacifica					
Thysanoëssa inermis		130	17	41	6
Thysanoëssa longipes					
Thysanoëssa raschii					
Thysanoëssa spinifera		13			

Table 3. (continued)

Taxon	Station Number	25	26	27	28
	Depth of Tow (m)	74	58	50	78
Decapoda					
Unidentified shrimp larvae					
Hippolytidae - unidentified spp.		280	137	1704	1112
Pandalidae					
Pandalus borealis I					
Pandalus borealis II			23	33	
Pandalus borealis III		7			
Pandalus montagui tridens I		26	1003	66	1379
Pandalus montagui tridens II		7	296	33	
Pandalus stenolepis I		85	365		45
Pandalus stenolepis II		46	228		
Paguridae					
Unidentified zoea		442	68	1524	456
Lithodidae					
Unidentified zoea		74	6	32	56
Paralithodes camtschatica I zoea		33		98	12
Paralithodes camtschatica IIzoea		33		50	
Paralithodes camtschatica IIIzoea		13		32	
Paralithodes platypus I zoea					
Majidae					
Unidentified zoea					100
Oregoniinae spp. zoea		33		1098	746
Chionoecetes opilio I zoea		130	445		
Chionoecetes bairdi I zoea					
Chionoecetes bairdi megalopa					
Atelecyclidae					
Erimacrus isenbeckii I zoea					
Erimacrus isenbeckii II zoea					
Cancridae					
Cancer spp. I zoea		20		16	39
Pinnotheridae - unidentified zoea		13		32	

Table 3. (continued)

	Station Number	25	26	27	28
Taxon	Depth of Tow (m)	74	58	50	78
Chaetognatha					
Sagitta elegans		65	23	115	83
Eukrohnia hamata		33	23		
Cnidaria					
Hydrozoa					
Bougainvilliidae					
Perigonimus yoldia-arcticae					
Perigonimus spp.					11
Rathkea octopunctata					17
Bougainvillia superciliaris					6
Tubulariidae					
Corymorpha flammea					6
Tubularia prolifer		319	17	25	6
Plotocnide borealis		7			
Corynidae					
Unidentified spp.					
Coryne principes		7			6
Campanulinidae					
Aequorea forskalea				16	
Trachynemidae					
Aglantha digitale		202	371	90	22
Aeginidae					
Aeginopsis laurentii					
Diphydidae					
Dimophyes arctica					6
Scyphozoa - unidentified ephyra				8	6
Ctenophora					
Beroe cucumis					
Beroe sp.					

Table 3. (continued)

	Station Number	25	26	27	28
Taxon	Depth of Tow (m)	74	58	50	78
Echinodermata					
Ophiuroidea					
Unidentified ophiopluteus larvae					33
Echinoidea					
Unidentified echinopluteus larvae					
Holothuroidea - unidentified sp.					
Mollusca					
Gastropoda					
Unidentified veliger larvae		13			
Thecosomata					
Limacina helicina		2548	11765	6028	95
Gymnosomata					
Clione limacina			23	25	
Bivalvia - unidentified immature spp.					
Cephalopoda					
Coleoidea - unidentified immature sp.					
Theuthidida - unidentified sp.					
Octopodida - unidentified sp.			17		
Nematoda - unidentified spp.			6		
Protozoa					
Actinopodea					
Radiolaria - unidentified sp.					
Rhizopodea					
Foraminiferida - unidentified sp.					

Table 3. (continued)

Taxon	Station Number	25	26	27	28
	Depth of Tow (m)	74	58	50	78
Urochordata					
Larvacea - unidentified spp.		33	154	33	228
Oikopleuridae					
Oikopleura spp.		13			
Fritillariidae					
Fritillaria borealis		124	74	82	234
Chordata					
Unidentified fish eggs *ca.* 1 mm					
Unidentified fish eggs *ca.* 2 mm		52	51		
Gnathostomata I					
Osmeridae					
Mallotus villosus larvae				8	
Myctophidae					
Stenobrachius leucopsarus juvenile					
Gadidae					
Unidentified larvae		7			
Gadus macrocephalus larvae			74		33
Theragra chalcogramma larvae					
Gnathostomata II - unidentified larvae				8	
Scorpeanidae					
Sebastes sp. larvae					
Hexagrammidae					
Hexagrammos stelleri larvae					
Cottidae					
Unidentified sp. larvae			6	25	11
Artedius spp. larvae					6
Myoxocephalus sp. larvae		13			
Triglops sp. larvae					
Agonidae - unidentified larvae					6
Cyclopteridae - unidentified larvae				16	6

Table 3. (continued)

Taxon	Station Number Depth of Tow (m)	25 74	26 58	27 50	28 78
Bathymasteridae - unidentified larvae			11		
Stichaeidae					
Unidentified larvae					
Lumpenus sp. larvae					
Pholidae - unidentified larvae				8	
Ammodytidae					
Ammodytes hexapterus larvae		7	6	721	28
Pleuronectidae					
Atheresthes sp. larvae					
Hippoglossoides sp. eggs		7	131	49	39
Lepidopsetta bilineata larvae		221	51	8	6
Reinhardtius hippoglossoides larvae					
Unidentified animals					
Unidentified sp. # 1					
Unidentified sp. # 2					

Other organisms present at various stations were shrimp larvae, fish eggs and larvae, barnacle nauplii, cyprid larvae, ostracods, polychaetes and their larvae, nematodes, cephalopods, echinoderm larvae, mysids, cumacea, isopods, cnidarians, ctenophores, foraminiferans, radiolarians, and a few unidentified organisms.

At stations 6 to 10 in Bering Strait, calanoid copepods were the most abundant organisms followed by *Sagitta elegans*. At stations between St. Lawrence Island and Nome (stations 1 through 5, 12 through 14, and 17), *Sagitta elegans* was the most abundant organism except at stations 1, 5, 13, and 17 taken with the 0.75 m ring net, where calanoid copepods were the most abundant. The most abundant organism at station 16 off the northwest end and station 15 north of St. Lawrence Island was *Sagitta elegans*, while at station 18 off the east end of St. Lawrence Island, calanoid copepods and *Sagitta elegans* were equally abundant. At station 19 near St. Paul Island, calanoid copepods and crab larvae were dominant. The samples collected at stations 20 and 22 on the shelfbreak contained mostly calanoid copepods, along with a large number of amphipods at station 22. Calanoid copepods were also the most abundant organisms in samples from stations 21 off the shelf, 23 and 24 on the west end of Unimak Pass, and 25 through 28 east of Unimak Pass.

VII. Discussion

Nearly all reports of chlorophyll *a* and primary productivity measurements fro the Bering Sea are for the area south of St. Lawrence Island (Holmes 1958; Kawamura 1963; McAlister *et al.* 1968; Taniguchi 1969; Taguchi 1972; McRoy *et al.* 1972; Alexander and Cooney 1979) and were made during the summer, except for McRoy *et al.* (1972) who also worked in winter and Alexander and Cooney (1979) who worked all year except for midwinter. Alexander and Cooney (1979) also measured chlorophyll *a* concentrations in sea ice near Nome in spring. McRoy *et al.* (1972) give an integrated value of carbon fixed for one station in Bering Strait during June of 4.1 g C m^{-2} day^{-1}, one of the highest values measured any where in the world ocean.

Motoda and Minoda (1974) summarized the rates of primary productivity for the area south of St. Lawrence Island. In summer, primary productivity in surface waters ranged from 0.8 mg C m^{-3} hr^{-1} in the western region to 3 mg C m^{-3} hr^{-1} in the southern shelf area. Spring values from the *Polar Sea* data ranged from 0.12 to 12.27 mg C m^{-3} hr^{-1} at the surface and from 0.28 to 17.16 mg C m^{-3} hr^{-1} at the depth of greatest carbon uptake, usually at 15 to 20 m.

There appears to be no correlation between the presence of ice and high levels of primary productivity in the northern Bering Sea (Table 4). High and low primary productivity occurred at stations with no ice cover and with 8 oktas (100%) ice cover, although the highest integrated productivity occurred at station 12 with no ice cover.

Nutrient depletion was evident only at station 2 and perhaps at station 10 where nitrate concentrations were < 1.4 μg at ℓ^{-1} and phosphate concentrations were < 1 μg at ℓ^{-1}.

Table 4. Comparison between ice cover and primary productivity in the northern Bering Sea, 19-30 April 1979.

Sta	Prim Prod ($mg\ C\ m^{-2}\ hr^{-1}$)	Ice (oktas)
North of the Ice Edge		
1	179.88	8
4	63.26	5-6
5	87.87	6-7
6	36.37	7-8
9	57.25	7-8
10	247.55	7-8
11	19.82	7-8
14	9.05	4-5
16	20.44	1-3
South of the Ice Edge		
2	60.39	0
3	211.02	0
12	397.64	0
13	37.63	< 1
15	10.69	0
17	6.25	0
18	90.27	0

At the southern Bering Sea, Gulf of Alaska, and Shelikof Strait stations, carbon uptake was extremely variable while nutrient concentrations were always high.

Phytoplankton standing stock samples have not been analyzed for this cruise. Possible species differences between areas or health conditions of the cells may help to explain some of the differences between stations.

In the southeastern Bering Sea, Cooney (Alexander and Cooney 1979) divided the research area into regimes based on depth and found general distributions of zooplankton corresponding with these regimes. Table 5 lists taxa from the *Polar Sea* cruise based on geographic area and, to some extent, on depth.

It is difficult to compare the *Polar Sea* data with that of Cooney because he worked only in the southeastern Bering Sea and had samples from several cruises spread over several seasons, whereas the *Polar Sea* samples are primarily from the area north of St. Lawrence Island and are from only one cruise. The *Polar Sea* southern shelf area, < 200 m, corresponds most closely to Cooney's central shelf regime, and southern area > 200 m to his outer shelf regime. Only *Sagitta elegans* was numerically important in the central shelf - southern shelf area of both studies and no species were common in the outer shelf - southern area > 200 m areas. Only the copepods have not been identified to species for the *Polar Sea* samples and there might be some species overlap between the two studies in this large and numerically important group.

There is a discrepancy between this report and earlier RU 359 reports with regard to mesh sizes of the nets used. Bongo net mesh sizes have been reported to be 505 and 333 µm. Better measurement techniques now show that the 505 µm is 500 µm and the 333 µm is 335 µm (Halstead, East Side Net Shop, pers. comm.).

A problem occurred in trying to distinguish between two species of *Parathemisto* (Amphipoda) that have been reported in the Bering Sea. Bowman (1960) discusses methods of distinguishing between the species *Parathemisto pacifica* and *P. japonica* and gives incomplete ranges for both. *Parathemisto japonica* is reported to occur in the Okhotsk Sea, Sea of Japan, western North Pacific off the east coasts of northern Japan and the southern Kuriles. The extent of the eastward distribution is not known, but at some distance it is replaced by *P. pacifica*, which includes the *P. japonica* reported in the Bering Sea (Behning 1939; Bulycheva 1955; Vinogradov 1956). While Bowman (1960) found it possible to distinguish a very young female *P. japonica* by the fact that antenna 2 is longer than antenna 1, he also showed a very young female specimen of *P. pacifica* in Fig. 3b with antenna 2 longer than antenna 1.

Cooney (1978b) found *P. japonica* in Norton Sound and the southeastern Bering Sea, but from the information presented here and in Table 6, all *Parathemisto* in the 1979 *Polar Sea* collections were determined to be *P. pacifica*.

Table 5. Distribution patterns of zooplankton in the Bering Sea based on geographic area, 17 Apr - 6 May 1979.

A. Northern shelf area - St. Lawrence Island to Bering Strait

Clione limacina
Thysanoëssa raschii
Sagitta elegans
Beroë cucumis
Unidentified gadid larvae

B. Southern shelf area - < 200 m (sta. 19)

Limacina helicina
Sagitta elegans
Decapod larvae

C. Southern area - > 200 m (sta. 20, 21, 22, 23, 24)

Thysanoëssa spinifera
Euphausid larvae
Parathemisto pacifica
Eukrohnia hamata
Larvaceans

D. Gulf of Alaska - Shelikof Strait

Limacina helicina
Calanoid copepods
Euphausid larvae
Decapod larvae

E. No consistent area

Aglantha digitale
Other Cnidaria
Parathemisto pacifica
Thysanoëssa inermis
Thysanoëssa longipes
Miscellaneous amphipods
Calanoid copepods
Barnacle larvae

Table 6. Distinguishing characteristics of *Parathemisto japonica* and *P. pacifica* (after Bowman 1960).

Parathemisto japonica	*Parathemisto pacifica*	1979 *Parathemisto*
Adult females (even very young specimens) with antenna 2 longer than antenna 1	Adult females (even very young specimens) with antennae 1 and 2 subequal in length	Adult females with antennae subequal and unequal in length
Development of pereopodal setae on pereopod 6 (especially on the posterior margin) more conspicuous	Not as conspicuous	No specimens with conspicuous setae on posterior margin of pereopod 6
Maxilliped with 13 setae (Fig. 3j in Bowman)	Maxilliped with 6 setae (Fig. 1e in Bowman)	Maxilliped with 6 setae or less
Adults 9 to 17 mm in length	Adults 4.5 to 8.5 mm in length	All specimens less than 9 mm in length

VIII. Conclusions

It is difficult to reach conclusions concerning the phytoplankton and primary productivity without knowing what species were present in the samples. Productivity in the northern Bering Sea was apparently independent of ice conditions and nutrient concentrations.

For the zooplankton, copepods were important at all stations, but these have not been identified to species. Comparisons between the *Polar Sea* samples and Cooney's (Alexander and Cooney 1979) Bering Sea regimes is difficult without this copepod data.

Taxonomic problems have not been resolved with regard to some of the major organisms in the area. This is true not only of the zooplankton species discussed here, but also of the phytoplankton.

The study reported here is based on only one short cruise. Ice, weather, and other factors in other years might show very different conditions.

IX. Needs for Further Study

Additional cruises, especially in the northern Bering Sea, at the same time and extending later into the spring-summer as the ice retreats, would provide additional information concerning the plankton communities during the critical time of ice breakup, including data on annual variability.

Studies of the ice algae, probably done with an ice corer and deck incubation techniques because of the problems with doing in situ studies in an area of constantly shifting ice, would provide information on the importance of the ice community to the area. Many chlorophyll samples, collected over a wide geographic area either with an ice corer or an in situ technique (Don Schell, RU 537) would provide needed information on the distribution and abundance of the ice algae.

X. Summary of Quarter's Activities

A. Laboratory Activities

Ananlysis of zooplankton samples was completed and the data put into OCSEAP formats for submission to NODC.

XI. Auxiliary Material

A. Bibliography

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B. Papers in Preparation or Print - None

C. Oral Presentations - None

D. Acknowledgments

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RECEPTORS-LITTORAL

CONTENTS

Contract 03-5-022-81
Research Unit 356
April 1, 1979 to March 31, 1980
11 pages plus 230 appended pages

ANNUAL REPORT

Environmental Assessment of Selected Habitats in Arctic Littoral Systems

Principal Investigator: A. C. Broad,
Western Washington University

A. C. Broad
K. H. Dunton
Helmut Koch
D. T. Mason
D. E. Schneider
Susan V. Schonberg

TABLE OF CONTENTS

I. Summary of objectives, conclusions and implications with respect to oil and gas development.

A. Objectives for 1979: Our objectives for the year are those of our fiscal 1979 and 1980 proposals.

1. Continuation of the overall community survey of the Stefansson Sound Boulder Patches.
2. Study the growth rate of *Laminaria solidungula* through the winter, and initiate studies of growth of soft corals.
3. Determine sensitivity of epilithic organisms of the Stefansson Sound kelp community to sedimentation and relate this to annual cycles.
4. Investigate recolonization rates of denuded and new surfaces in Stefansson Sound.
5. Define ecological interactions and physical parameters that may be limiting in the kelp communities.
6. Complete investigations of food and energy sources of littoral and inshore Beaufort Sea species.
7. Investigate metabolic activity of selected major species of the nearshore and inshore environment during the winter.
8. Through experimental manipulation of environmental factors, determine physiological responses and tolerances of key invertebrates.
9. Initiate investigations of the effects of Alaskan North Slope crude oil on Beaufort Sea invertebtates, especially when under the physiological stresses associated with winter conditions.
10. Assess the importance of detritus of terrestrial origin in Arctic food chains through controlled feeding experiments.
11. Complete laboratory analysis of nearshore and inshore samples collected in the Beaufort and Chukchi Seas since 1975.
12. Continue reporting data analyses from prior years.

B. Conclusions. The objectives outlined above are dealt with in separate, appended reports. Major conclusions from these appendices are abstracted below.

1. The Stefansson Sound kelp community is dominated by the brown alga, Laminaria solidungula. This plant completes over 90 per cent of its annual linear growth during the winter, usually in complete darkness under a turbid ice canopy. Growth of plants exposed to light under a clean ice canopy, however, is even greater, indicating photosynthesis is possible in the late winter and spring.

2. The ability of these plants to grow in Stefansson Sound, regardless of winter light conditions is noteworthy. Few if any ice algae occur under turbid ice and thus little contribution to primary productivity is made by the micro-algae in these (turbid) areas. Macroalgae, however, are capable of photosynthesis during the summer months despite low nutrient concentrations in the seawater. The near guaranteed annual contribution of these benthic algae with respect to total carbon input into the arctic ecosystem is not yet known

3. Several species of amphipods, a polychaete worm and the arctic cod inhabit the turbid ice canopy through the winter. Many of the animals are in reproductive condition. They are seldom found under clean, congelation ice or on the bottom in this area. It is not known what role the turbid ice canopy plays in the life cycle of these invertebrates. The large amount of oil within the animals and their empty guts indicate they are not feeding, but are living and producing gametes from stored food reserves.

4. Sedimentation in Stefansson Sound is highest during the fall and late spring or early summer months. The sediments cover organisms colonizing bare substrata and may slow the recolonization process by smothering organisms or preventing settlement of new areas.

5. Quantitative studies have revealed a rich faunal assemblage on rock surfaces which, based on our current observations of recolonization, may have taken years to establish.

6. Competition between established epilithic biota for space and the high utilization of the benthic algae by epizoic animals indicates that space is one of the most limiting resources in this community.

7. On the seafloor, cores taken under boulders show a greater biomass and diversity of biota than do cores taken between rocks. This may be attributed to differences in grain size and sediment compaction between the two areas. Sediments under rocks are softer and less consolidated than between rocks. In addition, sloughed off material from rock surfaces accumulates around the boulders and cobbles contributing organic materials to the sediments found there.

8. Many of the arctic, shallow water, epibenthic invertebrate species tested were found to survive well at both high and low salinities. Generally, however, spontaneous activity ceased (and ecological death occured) at salinities that actually may be reached in the deeper parts of lagoons during late winter or early spring. Results of physiological experiments were consistent with the absence of *Mysis* species from lagoons during the winter. The most salinity-tolerant species tested were the amphipods, *Boeckosimus affinis* and *Onisimus litoralis*.

9. Metabolic activity of *Mysis littoralis* and *Boeckosimus affinis*, both euryhaline species, shows a high independence of salintiy within the tolerance range. The metabolism of *Anonyx nugax*, the most stenohaline amphipod tested, was depressed at salinities as low as 20‰ or as high as 45‰.

10. *Boeckosimus affinis* has a greater survival (longer survival time) during freezing than has *Anonyx* nugax.

11. *Mysis littoralis* is sensitive (depressed activity) at all salinities to even light ($50\mu\ell$-ℓ^{-1}) dispersions of North Slope crude oil, and this sensitivity is enhanced by salinity stress. The same depression of activity was noted in *Boeckosimus affinis* and *Anonyx nugax*. Currently available results show that *B. affinis* from Stefansson Sound (in the center of the area most

likely for early development) are more sensitive to oil than are those from Elson Lagoon, but this difference was not noted for Mysis. Metabolic activity of all three species was altered by exposure to light oil dispersions, and this effect was heightened by salinity stress.

12. Detailed, species-specific analyses of nearshore and inshore samples taken since 1975 and reported previously in generalities much as abundance data by major groups have been initiated. The contribution these data can make to life history and ecology studies is illustrated in the treatment of two haustoriid amphipod species, Pontoporeia affinis and P. femorata in appendix 3.

13. Infaunal benthos of the nearshore region of the Beaufort Sea coast is low in diversity, biomass and number of organisms, and probably is largely repopulated annually after the shorefast ice melts. Samples taken early in the open water season will reflect this seasonal low in biota. Motile, epibenthic crustaceans, however, are at least as abundant early in the season and in the shallowest water as they are elsewhere. River deltas are especially poor in both infaunal and epifaunal organisms.

14. The amphipod, Gammarus setosus can in the laboratory ingest and assimilate peat from eroded tundra vegetation, silty sediments, Laminaria fragments, and, by observation at least, a variety of other kinds of organic matter of animal origin.

15. Fluxes of fresh water and of salt may be the primary mediators of the development in arctic marshes of warm, concentrated lakes.

C. Implications:

1. The Stefansson Sound kelp community in boulder patches widely distributed in the area is a biologically unique element of the Beaufort Sea environment that is located in a particularly sensitive place: near the geographic center of the region most likely to be developed first. The region not only contains

species and associations that are rare or non-existent elsewhere in the western Beaufort, it also has the highest biomass of infaunal benthos currently known in the inshore region. The relationship (if any) between these is unknown.

The epilithic community of the boulder patches is now believed to be slow to develop with a standing crop that is several years old. Individually, the organisms are susceptible to smothering by sedimentation which is naturally heavy in Stefansson Sound in late fall and early winter. Activities that might add to this sediment load could be dangerous to the community.

Production in Stefansson Sound probably results primarily from summer photosynthetic activity, possibly only of the macroalgae, although linear growth occurs mainly during the winter. This delay in utilization of energy reserves created in summer may result from nutrient deficiencies at that time. Thus, increased turbidity in summer might seriously affect production, and interference with movement of nutrients in winter, possibly the result of onshore flow of surface water, could impair growth. The kelps which dominate the entire community and provide the microhabitats for many of the other organisms are probably dependent on continued reasonable clarity of water during the summers and no interference with onshore flow in winter. Developments in Stefansson Sound, therefore, should incorporate measures to minimize contribution to turbidity and sediment load.

2. Many invertebrates of the shallow Beaufort Sea are sensitive to Prudhoe Bay crude oil, and this sensitivity is enhanced by the stresses imposed by winter conditions. At least initially, drilling and other activities probably will be from artificial islands or other structures that themselves minimize the liklihood of introducing petroleum directly to the water or beneath ice. Many of those animals most stressed in the laboratory by conditions likely to be encountered in winter, however, move seaward as ice forms, and are not abundant in the inshore region during the winter. We do not believe that our results of physiological and stress studies have particular implications (other than customary precautions) for development of petroleum

resources inside the barrier islands or, generally, in shallow water where planned technology seems to minimize those risks we find to be greatest. These findings, however, are more germane to development in depths of water too great for island construction or where pack ice or other factors make seafloor operations or drilling from platforms appear to be viable options. Since the nearshore waters are repopulated annually by mysids and other crustaceans that move offshore in winter, and since these nearshore areas are the principal feeding sites of most arctic fish, the region seaward of the shear ice zone becomes, in effect, a seasonal extension of this trophically imporant region. Our results point to the potential of transport of a winter effect in the region at the shear zone to the nearshore feeding grounds in summer.

3. Finally, our results further support the previously expressed notion that creation of artificial islands in river deltas probably has less effect on infaunal benthos than would the same island elsewhere.

II. Introduction: The body of this report is in the form of 6 appended sections. Each treats separately appropriate methods, results and conclusions. The summary of conclusions given above is abstracted from these appendices, but does not necessarily incorporate all findings of the several projects.

SUMMARY OF FOURTH QUARTER OPERATIONS

I. Field and Laboratory Activities.

A. Field work

1. Personnel

a. At NARL, Barrow: physiological investigations

(1) D. E. Schneider: February 18 to March 3
(2) James Hanes: January 1 to February 26, March 9 to 18, March 21 to 31
(3) Rick Yackley: January 1 to March 31
(4) Mark Childers: March 21 to 31

b. At Deadhorse and Stefansson Sound Dive Site

(1) K. H. Dunton: February 18 to March 9
(2) John Olson: February 18 to March 9
(3) Gene Cinkovich: February 18 to March 9
(4) James Hanes: February 26 to March 9

2. Field trip schedule

a. February 18: Dive team (all except James Hanes) arrives at Deadhorse.

b. February 19: Prepare field equipment used to locate pinger and prepare field camp (parcoll) for airlift to Stefansson Sound. Travel by NOAA helicopter.

c. February 20-25: Locate DS-11 on February 20, cut dive hole and install NARL parcoll between 21st and 25th. No helicopter support on February 22 and 23 due to high winds, fog and low temperatures. Travel by NOAA helicopter.

d. February 26: Diving studies initiated; start arctic cod sampling program for LGL on separate OCS contract funding. James Hanes arrives from NARL in afternoon via commercial jet. Travel by NOAA helicopter.

e. February 27 - March 7: Divers conduct benthic studies at DS-11. No diving on March 2 due to bad weather. Over 45 dives completed during this period. Travel by ERA (212) helicopter on March 5 and 6. Travel all other days by NOAA (205) helicopter. Dismantle parcoll on March 7 (late afternoon).

f. March 8: Retrieve parcoll and field equipment from DS-11 Repack and store parcoll in Deadhorse along with other NARL equipment.

g. March 9: James Hanes returns to Barrow on NOAA helicopter freight flight. Dunton, Cinkovich and Olson depart Deadhorse for Bellingham in p.m.

3. Laboratory experiments: During the fourth quarter activities of the winter physiology group of RU-356 consisted of the following:
    a. Quantitative measures of activity for *Saduria entomon* and *Anonyx nugax* exposed to gradual salinity changes were completed.

    b. Salinity tolerance experiments were conducted on *Mysis littoralis* and *Anonyx nugax* to fill in existing data gaps. The results are presented in the 1980 annual report.

    c. Salinity tolerance experiments were completed for the following new species: *Pontoporeia femorata*, *Aceroides latipes*, *Onisimus litoralis* and *Tryphosella schneideri*. The results of these experiments are presented in the 1980 annual report.

    d. Salinity tolerance experiments are in progress for *Pontoporeia femorata*, *Aceroides latipes* and an as yet unidentified anemone.

    e. Metabolic rate measurements are in progress for the anemone mentioned above and for the bivalve mollusc *Liocyma fluctuosa*.

    f. Field activities have included installation and maintenance of two dive huts, one near Plover Point in Elson Lagoon, the other near NARL, and perfecting collecting methods for benthic animals.

    g. Data analysis and preparation of the annual report.

B. Scientific Party (except as noted, all of Western Washington University).

1. A. C. Broad, Principal Investigator (not on salary to contract)
2. D. E. Schneider, Associate Investigator
3. K. H. Dunton, Associate Investigator
4. Helmut Koch, Laboratory Supervisor
5. James Hanes, Marine Technician
6. Mark Childers, Research Aide
7. Susan V. Schonberg, Research Aide (half time)
8. Richard Yackley, Research Aide
9. Jonathan Zehr, Research Aide (hourly wages)
10. Laboratory Assistants (hourly wages)
    a. James Bock
    b. Susan Burgdorff
    c. Kara Cameron
    d. Dawn Christman
    e. Geoffrey Pounds
    f. Russell Thorson
11. Work study students (no cost to contract)
    a. Sandra Bohenstiehl
    b. Gary Smith
12. Contracted services (not University employees)
    a. Gene Cinkovitch, diver
    b. John Olson, diver

C. Methods: see text of appropriate appended sections.

D. Sample locations: See appendices I and II.

E. Data collected and analyzed: See appendices I and II.

F. Milestone chart update: none required.

II. Results:

Table 1 is a modification of one presented earlier (September, 1979), and gives the current status of analysis of all samples made by RU-356 from 1975 through 1978.

Other results are incorporated in appendices 1 to 4.

TABLE 1. Status of littoral, nearshore and inshore samples collected by RU356 as of 3/15/80.

RU356 TEAM[1]	AREA	SAMPLES COLLECTED					SAMPLES ANALYZED					INTERTIDAL DATA FORMAT				REMARKS
		S	B	E	OB	P	S	B	E	OB	P[2]	C[3]	P[4]	TAPE[5]	NODC[5,6]	
15	BFT	118	242	37	127	0	118	242	37	127	-	yes	yes	1976	770113	Shore samples east of Canning River
25	BFT	27	118	33	49	0	27	118	33	49	-	yes	yes	1976	H08J24	Shore samples between Canning & Colville Rivers
35	BFT	13	128	16	34	0	13	128	16	34	-	yes	yes	1976	M10P34	Shore samples west of Colville River
55	BFT	0	0	0	22	2	0	0	0	22	-	yes	yes	1976	761229	Misc. shore samples
16	BFT	41	169	20	29	21	41	169	20	29	-	yes	yes	1977	780218	Shore samples
26	BFT	53	178	31	0	25	53	178	31	0	-	yes	yes	1977	780219	Lagoon samples
36	BFT	17	34	14	1	14	17	34	14	1	-	yes	yes	1977	780214	ALUMIAK samples
46	CHK	39	119	21	49	18	39	119	21	49	-	yes	yes	1977	780217	Shore samples north of Point Hope
56	CHK	19	94	37	57	14	19	94	37	57	-	yes	yes	1977	780215	Shore samples, Kotzebue Sound
66	CHK	31	101	23	65	32	31	101	23	65	-	yes	yes	1977	780216	Shore samples, Seward Peninsula
17	CHK	50	306	64	97	53	50	306	64	97	-	no	no	(6/80)	(7/80)	Shore samples. but some ID problems (algae)
27	BFT	42	125	41	0	41	42	125	41	0	-	yes	yes	1979	790317	ALUMIAK samples
37	CHK	48	266	22	83	31	48	266	22	83	-	no	no	(8/80)	(9/80)	Shore samples. Some ID (algae) incomplete
47	BFT/CHK	30	187	13	6	14	30	187	13	6	-	yes	yes	1979	791121	Shore samples
57	BFT	44	346	56	29	46	44	346	56	29	-	yes	yes	1979	790411	Shore samples
18	BFT	0	240	120	0	60	0	240	120	0	-	yes	yes	1979	791215	Shore samples
38	BFT	0	77	18	19	18	0	77	18	19	-	yes	yes	1980	800121	ALUMIAK samples.
TOTALS		572	2730	566	667	389	572	2730	566	667	-					

[1] Last digit is year of field activity

S=Substrate
B=Benthos
E=Epibenthos
OB=Other, biol.
P=Plankton

[2] Analysis of plankton not reported

C[3]=Coded
P[4]=Punched
[5] Dates in parentheses are estimates
[6] Six digit numbers are NODC file ID's.

III. Estimate of funds expended.

	Amount Budgeted[1]	Amount Spent	Amount Remaining
Salary PI	$ 72,563	$ 64,966	$ 7,597
Salaries, Associates	153,278	143,275	10,003
Salaries, other	283,269	244,810	38,459
Fringe	99,835	68,577	31,258
Travel & Freight	63,124	50.940[3]	12,184
PI Logistics	41,613	37,860	3,753
Supplies & Contracts	62,483	60,218[3]	2,265
Equipment	49,047	26,669[3]	22,378
Computer Costs	7,000	5,441[3]	1,559
Overhead	224,806[2]	175,532	49,274
Totals	$1,057,018	$878,288	$178,730

[1] Includes original contract (1975) and modifications 1-11 (through fiscal 1980).

[2] Western Washington University Controller's Office calculates allowable overhead at $217,435.

[3] Total as of February 29, 1980.

Ecology of the Stefansson Sound Kelp Community: Preliminary Results of *In Situ* and Benthic Studies

K. H. Dunton and S. V. Schonberg

INTRODUCTION

In July, 1978 the first comprehensive survey of an arctic kelp community began in an area of Stefansson Sound known as the "boulder patch." Discovered by marine geologists in 1971 and 1972 (Reimnitz and Ross, 1978), it lay unexplored by biologists for several years. Following the geological and biological investigations conducted by Reimnitz (RU-205) and Dunton (RU-356) in the summer of 1978, much attention has been directed toward this region.

The Stefansson Sound kelp community possesses the richest and most diverse fauna found in the American Beaufort Sea. It also lies in the center of a potentially rich oil and gas field. Our studies have been directed at: (1) defining the biological community and its physical environments; (2) the dynamics of community development; (3) the productivity of the benthic algae; and (4) determining the behavioral and growth responses of organisms to high levels of turbidity and unusually low light levels. This report presents the results of these studies which are a part of a major integrated winter science program of OCSEAP.

A preliminary survey of the boulder patch flora and fauna was completed by Dunton and Schonberg (1979) through a major diving effort in Stefansson Sound. Our current effort is directed toward a quantitative analysis of the benthic biota. This includes sampling the epilithic community on the boulders as well as the infaunal assemblage around and under them. We find quantitative analyses of this type important for the purposes of biological assessment and in the evaluation of community structure.

One of the most interesting studies in progress in Stefansson Sound involves the pattern of growth employed by the kelp, *Laminaria solidungula*. This plant is a perennial brown alga restricted mostly to the Arctic Ocean (Kjellman, 1883) and is abundant on rocks in Stefansson Sound where it constitutes 80 percent of the algal biomass of 1.8 to 3.3 kg/m^2. Here it lives at a depth of 5 to 8 meters in relatively quiet waters protected from serious and frequent ice gouging. Our interest in L. solidungula is twofold: (1) it contributes an unknown quantity of dissolved and particulate organic matter to the nearshore environment; and (2) it is a potentially valuable plant in monitoring studies since its growth pattern is a reflection of several physical and chemical factors. Recently Broad (1979) determined that the benthic biomass of animals collected in grab samples was about six times greater inside Stefansson Sound-Leffingwell Lagoon than outside the barrier islands. It is unknown what role benthic algal productivity may play in this.

In addition to the results of algal productivity studies, the winter sampling program led to the discovery of turbid ice, an unusual underwater formation encountered at several locations in Stefansson Sound. This appears to be a widespread phenomenon with far reaching implications for biologists, marine geologists and ice physicists. The importance of turbid ice to the biological environment is reflected in the abundance of biota inhabiting this peculiar ice layer. These organisms include the arctic cod and several species of normally epibenthic invertebrates, many gravid. The formation of turbid ice also has a significant effect on total productivity in the benthic macro algae. Due to the reduction in light, growth in Laminaria solidungula under turbid ice is reduced 50 per cent from that of plants under clean ice (Dunton and Reimnitz, 1980).

Sedimentation during the fall and late spring is seen as an event that may be detrimental to recolonization on denuded rock surfaces. Accumulated sediments may smother existing organisms in newly colonized areas. Hydroids, the predominant colonizers observed on denuded rock surfaces, are exposed to accumulations of sediment which sometimes cover them completely. It is not known how this silt affects their growth and the growth of filter feeding organisms in Stefansson Sound. Preliminary results of these studies are inconclusive due to the extremely slow rate of recolonization. New comparative studies are now underway that include monitoring the behavior of organisms, and the use of new experimental approaches to examine the recolonization process.

STUDY AREA

The Biological Environment

The Stefansson Sound boulder patch supports a well established kelp community characterized by several species of red and brown algae, and a diverse assortment of invertebrate life representing every major taxonomic group (Fig. 1.1). The most conspicuous and dominant member of the community is the kelp, *Laminaria solidungula* which is circumpolar in distribution. Two other kelp species, *Laminaria saccharina* and *Alaria esculenta*, appear occasionally and together with *L. solidungula* form a brown algal overstory. In areas where kelp cover is reduced or absent, another floral assemblage, typified by several species of filamentous and bladed red algae, dominates. These species include *Phycodrys rubens*, *Neodilsea integra*, *Phyllophora truncata*, *Rhodomela subfusca* and to a lesser extent, *Odonthalia dentata* and *Ahnfeltia plicata*. These red algal species, along with *Lithothamnium*, a widespread encrusting red alga comprise a patchy algal understory. To a large degree, the diverse and rich assemblage of invertebrate and vertebrate animals is dependent on the microhabitats and additional substrate space afforded to them by the algal community.

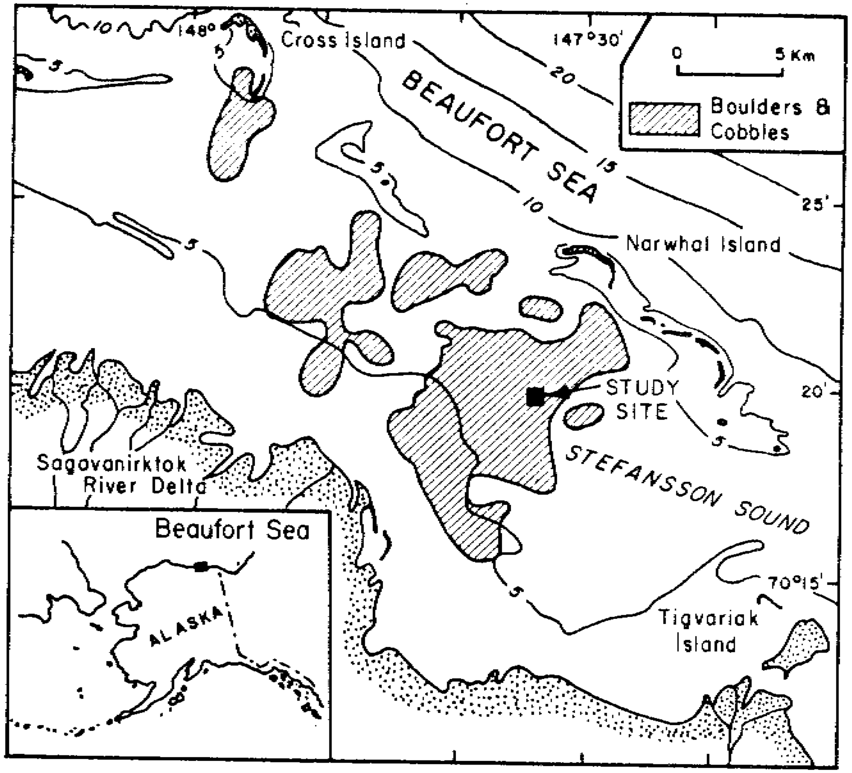
Of the invertebrate phyla, the sponges and the cnidarians are the most conspicuous. These include the sponges *Phakettia cribrosa*, and *Choanites lutkenii* and the soft coral *Eunephtyes rubiformis*. Other common organisms include seastars, hydroids, sea anenomes, sea squirts, nudibranchs, chitons and bryozoans.

Dive Site 11

The major portion of the diving effort is conducted at Dive Site 11 (DS-11) in the Stefansson Sound boulder patch (70° 19.25'N, 147° 35.1'W; Fig. 1.2). The site is located between Foggy Island Bay to the south and the McClure Islands to the north. The Sagavanirktok River discharges into Stefansson Sound about six miles southwest of DS-11. Water depth at this site ranges from 5.5 to 6.5 meters. The cover of boulders and cobbles on the seafloor at DS-11 averages 42 per cent. This represents the densest concentration of rocky material that we have seen in Stefansson Sound.

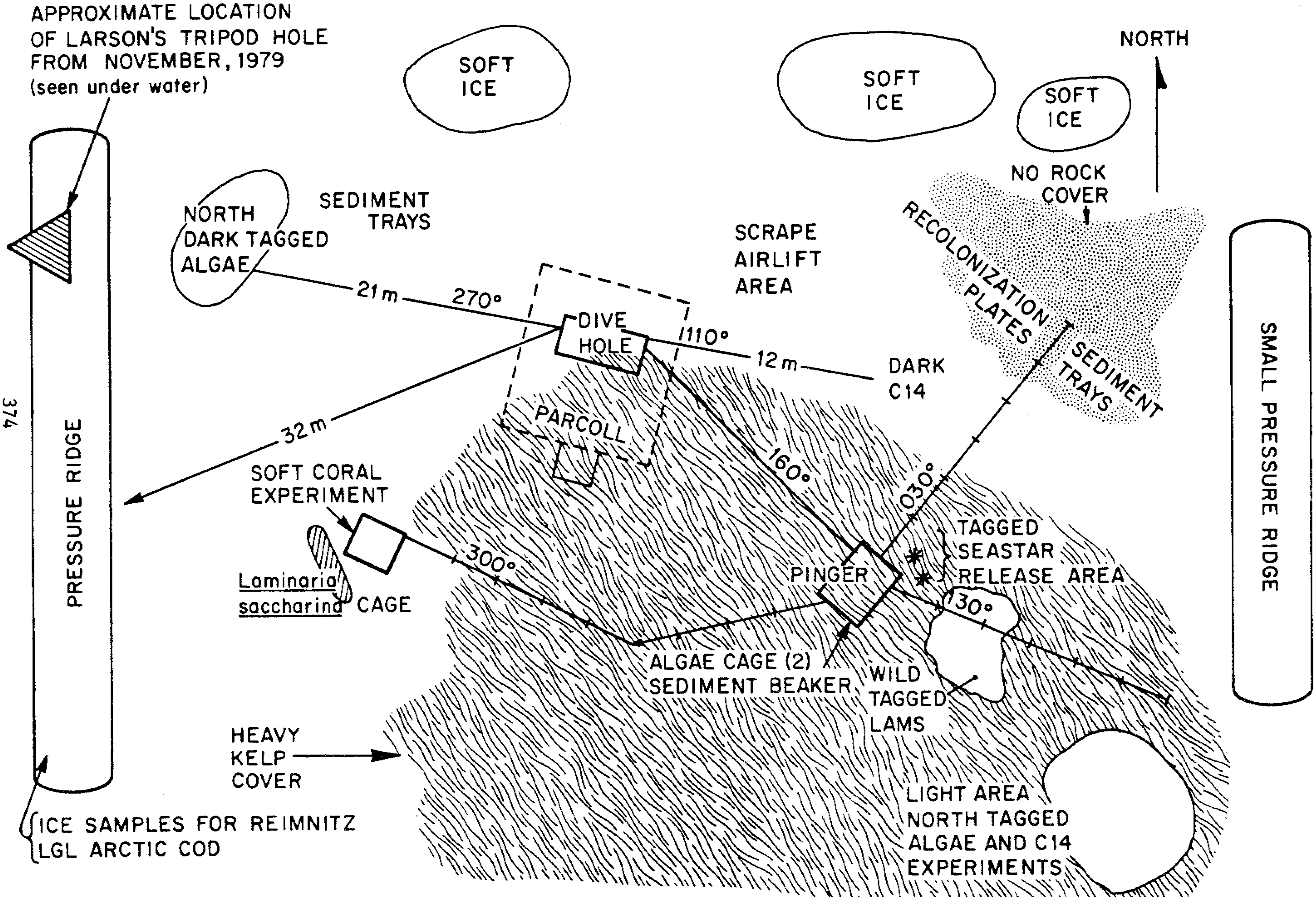
Figure 1.1: The arctic kelp, Laminaria solidungula, and an assemblage of soft corals, sponges, and red algae characterize the sea floor 32 kilometers northeast of Prudhoe Bay, Alaska. L. solidungula flourishes here, despite nine month periods of continuous darkness in sub-freezing waters.

Figure 1.2. A map of boulder and cobble distribution in Stefansson Sound showing the location of Dive Site 11.


10
148°
5
Cross Island
147°30'
0
5 Km
Boulders & Cobbles
BEAUFORT SEA
20
15
10
5
25'
Narwhal Island
STUDY SITE
20'
Sagavanirktok River Delta
STEFANSSON SOUND
70°15'
Tigvariak Island
Beaufort Sea
ALASKA

Since August, 1978, DS-11 has been the focus of our research effort in Stefansson Sound. The site is marked with a pinger at the center of the study area. Three transect lines, consisting of steel pipe marked in meters, are used by divers for orientation underwater and as an aid to locate in situ experiments (Fig. 1.3). This system is especially valuable during periods of poor water visibility and enables divers accurately to stake out distances underwater for scientific purposes.

Figure 1.3. A map of the seafloor at DS-11 showing the location of transect lines, *in situ* experiments, and the location of turbid ice in February, 1980.


APPROXIMATE LOCATION OF LARSON'S TRIPOD HOLE FROM NOVEMBER, 1979 (seen under water)
SOFT ICE
SOFT ICE
SOFT ICE
NORTH
NO ROCK COVER
RECOLONIZATION PLATES
SEDIMENT TRAYS
SMALL PRESSURE RIDGE
PRESSURE RIDGE
NORTH DARK TAGGED ALGAE
SEDIMENT TRAYS
SCRAPE AIRLIFT AREA
21 m
270°
DIVE HOLE
110°
12 m
DARK C14
32 m
PARCOLL
160°
030°
SOFT CORAL EXPERIMENT
Laminaria saccharina CAGE
300°
PINGER
TAGGED SEASTAR RELEASE AREA
130°
ALGAE CAGE (2)
SEDIMENT BEAKER
WILD TAGGED LAMS
HEAVY KELP COVER
LIGHT AREA NORTH TAGGED ALGAE AND C14 EXPERIMENTS
ICE SAMPLES FOR REIMNITZ
LGL ARCTIC COD

METHODS

Summer Field Sampling and Logistics

The field team for this project consists of a team leader/diver, and three SCUBA divers. During the summer we operate from Narwhal Island, about five miles from the principal dive sites in Stefansson Sound. Facilities are provided by the Naval Arctic Research Laboratory which maintains a camp on the island. Other field support including NOAA helicopter assistance, housing facilities in Deadhorse, and a 21 foot Boston Whaler is provided by OCSEAP. The Boston Whaler is used in transportation to and from the dive sites during the summer period.

Dive Site 11 was discovered in 1978 and has been marked since then by an underwater, Helle acoustical pinger. Buoyed flags or other surface markers are of little use because they are so often removed by drifting ice, which can occur in Stefansson Sound in summer as well as at other times. The research site, then, was marked by an underwater acoustical beacon and relocated seasonally and daily during field trips, with a Helle directional receiver.

Winter Field Sampling and Logistics

Data from _in situ_ experiments were collected at DS-11 in March, May and November 1979 by diving through the ice canopy. A Helle pinger receiver was used to locate the site in November, and a flag was erected for the duration of the winter. No measurable movement of the ice canopy was noted between March and May, 1979 and between November, 1979 and February, 1980. Divers worked from a dive hole located inside a heated 16 x 20 foot NARL parcoll. OCSEAP provided field logistic support, lodging in Deadhorse and NOAA helicopter assistance.

Because flocculent sediment was easily stirred up by turbulence, sampling was done by one person at a time in November. In other periods diving was done in tandem. The divers were tethered to the surface and equipped with a complete back-up air support system. Underwater lights were used for illumination since total darkness prevailed. We used an underwater communications system for transmitting data and for safety.

In Situ Biological Studies

The following *in situ* experiments are in progress at DS-11 (methods are given with results): An asterisk indicates that data are still being collected or analyzed.

1. The strategy and pattern of growth in the kelps *Laminaria solidungula* and *L. saccharina*.
2. Comparative experiments on the growth of *L. solidungula* under light and in complete darkness.
3. *Primary productivity in *L. solidungula*.
4. Recolonization of denuded rock surfaces by benthic organisms.
5. *Behavioral studies on the soft coral *Eunephtyes rubiformis*.
6. *Feeding and migratory behavior of seastars.
7. Physical and biological investigation of the turbid ice canopy.

Quantitative Sampling and Physical Observations

The quantitative physical and biological data collected at DS-11 include:

1. Biomass of the epilithic flora and fauna.
2. Density and biomass of infaunal biota, from under boulders and between boulders.
3. Hydrographic data.
4. Observations of visibility, water currents and sediment accumulations.

0.05 and 0.25 m^2 Scrapes

We used an airlift to collect samples on the biomass and density of invertebrates and algae on rock surfaces. Two sized framers (0.05m^2 and 0.25m^2) were used. All animals and algae living within a designated quadrat were scraped off the rock surface and sucked into a 1mm mesh bag. Two divers, one scraping and one operating the airlift were used in this sampling task.

0.01 m^2 Cores

Six 10 cm square cores were used to sample the benthic infauna between boulders and under boulders at DS-11. The cores were taken by one diver using an airlift with a 1 mm mesh bag attached. The average depth of penetration of these cores into the sediments was 3 cm.

Hydrographic Data

Measurements of salinity and temperature were taken frequently at DS-11. An SCT meter (YSI, Model 33) was used to collect data at the surface and at one meter intervals to the bottom.

Physical Observations

Through communication with surface personnel, divers were periodically asked to provide information on the physical environment. This included their observations on water turbidity and visibility, currents, sediment accumulation on rocks or on biota and any other pertinent observations.

Laboratory Techniques

All cores and epifauna samples were sorted and identified under a dissecting microscope. Biota from the core samples were separated to species, counted and weighed. All organisms were in an entire state except some of the polychaetes. Only the head portion of the worm was counted as an individual. No tubes or nonliving fractions were included in the biomass except for the shells of pelecypods, gastropods and ostracods. The biomass was determined from a wet weight taken after the excess water was blotted off the animal. The organisms were weighed on a Sartorius balance accurate to ± 1 mg.

RESULTS AND DISCUSSION I: WINTER PROCESS STUDIES

The Pattern of Growth in the kelp *Laminaria solidungula*

The pattern and mechanisms of growth in arctic marine benthic algae that survive in total darkness for prolonged periods are poorly understood. High latitudes are characterized by periods of complete darkness in winter with low sun angles and short days prevailing in the late fall and early spring months. Photosynthetic activity in polar seas is further restricted by ice and snow cover that reduce light penetration to near or below compensation irradiance, even under conditions of 24 hour daylight with the sun high overhead (1). Such observations have led to the hypothesis that arctic algae are heterotrophic (1,2) but this has not been demonstrated in any macroalgal species. Another possibility is that the adjustment to the annual periodicity in light availability may be dependent on the storage and translocation of food reserves. This phenomenon is common in higher plants, but is known only in a few brown algae, including some species of *Laminaria* (3). Accumulation of photosynthate during the spring and summer and translocation of these food reserves play a significant role in the seasonal growth pattern of some temperate laminarids (4, 5) but not in others (6). Here we present data concerning the seasonal pattern of growth in field populations of the arctic kelp, *Laminaria solidungula*, and offer evidence that, although size increases occur over nine months of continuous darkness, growth is a function of photosynthetic activity rather than heterotrophy.

Between August, 1978 and November, 1979, divers visited an acoustically marked study site in the Stefansson Sound kelp community at approximately three month intervals. Holes punched in the frond of *L. solidungula* provided a means to determine growth, measured as increase in length, during each visit. The frond of *L. solidungula* is divided into ovate blades by constrictions which form annually in late November. Each ovate blade represents a year's growth, and many specimens have a frond divided in four parts, enabling measurement of the three previous years of growth (the fourth or last blade is usually incomplete). Most plants range from 60 to 160 cm in length and are 7 to 17 cm wide, with the length of the stipe varying in size from 59 to 20 cm according to the age of the plant. Holes punched along the frond from base to tip show that the meristematic region is located at the base of the frond, near the stipe, as in many other Laminariaceae. To measure linear growth, holes were punched in tagged, numbered plants in August, 1978, above the basal meristematic region in the first blade, at a measured distance of 10 cm from the junction of stipe and frond. On subsequent visits the new distance from the hole to the junction of the stipe and frond was measured and the net increase in length calculated. During the period of total ice cover, which reached a thickness of 1.8 m by May, all plants were exposed to complete darkness resulting from a large amount of finely disseminated sediment within the ice.

The light available for photosynthesis between October and July is dependent on the conditions of ice formation and therefore varies from year to year. In Stefansson Sound, development of the ice canopy included the widespread occurrence of turbid ice, a result of underwater ice formation (7). We found turbid ice blocked light transmission completely, even during periods of 24 hour daylight. In May, 1979, illumination under turbid ice was less than 0.01 lux at midday, and light energy was not detectable. Despite the widespread distribution of turbid ice in Stefansson Sound, 'windows' of clean ice occurred that allowed light to penetrate to the bottom. Light energy in May at one such location in the boulder field, designated as site 2, ranged from 1.8 to 3.5 $\mu E\ s^{-1}\ m^{-2}$. Illumination under a similar ice canopy in April was 124 lux (2.4 $\mu E\ s^{-1}\ m^{-2}$). This represented 0.57 per cent of the total incident illumination of 21.5 Klux at the upper surface of the ice (8).

The results of the growth measurements on L. solidungula between August, 1978 and November, 1979 are given in Table 1.1. A new blade and constriction was produced and an average of 14.5 cm (N=19) of linear growth occurred in total darkness from mid November to early March. The new blades continued to grow through spring despite the darkness that persisted beneath the ice until break-up in mid July. In both summer periods (August to November, 1978 and 1979) which were largely ice free, linear growth averaged less than 2 cm. Blades that started to grow in November, 1978, averaged a total length of 26.1 cm by November, 1979, when a new constriction formed. This seasonal pattern of growth parallels that of Laminaria

Table 1.1. Linear growth increments of tagged L. solidungula plants between August 1978 and November 1979. Linear growth occurred in complete darkness from late October to early July.

	1978 Aug. 18- Nov. 12	1979 Nov. 12- March 7	March 7- May 16	May 16- Aug. 1	Aug. 1- Nov. 21
Mean linear increase (cm)	1.22	14.49	5.22	4.47	1.91
Standard Deviation	0.48	7.10	3.36	1.70	0.82
Number of measurements	22	19	19	17	17
Growth (cm) per week	0.10	0.88	0.52	0.41	0.12

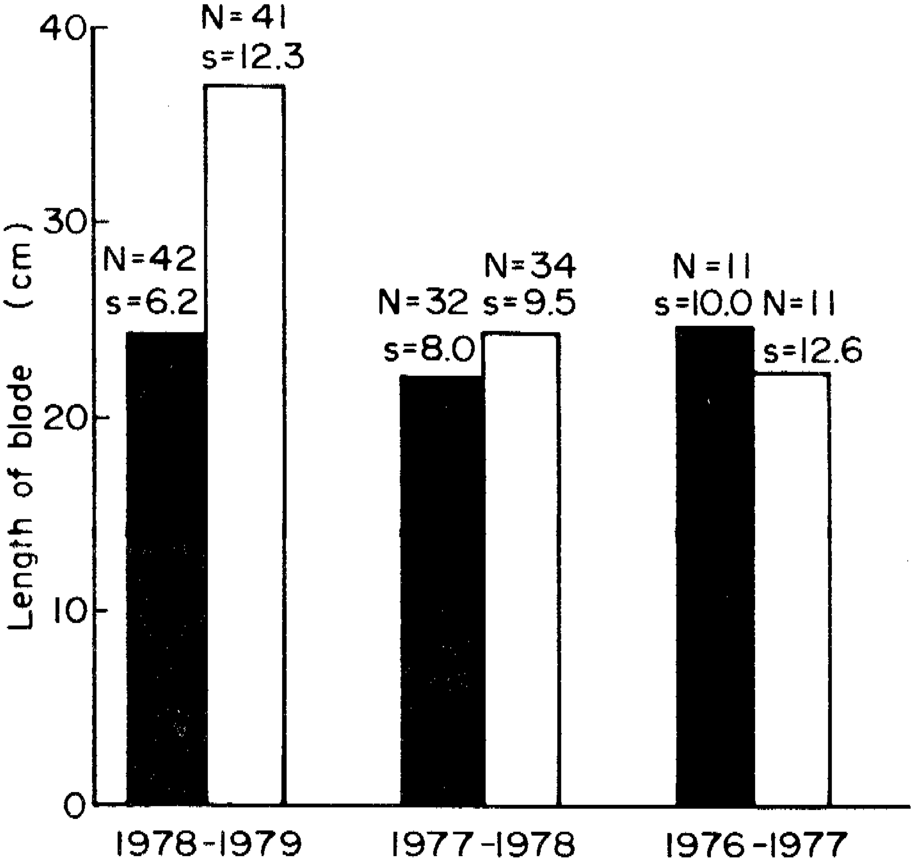
species at lower latitudes, which exhibit their greatest growth in late winter or early spring (4, 6) before light energy has increased to its annual maximum.

The formation of a new constriction in November, 1978, followed by the growth of a new blade, made it possible to monitor linear growth in untagged plants subjected to different light conditions at other sites. The distance from the junction of stipe and frond to the first constriction gave an accurate measurement of total linear growth since the preceding November. Linear growth in previous years was also assessed by measuring the distance between successive constrictions up the frond. Two acoustically marked sites, site 1, located under turbid ice near the tagged plants, and site 2, 200 m distant under clear ice, were chosen for the comparative study. Plants were collected for measurement following ice break-up in late July, 1979.

The growth of L. solidungula over the past years at two locations, differing with respect to ice cover during the 1978-79 winter, is shown in Fig. 1.4. With the exception of the latest growth cycle at site 2, where plants were exposed to light under the ice canopy in the spring of 1979, linear growth between years and between sites is not significantly different (analysis of variance [ANOV] completely randomized design, Student-Newman-Keuls test [SNK], $P > .50$). This similarity in growth suggests that turbid ice was present at both locations in the winter seasons of 1976-1977 and 1977-1978. The greater growth in plants under clean ice in 1979 is significant (SNK, $P < .0001$) and suggests that these plants are actively photosynthesizing under the ice canopy. The length of the basal blades in plants that had grown under clean ice at site 2 was 37.7 cm compared to 24.1 cm under turbid ice at site 1.

Although growth is usually temporally associated with photosynthesis in algae, there is evidence that for some algae growth in size may lag behind photosynthesis under adverse conditions. Lüning (9) found that L. hyperborea can produce a new blade after six months of continuous darkness and suggested that this growth was due to the utilization of reserve materials stored in the old frond. If winter growth depends on the accumulation of reserves produced by photosynthesis, then a relationship should exist between the size of the plant, i.e., the amount of stored food

Figure 1.4. Annual linear growth in L. solidungula at two adjacent sites since 1976-1977. The number of plants ampled (N) and the standard deviation (s) is listed above the bars. The difference in linear growth between the two sites in 1978-1979 is significant (ANOV, P < .0005). Site 1 is indicated by solid bars, site 2 by open bars.



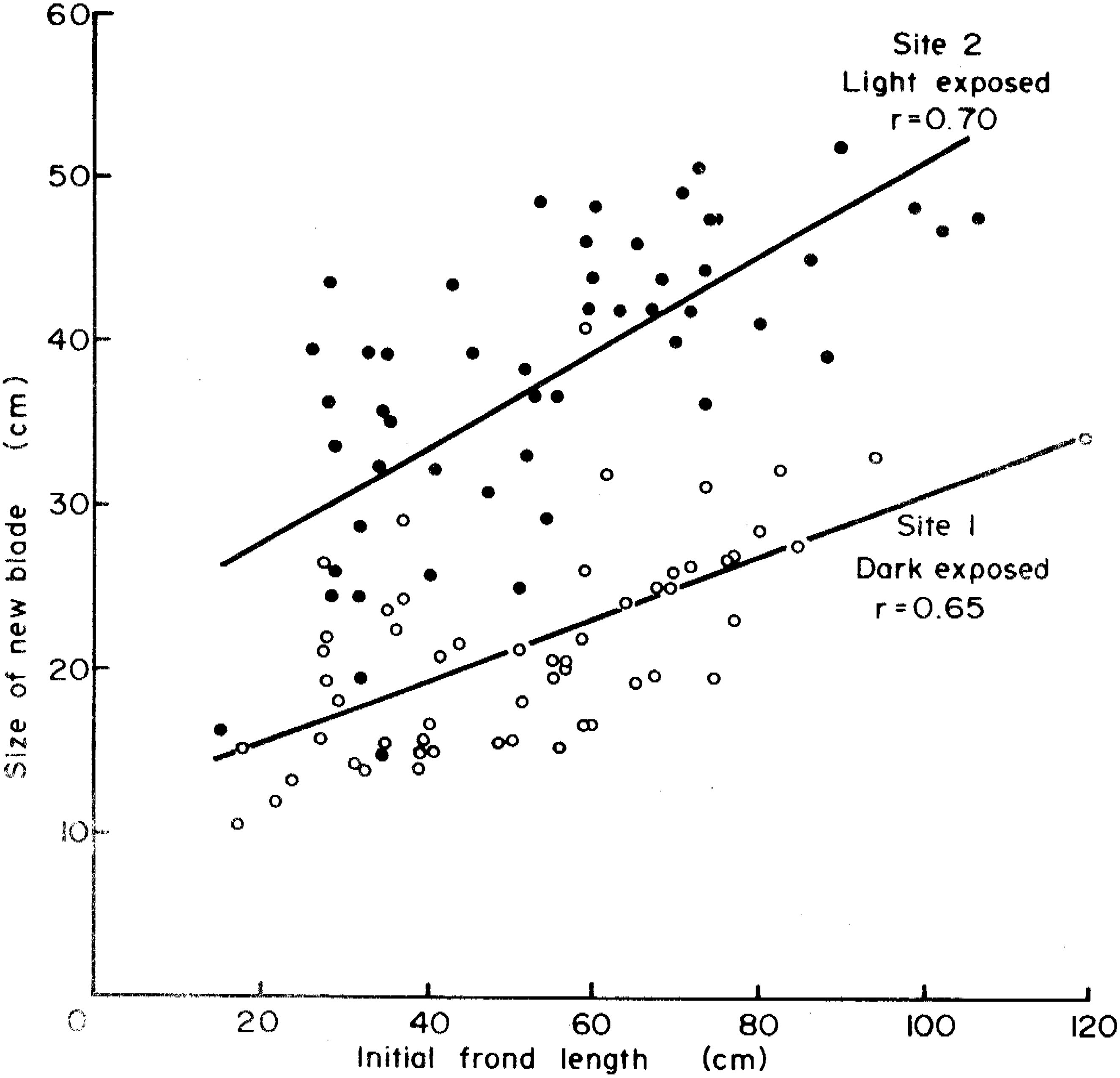
40
30
20
10
0
Length of blade (cm)
N=42
s=6.2
N=41
s=12.3
N=32
s=8.0
N=34
s=9.5
N=11
s=10.0
N=11
s=12.6
1978-1979
1977-1978
1976-1977

reserves, and the size of the new blade produced during the winter growth period. Such a relationship appears to exist for L. solidungula (Fig. 1.5). The length of the new blade in plants measured in May was directly proportional to the initial frond length (the total frond length minus new blade growth) (linear regression analysis, $P < .0005$).

The significance of food storage in growth of L. solidungula is reflected in its ability to produce a new blade and complete over 90% of its annual linear growth in darkness during a nine month winter period. The apparent dependence of this plant on stored food reserves, accumulated via a photosynthetic pathway, indicates that heterotrophy is not the determining factor in growth. We have also found that, if translocation of these reserves is prevented by making a transverse slit in the basal blade prior to the onset of winter growth, a new basal blade does not form and no linear growth occurs.

The linear increase that occurs in L. solidungula plants exposed to light in winter and lack of linear growth in all plants during the ice-free summer months, may be explained by decreased availability of nutrients in summer. In the north Atlantic, nitrate is an important factor in the seasonal growth of L. longicruris, and seeding these plants with $NaNO_3$ during the summer resulted in an increased linear growth, comparable to spring rates (10). In the Beaufort Sea, nitrate concentration is low during the summer following the spring phytoplankton bloom but steadily increases as winter approaches (11). In three other species of Laminaria in the north Atlantic, one of which is present in the Stefansson Sound kelp community, dry weight of the frond increases from a minimum in March to a maximum in October as does the content of two storage products, mannitol and laminarin (12). Thus L. solidungula may photosynthesize and build a carbohydrate reserve in the summer for winter growth when light is limited but nitrate is available. At that time linear growth in the new blade may be supplemented by spring photosynthesis, but growth is primarily a function of the amount of carbohydrate stored in the old frond and must be dependent on an effective translocation system. Current field studies, focused on L. solidungula should provide a better knowledge and understandin of the strategy employed by algae that flourish in an arctic environment.

Figure 1.5. The relationship of initial frond length (prior to winter growth) to new blade length in _L. solidungula_ plants exposed to light (site 2) and to continuous darkness (site 1). Measurements were collected in May, 1979.


Site 2
Light exposed
r=0.70
Site 1
Dark exposed
r=0.65
Size of new blade (cm)
Initial frond length (cm)
60
50
40
30
20
10
0
20
40
60
80
100
120

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Physical Processes: Ice and Seawater

The phenomenon of turbid (slush) ice, first reported by divers at DS-11 in November, 1978 (Reimnitz and Dunton, 1979) occurred again in the 1979-80 winter in Stefansson Sound. Although extensive in distribution, the thickness of the turbid ice in the winter of 1979-80 was much reduced from the previous year. By February, 1980 most of the turbid ice appeared to have been incorporated into the solid, one meter thick ice canopy. Cores taken in that month show a layer of dirty ice, 10 to 25 cm thick sandwiched between two clean ice layers, the top one about 20 cm thick. Underwater, the lower surface of the ice appeared smooth except for occasional stalactites, and complete darkness prevailed.

However there was considerable variety in ice character at DS-11. In some areas, the ice was completely free of sediment allowing light to penetrate, and flashlights were not needed here. Thirty meters west of the DS-11 pinger, a huge, impressive underwater pressure ridge of turbid ice was located. This ridge was in the approximate position from which Dr. Larson's tripod had been retrieved during the previous November. A large, triangular-shaped depression free of turbid ice permitted light penetration and is believed to be from the hole cut to recover the tripod.

This underwater pressure ridge extended to within 2 m of the seafloor and was aligned in a north-south direction. The turbid ice in the ridge was of variable thickness, ranging between 5 and 50 cm, and underlain by hard ice. The impression of the divers was that the ridge consisted of ice blocks 10 to 30 cm thick piled obliquely to one another. Surface roughness on top of the ice in this same region was also considerable, up to 60 or 70 cm. It is not known how much of this roughness can be attributed to ice blocks that were removed from the tripod hole in November.

The ice crystals associated with the turbid ice layer were among the largest we have seen underwater. Many averaged 5-6 cm in diameter; some were larger. They do not appear to be oriented in any consistent direction or pattern. Numerous organisms were found attached and living among these platelets. They included amphipods and a polychaete worm and are discussed in a separate section.

A second ice phenomenon was observed in May, 1979 when working under a clean ice canopy. At this site, 200 m northwest of DS-11, we encountered large, dinner plate sized ice crystals. These ice platelets were very thin, easily broken up and appeared in large masses to small isolated patches under the ice. They formed large sheets under the hard ice and also formed rapidly where the divers were placing pitons and cores for phytoplankton experiments. These large ice platelets were arranged randomly, forming a dense and overlapping matrix of crystals. One diver reported that the bottom layer of this ice consisted of flat crystals parallel to the seafloor at one place. Martin and Kauffman (1974) have induced identical crystal growth in laboratory experiments under certain hydrographic conditions. These involve a fresh water layer at a temperature of 0°C floating over seawater at its freezing point and under an ice layer. These conditions were present at this site in Stefansson Sound.

A prominent underwater feature noted by divers at several locations was the distinct separation of two layers of water: a clear, highly saline, bottom layer and a 'blurry', low salinity top layer. The top layer, which contacted the ice, was between 100 and 50 cm thick, varying from day to day over the duration of our diving program. Usually the boundary between the two layers was distinct, other times it was not. From below this boundary the water above appeared as a cloudy layer; within the top layer it was difficult to see anything but blurry images unless the subject was examined at close range.

A tabulation of salinities and temperatures recorded at one site on May 20 to document this halocline and record the temperatures and salinities in the ice platelet layer follows:

Location	Salinity	Temperature
Bottom (5.5 m)	29.5	-2.0
Under Ice (hard)	15.4	-1.1
Ice Platelets	15.4	-1.2
Under Ice (hard)	15.5	-1.3
Halocline Contact (2.5 m)	25.5	-1.3

A summary of the physical data collected at DS-11 in Stefansson Sound is presented in Table 1.2. Winter currents were observed to be primarily northwesterly. Visibility appeared to be directly related to sediment accumulations, in both summer and winter months. The highest sedimentation

Table 1.2. Summary of the physical data collected at DS-11 since November, 1978. Values shown indicate the mean of several measurements taken on the seafloor.

Physical Parameter	Nov. 78	Mar. 79	May 79	July 79	Nov. 79	Feb. 80
Temperature (°C)	-2	-2	-2	-1	-2	-2
Salinity (ppt)	29.8	33.5	31.5	29.9	35.8	34.6
Visibility (m)	2	10+	10+	3-4	2	10+
[1]Siltation (mm)	3-5	1-2	< 1	1-2	2-3	< 1
[2]Currents	none	ESE WSW	N	NW SW E	none	NW N SW SW

---

[1] Values shown are accumulations between sampling periods, starting from August, 1978.

[2] Directions shown are all those reported by divers during a sampling period.

appeared to occur during ice break-up in June/July and during freeze-up in September/October.

Turbid Ice Organisms

During the November, 1978 and March, 1979 field seasons we observed an assemblage of mobile organisms clinging to the soft, turbid underice surface at DS-11. This was again observed in our second year of winter study during November, 1979 and February, 1980. Several key species were found here in abundance, including the arctic cod, a polychaete worm, and several species of amphipods. Many of the invertebrates were in reproductive condition. The following is a discussion of the fauna which occurs in this soft ice canopy.

Samples of the turbid ice and its associated fauna were taken on March 12, 1979. Table 1.3 lists the species found in the samples with indications of their reproductive state and size range.

The large scaleworm Antinoella sarsi and the amphipod Gammaracanthus loricatus were the dominant invertebrate animals collected. Four other amphipod species also were found in small numbers. Many arctic cod were seen. Many of the invertebrates were gravid, but a larger fraction was not. The G. loricatus in a reproductive state were larger (3-5 cm) than their non-gravid counterparts (2-4 cm).

During the ice free season these organisms inhabit the basal portion of the water column or are benthic dwellers. Initially we hypothesized that the animals were ingesting some organic materials present in the dirty ice. But microscopic analysis of the sediments in the turbid ice have revealed these sediments to be primarily inorganic. The digestive tracts of the amphipods and worms were examined for food materials, and they appeared empty.

All of the invertebrate animals contained profuse amounts of yellow oil. The large droplets were visible with the naked eye through the organisms' external covering. It may be this large oil fraction that caused the animals to initially rise to the underice surface and enabled them to walk around and sit on the ice, defying gravity. MacGinitie (1955) refered to the storage of oil in shrimp, copepods and amphipods in the Arctic. He suggested that this stored oil is used by the animal in the winter as a

Table 1.3. An annotated list of the organisms collected under the turbid ice canopy in November, 1978 and March, 1979.

Organism	Number in Sample	Reproductive State	Length Range (cm)
INVERTEBRATA			
POLYCHAETA			
Antinoella sarsi	numerous	gravid	3-7
AMPHIPODA			
Gammaracanthus loricatus	14	4-gravid 10-not gravid	3-5 2-4
Gammaraus setosus	2		
Melita formosa	1	gravid	
Onisimus litoralis	2		
Weyprechtia pinguis	1		
VERTEBRATA			
OSTEICHTHYES			
Boreogadus saida	numerous		

food reserve or as an energy source in the production of eggs and sperm. It is plausible that these underice organisms are also using their oil supply for those purposes, as their digestive tracts were empty and some individuals were gravid.

At this time we do not understand the complete significance of the soft ice canopy with respect to the life cycle of these invertebrate species. Arctic cod (Boreogadus saida) are also commonly found in association with this soft ice. They may be present due to the abundance of amphipods, an important food source. Further study of the fauna and sediments that characterize the turbid ice is planned.

Recolonization of Denuded Boulders

In an effort to observe processes of recolonization, 0.05^2 plots were scraped clean of encrusting fauna and flora on fourteen boulders at DS-11. Three boulders were denuded in August, 1978, two in November, 1978, six in March, 1979, and three in May, 1979 (Table 1.4). Photography along with observations made by the divers were used in monitoring the process of recolonization in the denuded plots. Here we present some preliminary observations on the experiment.

The rocks denuded in August, 1978, were analyzed seven months later in March, 1979. During this period a silt layer developed on the scraped plots and small scattered hydroids were visible on all three replicates. In two of the quadrats a small bladed red alga was also seen. A month later in May, 1979, the plots were again examined, but appeared similar to that seen in March. In July, 1979, almost a year after the initial scraping, more observations were made. The denuded plots had very heavy silt covers. It appeared that the scattered hydroids had stabilized a layer of sediment from which their highest parts barely poked out. Animal tracks were seen on two of the plots.

Two boulders were scraped in November, 1978. By March, 1979, one quadrat showed scattered hydroids and the other appeared bare. In May, the silt cover was greater, but there were no other observed changes. In July, 1979, the boulders had a very heavy silt cover. One plot (#5) continued to be void of attached life forms. On the second plot (#4) tips of hydroids were seen at the surface of the heavy silt layer.

Table 1.4. Pattern of recolonization of .05 m^2 plots on boulders denuded at different times at DS-11.

Quadrat Number	Date Last Scraped	March, 1979	May, 1979	July, 1979
1	Aug., 78	Even, medium silt cover. Scattered hydroids. Small bladed red alga.	Even, medium silt cover. Few hydroids. Small bladed red alga.	Heavy silt cover. Very few hydroids. Animal tracks.
2	Aug., 78	Even, medium silt cover. Scattered hydroids. Small bladed red alga.	Even, medium silt cover. Sparse, scattered hydroids.	Very heavy silt cover. A few hydroids. Animal tracks.
3	Aug., 78	Even, medium silt cover. Scattered, small hydroids.	Light silt cover. Numerous small hydroids concentrated in one area.	Heavy silt cover. Scattered small hydroids.
4	Nov., 78	Silt only in rock cracks. Scattered hydroids.	Even, medium silt cover. Many small hydroids.	Heavy silt cover. Many small hydroids poking out from silt.
5	Nov., 78	Patchy silt cover. No recolonization.	Even, medium silt cover. No recolonization. Animal tracks.	Heavy, even silt cover. No recolonization.
6	Mar., 79		Even, light silt cover. Few small hydroids.	Heavy, even silt cover. Scattered small hydroids. One mysid.
7	Mar., 79		Silt only in rock cracks. Few small hydroids.	Even, medium silt cover. Scattered hydroids. Animal tracks.
8	Mar., 79		Even, light silt cover. No recolonization. One amphipod.	Heavy, even silt cover. No recolonization.
9	Mar., 79		Even, light silt cover. No recolonization. One amphipod.	Uneven, medium silt cover. One mysid.

Table 1.4, continued

Quadrat Number	Date Last Scraped	March, 1979	May, 1979	July, 1979
10	Mar., 79		Even, light silt cover. No recolonization. One amphipod.	Even, heavy silt cover. No recolonization.
11	Mar., 79		Even, light silt cover. No recolonization One polychaete.	Even, heavy silt cover. No recolonization
12	May, 79			Even, medium silt cover. A few scattered hydroids. Two mysids.
13	May, 79			Even, medium silt cover. No recolonization.
14	May, 79			Even, medium silt cover. Some scattered hydroids.

Six quadrats were scraped in March, 1979, and examined two months later. Two of these were lightly recolonized with small hydroids. Amphipods, polychaetes and animal tracks were common on many of the scraped plots. In May the silt cover was even, and very light. By July, silt had accumulated, but no additional recolonization had occured.

In May, 1979, three more boulders were scraped. By July, two of the scraped areas showed a few scattered hydroids, and the third remained bare except for a medium silt cover.

Our sampling at DS-11 has shown the most common hydroid, Sertularia cupressoides to be reproductive in the summer months. There are, however, several other species of thecate hydroids that live in this area. Not all the quadrats showed similar trends during each time period. Most often, part of the plots showed recolonization and part remained bare.

The seasonal fluctuation in silt accumulation on scraped surfaces may be the determining factor in the recolonization process. In March most of the boulders had a patchy but medium (≈ 2 mm) cover of silt. In May the silt layer was medium to light (< 1 mm), and in July it was very heavy (3-4 mm). This heavy silt layer covered some of the hydroids completely and left only the tops of the longer ones exposed. It is possible that under these conditions the organisms were smothered. Subsequent observations in March, 1980 showed a slight reduction in the number of hydroids in the plots as compared to the previous year.

The slow rate of recolonization on denuded rock surfaces may be the results of both heavy siltation and grazing by epibenthic invertebrates. In striving for a more precise picture of recolonization, we have introduced a series of plexiglass plates which can be lifted from the water and studied under a microscope. This experiment began in March, 1980 and will continue through the year.

RESULTS AND DISCUSSION II: QUANTITATIVE STUDIES

Biomass of the Epilithic Fauna and Flora: Preliminary Results of 0.05 m^2 and 0.25 m^2 Scrapes

In March, 1979, a 0.25 m^2 area was scraped from each of four large boulders. These boulders were chosen for their predominant cover of brown algae. The wet weight and density (when possible) of organisms in these scrapes are presented in Table 1.5. The brown algae had the highest mean biomass of 2190.33 gm^{-2}. The total mean biomass of the invertebrates was 10.691 gm^{-2}, with the red algae having a mean biomass of 8.49 gm^{-2}. The faunal understory was composed of sponges, hydrozoans, soft corals, polychaetes, amphipods and a variety of bryozoans. We found the hydroid *Sertularia cupressoides* to support a tiny complex community of its own. Amongst its stems and branches are found sponges, worms, bivalves, forams and many bryozoans and egg cases.

In July, 1979, two 0.25 m^2 and four 0.05 m^2 scrapes were taken from boulders with predominently invertebrate covers. In Table 1.6 the biomass of the major groups found in these scrapes is shown along with the biomass from the kelp dominated scrapes taken in March, 1979. A much greater diversity of species is seen in the invertebrate dominated scrapes, and the faunal biomass is considerably greater. Sponges, hydroids, chitons, polychaetes, bryozoans and red algae are the most prolific community members. Many of the bryozoans grow in small patches on the blades and filaments of the red algae and wrapped around hydroids. These bryozoans were separated from the bulk of the host organism, but in some cases small pieces of the host were still attached to the bryozoan. This causes some weighing error in the group Cheilostomata, but is necessary to prevent abliteration of the sampled species.

This data shows that the boulders do not have a uniform cover. Some are dominated by brown algae, others show combinations of kelp, red algae and invertebrates, and some are simply covered by epilithic fauna. There appears to be competition for space on these hard substrates. The boulders are densely covered with organisms, many of which have other species living on them.

The variability in this community indicates the need for a more intense quantitative sampling effort to assess the richness of the flora and

Table 1.5. Mean density and biomass of fauna and flora from .25 m^2 scrapes dominated by brown algae. Samples were collected in March, 1979 at DS-11. N = 4.

ORGANISM	N/m^2	g/m^2	COMMENTS
INVERTEBRATES			
FORAMINIFERA	50	0.002	
PORIFERA			
CALCAREA			
Unknown species	1	0.004	
DEMOSPONGIAE			
Halichondria panicea	-	1.407	Attached to Laminaria blades and Sertularia.
Haliclona gracilis	-	0.015	Scraped off of rock surface.
Phakettia cribrosa	4	0.531	Juveniles. Attached to Sertularia.
CNIDARIA			
HYDROZOA			
Abietinaria abietina	-	0.001	
Campanularia sp.	-	0.001	Wound up stem of Sertularia.
Sertularia cupressoides	-	1.551	
Thuiaria sp.	-	0.151	
ANTHOZOA			
ALCYONARIA			
Eunephtyes rubiformis	1	0.036	Juveniles.
Eunephtyes fruticosa	1	1.574	Juveniles.
NEMATODA	1	0.001	
ANNELIDA			
POLYCHAETA			
Cirratulus cirratus	1	0.029	
Nereis zonata	1	0.005	
Spirorbis sp.	8	0.008	
Polychaete fragments	-	0.003	
MOLLUSCA			
POLYPLACOPHORA			
Amicula vestita	2	3.869	

Table 1.5, continued

GASTROPOD EGGS	1	0.002	Transparent half-sphere. 7 mm
ARTHROPODA			
CRUSTACEA			
AMPHIPODA			
Anonyx nugax	6	0.171	
Boeckosimus affinis	1	0.012	
Boeckosimus plautus	19	0.153	
Calliopiidae	1	0.002	
Halirages sp.	8	0.011	
BRYOZOA			
CTENOSTOMATA			
Alcyonidium mytili	-	0.725	
CHEILOSTOMATA			
Callopora lineata	-	0.009	This group of bryozoans were all found encrusting Sertularia.
Cauloramphus intermedius	-	0.010	
Electra crustulenta	-	0.004	
Eucratea loricata	-	0.199	
Hippothoa hyalina	-	0.018	
Membraniporidae	-	0.008	
ECHINODERMATA			
ASTEROIDEA			
Unknown species	-	0.181	Juveniles.
INVERTEBRATE TOTAL		10.691	
ALGAE			
PHAEOPHYTA	-	579.478	
RHODOPHYTA	-	2.123	

Table 1.6. A comparison of the mean biomass of organisms collected in scrapes at DS-11. The boulders scraped in March were dominated by brown algae. The July scrapes were from boulders with a predominant invertebrate and red algae cover.

ORGANISM	March, 1979 N=4 (.25m^2) g/m^2	July, 1979 N=6 $\left[\begin{matrix}2\ (.25m^2)\\4\ (.05m^2)\end{matrix}\right]$ g/m^2
INVERTEBRATES		
FORAMINIFERA	0.002	0.232
PORIFERA	1.957	7.851
CNIDARIA		
HYDROZOA	1.704	12.038
SCYPHOZOA		0.012
ANTHOZOA	1.610	4.866
NEMERTEA		0.027
NEMATODA	0.001	0.018
ANNELIDA		
POLYCHAETA	0.045	7.184
MOLLUSCA		
GASTROPODA		0.527
POLYPLACOPHORA	3.869	16.242
PELECYPODA		0.284
NUDIBRANCHIA		0.011
ARTHROPODA		
HALACARIDAE		0.012
CRUSTACEA		
OSTRACODA		0.002
CIRRIPEDIA		0.002
COPEPODA		0.011
CUMACEA		0.012
ISOPODA		0.004
AMPHIPODA	0.349	4.296

Table 1.6, continued

BRYOZOA		
CTENOSTOMATA	0.725	5.895
CHEILOSTOMATA	0.248	38.824
ECHINODERMATA		
ASTEROIDAE	0.181	0.142
UROCHORDATA		
ASCIDIACEA		4.471
ALGAE		
CHLOROPHYTA		0.073
PHAEOPHYTA	2190.33	2.361
RHODOPHYTA	8.49	206.801

fauna. Our ultimate goal is to develop a sufficient data base and knowledge of the epilithic communities to permit reasonable estimates of biomass to be made from photographs.

Infaunal Biota

Since March, 1979, quanitative cores of the benthos have been taken during each field season at DS-11. From these samples we have learned the identities of many infaunal inhabitants and their abundance in the community. We also discovered that the group of animals living in the open areas of seafloor between boulders is quite different from the assemblage found under boulders.

Table 1.7 presents a list of animals collected in cores taken in May and July, 1979, from under boulders, and in March and July, 1979 from between boulders. A striking difference is seen in the polychaete worms. Thirty-four species were found in samples from under boulders, as compared to sixteen species from between boulders. The molluscs also showed a higher diversity under boulders with ten species, while only four species were found in cores taken between boulders. The biomass of these two groups was also higher under the boulders.

The amphipod group was fairly diverse in samples taken both between and under boulders. They are not however, true inhabitants of the sediment. Many amphipod species are known to burrow into the top layers of the substrate, but are also capable of swimming into the water column. It is difficult to say whether members of this group were collected in the sediments or in the near-bottom water column at the time of sampling. It's likely that many of these animals were at the water-substrate interface and inadvertently sucked up in the airlift with the core samples.

Bryozoans of both upright and encrusting varieties were found in the under boulder cores. These are epibenthic organisms and do not live in the sediment. The encrusting varieties were found on pieces of the hydroid Sertularia, on small pebbles and attached to dead pieces of Lithothamnium, an encrusting alga. We are not sure why this group in so well represented in the cores. One possible explanation is that organic residues were swept from the non-boulder areas and collected around and under the boulders forming a surface layer. This layer would include organisms

Table 1.7 . Mean density and biomass of infaunal species collected in four .01 m^2 cores from under boulders and between boulders at DS-11.

ORGANISM	Cores from Under Boulders				Cores from Between Boulders			
	May, 1979		July, 1979		March, 1979		July, 1979	
	N/m^2	g/m^2	N/m^2	g/m^2	N/m^2	g/m^2	N/m^2	g/m^2
FORAMINIFERA			200	0.425	300	0.375	50	0.050
PORIFERA								
Choanites lutkenii					-	0.550		
Halichondria panicea					-	0.025		
Haliclona gracilis	-	0.100						
Phakettia cribrosa								
CNIDARIA								
THECATE HYDROZOA								
Campanularia sp.	-	0.025						
Sertularia cupressoides	-	1.500						
ANTHOZOA								
Halcampa decemtentaculata			25	0.025				
NEMERTEA	75	0.225	50	0.175	75	0.050	25	0.150
NEMATODA	1550	0.275	650	0.100	500	0.100	700	0.200
ANNELIDA								
POLYCHAETA								
Allia sp.	150	0.425	25	0.100				
Ampharete vega	450	0.300	100	0.050			150	0.250
Ampharete sp.							25	0.025
Brada villosa	100	1.375	50	0.475				
Capitella capitata	2825	3.325	475	0.650	100	0.050	25	0.025
Capitellidae fragments			0	0.125			0	0.025
Chaetozone setosa	75	0.075						
Chone duneri	225	0.150	125	0.075				
Cirratulus cirratus	100	0.093	50	0.850	25	0.075		
Clymenura polaris	50	0.075	25	0.050				
Eteone longa			25	0.075				

Table 1.7, continued

ORGANISM	Cores from Under Boulders				Cores from Between Boulders			
	May, 1979		July, 1979		March, 1979		July, 1979	
	N/m^2	g/m^2	N/m^2	g/m^2	N/m^2	g/m^2	N/m^2	g/m^2
Exogone dispar	750	0.175	125	0.050	75	0.050		
Exogone naidina	1575	0.200	750	0.125	525	0.125	175	0.125
Exogone sp.							25	0.025
Haploscoloplos elongata	325	30.950			25	0.475		
Lumbrineris fragilis	550	0.875	150	0.200	100	0.225	125	0.125
Maldanidae fragments	75	0.050			25	0.025	50	0.075
Nereimyra sp.	125	0.050						
Nereis zonata	50	2.750						
Orbiniidae fragments			0	0.975				
Parahesione sp. (?)			50	0.050				
Pholoe minuta	100	0.900	25	0.075				
Pionosyllis sp.	75	0.075						
Pista cristata	300	0.538			150	0.225		
Polycirrus medusa	475	18.225						
Prionospio cirrifera			25	0.025				
Pygospio elegans	100	0.025						
Polychaete fragments			0	1.250	125	0.125		
Sabellidae			25	0.025				
Shistomeringo sp.	450	0.600	125	0.100				
Sphaerosyllis erinaceus			25	0.025				
Spio filicornis	150	0.100	125	0.050				
Spionidae fragments	100	0.025			25	0.025	25	0.025
Spirorbis sp.					150	0.050		
Syllidae			25	0.025				
Terebellides stroemi	250	2.000	425	1.550			100	1.050
Tharyx sp.	375	0.650	100	0.125	25	0.025		
OLIGOCHAETA	75	0.075						
MOLLUSCA								
GASTROPODA								
PROSOBRANCHIA								
Margarites vorticifera	25	1.950						

Table 1.7, continued

	Cores from Under Boulders				Cores from Between Boulders			
ORGANISM	May, 1979		July, 1979		March, 1979		July, 1979	
	N/m^2	g/m^2	N/m^2	g/m^2	N/m^2	g/m^2	N/m^2	g/m^2
Oenopota sp.	75	1.650	25	0.075	25	0.025	75	0.650
Polinices pallidus	25	1.200						
Unknown (juvenile)					25	0.025		
POLYPLACOPHORA								
Ischnochiton albus	25	0.650						
PELECYPODA								
Astarte borealis	125	29.100						
Astarte montagui					25	0.075	75	0.050
Boreocola vadosa	25	0.025						
Macoma alaskensis	75	2.050						
Macoma loveni			25	0.450	25	5.975		
Macoma sp.	75	0.400						
Portlandia arctica			50	0.425				
ARTHROPODA								
CRUSTACEA								
OSTRACODA			50	0.050				
COPEPODA	375	0.150	175	0.100	600	0.175		
CUMACEA								
Brachydiastylis resima	275	0.175	400	0.850	200	0.350	125	0.175
Diastylis sp.			25	0.025				
Leucon nasicoides	25	0.025						
Leucon sp.			50	0.025				
TANAIDACEA								
Leptognathia gracilis	50	0.050	275	0.075	25	0.025	100	0.075
ISOPODA								
Unknown sp.			25	0.025				
AMPHIPODA								
Aceroides latipes			25	0.050				
Anonyx nugax	25	0.375			25	0.100		
Boeckosimus plautus					125	0.500		
Byblis gaimardi					25	0.350		

Table 1.7, continued

ORGANISM	Cores from Under Boulders				Cores from Between Boulders			
	May, 1979		July, 1979		March, 1979		July, 1979	
	N/m^2	g/m^2	N/m^2	g/m^2	N/m^2	g/m^2	N/m^2	g/m^2
Halirages sp.	100	0.250	50	0.050	25	0.050	25	0.025
Monoculodes packardi					25	0.050		
Monoculodes sp.	75	0.325					25	0.025
Oedicerotidae					25	0.050		
Pareodiceros lynceus	25	2.850			25	1.875		
Pareodiceros propinquis	25	0.025						
Pleusymtes sp.					25	0.025		
Rhachotropis inflata	50	0.125			25	0.050		
Rozinante fragilis	25	0.300						
Stenothoidae	25	0.025						
Amphipods fragment	0	0.025					0	0.050
SIPUNCULA							25	0.025
PRIAPULIDA								
Priapulis caudatus			25	6.125	25	2.000		
BRYOZOA								
Alcyonidium gelatinosum	-	0.675						
Alcyonidium mytili	-	0.650						
Alcyonidium sp.	-	5.550						
Cauloramphus intermedius	-	0.325	-	0.225				
Electra crustulenta	-	1.050	-	0.325				
Eucratea loricata	-	2.300						
Flustrella fragments			-	4.450				
Flustrella sp.			-	0.675				
Hippothoa hylina	-	1.725	-	0.600				
Porella saccata			-	2.075				
Rhamphostomella sp.	-	0.650						
Umbonula arctica			-	0.050				
Unknown species	-	0.025	-	0.075				
ECHINODERMATA								
ASTEROIDEA								
5 rayed juveniles							25	0.775

naturally sloughed off from the boulders. Since bryozoans tend to grow on the other organisms, they also move when the host organism detaches or dies.

One important observation made here concerns the large number of bryozoans attached to pieces of dead Lithothamnium, which is a predominant organism in this community. We have often wondered what limits its total takeover on rock surfaces. It may be that the growth of the bryozoan over this alga eventually kills it, causing detachment of both species and exposing a new substrate for recolonization.

We believe that substrate composition may play an important role with respect to the differences in the infaunal assemblages observed under boulders and between boulders. It appears that the sediment grains under rocks are large and loose, while the bottom between rocks is stiff fine grained clay. Sediment samples have been taken and are presently being analyzed.

SUMMARY AND CONCLUSIONS

The Stefansson Sound kelp community is dominated by an arctic kelp, Laminaria solidungula, which is capable of completing over 90 per cent of its annual linear growth in complete darkness under a turbid ice canopy. Linear growth increases by a factor of 50 per cent in plants exposed to light under a clean ice canopy. The ability of these plants to grow in Stefansson Sound, regardless of winter light conditions, is noteworthy. Ice algae do not occur under turbid ice and thus little contribution is made by these micro-algae with respect to primary productivity in these areas. But the macro algae are capable of photosynthesis during the summer months despite low nutrient concentrations in the seawater. The significance of primary productivity in these benthic algae with respect to their total carbon imput into the arctic ecosystem is not yet known.

Several key invertebrates and one important species of fish inh[illegible] turbid ice canopy through the winter period. These include several species of amphipods, a polychaete worm and the arctic cod. Many of the animals are in reproductive condition and are seldom found under clean congelation ice or on the bottom in this area. It is unknown what role the turbid ice canopy plays in the life cycle of these invertebrates. The large amount of oil within the animals and their empty guts indicate they are not feeding, but are living and producing gametes from stored food reserves. The turbid ice may act as a mechanism of gamete dispersal for these animals.

A pattern has emerged which shows sedimentation to be highest during the fall and late spring/early summer months. The sediments cover organisms colonizing bare substrata and may slow the recolonization process by smothering organisms or preventing settlement of new species. Quantitative studies have revealed a rich faunal assemblage on rock surfaces which may have taken years to establish based on our current observations of a slow recolonization rate. Biological interactions are likely to occur between established organisms in the form of competition for limited rock space.

On the seafloor, cores taken under boulders show a greater biomass and diversity of biota than do cores taken between rocks. This may be attributed to differences in grain size and sediment compaction between the two areas. Sediments under rocks are softer and less consolidated than between rocks. In addition sloughed off material from rock surfaces accumulate around the boulders and cobbles contributing organic materials to the sediments found there.

In summary, winter studies have enabled us to identify some of the physical events that play a major role in the biological environment of Stefansson Sound. *In situ* studies and quantitative analyses of the epilithic and seafloor biota have also shown that biological processes are slow and the distribution of populations is highly variable. Further studies are needed to provide a better understanding of population structure and the distribution of organisms before environmental decisions are made with respect to oil and gas development.

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Appendix 1: Organisms collected and identified from DS-11 since February, 1979 that were not reported in our 1979 annual report.

- PORIFERA
  - CALCAREA
    - Unidentified species
- CNIDARIA
  - HYDROZOA
    - Campanularia sp.
  - ANTHOZOA
    - ACTINARIA
      - Halcampa decemtentaculata
    - ALCYONARIA
      - Eunephtyes fruticosa
- ANNELIDA
  - POLYCHAETA
    - Allia sp.
    - Ampharete vega
    - Brada villosa
    - Capitella capitata
    - Chaetozone setosa
    - Chone duneri
    - Clymenura polaris
    - Eteone longa
    - Exogone dispar
    - Exogone naidina
    - Haploscoloplos elongata
    - Lumbrineris fragilis
    - Nereimyra sp.
    - Parahesione sp. (?)
    - Pholoe minuta
    - Pionosyllis sp.
    - Pista cristata
    - Polycirrus medusa
    - Prionospio cirrifera
    - Pygospio elegans
    - Shistomeringo sp.
    - Sphaerosyllis erinaceus
    - Spio filicornis
    - Terebellides stroemi
    - Tharyx sp.
  - OLIGOCHAETA
- MOLLUSCA
  - GASTROPODA
    - Polinices pallidus
  - NUDIBRANCHIA
    - Cadlina spp.
    - Dendronotus sp.
    - Dorididae
    - Eubranchus sp.
  - PELECYPODA
    - Boreocola vadosa
    - Macoma alaskensis
    - Macoma loveni
    - Portlandia arctica
- ARTHROPODA
  - CRUSTACEA
    - OSTRACODA
    - COPEPODA
    - CUMACEA
      - Brachydiastylis resima
      - Diastylis sp.
      - Leucon nasicoides
      - Leucon sp.
    - TANAIDACEA
      - Leptognathia gracilis

ISOPODA

- Unknown species

AMPHIPODA

- Aceroides latipes
- Anonyx nugax
- Boeckosimus affinis
- Boeckosimus plautus
- Byblis gaimardi
- Monoculodes packardi
- Pareodiceros lynceus
- Pareodiceros propinquis
- Pleusymtes sp.
- Rhachotropis inflata
- Rozinante fragilis

SIPUNCULA

- Unidentified species

PRIAPULIDA

- Priapulis caudatus

BRYOZOA

- Alcyonidium mytili
- Electra crustulenta
- Porella saccata
- Rhamphostomella

Physiological Responses of Arctic Epibenthic Invertebrates to Winter Stresses and Exposure to Prudhoe Bay Crude Oil Dispersions

D. E. Schneider

INTRODUCTION

Studies of the physiological responses of arctic marine invertebrates to environmental stresses are rare. Those that do exist, for example Percy (1975) and Busdosh and Atlas (1975), have mainly dealt with conditions relevant to the ice free summer season. Almost nothing is known about the response of these animals to winter environmental stresses.

One of the most serious environmental challenges faced by arctic shallow-water animals is the seasonal variation in salinity. During formation of sea ice, ions are excluded from the crystalline structure. A high proportion of these ions leave the ice as a brine solution, and since this is more dense than the surrounding seawater it tends to sink. In lagoon systems or other bodies of water with restricted circulation, the brine collects in the deeper pockets and elevates the salinity. The onset of hypersaline conditions is gradual and maximum salinities coincide with maximum ice thickness in late April or May. Values of 38 - 40‰ are routinely seen and in the deepest parts of Simpson Lagoon and certain areas in Elson Lagoon salinities of 55 - 60‰ are not uncommon (Schell, 1975). In shallow areas where the ice nearly freezes to the bottom, Schell (1975) has observed extremely high salinities ranging from 126 to 182‰. During the period of ice melt and breakup extremely low salinities, approaching freshwater, are seen in shallow waters. The less dense melt water tends to layer over the higher salinity deeper water producing a vertical salinity stratification. Stratified conditions persist during the early ice free season until wind and currents eventually mix the water column. The seasonal range of salinities in the arctic shallow-water greatly exceeds that seen in most temperate zone areas and provides a serious physiological challenge for those organisms inhabiting this region.

Other environmental factors faced by arctic animals during the winter include low temperatures at or slightly below the freezing point of seawater and extremely low light levels. Animals swimming in the water column may be exposed to supercooled or ice crystal laden seawater and may therefore run the risk of freezing. However, marine invertebrates usually remain isosmotic or slightly hyperosmotic to the ambient seawater (Potts and Parry, 1964) and are not likely to freeze before the surrounding seawater. Antarctic invertebrates have been reported to use hyperosmotic regulation to avoid freezing (Rakusa-Suszczewski and McWhinnie, 1976) and if this mechanism is used by arctic invertebrates, the lower winter temperatures may not present a serious threat to survival.

Another aspect of low winter temperatures is the potential depression of metabolic rates and activity levels. Poikilotherms are known to have the capacity to compensate for low habitat temperatures by elevating their metabolic rates (Vernberg and Vernberg, 1972) and arctic animals have been shown to have metabolic rates that are not dissimilar from those of temperate zone species at their respective habitat temperatures (Scholander et al. 1953). However, studies on the metabolism of arctic animals during the actual winter season are rare and further information is needed.

The rationale for studying the physiological responses of arctic invertebrates to winter conditions is that this information permits one to predict the habitat requirements of the species. A knowledge of tolerance ranges and sublethal physiological responses allows identification of habitat conditions that would not be favorable for survival. Although physiological adaptations are not always the primary determinants of distribution patterns, they are apt to be more significant in extreme environments such as the arctic shallow-water system. The predictive aspect of physiological studies is particularly attractive when dealing with the harsh field conditions of an arctic winter where it is often difficult to obtain an adequate number of samples in the field to determine distribution patterns. Furthermore, a knowledge of the normal physiological responses to environmental stresses provides a baseline for evaluating the effects of pollutants that may be introduced during offshore oil exploration and production phases.

Several studies have been made on the response of arctic marine invertebrates to crude oil exposure (Percy and Mullin, 1975; Busdosh and Atlas, 1977). These studies have tended to focus on conditions that occur during the ice free months and further information is needed under winter environmental conditions. Also the number of species studied so far is small and information on the crude oil sensitivity of some important food species for higher trophic levels (e.g. mysids) is lacking.

This study focuses on the tolerance and metabolic response of selected epibenthic and benthic arctic invertebrates to winter stresses, particularly hypersaline and crude oil stress, in an attempt to fill some of the data gaps mentioned above. As this project is continuing during FY'80, some of the information presented in this progress report may be expanded or refined. A final report will be prepared by the end of FY'80.

METHODS

Collection of Animals for Physiological Experiments

Amphipods were collected with amphipod traps baited with sardines. The traps were constructed from clear acrylic tubing about 10 cm diameter and 30 cm long with a cone of fiberglass window screening in each end. Traps were deployed through a 20 cm diameter hole drilled in the ice and were left on the bottom for no longer than 24 hours. Upon retrieval the traps were immediately immersed in a bucket of freshly obtained seawater and promptly returned to the laboratory. Mysids were collected by SCUBA divers using hand dip nets. The nets were provided with a long bag and a mesh funnel insert which facilitated retention of the captured mysids during the dive. Benthic species such as polychaete worms were either collected by hand during diving operations or by a Ponar grab sampler deployed through an ice hole.

The primary collecting site for the amphipods, *Anonyx nugax*, *Onisimus litoralis*, and *Tryphosella schneideri*, the mysid, *Mysis littoralis* and the isopod *Saduria entomon* was located about 400 to 500 m from shore adjacent to the Naval Arctic Research Laboratory at Barrow. The amphipod, *Boeckosimus affinis* was primarily collected in Elson Lagoon near Pt. Barrow. Specimens of *A. nugax*, *B. affinis*, *Atylus carinatus*, and *M. littoralis* were also collected at the Stefansson Sound boulder patch (Dive Site 11) to permit comparisons of animals from the lease area with those from Barrow.

Laboratory Maintenance of Animals

Animals were maintained at 32‰ salinity and -1.0°C in Percival constant temperature incubators. Photoperiod was adjusted to match the ambient photoperiod of the season when the animals were collected. The animals were stored in either polystyrene or polyethylene boxes and the seawater was not aerated. The oxygen content of the water in the containers was checked several times by Winkler titration and was found not to fall below 75% of saturation. Animals were not fed during maintenance and experimental procedures, but some food intake invariably occurred as a result of consumption of the few individuals that died during storage. Survival was excellent under these maintenance conditions and the animals appeared to be in good health for periods well exceeding one month. Generally laboratory maintenance for the animals used in experiments did not exceed two to three weeks to avoid potential problems from long-term storage.

Salinity Tolerance Experiments

Two types of salinity tolerance experiments were run on the major species studied. Acute tolerance experiments were conducted by immediate transferring animals from their normal salinity of 32‰ to a test salinity either above or below this point. Survival of the animals was monitored at least daily for 7 days. In some experiments survival was monitored at 3, 6, 12 and every 12 hours for the 7 day period. In addition, the activity level of each individual was subjectively rated at each observation period using the following scale:

4 - normal locomotor activity

3 - slightly reduced locomotion but still spontaneous or only requiring slight prodding.

2 - loss of spontaneous locomotion. Some locomotion is still possible but requires extensive prodding.

1 - greatly reduced activity, only minor appendage movement is possible and no locomotion occurs

0 - dead, no appendage movement even with extensive prodding.

Gradual tolerance experiments were conducted by transferring animals at 5‰ increments upwards or downwards from the normal salinity of 32‰ every 2 days. Survival and the activity level were rated daily. Salinity transfers continued until no survivors remained. Presumeably this procedure allows some degree of acclimation to occur as stressful salinities are gradually approached. The choice of a 2 day adjustment at each new salinity is largely arbitrary but is based upon the capabilities of some crustaceans to complete most of their osmoregulation to a new salinity in 2 to 3 days (Dehnel, 1962).

All salinity tolerance experiments were conducted at a temperature of -1.0°C and under a photoperiod that matched the ambient photoperiod of the season during which the animals were collected. Acute tolerance experiments were carried out in polyethylene freezer boxes containing about 350 ml seawater of the appropriate salinity. Salinities above that of normal seawater were prepared by adding brine obtained by freezing buckets of seawater.

Dilute salinities were obtained by dilution of fresh seawater with distilled water. Salinities were routinely measured with an A-O Goldberg optical salinometer. Five animals were placed in each box and a total of 10 animals was exposed to each test salinity in each experiment run. The gradual salinity tolerance experiments were conducted in larger polystyrene boxes containing either 1 or 2 l of seawater. A total of 20 animals was exposed to either the increasing or decreasing salinity series in each experiment run.

Double Stress - Salinity and Crude Oil Tolerance

Double stress experiments in which the animals were exposed to hypersaline conditions along with dispersions of crude oil in seawater were run for the more abundant epibenthic species. Animals were exposed to the double stress conditions in accordance with the procedures described for acute tolerance tests above with the following modifications. Crude oil dispersions were prepared daily as described below using seawater of the approporiate salinity. After equilibration of the dispersions to -1.0°C, the animals were acutely transferred to the test conditions. Survival and the subjective activity rating was monitored at 24 hour intervals for 4 days. Animals were transferred to freshly prepared oil dispersions at 24 hour intervals immediately following each observation period. The experiments were run in 32 oz. wide mouthed screw capped glass jars to facilitate cleanup procedures. Each jar contained 350 - 400 ml of the oil-seawater disperion and 5 individuals of the test species. A total of 10 individuals was exposed to each test condition in each experiment run.

Preparation of Oil - Seawater Dispersions

Preparation of oil-seawater dispersions followed the method of Percy and Mullin (1975) closely. Seawater was adjusted to the desired test salinity, filtered through a 0.45μ Millipore filter, and equilibrated to room temperature. Prudhoe Bay crude oil, which was stored in tightly capped vials in a freezer under dark conditions, was added to 500 ml aliquots of the seawater in 1000 ml erlenmeyer flasks in the following concentrations:

a) Seawater only, no oil (control)

b) 25μl of crude oil per 500 ml of seawater
c) 100μl of crude oil per 500 ml of seawater
d) 250μl of crude oil per 500 ml of seawater

The erlenmeyer flasks were stoppered and placed on a wrist-action shaker (252 oscillations per minute) for one hour. The dispersions were then immediately transferred to 500 ml glass separatory funnels and allowed to stand undisturbed for 3 hours. At the end of this period, the lower 400-450 ml of the oil-seawater dispersion was slowly drained into 32 oz. glass jars. The upper layer containing coalesced oil was discarded. The jars were then capped and transferred to an incubator set at -1.0°C and allowed to thermally equilibrate before receiving the animals. The decision to prepare the dispersions at room temperature was based upon the findings of Percy and Mullin (1975) that dispersions prepared at 20 - 22°C are more stable than those prepared at 0°C yet they both contain essentially the same average amount of oil over a 24 hour period. No attempt was made to analyze the actual oil content of these dispersions during the 1978-79 winter season, however analysis of the oil content of standard dispersion. is planned for the 1979-80 winter season.

Metabolic Rate Determinations

Metabolic rates of common epibenthic and a few benthic animals were determined as O_2 consumption with a Gilson Differential Respirometer outfitted with the all glass manometer system. Standard 15 ml respirometer flasks with one sidearm and no center well were used for most determinations. Flasks contained 5 ml of seawater of the desired salinity in the main compartment and 0.2 ml of 20% KOH in the sidearm as a CO_2 absorbent. A single individual of the test species was placed in each flask. Bath temperature was -1.0°C for all runs and the flasks were equilibrated for approximately one hour before the determinations started. Runs conducted during the winter dark period were done in total darkness. Readings were made with a small flashlight equipped with a dark red lens. Runs conducted during the spring were done in subdued light. Readings were taken at hourly intervals for a period of 7 hours. Upon completion of the run, the animals were removed, briefly rinsed in distilled water, and dried at 70°C for 48 hours. Dry body weights were determined with a Cahn model DTL electrobalance.

Interval volume changes were corrected using the average change of two blank flasks. Metabolic rates were calculated as $\mu\ell O_2$/gm hr at STP. These values were then used in a linear regression analysis of the log $\mu\ell O_2$/gm hr against dry body weight. The slope of this relationship was then used to correct all of the metabolic rates to a standard body weight that approximates the mean body weight for the population under study. In this way variations in body weight between experimental groups was eliminated as a variable. The equation used to correct the metabolic rates to a standard body weight is:

$$Z = \log \mu\ell O_2/\text{gm hr} + b\,(\log \text{standard weight} - \log \text{dry body weight})$$

where b is the slope of the linear weight regression. The Z values for the different treatment groups in an experiment were then subjected to an analysis of variance to determine significance of treatments. All calculations were performed on a Texas Instruments Model 59 programmable calculator.

Effect of Salinity and Oil-Seawater Dispersions on Metabolic Rates

The effect of salinity on metabolic rate was determined for the three most common epibenthic invertebrates, *Mysis littoralis*, *Anonyx nugax* and *Boeckosimus affinis*. All 3 species were run at 15, 20, 32, 40, 45, and 50‰. In addition *M. littoralis* was run at 10‰ and *B. affinis* was run at 5, 10 and 55‰. The animals were acclimated to the test salinities for 6 days before they were run. All acclimations and metabolic rate determinations were made at -1.0°C and the animals were not fed during these procedures. In most cases a total of 16 animals was run at each salinity.

The combined effect of salinity and oil-seawater dispersions was also investigated for the above 3 species. For each species combinations of oil and salinity stress were selected that would not be lethal to most of the animals over the experimental period. Two different lengths of exposure to oil dispersions were used. Initially animals were exposed to the oil-seawater dispersions for 12 hours prior to a run. When it became evident that the effects of a 12 hour exposure were minimal, the exposure period was extended to 36 hours in later experiments. The following combinations were run for each species:

Species	Collection Site	Test salinities	Test Oil Conc. per 500 ml	Duration of Oil Exposure
Mysis littoralis	Barrow	32,40,45,50‰	0,25,100μℓ	12 hr
Mysis littoralis	Barrow	10,32,45,50‰	0,25,100μℓ	36 hr
Mysis littoralis	Stefansson Sound	45‰	0,25μℓ	12 hr
Anonyx nugax	Barrow	32,40,45‰	0,25,100,250μℓ	12 hr
Boeckosimus affinis	Elson Lagoon	32,40,50‰	0,25,100μℓ	36 hr
Boeckosimus affinis	Stefansson Sound	32,40,45,50,55‰	0,25μℓ	12 hr

Animals in the above experiments were moved to their test salinities gradually in 5‰ increments every 2 days. After reaching the test salinity they were allowed to acclimate for 6 days prior to a run. Exposure to oil-seawater dispersions were initiated during the 12 or 36 hour period just prior to a run. Oil dispersions were prepared in seawater at the test salinity as described previously. In those experiments where a 36 hour exposure period was used, animals were transferred to a fresh dispersion after the first 24 hours of exposure. The water used in the respirometer flasks was an oil-seawater dispersion at the test salinity that had been prepared 12 hours earlier. All runs were conducted at -1.0°C and in subdued light.

Freezing Tolerance

A small number of freezing tolerance experiments were conducted on 2 common amphipod species, *Anonyx nugax* and *Boeckosimus affinis*. Animals were exposed to freezing conditions in 8 dram shell vials containing about 20 ml of 32‰ seawater. Each vial was provided with a rubber stopper with a thin glass tube that extended to the bath surface and served as an air vent. Vials were attached to vertical wire racks to facilitate removal of batches at different times during the exposure period. Prior to transfer of the animals, the vials filled with seawater were placed in the constant temperature bath set at -2.8°C and allowed to equilibrate. The vials were then briefly removed from the bath and one amphipod was placed in each vial. The vials were then resubmerged and once again equilibrated to the bath temperature. The seawater never froze during these equilibration periods and it was necessary to seed each vial with ice crystals to initiate freezing. Seeding was accomplished by packing snow into the end of a long glass capillary tube, inserting this down the air vent tube into the vial, and blowing the crystals into the supercooled seawater. Once seeding was accomplished the seawater in the vial froze within several minutes. Animals were exposed in the frozen vials for periods of 1, 3, 4, 5, and 8 hours. At the end of each period a batch of 6 to 10 vials was removed and the animals were transferred back into -1.0°C seawater for recovery. Survival and general condition of the animals was monitored at 24 and 48 hours after return to the recovery container.

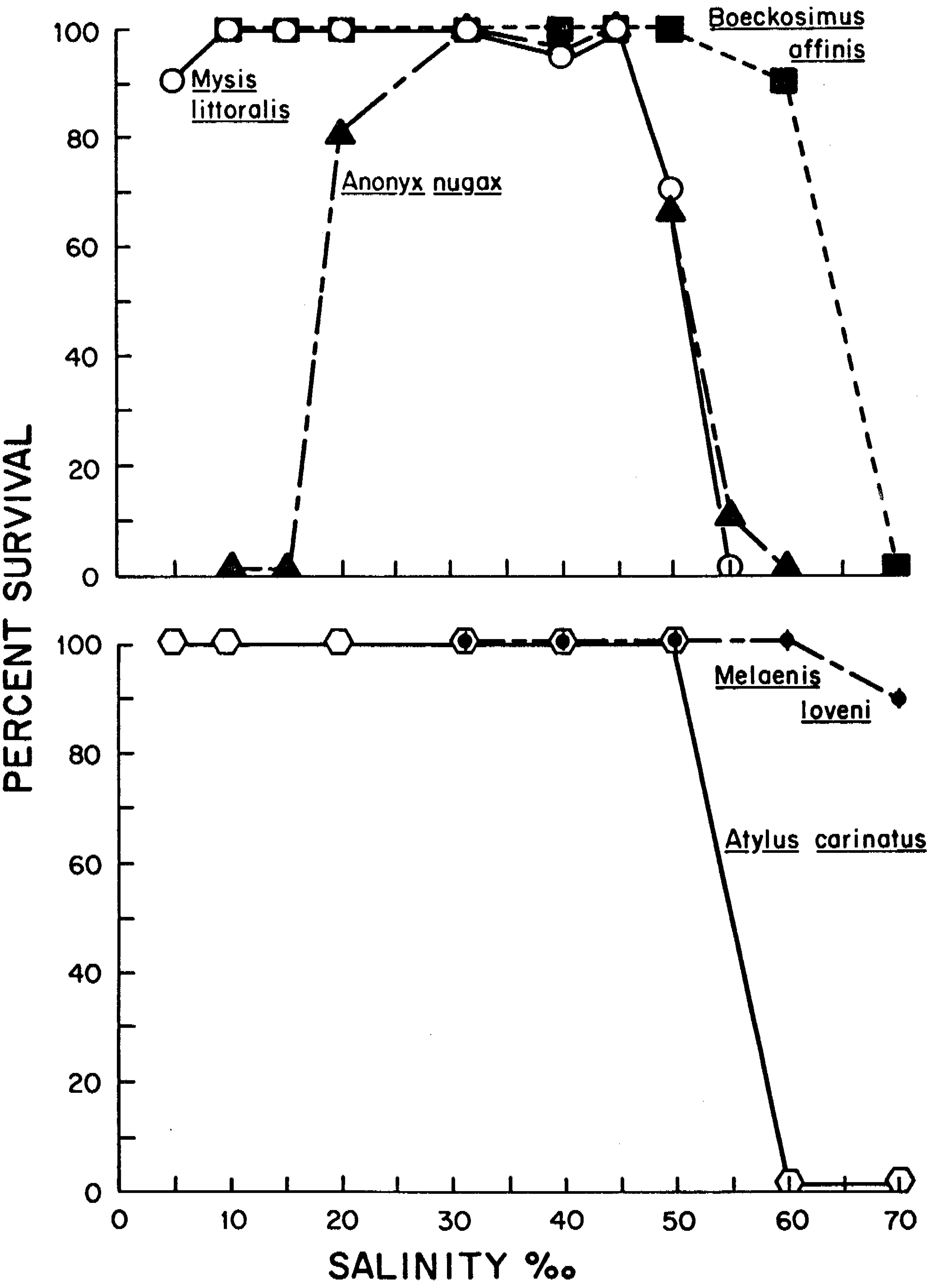
RESULTS AND DISCUSSION

Acute Salinity Tolerance Experiments

The response of several common benthic and epibenthic invertebrates to salinity stress under winter conditions of temperature (-1.0°C) and photoperiod indicates that many of these animals are very euryhaline. The percent survival after 96 hours for animals acutely exposed to test salinities is shown in Figs. 1 and 2. Although data was collected for 7 days in these experiments, the survival at 4 days was nearly the same as that recorded for 7 days exposure. In a few experiments survival had dropped by 10% between 4 and 7 days, but there was no difference in many experiments. The amphipods *Boeckosimus affinis* (Fig. 1A) and *Onisimus litoralis* (Fig. 2A) appear to be the most euryhaline species studied in that they survive exposure to salinities from 5 or 10‰ to at least 65‰. The scale worm *Malaenis loveni* (Fig. 1B) may show an equally impressive range, but the lack of data at low salinities precludes making a definitive statement at this time. The benthic haustoriid amphipod *Pontoporeia femorata* (Fig. 2B) appears to tolerate hypersaline stress slightly less successfully than the above species in that survival occurs at 60‰ but not at 65‰. The remaining amphipods *Anonyx nugax* (Fig. 1A), *Tryphosella schneideri* (Fig. 2A), *Atylus carinatus* (Fig. 1B), and *Aceroides latiper* (Fig. 2B) and the mysid *Mysis littoralis* (Fig. 1A) are all similar in their ability to tolerate hypersaline conditions. Survival above 55‰ is at best poor for all of these species, and none survive 60‰. Of the species for which a complete range of salinities were tested, *Anonyx nugax* is clearly the most stenohaline animal. Survival in brackish waters below 20‰ is poor. In contrast, *Atylus carinatus* and *Mysis littoralis* survive dilutions of seawater at least down to 5‰ quite well. These two species are clearly euryhaline yet do not have quite as wide a tolerance range as *Boeckosimus affinis* and *Onisimus littoralis* mentioned above.

The activity rating made during the acute salinity tolerance experiments may provide a more ecologically relevant basis for establishing tolerance ranges. When exposed to stress conditions the animals become immobile considerably sooner than data on complete death would suggest. In the scale used to rate activity, a rating of 2 indicates the point at which spontaneous locomotion has ceased. Presumably at this point the

Figure 1. Acute 96 hour salinity tolerance of arctic epibenthic marine invertebrates at -1.0°C. A. top panel; B. bottom panel.

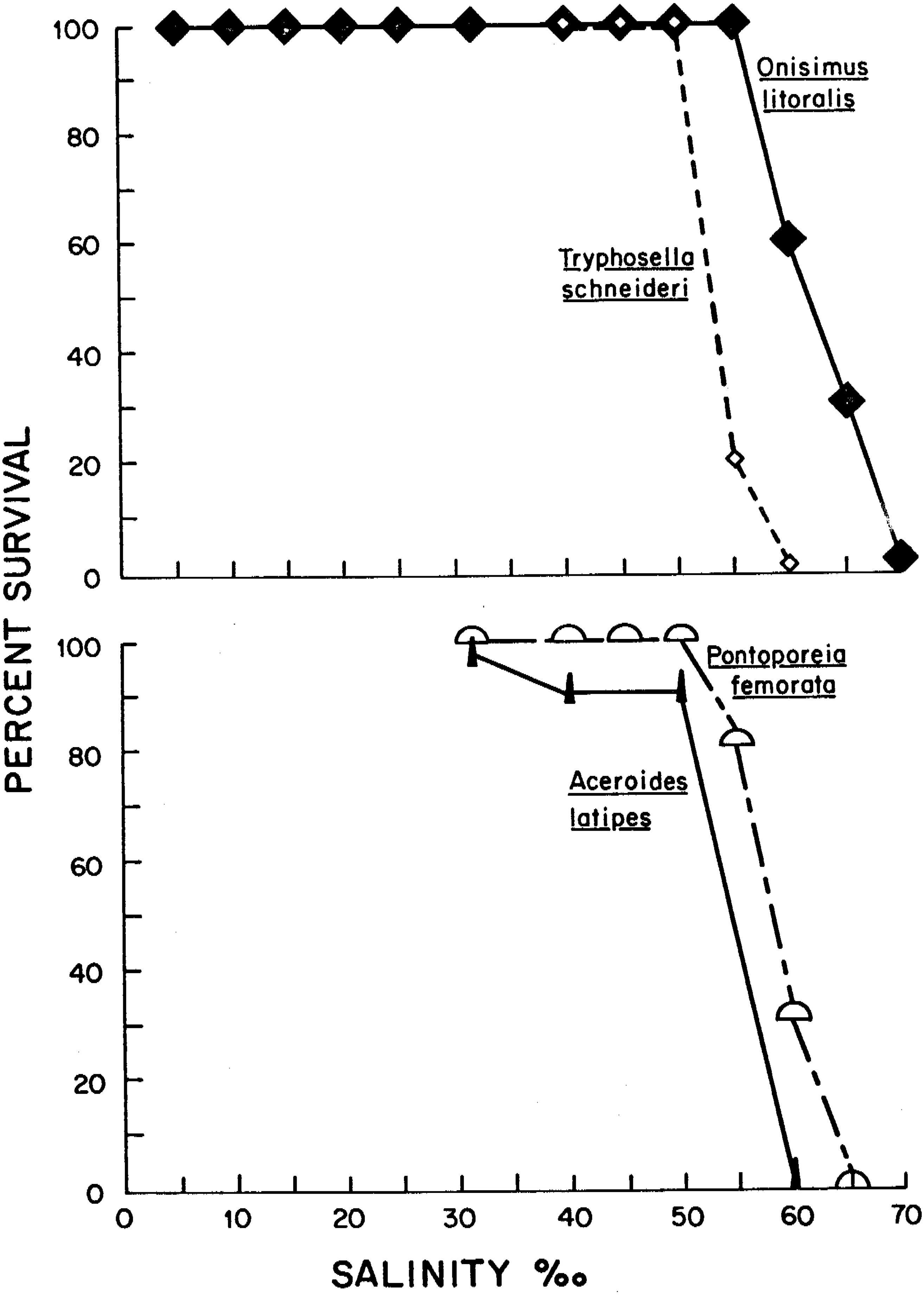


Boeckosimus affinis
Mysis littoralis
Anonyx nugax
Melaenis loveni
Atylus carinatus
PERCENT SURVIVAL
100
80
60
40
20
0
0
10
20
30
40
50
60
70
SALINITY ‰

Figure 2. Acute 96 hour salinity tolerance of arctic marine invertebrates at -1.0°C.

A. top panel - epibenthic amphipods

B. bottom panel - benthic amphipods


100
80
60
40
20
0
Onisimus litoralis
Tryphosella schneideri
100
80
60
40
20
0
Pontoporeia femorata
Aceroides latipes
PERCENT SURVIVAL
0
10
20
30
40
50
60
70
SALINITY ‰

animal would become much more susceptible to predation in its natural habitat and might be considered ecologically dead. The mean activity ratings from the acute salinity tolerance experiments are presented in Figs. 3 and 4. The same general trends that were noted for the survival data are seen here, but the salinity ranges for spontaneous locomotion are narrowers. Onisimus litoralis (Fig. 3B) and Boeckosimus affinis (Fig. 3A) are again the most euryhaline species. O. litoralis maintains spontaneous locomotion from < 5 to about 58‰ and B. affinis from < 10 to about 55‰. Atylus carinatus (Fig. 3B) is slightly less euryhaline with a salinity range for spontaneous activity from <5 to about 53‰. More data is needed on this species to firmly establish the upper end of the range because determinations were made at 10‰ intervals. Mysis littoralis (Fig. 3A) maintains spontaneous activity from <5 to about 50‰. In contrast, Anonyx nugax (Fig. 3A) is again the most stenohaline species and maintains spontaneous locomotion over the considerably narrower range of about 19 to 46‰. The decreased activity ratings at 20 and 40‰ are significantly different ($p = 0.05$) from that at 32‰ according to Mann-Whitney tests. Data over the complete salinty range is not yet available for the two more benthic amphipods. Pontoporeia femorata and Aceroides latipes (Fig. 4) but these species maintained spontaneous activity up to about 47‰ and 43‰ respectively. Their responses appeared similar to that of Anonyx nugax in that activity was more sharply depressed by elevated salinities than it was in the more euryhaline species. The decreased activity ratings at 40 and 45‰ for P. femorata and at 40‰ for A. latipes are significantly different ($p = 0.05$) from those at 32‰ according to Mann-Whitney tests.

Gradual Salinity Tolerance Experiments

Gradual salinity tolerance experiments were conducted on several of the most common epibenthic invertebrates. In general, the more gradual approach to stressful salinities allowed a somewhat wider range of salinities to be tolerated. Mysis littoralis (Fig. 5A) tolerated successive dilutions down to 0.5‰ and increases of salinity up to 55‰. Compared to the acute tolerance experiment (Fig. 1A) this represents about a 5‰ increase at the upper end of the range. Tolerance to low salinities appeared somewhat lower than in the acute experiment in that

Figure 3. Effect of acute salinity transfers on activity of arctic epibenthic marine invertebrates after 96 hours exposure to test salinities at -1.0°C. The following subjective activity rating scale was used:

4 = normal
3 = slightly reduced
2 = loss of spontaneous locomotion
1 = greatly reduced
0 = dead

A. top panel; B. bottom panel

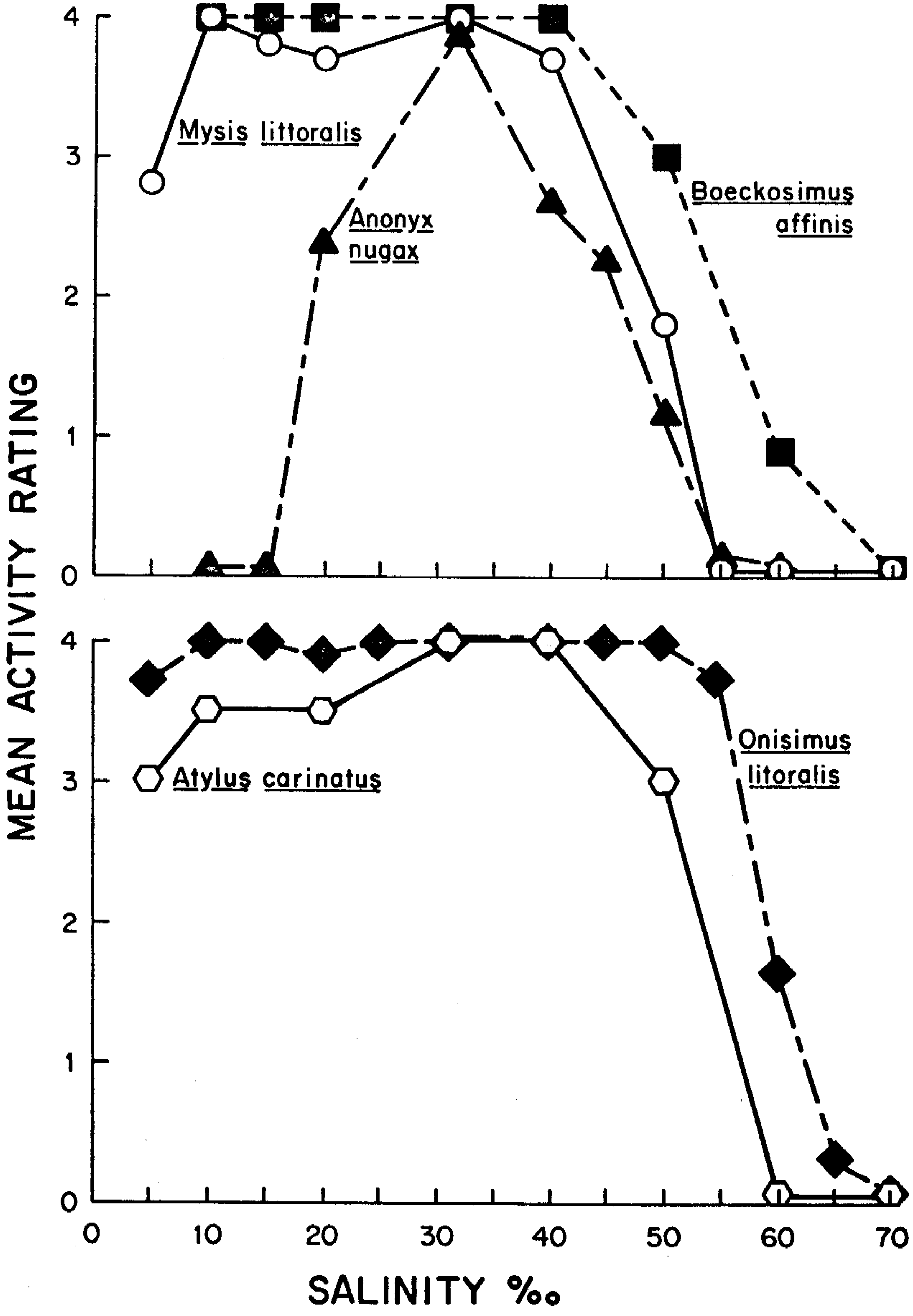

MEAN ACTIVITY RATING
4
3
2
1
0
Mysis littoralis
Anonyx nugax
Boeckosimus affinis
4
3
2
1
0
Atylus carinatus
Onisimus litoralis
0
10
20
30
40
50
60
70
SALINITY ‰

Figure 4. Effect of acute salinity transfers on activity of arctic benthic marine amphipods after 96 hours exposure to test salinities at -1.0°C. Activity rating scale as in Figure 3.

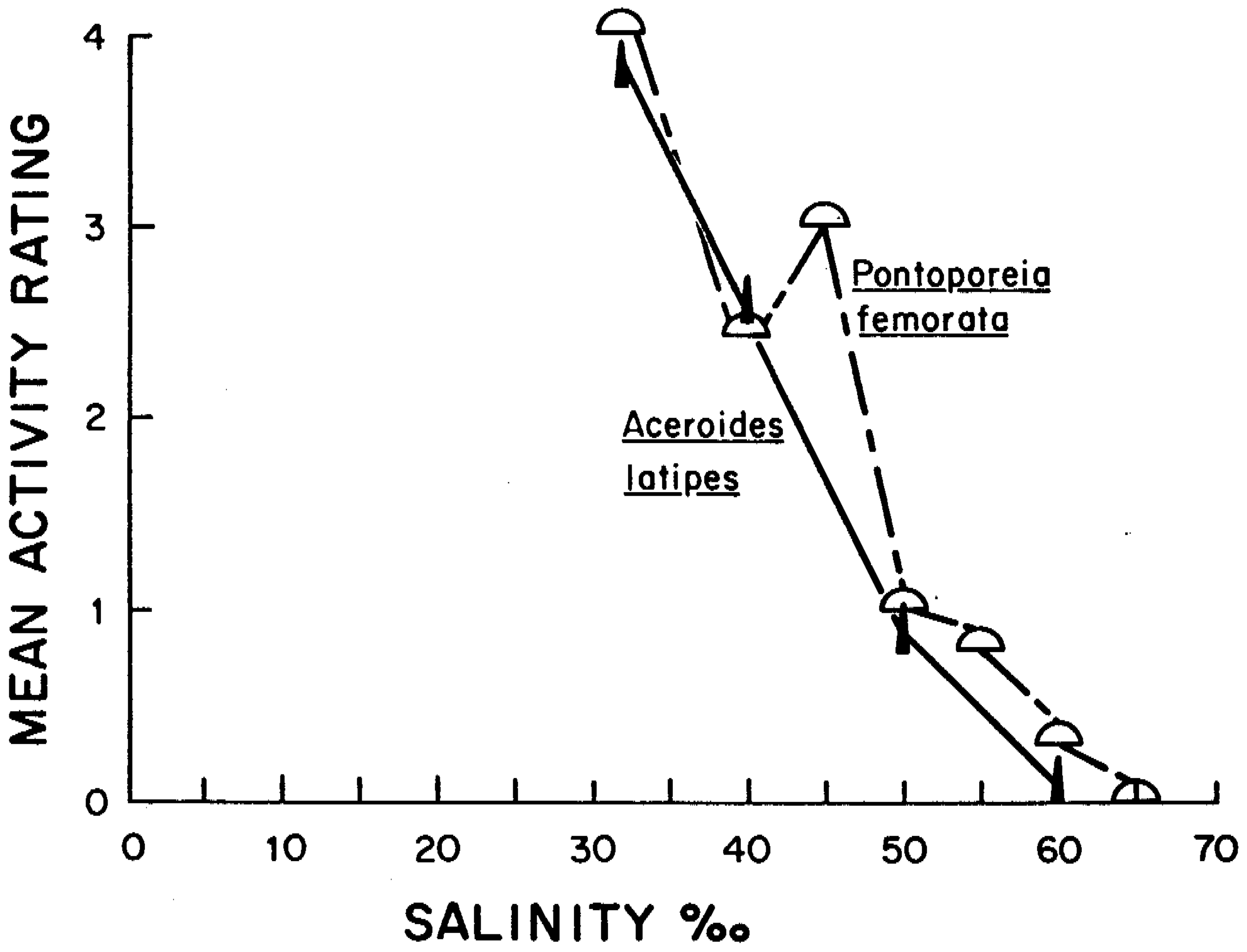
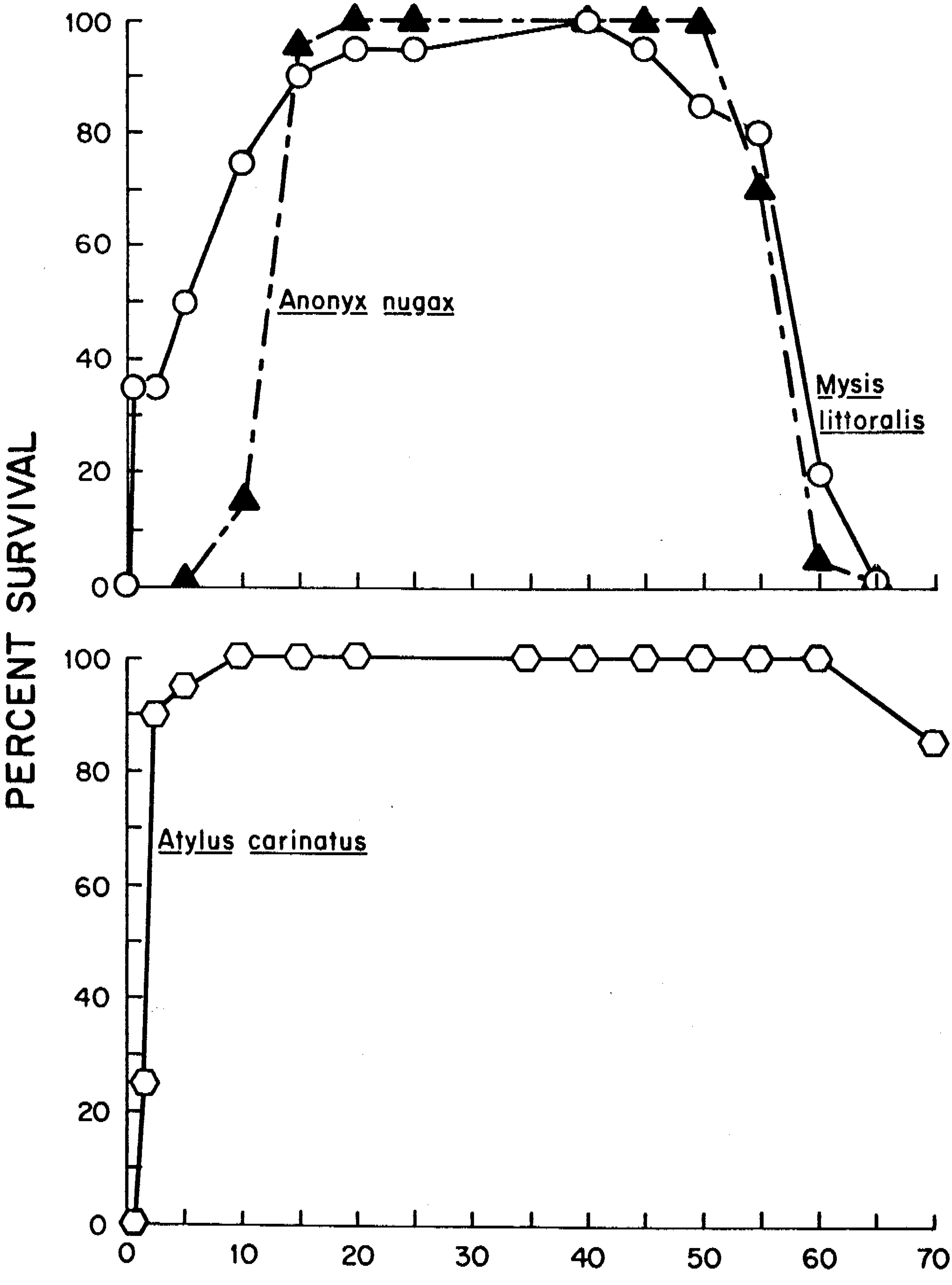

MEAN ACTIVITY RATING
4
3
2
1
0
0
10
20
30
40
50
60
70
SALINITY ‰
Pontoporeia femorata
Aceroides latipes

Figure 5. Gradual salinity tolerance of arctic epibenthic marine invertebrates at -1.0°C. Animals were transferred from 32‰ to either higher or lower salinities in 5‰ increments every 48 hours. Survival is recorded after 48 hours in each new salinity. A. top panel; B. bottom panel.


100
80
60
40
20
0
Anonyx nugax
Mysis littoralis
PERCENT SURVIVAL
100
80
60
40
20
0
Atylus carinatus
0
10
20
30
40
50
60
70
SALINITY ‰

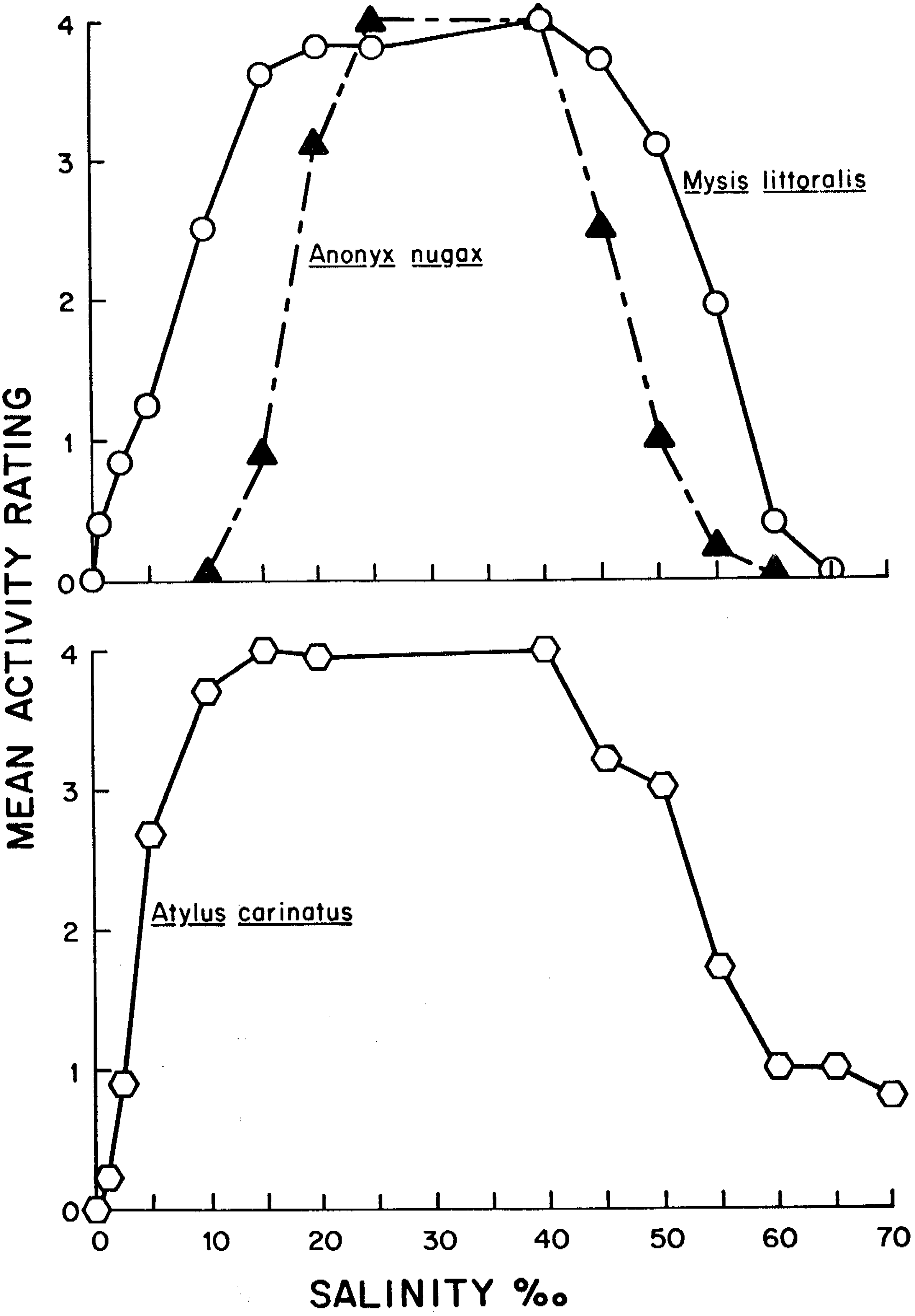
survival at 5‰ was only 50% compared to 90% in the acute run. Anonyx nugax (Fig. 5A) also survived over a greater range of salinities, with the gradual transfers. Survival was well above 50% between 15 and 55‰. The most impressive increase was seen for Atylus carinatus (Fig. 5B) which survived well from 2.5 to 70‰. Complete mortality had occurred at 60‰ in the acute run for this species.

In contrast to the above results, gradual transfers to stressful salinities did not improve the range of salinities for spontaneous locomotion. The activity rating for Anonyx nugax (Fig. 6A) falls to 2 at about 18 and 46‰, almost an identical range to that obtained with acute transfers. Likewise the range for spontaneous locomotion for Atylus carinatus (Fig. 6B) is about 4 to 53‰, the same as found in the acute experiment. Mysis littoralis (Fig. 6A) has a range for spontaneous locomotion of about 8 to 55‰. In this case the response at low salinity is poorer than that found in the acute experiment where activity was maintained to below 5‰. The upper limit for spontaneous activity is enhanced by about 5‰ by the gradual transfer process.

Conclusions from Salinity Tolerance Experiments

Almost no information is available on the tolerance of arctic marine invertebrates to natural environmental stresses. However, two studies (Percy, 1975 and Busdosh and Atlas, 1975) have dealt with the ability of the amphipod Boeckosimus affinis to tolerate salinity extremes. Percy (1975) studied a population of this species from the Eskimo Lakes area east of the Mackenzie River delta. This population survived acute salinity transfers over the range of 5 to 35‰; considerably narrower than the <10 to 65‰ range reported in this study. The discrepency may be the result of several factors. The Eskimo Lakes population inhabits an area of brackish water (9.9 to 17.2‰) and the animals used in Percy's (1975) study were maintained at 17‰ prior to testing at salinity extremes. The Elson Lagoon population used in this study inhabits an area of higher salinity (32‰). In one experiment Percy (1975) found that acclimation of his test animals to 34‰ for 2 weeks increased survival at 40‰, suggesting that some of the population differences might be due to the local salinities to which the populations had become acclimatized. Busdosh and

Figure 6. Effect of gradual salinity transfers on the activity of arctic epibenthic marine invertebrates at -1.0°C. Animals were transferred from 32‰ to either higher or lower salinities in 5‰ increments every 48 hours. Activity was rated after 48 hours in each new salinity using the scale in Fig. 3. A. top panel; B. bottom panel.


MEAN ACTIVITY RATING
4
3
2
1
0
Mysis littoralis
Anonyx nugax
4
3
2
1
0
Atylus carinatus
0
10
20
30
40
50
60
70
SALINITY ‰

Atlas (1975) report survival of their Elson Lagoon population of *B. affinis* over a salinity range of 4 to 50‰ which is in closer agreement with the range observed in this study. Both of the above previous studies were carried out at higher temperatures than that used in the present study. Some of the differences noted may be the result of these temperature differences. Percy (1975) reports better survival of *B. affinis* at high salinities when acclimated to 0°C rather than 8°C. Since our runs were conducted at -1.0°C rather than at 5 or 15°C as used by Busdosh and Atlas (1975), increased survival at high salinities is to be expected.

Species differences in the ability to tolerate salinity extremes suggest that seasonal differences in distribution may be expected. *Mysis littoralis* tolerates brackish waters down to 5‰ well but appears to only have moderately good abilities to tolerate hypersaline conditions. During the winter, as ice cover and hypersaline conditions increase in lagoons *M. littoralis* might be expected to avoid these conditions by migration to more stable oceanic waters. However, their ability to tolerate low salinities would permit migration back into lagoons during the ice free period when more brackish conditions prevail. Griffiths and Dillinger (1979), in fact, hypothesize movements of this type for *M. littoralis* based upon biological sampling at different seasons. Without getting into the question of causal relationships, it is at least interesting to note the close correlation between physiological capabilities and seasonal distribution patterns.

Boeckosimus affinis is tolerant of brackish waters and is more tolerant of hypersaline conditions than *M. littoralis*. This suggests that *B. affinis* may be able to function in at least the moderately hypersaline areas of lagoons during the winter and may not be forced to migrate to oceanic waters. The low salinity tolerance of this species would permit it to remain in the brackish waters of lagoons during the ice free season. In our efforts to collect amphipods for this study we consistently found *B. affinis* in Elson Lagoon, but never caught them in traps set in the more oceanic waters of the Chukchi Sea near the Naval Arctic Research Lab. Apparently Busdosh and Atlas (1975) were able to collect this species in Elson Lagoon during June and July. Percy (1975) has reviewed the distribution of *B. affinis* and indicates that it has most frequently been found in brackish water conditions with a few exceptions where it has been reported from more oceanic waters. The broad range of salinities reported for this species in the literature is not inconsistent with the tolerance range described in this study.

Onisimus litoralis would appear to have similar salinity tolerance capabilities to that found for *B. affinis*. Detailed information on the distribution and salinity preference of this species seems to be lacking in the literature. However Gurjanova (1938) (cited in Zenkevitch, 1963) indicates that *O. litoralis* prefers lowered salinities. We have commonly caught this species during both summer and winter in the oceanic waters of the Chukchi Sea near Barrow. Griffiths and Craig (1978) report collecting this species in low numbers during the summer in Simpson Lagoon. *O. litoralis* therefore appears to inhabit a wide range of conditions which is not inconsistent with its broad salinity tolerance range.

Anonyx nugax has consistently been the most common amphipod species caught in our traps set in the Chukchi Sea near the Naval Arctic Research lab (NARL). It was also, along with *B. affinis* one of the most common amphipods trapped at the Stefansson Sound boulder patch (Dive Site 11) in November, 1978. This species has not appeared in our lagoon collections and during the summer months it becomes relatively rare in the shallow waters of the Chukchi Sea near NARL. No information on its habits was available in the literature. Since *A. nugax* appears to be relatively stenohaline from the results of this study, it is postulated that this species is restricted to oceanic waters of near normal salinity. The disappearance of the bulk of the population from the shallow Chukchi waters during the ice free season probably indicates migration to deeper more stable waters.

Atylus carinatus is similar to *Mysis littoralis* in its salinity response. Tolerance is good under brackish water conditions but only moderate in hypersaline waters. Activity becomes depressed at 50‰. Detailed information on distribution appears to be lacking for this species. Griffiths and Craig (1978) report the species in low abundance in Simpson Lagoon and at a shallow Beaufort Sea station adjacent to a barrier island in mid August. We collected large numbers of *Atylus* at the Stefansson Sound boulder patch (Dive Site 11) in May 1979 and Ken Dunton (personal communication) reported large numbers there in March 1980. During May 1979 there was about a 1 m thick layer of 15.5‰ water just beneath the ice but the water below the halocline where all of the *Atylus* were active (diver observation) was about 30‰. During the March 1980 period the salinity was about 37‰. It appears from these few observations that *Atylus carinatus* restricts its distrubtion to waters of near normal salinity. The salinity tolerance data suggests it could function in brackish water, but was seen to avoid these conditions in its natural habitat.

Data was collected on the remaining species only under hypersaline conditions so no conclusions can be drawn about the total tolerance ranges. The polychaete scale worm *Melaenis loveni* has been collected by our group in near normal salinities in the Chukchi Sea at NARL and in slightly hypersaline conditions (37‰) in the Stefansson Sound boulder patch (Ken Dunton, personal communication). The tolerance of this species is exceptionally good at high salinities so it should be able to withstand hypersaline lagoon conditions if some other factor does not prevent utilization of this habitat. *Pontoporeia femorata* and *Aceroides latipes* are both free burrowing benthic amphipods which we collected from Elson Lagoon. *Pontoporeia femorata* is reported to favor normal to lowered salinities (Gurjanova, 1938 cited in Zenkevitch, 1963). The collections made by this research unit (RU-356) indicate that the species reaches maximum abundance in waters greater than 2 m depth. *P. femorata* can tolerate salinities approaching 60‰ but its activity becomes severely depressed above 45‰. If it inhabits hypersaline regions of lagoons during the winter, our data suggests it must become inactive. Migration from these stressful conditions seems likely though but we have no information on its winter distribution. *Aceroides latipes* appears similar to *P. femorata* but there is no indication of its habitats in the literature. *Tryphosella schneideri* does not appear to tolerate salinities above 50‰ well. The only site at which we have encountered this species is in shallow Chukchi Sea waters near NARL in February 1980. No other information seems to be available on its distribution pattern. On the basis of its tolerance to hypersaline conditions and its rarity in shallow water samples, it is postulated that this species is restricted to more stable oceanic waters.

Effect of Salinity on Metabolic Rates

The effect of salinity on the metabolic rate was investigated in three common epibenthic invertebrates: *Mysis littoralis*, *Anonyx nugax* and

Boeckosimus affinis. Both M. littoralis and B. affinis show metabolic independence over a broad range of salinities (Fig. 7). For M. littoralis this range extends from 10‰, the lowest salinity tested, to 40‰. Above 40‰ the metabolic rate declines with increasing salinity. For B affinis the range of independence extends from 5 to 45‰ and then begins to decline. A. nugax, however, shows no independence from salinity and its metabolism becomes depressed at 20‰ and at 45‰. Although the mean metabolic rate for this species at 40‰ is considerably below that at 32‰, the two values are not statistically significantly different.

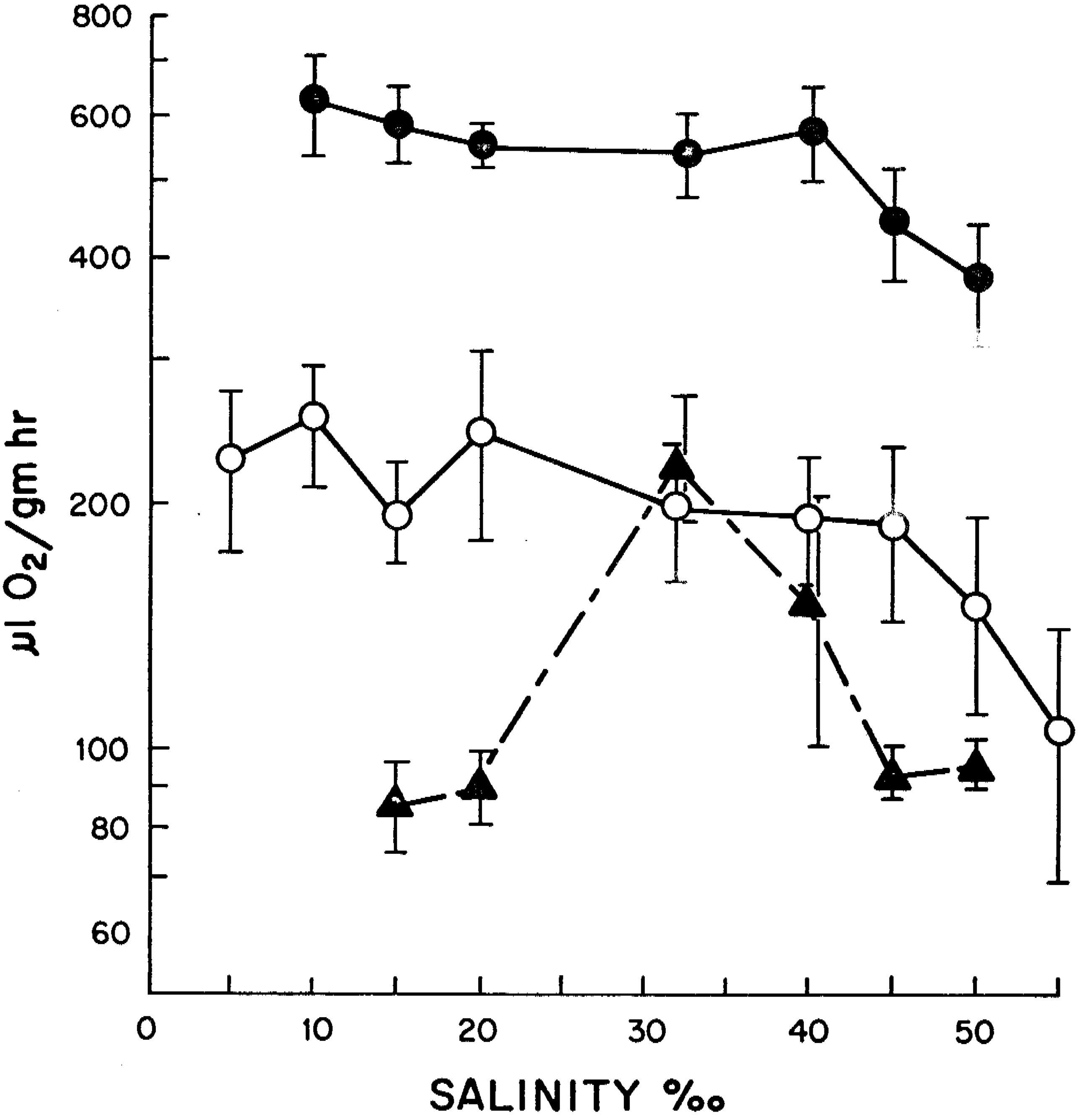
The trends seen in the tolerance and activity response of the species to salinity stress are evidently reflected in their metabolic response to this factor. Both of the euryhaline species, M. littoralis and B. affinis, are those that show metabolic independence from salinity. Furthermore, the breadth of the salinity range over which metabolism is not altered correlates with the degree of euryhalinity. The stenohaline species on the basis of tolerance, A. nugax, has its metabolic rate severely perturbed by salinities only slightly below or above normal oceanic salinities.

Percy (1975) and Busdosh and Atlas (1975) have reported on metabolic responses of B. affinis to salinity with somewhat different results than those reported in this study. Percy (1975) found that when the amphipods were acclimated to each salinity, as they were in the present study, the metabolic rate was independent of salinity over the range 10 to 25‰. At 30 and 35‰ metabolism was depressed. Busdosh and Atlas (1975) found this species to have salinity independent metabolism over the range 5 to 35‰, and metabolism was depressed at 45‰. In the present study, salinity independent metabolism was maintained up to 45‰. The differences in the upper end of the salinity independent region parallel the diffences in tolerance to hypersaline conditions reported in the three studies. As was mentioned previously, differences in habitat salinity regimes to which the populations have become acclimatized and temperatures at which the studies were carried out may account for the discrepencies.

The rates of metabolism shown in Fig. 7 have been corrected to the approximate average dry body weight for the populations being studied. These weights are 7 mg for M. littoralis, 20 mg for B. affinis and 100 mg for A. nugax. The absolute differences in metabolic rate are to a great extent the result of these differences in body weight, since small animals

Figure 7. Effect of salinity on the metabolic rates of arctic epibenthic marine invertebreates at -1.0°C. Animals were acclimated to the test salinities 6 days prior to a run. Metabolic rates were corrected to a standard dry body weight as follows for each species:

Mysis littoralis (closed circles) - 7 mg.
Boeckosimus affinis (open circles) - 20 mg.
Anonyx nugax (closed triangles) - 100 mg.


800
600
400
200
100
80
60
μl O₂/gm hr
0
10
20
30
40
50
SALINITY ‰

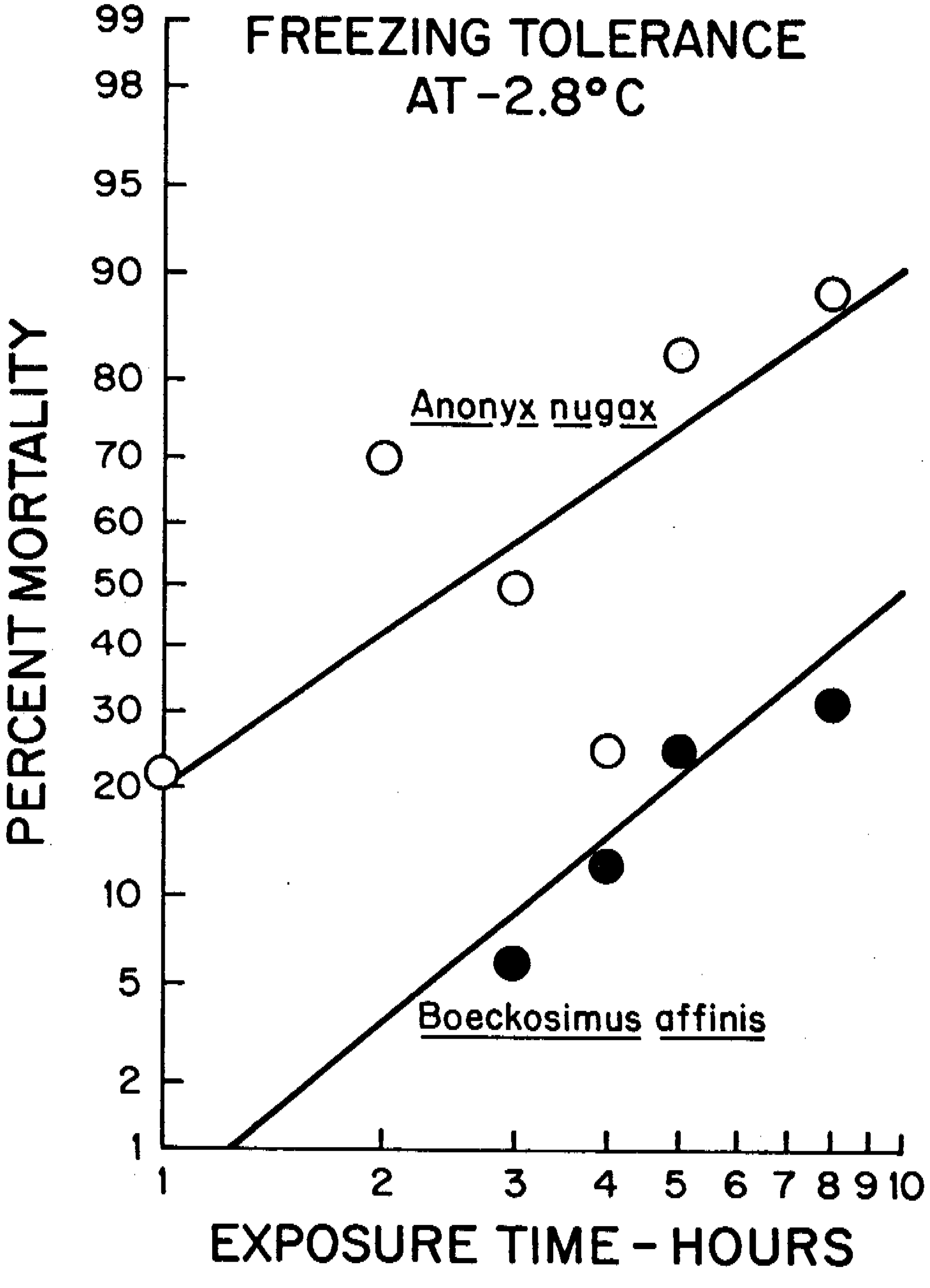
have a proportionally higher metabolism per unit weight than do large animals. If the metabolic rate for A. nugax at normal salinity (32‰) was corrected to the same body weight as the M. littoralis population (7 mg) the rates of the two species would be almost identical. Thus the differences in this case are entirely due to body size difference. On the other hand, B. affinis appears to have a proportionally lower metabolic rate than the other two species. Note that at 32‰ a 20 mg B. affinis has the same rate as a 100 mg A. nugax. If both of these were corrected to a similar body weight the rate for B. affinis would be lower. The reason for this may relate to the physical behavior of the species. Both M. littoralis and A. nugax tend to swim fairly constantly while B affinis has been observed to intersperse swimming with relatively long quiescent periods on the bottom.

All of the absolute rates shown appear normal for an invertebrate and compare favorably with rates for temperate zone crustaceans at their much higher habitat temperatures. That these normal metabolic rates are maintained at a temperature of -1.0°C indicates that these arctic animals have undergone metabolic compensation for their lower habitat temperatures (Scholander et al. 1953).

Freezing Tolerance

Three freezing tolerance runs were carried out at -2.8°C with each of the two common amphipods Anonyx nugax and Boeckosimus affinis. The data have been combined and are plotted (Fig. 8) as the percent mortality on a probability scale vs. the log of the exposure time. Although there is considerable scatter in the data the resulting curves are distinctly different. The median survival time for A nugax falls at about 2.5 hours while that for B. affinis is about 10 hours. The greater tolerance of B. affinis under these experimental conditions is not unexpected, as this species was found to have a higher tolerance to elevated salinities than A. nugax. During the freezing process in these experiments, the amphipods became trapped in a restricted pocket of fluid as the growing ice crystals surrounded them. Since this residual fluid contains the ions that were excluded from the ice crystalline structure, the salinity surrounding the amphipods was elevated. In addition the diffusion of oxygen into these brine pockets is also restricted by the surrounding

Figure 8. Freezing tolerance of arctic epibenthic amphipods at 32‰ salinity and -2.8°C. Mortality was determined after 24 hours recovery at -1.0°C.


FREEZING TOLERANCE
AT -2.8°C
PERCENT MORTALITY
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
Anonyx nugax
Boeckosimus affinis
1
2
3
4
5
6
7
8
9
10
EXPOSURE TIME - HOURS

ice and oxygen depletion may become an important variable. *B. affinis* is a somewhat smaller species than *A. nugax* and if similar sized animals are compared, *B. affinis* has a lower metabolic rate. Both of these factors might contribute to longer survival under the experimental conditions. It is not known whether the body fluids of any of the amphipods exposed to freezing conditions actually froze. It seems likely that without penetration of ice crystals through the body wall to seed crystal formation, the body fluids remained unfrozen in a supercooled state.

One conclusion seems obvious from these experiments. If either of these amphipod species become trapped in newly forming ice, they will not survive for prolonged periods. The likelihood of this occurring is reduced by the epibenthic habit of these species. Diver observations (J. Hanes) indicate that most of the activity of these species occurs near the bottom rather than at the ice undersurface.

Double Stress - Salinity and Crude Oil Tolerance

Standard 96 hour toxicity bioassays were conducted on *Mysis littoralis*, *Anonyx nugax*, and *Boeckosimus affinis* exposed to different concentrations of Prudhoe Bay crude oil dispersions and elevated salinities. The salinity series used in each experiment was chosen on the basis that it had been shown to be stressful but not lethal to more than 50% of the population in previous acute salinity tolerance experiments. Three concentrations of oil dispersions were used in these experiments and they will be designated:

1) Light = 25μℓ oil/500 ml seawater
2) Medium = 100μℓ oil/500 ml seawater
3) Heavy = 250μℓ oil/500 ml seawater

Mysis littoralis appears to be quite sensitive to crude oil dispersions. The survival data in Fig. 9A show that at normal salinity (32‰) no mortality occurs in light dispersions of Prudhoe Bay crude oil but almost complete mortality occurs in the medium dispersion. As the salinity stress is increased to 40 and 50‰ both light and medium oil dispersions become almost completely lethal. The mean activity ratings for this species at 96 hours are shown in Fig. 10A. Activity is severely depressed in both light and medium dispersions at all salinities. Even at 32‰ a

Figure 9. Effect of 96 hour exposure to Prudhoe Bay crude oil dispersions on the acute 96 hour salinity tolerance of arctic epibenthic marine invertebrates. The following concentrations of crude oil were used:

Control (open circles) - no oil
Light (closed circles) 25μℓ oil/500 ml seawater.
Medium (closed triangles) - 100μℓ oil/500 ml seawater.
Heavy (closed squares) - 250μℓ oil/500 ml seawater.

A. top panel; B. bottom panel

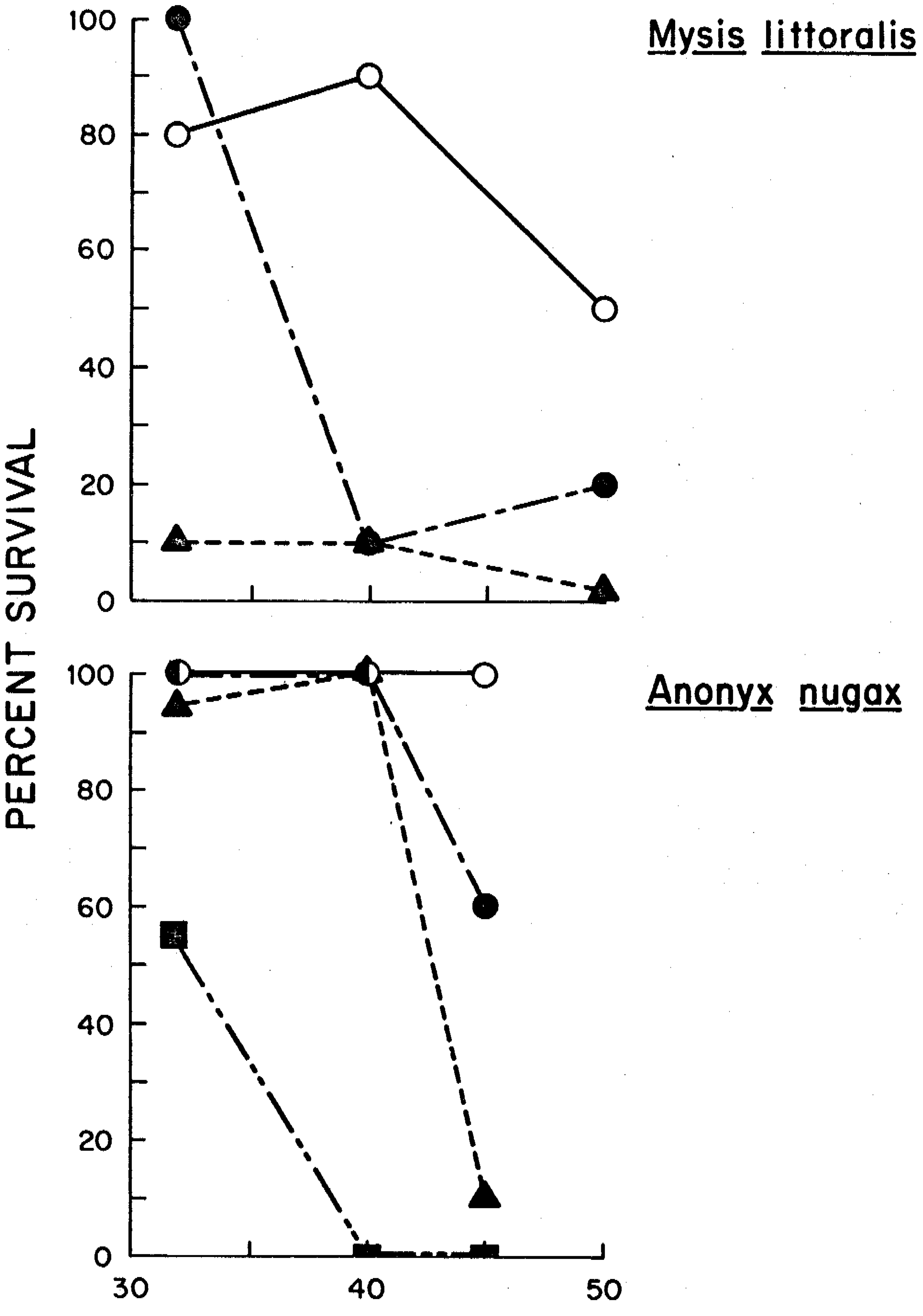
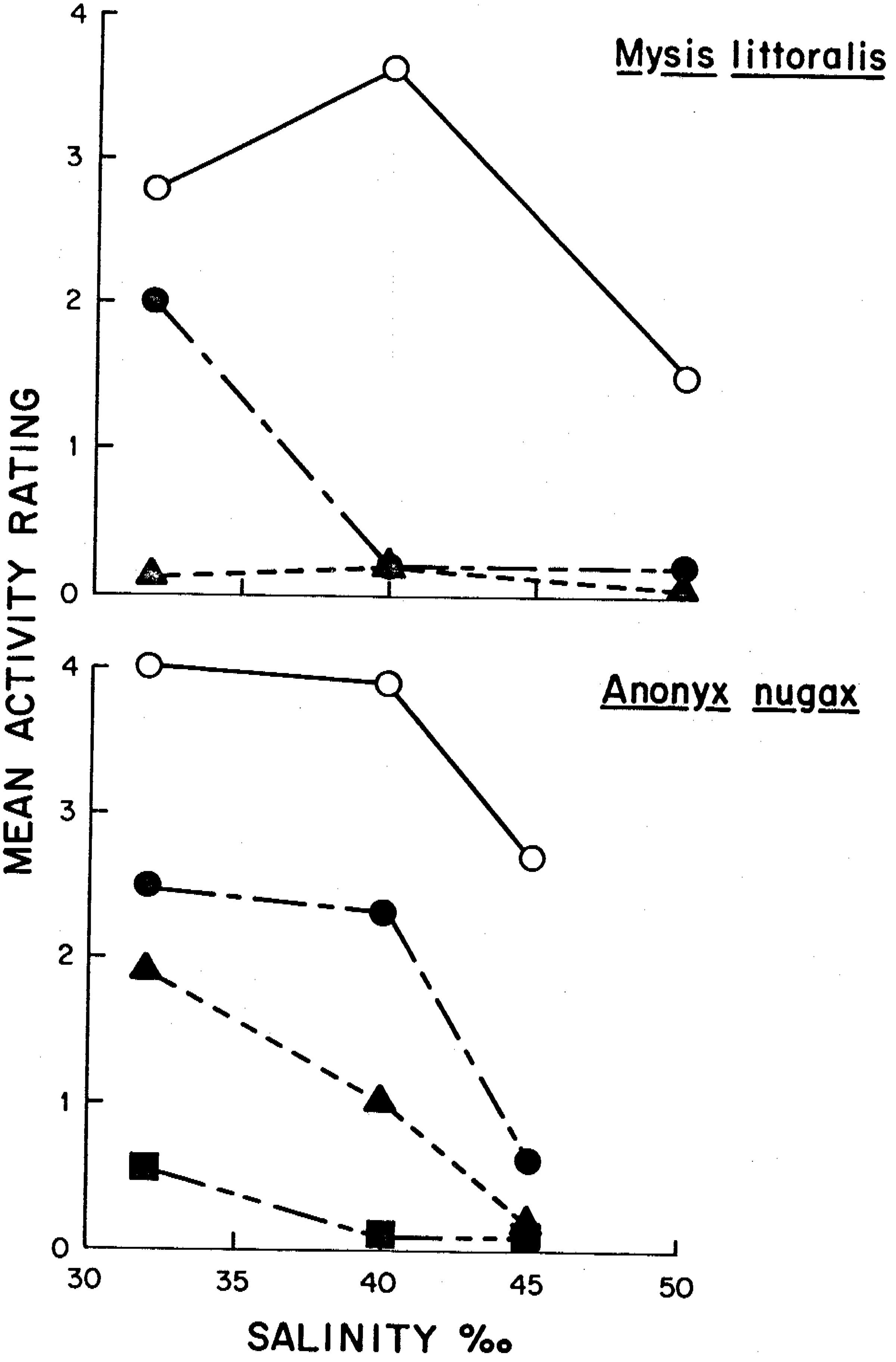

Mysis littoralis
Anonyx nugax
PERCENT SURVIVAL
100
80
60
40
20
0
100
80
60
40
20
0
30
40
50
SALINITY ‰

Figure 10. Effect of salinity and Prudhoe Bay crude oil dispersions on the activity of arctic epibenthic marine invertebrates after 96 hours exposure to the test conditions. Activity ratings scale as in Fig. 3. The concentrations of crude oil dispersions are as follows:

Control (open circles) - no oil
Light (closed circles) - 25μℓ oil/500 ml seawater
Medium (closed triangles) - 100μℓ oil/500 ml seawater
Heavy (closed squares) - 250μℓ oil/500 ml seawater

A. top panel; B. bottom panel


Mysis littoralis
Anonyx nugax
MEAN ACTIVITY RATING
SALINITY ‰
0
1
2
3
4
30
35
40
45
50

light dispersion causes a loss of spontaneous locomotion (rating of 2). However this point is not significantly different from the controls (no oil) according to a Mann-Whitney test. For some unknown reason there was a deterioration in the condition of the 32‰ control group in this experiment. At 50‰, even though the controls are more active than those exposed to either oil dispersion, there are no significant differences between the experimental groups. Under these conditions the salinity stress alone apparently accounts for most of the reduced activity.

Anonyx nugax appears somewhat less sensitive to crude oil dispersions than M. littoralis. At 32 and 40‰ survival is not affected by either light or medium oil dispersions (Fig. 9B). Heavy dispersions greatly reduce survival at 32‰ and are completely lethal at higher salinities. At 45‰ the light and medium oil dispersions result in high mortality. The activity ratings shown in Fig. 10B indicate that even though survival is good at 32 and 40‰ activity is significantly depressed by all of the oil dispersions. A medium dispersion eliminates spontaneous locomotion at 32‰. The effect of oil dispersions on activity does not appear to be strongly influenced by salinity in that activity is similarly depressed by each dispersion at all salinities. This contrasts with the strong interaction seen between salinity and oil effects in terms of survival. Mann-Whitney tests indicate that all of the treatments are significantly different at 32 and 40‰. At 45‰ the 3 oil dispersion treatments are significantly different from the control but not from each other.

Boeckosimus affinis from the Stefansson Sound boulder patch are moderately sensitive to crude oil dispersions. Both light and medium dispersions caused mortality at 32‰ (Fig. 11A) the latter resulting in 50% survival at 96 hours. At 40‰, survival of this population was less influenced by oil dispersions but at 50‰ mortality was high in the medium dispersions. The activity ratings (Fig. 12A) indicate that activity was depressed below the level of spontaneous locomotion by both light and medium dispersions at all salinities. All the treatments are significantly different at 32‰ according to Mann-Whitney tests. At 40‰ the two oil treatments are significantly different from the controls but not from

Figure 11. Effect of 96 hour exposure to Prudhoe Bay crude oil dispersions on the acute 96 hour salinity tolerance of Boeckosimus affinis from two different locations. The concentrations of crude oil dispersions are as follows:

Control (open circles) - no oil
Light (closed circles) - 25μℓ oil/500 ml seawater
Medium (closed triangles) - 100μℓ oil/500 ml seawater

A. top panel; B. bottom panel

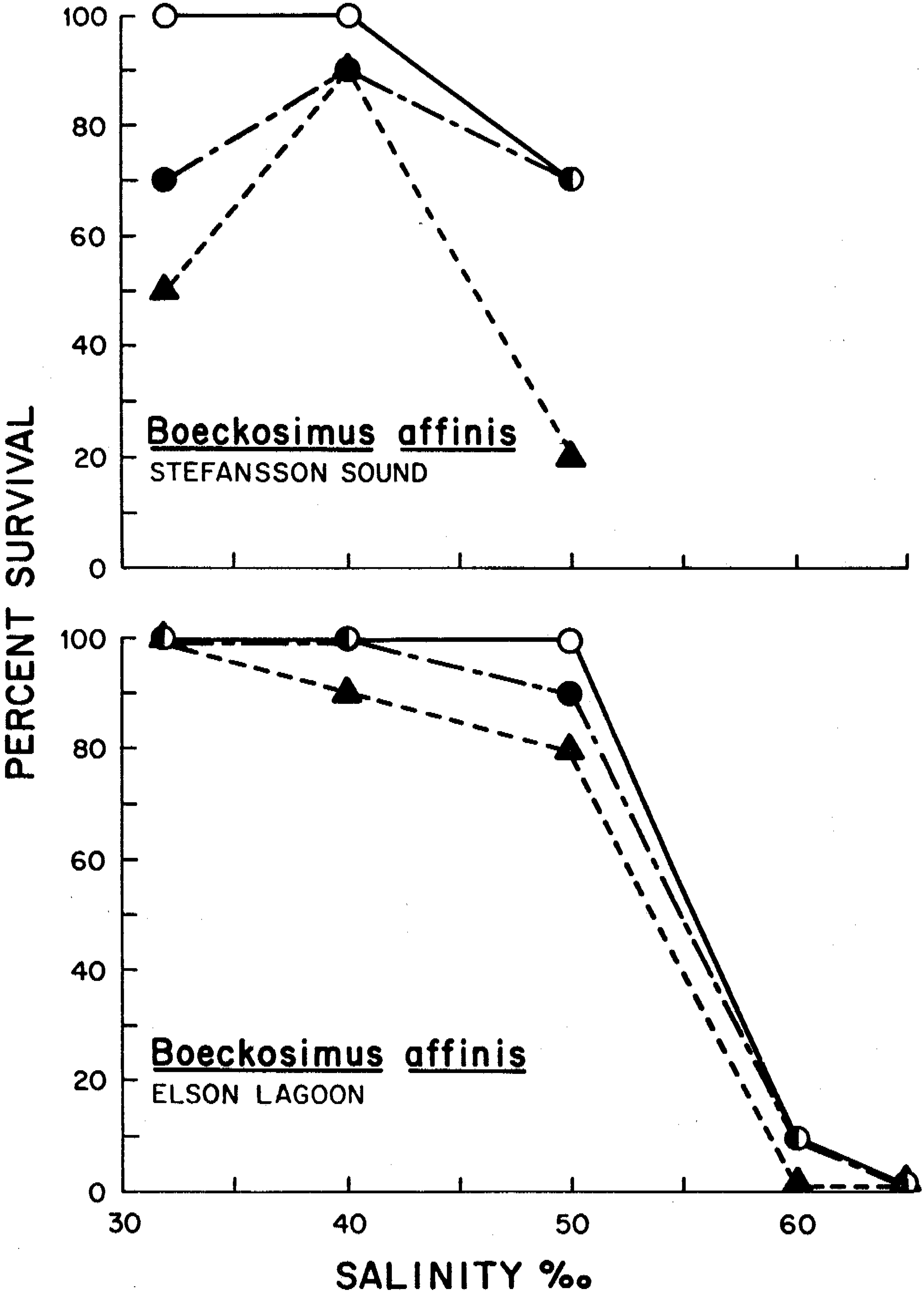
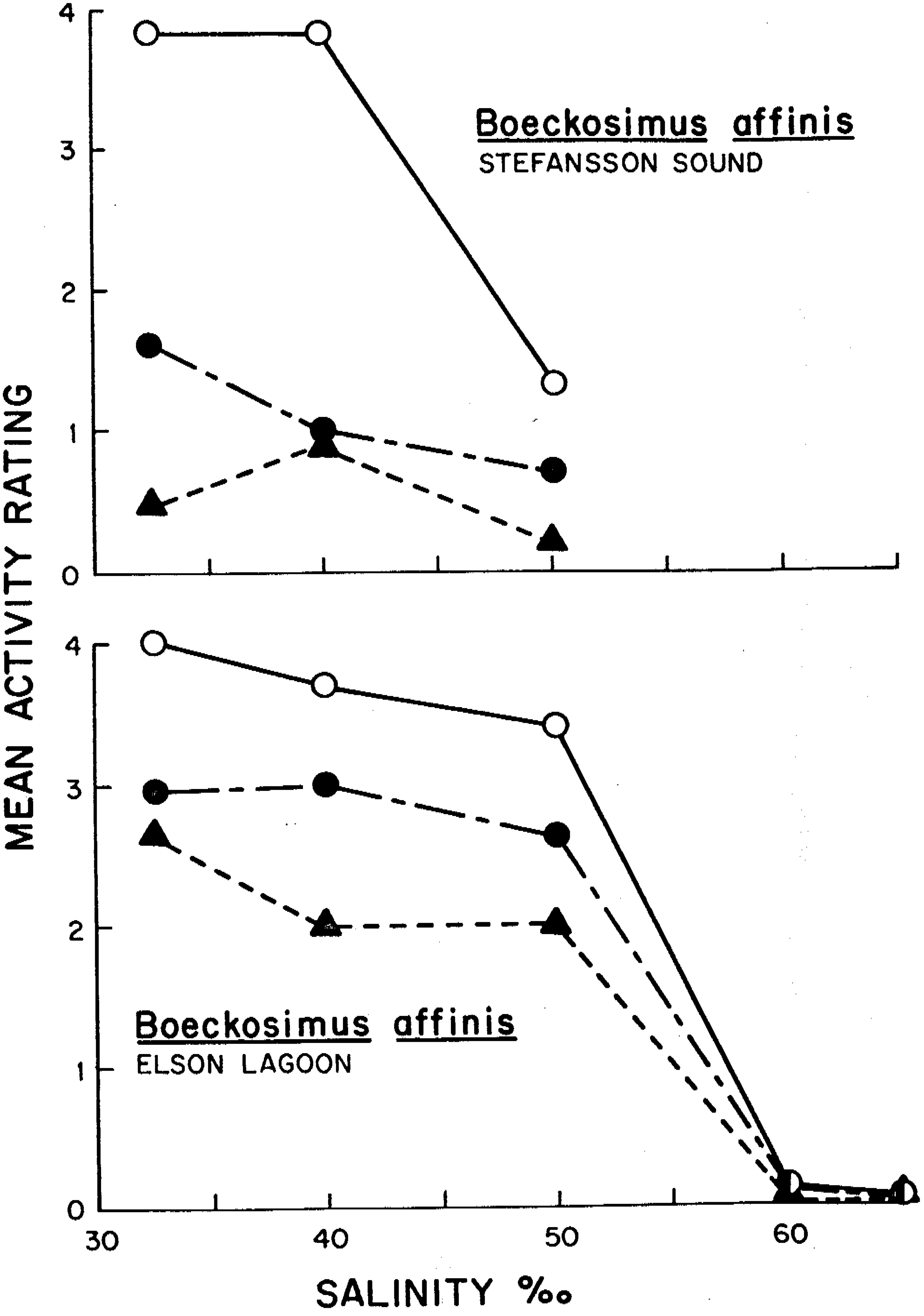

PERCENT SURVIVAL
100
80
60
40
20
0
Boeckosimus affinis
STEFANSSON SOUND
100
80
60
40
20
0
Boeckosimus affinis
ELSON LAGOON
30
40
50
60
SALINITY ‰

Figure 12. Effect of salinity and Prudhoe Bay crude oil dispersions on the activity of Boeckosimus affinis from two different locations. Activity was rated after 96 hours exposure to the test conditions using the activity rating scale in Fig. 3. The concentrations of crude oil dispersions are as follows:

Control (open circles) - no oil
Light (closed circles) - 25μℓ oil/500 ml seawater
Medium (closed triangles) - 100μℓ oil/500 ml seawater

A. top panel; B. bottom panel


Boeckosimus affinis
STEFANSSON SOUND
Boeckosimus affinis
ELSON LAGOON
MEAN ACTIVITY RATING
0
1
2
3
4
0
1
2
3
4
30
40
50
60
SALINITY ‰

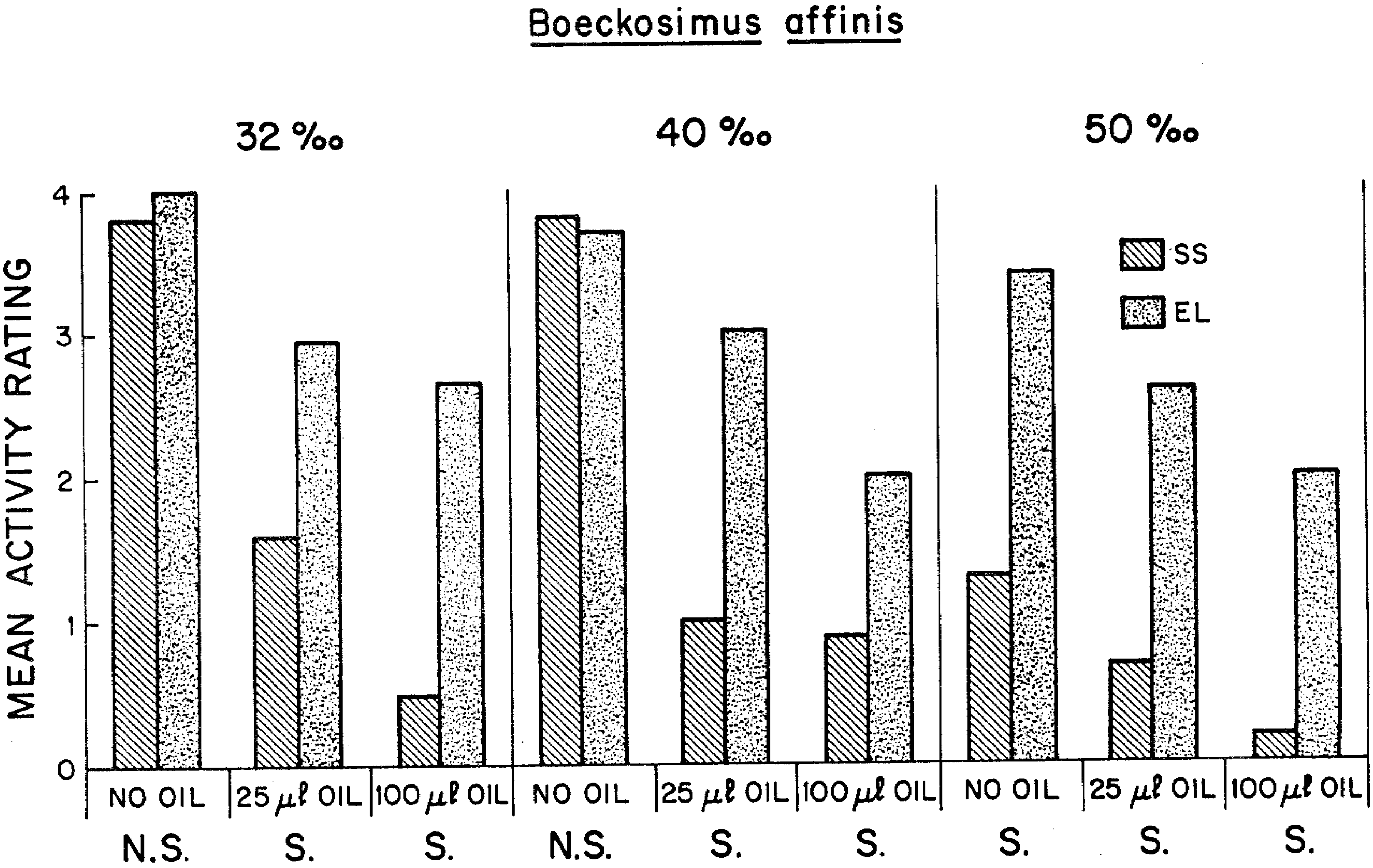
each other. At 50‰ only the medium dispersion is significantly different from the control treatment.

Boeckosimus affinis from Elson Lagoon appear less sensitive to oil dispersions that the population from Stefansson Sound. Fig. 11B shows that survival is only slightly reduced by light and medium oil dispersions at elevated salinities. Activity is significantly reduced from the control values at 32, 40 and 50‰ by both light and medium dispersions, however loss of spontaneous locomotion only occurs at 40‰ and above in the medium dispersion. At 60‰ and above the salinity stress alone causes nearly complete mortality and loss of activity. The poor performance of the controls at 60‰ was unexpected as the previous acute salinity tolerance experiment had indicated 90% survival for this population at that salinity. Seasonal differences could contribute to the discrepency as the acute salinity tolerance experiment was run in December while the oil tolerance experiment was run in May.

A direct comparison of the activity ratings for the Stefansson Sound and Elson Lagoon B. affinis populations is shown in Fig. 13. The Stefansson Sound population is significantly more sensitive to both light and medium oil dispersions than the Elson Lagoon population at all test salinities. Furthermore, the results under the control (no oil) conditions indicate that the Stefansson Sound population is also more sensitive to elevated salinity. Activity was significantly lower in this population than in the Elson Lagoon population at 50‰. The reason for population differences in sensitivity to oil dispersions is not known. Percy and Mullin (1975) have reported possible seasonal differences for oil toxicity in this species, but this mechanism seems unlikely in the present study in that the Stefansson Sound animals were tested in March and the Elson Lagoon animals in May. Population differences in salinity tolerance could be the result of acclimatization of populations to local differences in salinity regimes. Stefansson Sound receives more discharge from major rivers than Elson Lagoon and the seasonal salinity regime there may be different. The population of B. affinis studies by Percy (1975) inhabited a more brackish area than those in the present study and his amphipods were markedly less tolerant to elevated salinity.

Similar comparisons were made between populations of Mysis littoralis from Stefansson Sound and from the region near Barrow. The response of

Figure 13. Comparison of the effects of salinity and exposure to Prudhoe Bay crude oil dispersions on the activity of *Boeckosimus affinis* from two different locations. Exposure to the test conditions was for 96 hours. Statistical significance between the populations according to Mann-Whitney tests is indicated below. N.S. - $p > .05$, s - $p < .05$.


Boeckosimus affinis
32 ‰
40 ‰
50 ‰
MEAN ACTIVITY RATING
0
1
2
3
4
▨ SS
▨ EL
NO OIL
25 μl OIL
100 μl OIL
NO OIL
25 μl OIL
100 μl OIL
NO OIL
25 μl OIL
100 μl OIL
N.S.
S.
S.
N.S.
S.
S.
S.
S.
S.

the Stefansson Sound mysids was not significantly different than that of the Barrow animals when tested at 32‰ in light and medium dispersions of oil.

The results of these oil toxicity tests indicate that all three of the species studied are relatively sensitive to seawater dispersions of Prudhoe Bay crude oil. Either light or medium dispersions caused mortality and a significant reduction in locomotor activity at some salinities. In general the oil toxicity was enhanced as hypersaline stress increased. The implications of these findings for OCS oil development during the winter months seems obvious. An oil spill during this season when many of the shallow water epibenthic animals are stressed by hypersaline conditions may have significant impact upon the populations. It is not known whether exposure to low salinity stress similarly enhances oil toxicity. Further studies are needed to evaluate this aspect.

Previous studies on the toxicity of crude oil to arctic species have indicated a wide range of sensitivities (Percy and Mullin, 1975; Busdosh and Atlas, 1977). Both of these studies found that B. affinis was relatively sensitive to oil, in agreement with the findings of this study. The conditons of the toxicity test used in the present study are most similar to the procedures used by Percy and Mullin (1975) although out tests were run at lower temperatures and higher salinities and a different source of crude oil was used. They found that the species they studied fell into two distinct categories, sensitive and resistant, on the basis of survival under exposure to 1000μℓ of crude oil dispersed in 500 ml of seawater. Since all three of the species used in the present study showed considerable mortality in less concentrated oil dispersions than those used by Percy and Mullin (1975), they should all be considered sensitive species.

Effect of Oil Dispersions on Metabolic Rates

The metabolic rates of Mysis littoralis, Anonyx nugax and Boeckosimus affinis were determined under various salinities and oil dispersions in an effort to detect sublethal effects. Since the primary information desired from these experiments is the effect of oil, the results are presented as the percent change in metabolic rate from the control group. The controls are the no oil treatment group run at each salinity. All metabolic rates were corrected to a standard body weight that approximated the mean weight of the population being studied, before the percent changes were calculated. The absolute metabolic rates for these experiments appear in appendix tables 1-3. To test for significance of differences, a 1-way analysis of variance was run on the data at each salinity. If a significant oil treatment effect was indicated a Newman-Keuls multiple range test was performed to determine which means were significantly different.

Mysis littoralis exposed to light (25µℓ/500 ml) oil dispersions for either 12 or 36 hours had slightly increased metabolic rates at all salinities (Fig. 14). However, the rate was significantly greater than the conrols only for mysids tested at 32‰ and 36 hour exposure. Exposure to medium (100µℓ/500 ml) dispersions resulted in either a decrease of the amount of stimulation or an inhibition of metabolic rates compared to the control animals. The trend was particularly pronounced for a 36 hour exposure period where the inhibition was statistically significant at 10, 45 and 50‰.

Anonyx nugax showed the opposite trend in that exposure to a light disperson of crude oil inhibited metabolic rates (Fig. 15). Increasing the concentration of the oil dispersions to medium and heavy (250µℓ/500 ml) levels in most cases tends to cause either a decrease in the inhibiton or an enhancement of the metabolic rates. The trend is most obvious at the highest salinity tested, 45‰. At this salinity the inhibiton was significant with both light and medium dispersions, but the stimulation seen with the heavy dispersion was not statistically significant.

Boeckosimus affinis appears to respond to oil dispersions similarly to *A. nugax*. Except at 40‰, the Elson Lagoon population shows inhibition of metabolic rates when exposed to light dispersions and a tendency to reverse this trend in medium dispersions of crude oil. The response is most obvious at 32‰ where the metabolic rate was significantly inhibited in the light dispersion but not in the medium dispersion. The results at 40‰ show the opposite trend although the metabolic rates are not significantly different from the controls in either dispersion. The Stefansson Sound population was inhibited by light dispersions at all salinities tested, however the effect is statistically significant only at 45 and 50‰. The population differences seen here parallel the differences in activity levels reported in Fig. 13.

Figure 14. Effects of exposure to Prudhoe Bay crude oil dispersions on the metabolic rate of Mysis littoralis at different salinities. The volumes of oil indicated were dispersed in 500ml seawater. Mysids were acclimated to each test salinity for 6 days. Cases where the rates of the treated group differ significantly from the control group (ANOV and Newman-Keuls test, $p < .05$) are indicated by an asterisk.

Mysis littoralis

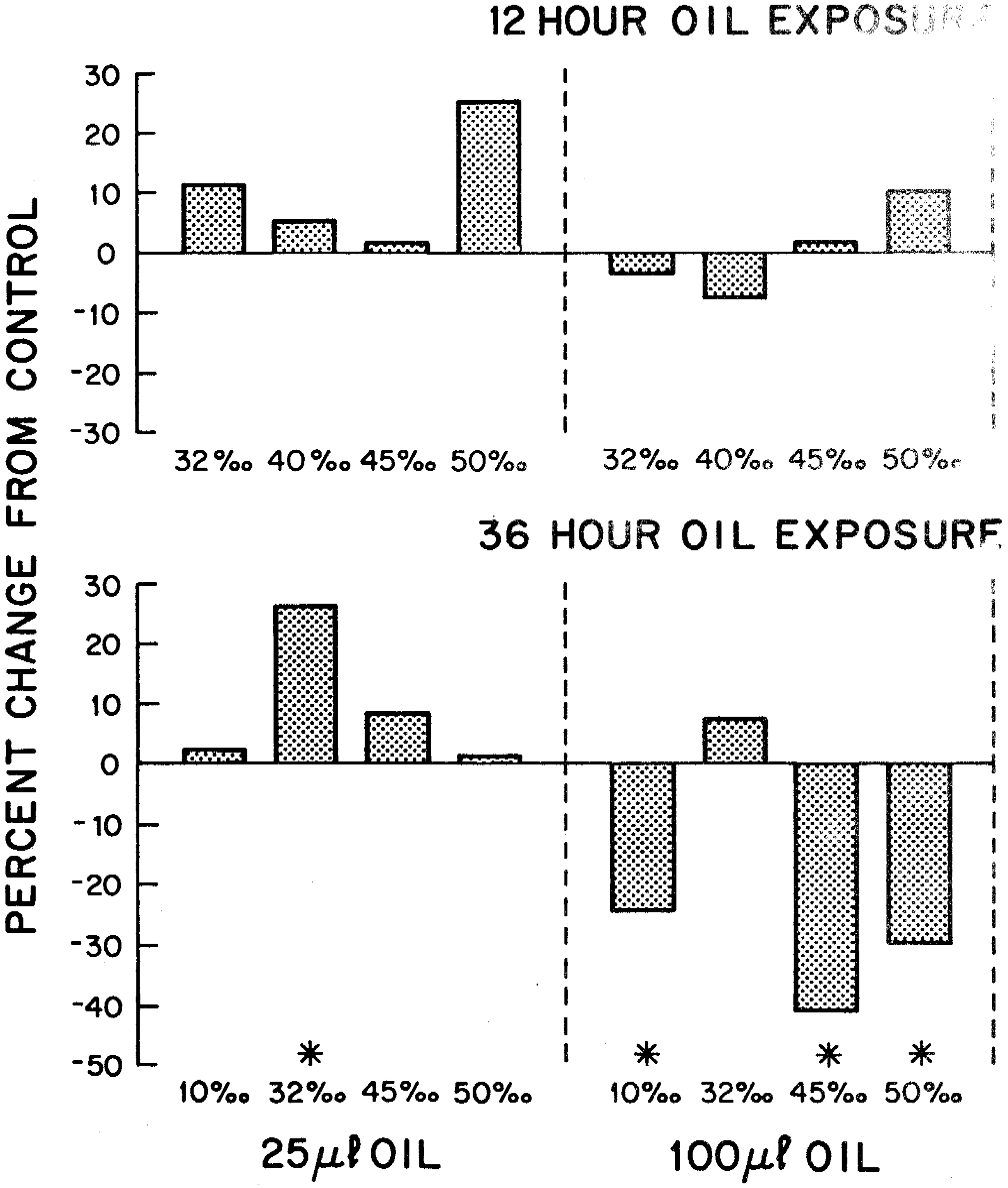
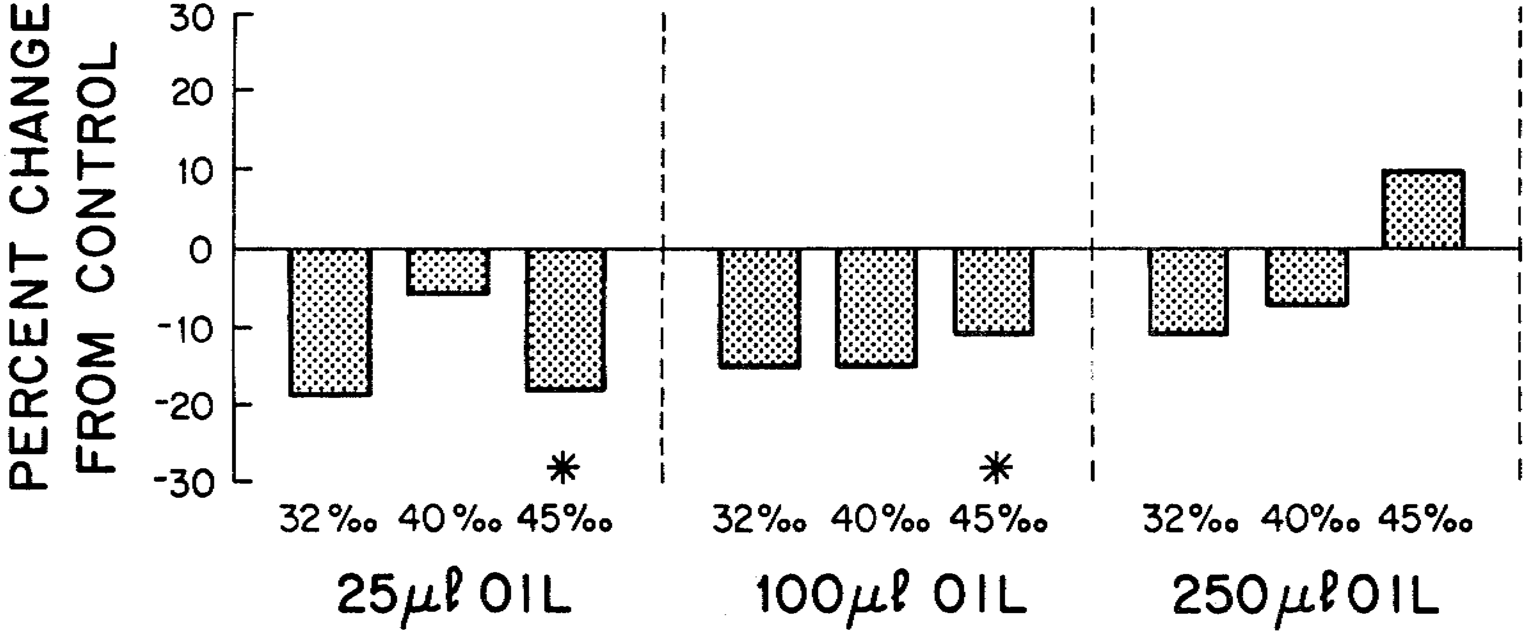


Figure 15. Effects of exposure to Prudhoe Bay crude oil dispersions on the metabolic rate of Anonyx nugax at different salinities. The volumes of oil indicated were dispersed in 500 ml seawater. Amphipods were acclimated to each test salinity for 6 days. Cases where the rates of the treated group differ significantly from the control group (ANOV and Newman-Keuls test, $p < .05$) are indicated by an asterisk.

Anonyx nugax

12 HOUR OIL EXPOSURE



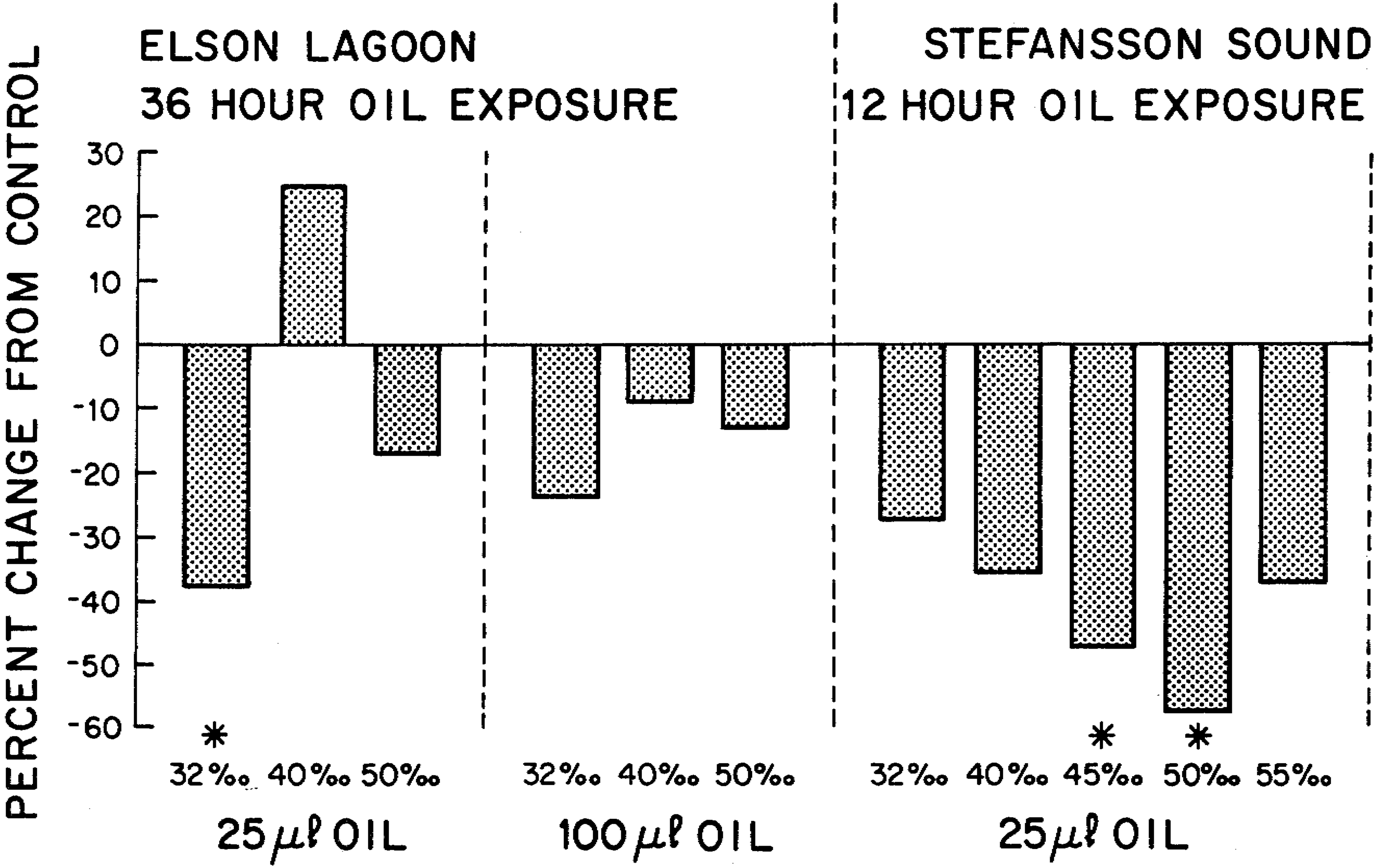
The metabolic response of marine invertebrates to crude oil exposure is highly variable and depends upon the experimental environmental conditions as well as the species being studied. Stimulation of metabolism by low oil concentrations followed by a decrease in stimulation or an inhibition at higher oil concentrations has been reported for the clam *Mya arenaria* (Stainken, 1978) and larvae of the horseshoe crab, *Limulus polyphemus* (Laughlin and Neff, 1977). At some temperatures the reversal of stimulation at high concentrations was not seen in the latter study. Other studies have reported an inhibition of metabolism at low oil concentrations followed by either a reversal of the inhibition or a stimulation of respiration at higher oil concentrations (Edwards, 1978; Percy and Mullin, 1975; Percy, 1977). Further increases in oil concentration have been found to reverse the stimulatory effect (Edwards, 1978). Percy (1977) postulates that the initial inhibitory effects on metabolism result from a decrease in activity. The subsequent stimulation of metabolism is thought to be an effect of soluble oil components upon the basal or standard metabolism required for maintenance.

Both of the above patterns were observed in this study. *A. nugax* and *B. affinis* tended to conform to the second pattern described above in that light dispersions were inhibitory. Support for Percy's (1977) hypothesis is seen in the close correlation between depressed locomotor activity (Figs. 10 and 11) and depressed metabolic rates (Figs. 15 and 16) for these two amphipods. The increased sensitivity of the Stefansson sound population of *B. affinis* for both of these functions is particularly noteworthy. The lack of a clear stimulation of respiration of *B. affinis* at higher oil concentrations is not inconsistent with Percy's (1977) data on this species. He generally did not obtain stimulation until his amphipods had been exposed to a dispersion of 1000μℓ oil/500 ml, a much higher concentration than those used in this study.

M. littoralis shows the first pattern described above in that there is no apparent inhibition of metabolism at the lowest oil concentration tested. It is possible that this pattern is not inconsistent with Percy's (1977) hypothesis. *M. littoralis* appears extremely sensitive to crude oil dispersions in that activity levels are severely depressed even in light dispersions (Fig. 10). In a sensitive species, a light

Figure 16. Effects of exposjre to Prudhoe Bay crude oil dispersions on the metabolic rate of Boeckosimus affinis at different salinities. The volumes of oil indicated were dispersed in 500 ml seawater. Amphipods were acclimated to each test salinity for 6 days. Cases where the rate of the treated group differ significantly from the control group (ANOV and Newman-Keuls test, $p < .05$) are indicated by an asterisk.

Boeckosimus affinis



dispersion (25μℓ/500 ml) may have already elevated standard metabolism and an even less concentrated dispersion may be necessary to observe an inhibition of respiration.

All three of the species studied have their metabolic rates significantly influenced by either light or medium dispersions of Prudhoe Bay crude oil, and the effects tend to be more pronounced at extreme salinities. Disturbances of metabolic rates are known to contribute to altered carbon flux through populations of marine animals (Bilfillan, 1975; Edwards, 1978). Consequently, an oil spill in the arctic shallow water, particularly during the winter when populations experience hypersaline stress, may have a significant impact upon the growth and energy flow through these epibenthic species. Since amphipods and particularly mysids have been shown to be important food sources for higher trophic levels (Craig and Griffiths, 1978; Johnson, 1978, 1979) disturbances of energy flow through these populations may have wide ranging consequenēces.

Conclusions

This study has established that many of the arctic shallow water epibenthic invertebreates are euryhaline. However, the upper salinity limits for survival and spontaneous locomotion for many species are approached in the deeper waters of lagoons during late winter and spring (Schell, 1975). To avoid these stressful conditions it is predicted that many of the species will migrate from lagoons during the winter. This prediction is supported by the seasonal distribution data for mysids obtained by Griffiths and Dillinger (1979).

Exposure of epibenthic invertebrates to Prudhoe Bay crude oil dispersions has shown that three of the most common species are sensitive to oil, particularly at elevated salinities where the animals may already be experiencing stress from that factor. These data suggest that an oil spill during the winter months may have more serious impact than one during a season with a less stressful salinity regime.

Table 2.1. *Anonyx nugax* = Metabolic rates determined at -1.0°C and corrected to a standard dry body weight of 45 mg. Animals were collected near Barrow, Alaska.

Oil Treatment	S‰	Date run	n	$\mu\ell O_2$/gm hr	$S_{\bar{x}}$
no oil	32	4/28	16	198.1	18.11
	40	4/14	16	170.4	10.93
	45	4/27	16	124.9	5.62
25µℓ oil 12 hrs	32	4/24	16	161.8	5.69
	40	4/16	16	160.3	9.61
	45	4/19	15	102.8	5.38
100µℓ oil 12 hrs	32	4/25	16	167.9	12.83
	40	4/17	15	143.9	6.08
	45	4/20	16	110.2	4.18
250µℓ oil 12 hrs	32	4/26	16	174.8	9.93
	40	4/18	16	157.1	6.66
	45	4/21	16	135.6	3.52

Table 2.2 . *Mysis littoralis* - Metabolic rates determined at -1.0°C and corrected to a standard dry body weight of 14 mg. Animals were collected near Barrow, Alaska.

Oil. con.	S‰	Date run	n	$\mu \ell O_2$/gm hr	$S_{\bar{x}}$
no oil	10	5/24	16	486.3	20.99
	32	5/15	16	461.3	25.30
	45	5/17	14	395.4	26.13
	50	5/21	5	354.7	19.16
36 hr 25$\mu\ell$ oil	10	5/25	15	497.5	22.34
	32	5/28	16	582.1	40.61
	45	5/18	12	426.3	32.48
	50	5/22	8	357.4	39.02
36 hr 100$\mu\ell$ oil	10	5/26	16	366.1	22.69
	32	5/16	16	496.8	26.77
	45	5/19	14	232.9	16.37
	50	5/23	10	252.0	7.16
no oil	32	4/3	16	497.9	32.81
	40	4/29	16	517.3	22.15
	45	4/22	16	389.2	21.03
	50	4/23	9	270.5	12.73
12 hr 25$\mu\ell$ oil	32	4/11	16	553.9	32.13
	40	4/5	16	543.4	31.48
	45	4/7	16	394.9	28.24
	50	4/9	10	338.1	17.77
12 hr 100$\mu\ell$ oil	32	4/4	14	482.8	22.17
	40	4/6	16	480.1	36.23
	45	4/8	9	396.7	32.54
	50	4/10	7	297.5	26.53

Table 2.3. *Boeckosimus affinis* - Metabolic rates determined at -1.0°C and corrected to a standard dry body weight of 20 mg (Elson Lagoon) and 7 mg (Stefansson Sound). Animals were collected in Elson Lagoon near Barrow, Alaska.

Location	Oil Treatment	S‰	Date run	n	$\mu\ell O_2$/gm hr	$S_{\bar{x}}$
Elson Lagoon	no oil	32	5/8	16	202.5	18.05
		40	5/4	16	242.6	14.91
		50	5/5	16	207.6	20.36
	36 hr 25μℓ oil	32	5/9	16	126.3	19.60
		40	5/2	16	301.8	47.25
		50	5/6	16	171.9	31.84
	36 hr 100μℓ oil	32	5/10	15	153.0	14.30
		40	5/3	16	220.4	22.22
		50	5/7	16	180.4	21.49
Stefansson Sound	no oil	32	3/8	16	256.5	29.98
		40	3/10	16	366.0	57.81
		45	3/12	16	152.4	18.12
		50	3/14	16	208.6	36.12
		55	3/16	16	176.3	32.84
	12 hr 25μℓ oil	32	3/20	16	186.0	24.54
		40	3/24	16	234.7	50.29
		45	3/26	15	79.6	3.40
		50	3/28	16	89.0	6.38
		55	3/30	9	110.6	15.91

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A Preliminary Study of the Distribution, Abundance and Reproductive Patterns of the Amphipods *Pontoporeia affinis* and *Pontoporeia femorata* in Barrier Island-Lagoon Ecosystems of the Western Beaufort Sea

Helmut Koch

INTRODUCTION AND OVERVIEW

More than 50% of the coastline of the Alaskan Beaufort Sea is skirted by discontinuous chains of barrier islands. Recent investigations of several partially enclosed lagoons and bays situated between these islands and the mainland coast have provided evidence which suggests that the physical, hydrological and biological dynamics of these systems may be different from those operating in more exposed coastal habitats and offshore regions (Alexander et al. 1975; Burrell et al. 1975; Craig and Griffiths 1978; Crane and Cooney 1975; Griffiths and Dillinger 1979; Griffiths et al. 1977; Schell 1975; Truett 1978, 1979). The following ecological parameters appear to be important in influencing both the qualitative and the quantitative character of the nearshore lagoon benthos.

Salinity and Temperature

Most Beaufort Sea lagoons and inner regions of bays have an estuarine character during the open water season, at which times their waters are relatively warm and brackish as a result of dilution with fresh water derived from melting ice, river discharge and general land drainage. These conditions seem to persist throughout the open water season, indicating that barrier islands may retard exchange processes between lagoon and offshore marine waters (Truett 1979). It has been suggested that the heavy utilization of nearshore lagoon areas by migrating anadromous fish (Craig and Griffiths 1978), and the apparent immigration of certain species of motile epibenthic invertebrates from offshore regions into the lagoons during the summer may, in part, be related to these warmer, estuarine conditions (Griffiths and Dillinger 1979).

Zenkevitch (1963) considers the nearshore Beaufort Sea to be part of the shallow high arctic brackish-water region. Several seas in the northern USSR fall into this same category, and Zenkevitch lists numerous benthic brackish-water relicts that occur there. There is considerable overlap between the species he lists and those that have been found in Beaufort Sea lagoons (personal observation), which suggests that the benthic lagoon fauna is well adapted to brackish-water conditions. Nevertheless, restricted exchange between lagoon and offshore waters, particularly in the shallower, more isolated portions of lagoons, can result in "psychrogenic hypersalinities" occasionally exceeding 60‰ during late winter and early spring (Schell 1975; Truett 1978). The effects of such high salinities on the relatively sessile, non-migratory infauna of deeper lagoon areas have yet to be established, but there is evidence that some of the motile species can tolerate salinities exceeding 40-50‰ (Schneider, this report). Further experimentation may reveal lagoon species to be generally more euryhaline than offshore benthic species, which probably experience near-normal salinities throughout most of the year.

Ice

Ice gouging and scouring have been implicated by numerous investigators as primary causes for the general lack of well-developed benthic communities in arctic littoral systems (Crane and Cooney 1975; Ellis 1960; Feder and Schamel 1976; MacGinitie 1955; Madsen 1936; Mohr and Tibbs 1963; Zenkevitch 1963). Photographs of the bottom, and direct observations by divers, have revealed that the benthic fauna associated with recent ice scouring is generally poorly developed compared to assemblages occupying surrounding, unaffected areas (Reimnitz and Barnes 1974). Although lagoon bottoms are subjected to some degree of ice scouring, the presence of intervening barrier islands may reduce its severity (Burrell et al. 1975; McRoy and Allen 1974; Truett 1978; M. Busdosh, pers. comm.). This may partially account for the generally higher benthic biomass (particularly of the sessile component) in deeper parts of lagoons, compared to that of more exposed coastal regions of similar depth (personal observation).

Detritus

Truett (1979) cites evidence which indicates that nearshore basins behind barrier islands may act as traps for detritus derived from river discharge, coastal erosion, and possibly from offshore regions via the landward component of bottom currents. Such detritus, with its associated epiflora (microalgae and bacteria), could prove to be a key source of energy for the benthic lagoon fauna, which appears to be composed predominantly of deposit-feeding detritivores. If lagoons act as detrital sinks, this may partially account for the greater densities of sessile deposit feeders in the deeper sections of lagoons compared to exposed nearshore regions of similar depth. Detrital availability, together with the warmer, brackish conditions prevailing in lagoons, may also explain the immigration of certain motile epibenthic species from offshore regions into the lagoons during the summer. This phenomenon has led to the notion that lagoons might act as summer nurseries for immigrating epibenthic species (Griffiths and Dillinger 1979), whose population centers are apparently located further offshore (Feder and Schamel 1976). Analysis of fecal pellets, and feeding experiments conducted during the summers of 1977 and 1978 by Schneider and Koch (1979), indicate that numerous littoral benthic species ingest terrestrially derived detritus (peat) which blankets the bottoms of many coastal lagoons.

Sediments

In the shallow regions of lagoons, near the gravelly mainland and barrier island beaches, gravelly sands are the predominant sediment types. The deeper sediments consist principally of sandy muds (silts) and muddy sands (personal observation). This basic pattern also emerged as a result of a detailed study of Simpson Lagoon sediments (Burrell et al. 1975). There are also indications that the sediments in the deeper parts of lagoons (3-4 meters) contain a higher proportion of the finer sediment fractions (primarily silts) than sediments at similar depths in more exposed coastal regions (personal observation). Burrell et al. (1975) have suggested that the preponderance of sediments in the silt size range in the deeper sections of Simpson Lagoon may be primarily a function of the "quiet" water environment of the lagoon, in which excessive turbulence is curtailed by the protection provided by barrier islands and a 9-month ice cover. The finer sediments of deeper lagoon areas, linked with a relatively "quiet" environment, are conducive to the establishment of a fairly diverse group of tube-building and burrowing benthic invertebrates, primarily polychaetes, amphipods (P. femorata, P. affinis) and bivalves. The tubes and burrows of these organisms probably increase both the stability and the spatial heterogeneity of lagoon bottoms, resulting in a greater variety of available microhabitats. Such animal-sediment interactions have been reported to contribute significantly to the diversity of sandy bottoms in coastal regions (Young and Rhoads 1971).

Primary Productivity

Differences in primary productivity (phytoplankton, benthic microalgae, epontic algae) between lagoon and non-lagoon systems have not yet been clearly established or well documented, although Alexander et al. (1975) found generally higher levels of primary production in higher salinity, deeper, offshore waters. Nevertheless, the rather consistent presence of partially digested planktonic and benthic diatoms in the guts and fecal pellets of numerous nearshore benthic invertebrates during the summers of 1977 and 1978 (Schneider and Koch 1978, 1979), suggests that they are an important seasonal dietary component for many lagoon species.

Preliminary analysis of data collected by RU 356 during July and August, 1975 to 1978, indicates that the summer standing crop biomass of the benthic infauna in the deeper parts of lagoons (3 to 4 meters) is considerably higher than at similar depths in more exposed coastal regions (58gm^{-2} versus 32gm^{-2}). The main difference in these figures is attributable to the greater abundance of the low-motility, sessile components of the lagoon benthos, primarily deposit and filter feeding polychaetes and bivalves, as well as the free-burrowing amphipods *P. femorata* and *P. affinis*. Since most of these organisms (with the possible exception of certain motile species) are not likely to engage in seasonal migrations into and out of the lagoons, their greater abundance and biomass in lagoons is probably not merely a summer phenomenon, but undoubtedly reflects basic differences in the above-outlined parameters between lagoon and non-lagoon ecosystems.

The degree to which biological interactions (competition, predation) determine the composition and stability of the benthos in various coastal habitats of the Beaufort Sea has yet to be established. I have found that, although the lagoon and non-lagoon benthic fauna at similar depths is not strikingly different qualitatively, the structural organization of the benthic communities appears to vary. Certain species (many of them relatively sessile) exhibit a stronger preference for, and dominance in the lagoon environment, whereas others are more successfully established in exposed sections of the coastline. This may reflect variability in both the physical regime and in the kinds of biological interactions occurring in the various coastal habitats.

These preliminary findings suggest that the nearshore environment of the western Beaufort Sea cannot be considered as a homogeneous unit, but consists of a variety of habitats, some of which probably exhibit unique attributes of benthic community structure and trophic organization. A basic understanding of the ecological relationships operating within these coastal subsystems, and the accurate assessment of the effects of any eventual man-induced environmental perturbation on their benthic communities, is only possible after critical examination of the biological-physical interactions occurring within them. This preliminary study on the distribution, abundance and reproductive patterns of _P. femorata_ and _P. affinis_ in the coastal lagoons represents an initial contribution towards that end.

METHODS

Field Sampling

Shallow water benthic samples, from shore to 2-3 meters, were collected primarily with an Ekman grab ($0.023m^2$) and screened in the field on 0.5 mm mesh prior to bagging. In 1976, the Ekman was also used to collect samples in the deeper parts of lagoons (up to 4 meters depth). After 1976, samples at depths exceeding 3 meters were generally taken with a Smith McIntyre grab ($0.1m^2$) from the RV ALUMIAK. These samples were washed on board in a cascading, multiple sieve system in which the controlling (lower) mesh size was of 0.423 mm NITEX.

The epibenthos was sampled with an epibenthic sled net (1.05 mm mesh), towed for 50 meters in shallow water and for 5 minutes (approximately 150 m) in deeper water.

All biological samples were preserved in 10% hexamine-buffered formalin.

Sediment samples were collected with either the Ekman or Smith McIntyre grab. Representative subsamples of approximately 500cc were retained for subsequent laboratory analysis.

Tempterature-Salinity profiles were determined with a Yellow Springs Instrument model 33 SCT meter.

Laboratory Processing

1. Preparation and Sorting of Biological Samples

All laboratory processing was conducted in the Arctic Research Laboratory, Western Washington University, Bellingham, Washington. Most biological samples were initially stained with a rose begal solution (0.19g/1) for 24 hours to facilitate the extraction of smaller organisms. Samples were then washed through a #35 (0.5 mm mesh) U.S.A. Standard Testing Sieve, after which the organisms were extracted, counted and separated into major taxa under 3X magnification (Luxo illuminated magnifier). The organisms were kept in 35% propanol prior to identification.

2. Wet and Dry Weights

After identification, the wet weight of each species was determined to the nearest milligram on a Sartorius top-loading balance (Sartorius 2355). Prior to weighing, animals were blotted on absorbent paper toweling to remove excess surface fluid. For _P_. _affinis_ and _P_. _femorata_, dry weights were determined to the nearest milligram after drying at 60°C for at least 24 hours. All weights should be considered approximate, since preservation in either formalin or alcohol can alter the actual weights of amphipods and crustaceans in general.

3. _P_. _affinis_ and _P_. _femorata_ Length Measurements

The amphipods were measured to the nearest millimeter with a plastic metric ruler attached to the bottom of a clear, 13.5 cm-diameter Petrie dish. All measurements were made under a 3X Luxo magnifier-illuminator. The amphipods were straightened by using a combination of jeweler's forceps and fine insect pins, and measured from the anterior edge of the head to the end of the first uropods.

4. Sediment Analysis

Coarse sediment samples with no or very little mud were oven-dried at 40°C after which the sample was hand-shaken in a #5 (-2ø) U.S.A. Standard Testing Sieve to remove the gravel fraction. The remainder of the sample was passed through a sediment splitter, split to an appropriate size (80-100 grams), and mechanically shaken for 15 minutes in a Ro-Tap through a series of standard sieves (-1ø to +4ø in 1ø intervals, plus pan). Each ø size fraction (and the pan or "mud" fraction) was weighed to the nearest

0.1 gram on a Cent-O-Gram triple beam balance. For this report, the -1ϕ to +4ϕ fractions were combined to represent the total sand fraction.

For samples with an appreciable mud fraction, two separate procedures were followed. Samples (or subsamples) analyzed for total mud only, without regard to the percentage of silt and clay, were oven-dried at 40°C and weighed (generally between 40 and 60 grams). The dried sample was placed in a beaker and covered with distilled water to which several drops of conc. NH_4OH dispersant were added. The sample was kept in the beaker for at least 24 hours and stirred frequently. It was then wet-sieved through the same standard sieve series used for the coarser sediment samples until the water passing through the +4ϕ sieve was clear. The various ϕ fractions were dried, weighed and totaled; the difference between this total and the initial dry weight of the sample was assumed to represent the dry weight of the mud fraction.

A wet-sieve-pipette methodology (Folk 1974) was used with samples analyzed for their silt and clay fractions. This method works well with small samples or subsamples (15-20 grams) and reduces the problem of particle aggragation since pre-drying of the sample is avoided.

STUDY AREAS

The major lagoon ecosystems sampled during the summers of 1975, 1976, 1977 and/or 1978 have been blocked off in Figure 1. The most intensive lagoon sampling occurred during July and August of 1976. Elson Lagoon extends from Pt. Barrow, eastward, toward Dease Inlet, north of Admiralty Bay. The lagoon is protected by an extensive chain of barrier islands (Plover Islands). Simpson Lagoon, east of the Colville River, is partially enclosed by the Jones Islands. Although Prudhoe Bay, as a whole, is not as well protected as the other systems, the inner sections of the bay are partially enclosed by the surrounding mainland and some protection may also be provided by several smaller barrier islands further offshore. The stations east of Prudhoe Bay (G0C → E59) are located shoreward of an extensive chain of barrier islands (Stockton Islands, Maguire Islands and the relatively large Flaxman Island), forming a lagoon ecosystem which has recently been referred to as Leffingwell Lagoon. The Barter Island block contains Kaktovic Lagoon, which is located off the eastern shore of Barter Island. The area just southeast of Nuvagapak Entrance encompasses Nuvagapak Lagoon.

Fig. 3.1. The coastline of the Western Beaufort Sea, Point Barrow to Demarcation Point. Blocked areas and labeled points represent major lagoons and bays sampled by RU 356 during the summers of 1975, 1976, 1977 and/or 1978.

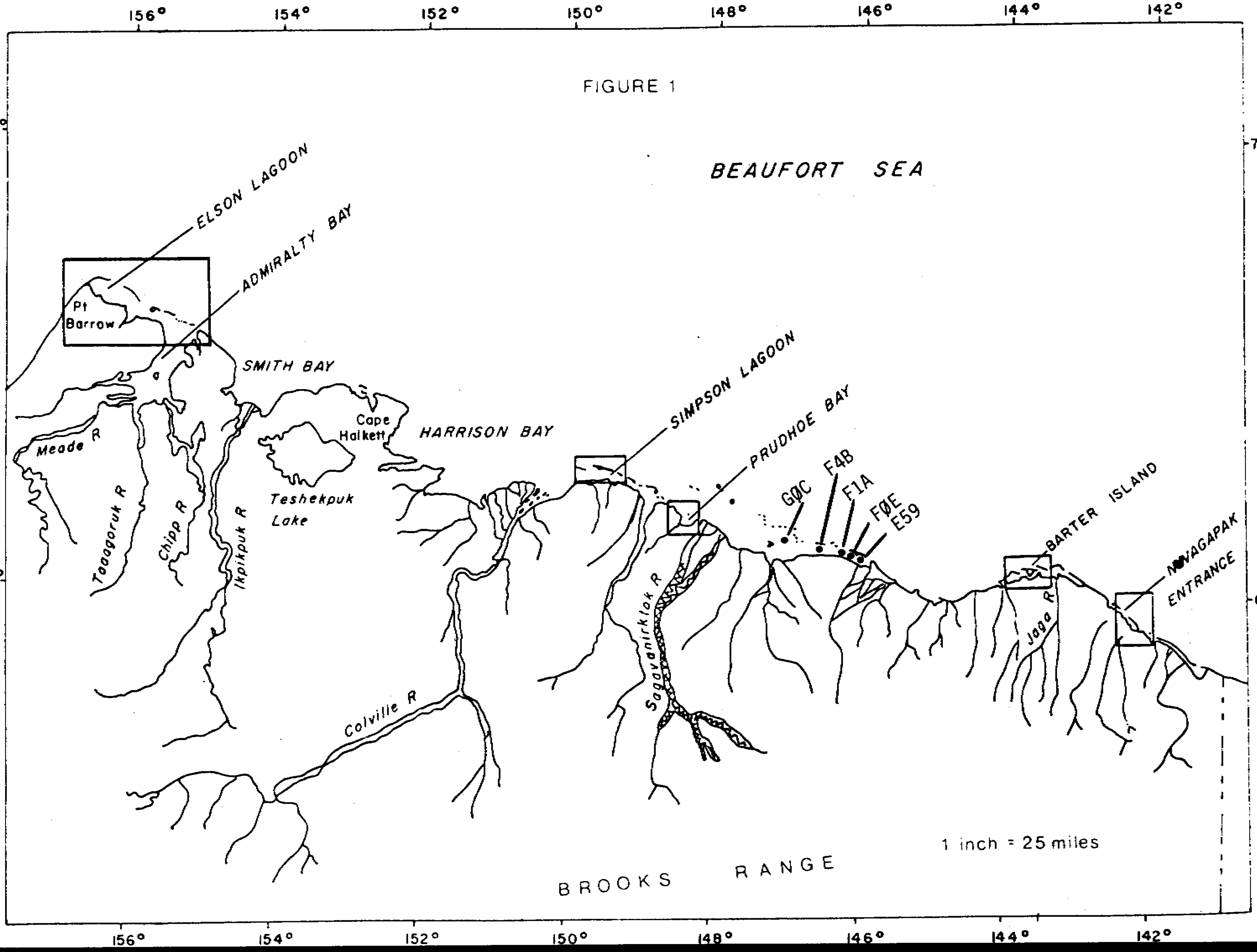


FIGURE 1

156°
154°
152°
150°
148°
146°
144°
142°
72°
70°
68°
BEAUFORT SEA
ELSON LAGOON
ADMIRALTY BAY
Pt Barrow
SMITH BAY
Cape Halkett
HARRISON BAY
SIMPSON LAGOON
PRUDHOE BAY
G0C
F4B
F1A
F0E
E59
BARTER ISLAND
NUVAGAPAK ENTRANCE
Meade R
Topagoruk R
Chipp R
Ikpikpuk R
Teshekpuk Lake
Colville R
Sagavanirktok R
Jago R
BROOKS RANGE
1 inch = 25 miles

Individual sampling sites (stations) within the various lagoons (except in Leffingwell Lagoon) have not been indicated, since the main purpose of this report is to define the overall distribution and abundance patterns of *P. affinis* and *P. femorata* within the general lagoon environment.

RESULTS AND DISCUSSION

The Lagoon Benthos

The major species making up the benthic lagoon fauna are ranked for various depth intervals in Table 1. Species were ranked according to their numerical abundance in each sample, using the ranking method presented in Table 2. The actual densities of individual species and their total scores as derived from the ranking method are not given, since it is my intention to show only the relative changes in dominance among the species, at various depths. The ranking is based on the combined summer Ekman grab samples (1975, 1976) from numerous coastal lagoons (Fig. 1), and therefore conceals any differences between individual lagoons, annual variations, and any changes in the densities of individual species between the months of July and August during which the samples were collected. The inclusion of several larger taxa, whose constituent species have not yet been identified, will introduce some error into the ranking scheme. Despite these generalizations and limitations, the relative species ranks are useful in describing what might be called the "average, overall" qualitative and quantitative summer composition of the benthos in the general lagoon environment.

A critical examination of Table 1 reveals both subtle and more obvious qualitative and quantitative (as expressed by rank) changes in the species composition of the benthic lagoon fauna at various depths. It is not within the scope of this report to comment on all of these, but it is apparent that the structural organization of benthic lagoon communities undergoes observable changes along the depth gradient. This undoubtedly reflects variability in both the physical regime and in the nature and intensity of biological interactions.

Enchytraeid oligochaetes, as a group, numerically dominate the lagoon shallows, especially between the shore and the 1-meter isobath. They are virtually non-existent in the deeper lagoon regions, where they appear to

Table 3.1. Rank order of abundance of species at various depths in lagoon ecosystems of the Western Beaufort Sea (See Fig. 1). Species were ranked according to the method of Sanders (1960), see Table .2. Species whose total scores were within 5 points of each other were arbitrarily considered to be of equal rank. Data used were from Ekman grab samples taken during the summers of 1975 and 1976 by RU 356. Letters in parentheses refer to major taxon to which the animal(s) belong(s): (A)=Amphipod (B)=Bivalve (D)=Diptera (G)=Gastropod (I)=Isopod (O)=Oligochaete (P)=Polychaete (PR)=Priapulid.

< 2 meters	2 - 2.5 meters	3 - 4 meters
1. *Enchytraeidae* (O) (Probably numerous species)	1. *Onisimus glacialis*	1. *Pontoporeia femorata*
2. *Onisimus glacialis* (A)	2. *Scolecolepides arctius*	2. *Terebellides stroemi* (P) *Tharyx* spp.
3. *Pontoporeia affinis* (A)	3. *Cyrtodaria kurriana*	3. *Liocyma fluctuosa* (B)
4. *Scolecolepides arctius* (P)	4. *Ampharete vega* (P)	4. *Ampharete vega*
5. *Chironomidae*-larvae (D)	5. *Halicryptus spinulosus*	5. *Cylichna occulta* (G) *Scolecolepides arctius*
6. *Pygospio elegans* (P)	6. *Saduria entomon*	6. *Boreacola vadosa* (B) *Halicryptus spinulosus*
7. *Saduria entomon* (I)	7. *Gammarus setosus* *Tubificidae* (O)	7. *Aricidea* spp. (P) *Tubificidae*
8. *Gammarus setosus* (A)	8. *Pontoporeia femorata* (A)	8. *Portlandia* intermedia (B)
9. *Cyrtodaria kurriana* (B)	9. *Chone* sp. (P)	9. *Prionospio cirrifera* (P)
10. *Halicryptus spinulosus* (PR)	10. *Tharyx* spp. (P)	10. *Cyrtodaria kurriana*

Table 3.2. Example of method used to rank the individual species in Table . After Sanders, 1960.

Numerical Rank of Species in Sample:	1	2	3	4	5	6	7	8	9	10	
Score of Rank:	10	9	8	7	6	5	4	3	2	1	
Number of Samples in which Species had given Rank:	10	6	9	6	7	0	7	4	1	1	Total Score:[b]
Score:[a]	100	54	72	42	42	0	28	12	2	1	→ 353

a: Score = No. of samples in which species had given rank X score of rank.

b: Total scores are used to rank species in Table .1.

be replaced by tubificid oligochaetes and a variety of polychaete species. Onisimus glacialis is the most abundant amphipod within 2.5 meters, but apparently does not penetrate significantly into the deeper parts of lagoons. Its importance in nearshore areas of Simpson Lagoon has been discussed by Griffiths and Dillinger (1979). Finally, Pontoporeia affinis, a dominant amphipod in lagoon shallows, is replaced by its congener P. femorata in progressively deeper lagoon areas. Between 3 and 4 meters, P. femorata is the numerically dominant benthic invertebrate in the general coastal lagoon environment of the Beaufort Sea.

Thorson (1957), in his lucid monograph on bottom communities, suggests that benthic communities dominated by amphipods (generally in norther latitudes) are mainly associated with estuarine, brackish-water conditions and relatively soft bottoms. He describes one such community, the boreo-arctic brackish-water Pontoporeia community. The characterizing species of this community are:

1. Pontoporeia affinis, haustoriid amphipod, occurring generally in shallower, sandier bottoms
2. Pontoporeia femorata, haustoriid amphipod, occurring in deeper, siltier bottoms
3. Bathyporeia pilosa, haustoriid amphipod (a species not occurring in the Beaufort Sea)
4. The large isopod, Saduria entomon
5. The priapulid, Halicryptus spinulosus
6. Larval Chironomidae

In the Baltic Sea, elements of this community exist at depths of 10 and 20 meters and down to about 200 meters, but in southern Iceland the community is found exclusively between 1 and 4 meters. Zenkevitch (1963) has reported elements of the Pontoporeia community from the brackish littoral regions of the White and Kara Seas, northern USSR. Table 1 clearly shows that this community also prevails in the coastal lagoons of the western Beaufort Sea, and I believe this is the first time it has been formally described for the nearshore regions of the Beaufort Sea. Owing to the particular characteristics of the Beaufort Sea lagoon environments, certain differences between the composition of the Beaufort Pontoporeia community and those described from other arctic regions by Thorson and Zenkevitch are to be expected. Thus, in the Beaufort Sea lagoons, the lysianassid amphipod *Onisimus glacialis* replaces the haustoriid *Bathyporeia pilosa* (which does not occur in the Beaufort) as a major characterizing species. Thorson's exclusion of enchytraeid oligochaetes as characterizing elements of the *Pontoporeia* community, despite their apparent abundance in many arctic littoral regions (Madsen 1936; Zenkevitch 1963), is probably based on their negligible biomass and the fact that they are most densely concentrated in the very shallow inshore regions (0.5 meters and less), into which the typical components of the *Pontoporeia* community do not penetrate significantly.

Overall, the existing evidence suggests that the benthic communities of shallow, brackish-water environments of many arctic regions are sometimes characterized by very similar faunas, of which the most consistently unifying constituents appear to be the amphipods *P. affinis* and/or *P. femorata*. The remainder of this report will deal with some aspects of their distribution, abundance and reproduction in coastal lagoons of the Beaufort Sea. A synopsis of data on the two species is given below.

Pontoporeia affinis Lindstrom

Family *Haustoriidae*, Subfamily *Pontopreiinae* (Bousfield, 1973). Free-burrower, Deposit Feeder (Bousfield 1973; Segerstrale 1973). *P. affinis* is found in brackish coastal waters off the northern USSR, Siberia, Alaska and Canada, and as a glacial relict in the Baltic Sea and lakes in North America and Eurasia (Segerstrale 1967). During the summer, it occurs in the shallows of northern lakes, but only where temperatures remain below 14.5°C (Bousfield 1958). Its presence in brackish northern seas suggests that it constitutes a remnant of the ancient arctic stock existing off the coasts of Northern Europe and North America during the glacial period. A part of this stock was apparently left behind and isolated in northern lakes as the glaciers retreated (Sars 1890).

Dunbar (1954) indicated that the species is found primarily in brackish water, especially near river mouths, and he collected it in Ungava Bay at stations of strong freshwater influence. Shoemaker (1920) found it in very shallow water in a semi-protected bay between Prudhoe Bay and Barter Island, Alaska. Zenkevitch (1963) reported it from several seas in the northern USSR, describing it as a eurybiotic, widely distributed species with a strong preference for brackish and freshwater conditions.

Dunbar (1954) found the maximum length of Ungava Bay specimens to be 14 mm, which he indicated was 3 mm longer than the maximum length measured by Segerstrale for arctic specimens.

The life-cycle and reproductive phase appear to be variable, depending on the environmental temperature, depth and photoperiod (Segerstrale 1967). In colder, northern marine waters, a 2-year life cycle prevails, with individuals not breeding until the winter of their second year; in shallow water, the young are released primarily during the following spring, although deeper-water populations appear to breed throughout the summer (Segerstrale 1967). Thorson (1957) indicated that in the Baltic Sea, the females live in shallow water for one year, and the males die off after mating one-half year earlier. Bousfield (1958) indicated that in the colder, northern regions, the males are pelagic in October, ovigerous females occur from November to April, and that their life span is slightly more than 2 years.

Pontoporeia femorata Kroyer

Family *Haustoriidae*, Subfamily *Pontoporeiinae* (Bousfield 1973). Free-burrower, Deposit Feeder? (Bousfield, pers. comm.). Maximum length, 13 mm (Bousfield 1973) *P. femorata* has a circumpolar, arctic and subarctic distribution (Bousfield 1973; Dunbar 1954; Sars 1890; Segerstrale 1967). Although it is abundant in shallow arctic waters (Dunbar 1954; pers. observ.), a review of the available literature suggests that it penetrates into deeper marine waters more frequently than *P. affinis*. Bousfield (1973) indicated that it burrows in muddy and sandy mud bottoms, in shallow water to more than 50 meters. MacGinitie (1955) collected it at 155 and 245 meters in soft mud in the Beaufort Sea. Sars (1890) noted it between 35 and 180 meters on muddy bottoms off the northern coast of Norway. It occurs as a glacial relict in certain sections of the Baltic Sea, but in contrast with *P. affinis* it is not able to tolerate salinities below 6‰ (Segerstrale 1967). Zenkevitch (1963) indicated that it is adapted to normal and somewhat lowered salinities. As with *P. affinis*, its life-cycle and reproductive phase are probably influenced by various physical parameters. Shallow-water populations appear to breed mainly during the winter, with maximum release of young occurring in the spring; in deeper water, breeding probably occurs during the summer as well (Segerstrale 1967). According to Bousfield (1973), this species has an annual life cycle, with ovigerous females occurring between October and February, and producing one brood per year; mature males are pelagic in the fall and winter. As with _P. affinis_, this species probably has a longer life span in colder, arctic waters.

Distribution and Abundance of _P. affinis_ and _P. femorata_

General Patterns

There is a striking spatial (depth) separation between lagoon populations of _P. affinis_ and _P. femorata_ during the open-water season (Table 3, Figure 2). These results were obtained from Ekman grab samples taken during the summers of 1976, 1977 and 1978 in the major lagoon and semi-protected bay ecosystems shown in Figure 1. The relatively high standard errors associated with the mean densities at various depths (Table 3) reflect considerable variability between samples, which is probably attributable to a combination of the following factors:

1. Differences between individual lagoons
2. Annual variations in density
3. Variations in density between the months of July and August during which the samples were collected
4. Natural patchiness of the populations

Despite this variability, it is clear that lagoon populations of _P. affinis_ are concentrated between 0.5 and 1.5 meters, whereas populations of _P. femorata_ reach peak densities between 3 and 4 meters. Although _P. femorata_ does not penetrate shoreward of the 2-meter isobath, _P. affinis_ does extend into the deeper parts of lagoons, where its densities are nevertheless considerably below those of _P. femorata_. This distinct spatial separation between two sympatric, congeneric species is probably effective in limiting the intensity of competition between the two species, particularly during times of recruitment of young and intensive feeding activity. Other reasons for this separation, and the factors which might account for this pattern will be discussed later.

The data derived exclusively from an extensive lagoon sampling survey conducted during the summer of 1976 have been analyzed separately, and the results are presented in tables 4, 5 and 6. The samples from all the lagoons were combined for the analysis. Again, a distinct spatial separation between lagoon populations of _P. affinis_ and _P. femorata_ is evident. _P. affinis_ was three times more abundant, and its wet weight standing crop

Table 3.3. Mean densities (per square meter) of *Pontoporia affinis* and *Pontoporeia femorata* in Ekman grab samples taken at various depths in lagoon ecosystems of the Western Beaufort Sea during the summers of 1976, 1977 and 1978. N = No. of samples $\overline{N}_{PA}$ = mean number of *P. affinis* $\overline{N}_{PF}$ = mean number of *P. femorata* SE = standard error.

Depth (M)	N	$\overline{N}_{PA}M^{-2}$ ± SE	$\overline{N}_{PF}M^{-2}$ ± SE
0.0 (water's edge)	60	0	0
0.5	80	170 ± 44	0
0.8	16	670 ± 235	0
1.0	38	98 ± 23	0
1.5	46	93 ± 33	0
2.0	79	58 ± 14	7 ± 4
2.5	57	40 ± 12	78 ± 23
3.0	63	13 ± 7	206 ± 43
3.5	14	47 ± 23	1252 ± 705
4.0	9	19 ± 11	904 ± 450

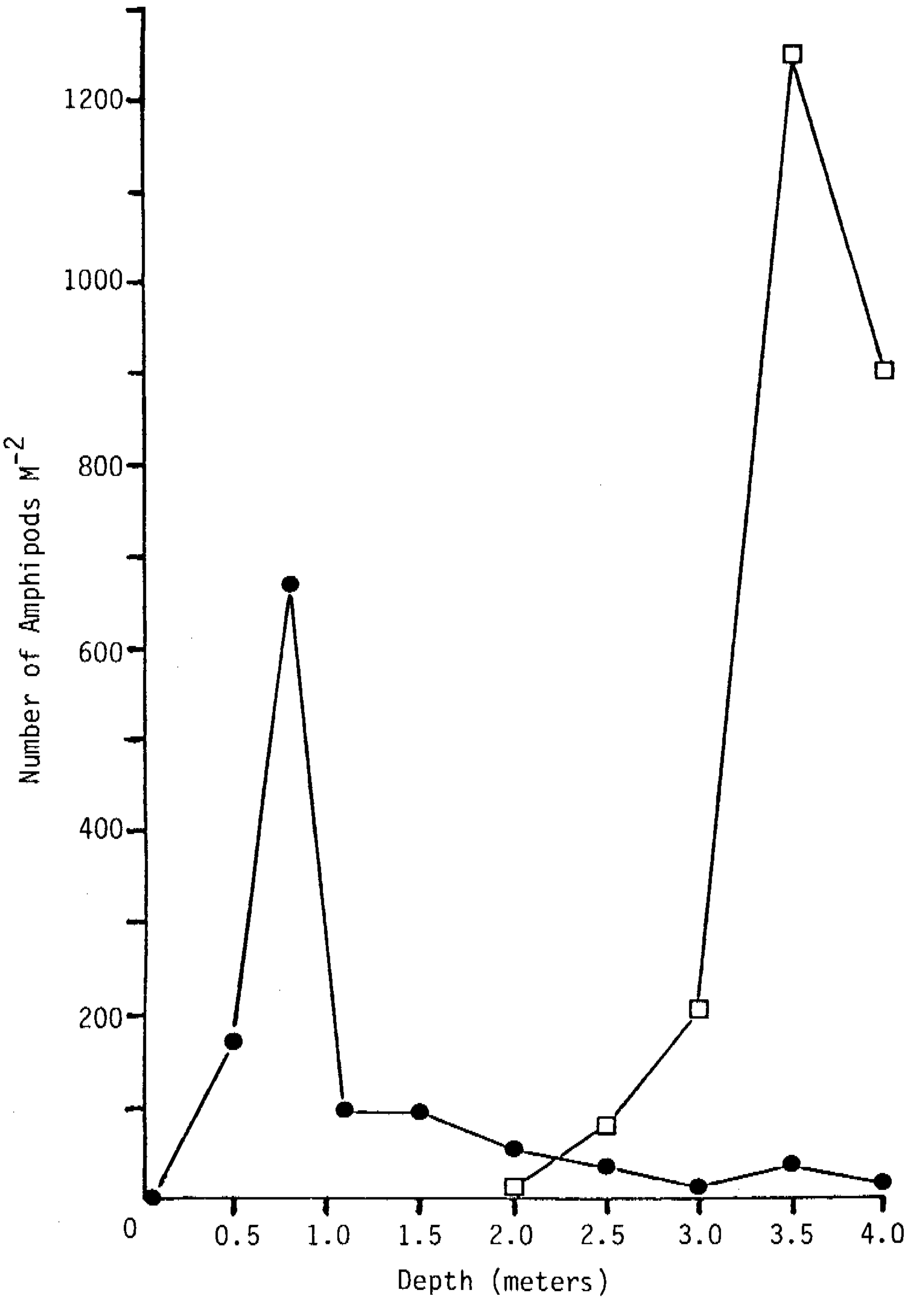


Figure 3.2. Densities of *P. affinis* (●) and *P. femorata* (□) at various depths in lagoon ecosystems of the western Beaufort Sea. (Plotted from data in Table 3.)

biomass was nearly three times as great in the lagoon shallows than in the deeper parts of the lagoons (Table 4). It occurred at 59% of the shallow-water stations, but at only 38% of the stations sampled in deeper water (2.1-4.0 meters). In contrast, P. femorata was essentially absent from the lagoon shallows, the populations being restricted entirely to the deeper sections of the lagoons (Table 5).

Results on the co-occurrence and numerical dominance of the two species (Table 6) show that between the lagoon shores and 2 meters, the species co-existed at only 1 out of a total of 17 stations sampled, and at that station, P. affinis was numerically dominant over P. femorata. Between 2.1 and 4.0 meters, the species co-occurred at 12 (28.6%) of the 42 stations sampled, with P. femorata dominant at 9 (21.4%) and P. affinis dominant at 3 (7.1%) of these stations.

The general trends which emerge from these results can be summarized as follows:

1. P. affinis is generally distributed over a greater portion of the depth gradient than P. femorata, occurring between 0.5 and 4.0 meters. It is most abundant in or on lagoon bottoms within the 2-meter isobath, where it is clearly dominant over P. femorata, which rarely invades the lagoon shallows. Between 2.1 and 4.0 meters, P. affinis is much less abundant, and is generally subordinate to P. femorata when the two species occur together.
2. P. femorata shows a much more restricted depth distribution than P. affinis in the lagoons, having a clear preference for the deeper lagoon regions and avoiding the shallows almost completely. In deeper water, it is both more abundant and ubiquitous than P. affinis (it occurred at twice as many deep-water lagoon stations than P. affinis, Tables 4 and 5).

Distribution and Abundance Within Individual Lagoons

Using the data from the 1976 lagoon sampling survey, I have analyzed the distribution and abundance of P. affinis and P. femorata within the individual lagoons. The results are presented in Table 7. It is apparent that the density and distribution patterns of P. femorata within each of the lagoons conforms, almost without exception, to the generalized lagoon pattern I have already established for that species. I have no explanation for the low densities of P. femorata in the deeper regions of Prudhoe Bay. Perhaps they prefer the outer bay regions over the inner sections sampled in 1976. Feder and Schamel (1976) reported a partial replacement of P. affinis by P. femorata at deeper, outer Prudhoe Bay locations.

Table 3.4. Sampling statistics for Pontoporeia affinis collected with Ekman grab in lagoon ecosystems of the Western Beaufort Sea, Summer 1976. N_{SA}=# of samples collected; N_{ST}=# of stations sampled; Biomass=grams wet weight.

Depth (M)	N_{SA}	Number M^{-2} ± SE (Range)	Grams M^{-2} ± SE (Range)	N_{ST}	Occurrence (Stations)
0 - 2.0	50	76 ± 26 (43-779)	0.143 ± 0.056 (0.011-2.164)	17	10 (=59%)
2.1 - 4.0	120	24 ± 6 (43-390)	0.056 ± 0.019 (0.011-1.772)	42	16 (=38%)

Table 3.5. Sampling statistics for Pontoporeia femorata collected with Ekman grab in lagoon ecosystems of the Western Beaufort Sea, Summer 1976. N_{SA}=# of samples collected; N_{ST}=# of stations sampled; Biomass=grams wet weight.

Depth (M)	N_{SA}	Number M^{-2} ± SE (Range)	Grams M^{-2} ± SE (Range)	N_{ST}	Occurrence (Stations)
0 - 2.0	50	* ------	---------	17	2 (=12%)
2.1 - 4.0	120	356 ± 96 (43-8,007)	1.051 ± 0.193 (0.011-8.741)	42	32 (=76%)

*Insignificant numbers in only 2 samples at 2 stations.

Table 3.6. Co-occurrence and dominance of Pontoporeia femorata and Pontoporeia affinis at lagoon stations sampled during Summer, 1976, in the Western Beaufort Sea. N_{ST} = number of stations sampled; P.F. = Pontoporeia femorata; P.A. = Pontoporeia affinis.

Depth (M)	N_{ST}	Co-occurrence (Stations)	Co-occurrence, P.F. Dominant	Co-occurrence, P.A. Dominant
0 - 2.0	17	1 (=5.9%)	0	1 (=5.9%)
2.1 - 4.0	42	12 (=28.6%)	9 (=21.4%)	3 (=7.1%)

Table 3.7. Mean densities and biomass per square meter of *P. affinis* and *P. femorata* within designated depth intervals in various lagoon ecosystems in the Western Beaufort Sea, Summer 1976. N=Number of Eckman grab samples $\overline{N}_{PA}$=mean number of *P. affinis* $\overline{B}_{PA}$=mean biomass (grams wet weight) of *P. affinis* $\overline{N}_{PF}$=mean number of *P. femorata* $\overline{B}_{PF}$= mean biomass (grams wet weight) of *P. femorata* SE=standard error.

Location	Depth (m)	N	$\overline{N}_{PA}M^{-2} \pm SE$	$\overline{B}_{PA}M^{-2} \pm SE$	$\overline{N}_{PF}M^{-2} \pm SE$	$\overline{B}_{PF}M^{-2} \pm SE$
Elson Lagoon, West (Pt. Barrow region)	0 - 2.0	0	-	-	-	-
	2.1 - 4.0	23	0	0	531 ± 196	2.126 ± 0.659
Elson Lagoon, East (Dease Inlet)	0 - 2.0	0	-	-	-	-
	2.1 - 3.3	12	33 ± 13	0.070 ± 0.037	101 ± 34	0.350 ± 0.091
Simpson Lagoon	0 - 2.0	12	256 ± 87	0.411 ± 0.183	0	0
	2.1 - 3.7	27	71 ± 24	0.186 ± 0.078	257 ± 48	0.797 ± 0.169
Prudhoe Bay	0 - 2.0	15	107 ± 61	0.272 ± 0.162	0	0
	2.1 - 4.0	21	15 ± 6	0.014 ± 0.007	7 ± 4	0.005 ± 0.004
Kaktovic Lagoon	0 - 2.0	12	7 ± 5	0.007 ± 0.005	4 ± 3	0.001 ± 0.001
	2.1 - 4.0	25	6 ± 4	0.009 ± 0.006	826 ± 410	1.909 ± 0.570
Nuvagapak Lagoon	0 - 2.0	11	0	0	0	0
	2.1 - 3.2	7	19 ± 9	0.031 ± 0.018	186 ± 81	0.428 ± 0.163

The population densities and distribution patterns of P. affinis showed some variation within the various lagoons. This is probably a reflection of a combination of physical-biological differences between the shallow, inshore regions of the individual lagoon ecosystems. I believe that the coastal populations of P. affinis are responding, at least partially, to a salinity gradient, actively seeking out areas with a strong estuarine character. There is considerable evidence that the distribution and abundance of benthic invertebrates in coastal arctic regions depends, to a great degree, upon their particular salinity preferences (Zenkevitch 1963). Regarding P. affinis, I believe that they respond not only to water of lowered salinity (some of which is derived from melting ice), but perhaps also to the physical-chemical properties of freshwater derived from river discharge during the summer months. If this is a valid hypothesis, then some of the variability between the population densities and distribution patterns of P. affinis among the various lagoons may be a function of the amount of river discharge into the lagoons. Although all the lagoons sampled in 1976 are essentially brackish, some of them probably have a more pronounced estuarine character than others. Thus, the western region of Elson Lagoon (Point Barrow region) is not strongly influenced by river discharge, and the apparent lack of P. affinis, at least in the deeper areas (Table 7), may partially reflect this. Unfortunately, no data are available for the inshore regions of Elson Lagoon. In contrast, P. affinis does occur in the deeper portions of eastern Elson Lagoon (Dease Inlet region). This area is influenced by the Meade River, as well as numerous smaller river systems which empty into Admiralty Bay. Simpson Lagoon is strongly influenced by the Colville and Kuparuk rivers, and Prudhoe Bay is affected by discharge from the Sagavanirktok and Putuligayuk rivers. Both Simpson Lagoon and Prudhoe Bay have well-established inshore populations of P. affinis (Table 7). Kaktovik Lagoon, although generally brackish (18‰), receives only minor quantities of fresh water from a few small tundra streams, the nearest large rivers being 9km to the east and 13km to the west (Griffiths et al. 1977). P. affinis was not abundant in Kaktovik Lagoon (Table 7), despite the fact that numerous areas within the lagoon were sampled. Nuvagapak Lagoon receives fresh water from several small river systems emptying into the northwestern, central and southeastern parts of the lagoon. P. affinis occurred in the deep-water samples but were not found in the lagoon shallows (Table 7). I suspect that the lack of P. affinis in the shallow-water samples is a sampling artifact since the inshore estuarine areas of the lagoon were not extensively investigated.

Overall, the data from the individual lagoons confirm the general pattern of spatial (depth) separation of populations of P. affinis and P. femorata within the coastal lagoon environments of the western Beaufort Sea. The following section of this report deals with some of the factors which influence this pattern.

Factors Contributing to the Spatial Separation and of the Reduction of Potential Competition between Lagoon Populations of P. affinis and P. femorata

Assuming that the spatial separation between lagoon populations of P. affinis and P. femorata represents a mechanism whereby potential or actual competition for resources (space, food, etc.) is lessened, it is important to define those environmental and biological factors to which the species may be responding differently. A conspicuous way in which similar, sympatric species can avoid competition is by selecting different habitats (Croker 1967). Since the physical-biological structure of inshore (<2 meters) and nearshore (>2 meters) lagoon bottoms appears to be different (personal observation, see The Lagoon Benthos, this report), they may represent different "habitats" in a general sense. Thus, the inshore-nearshore separation of P. affinis and P. femorata during the open-water season suggests differences in habitat selection, probably functioning through differences in the physiological and behavioral responses of the two species.

The following discussion deals with some of the factors to which P. affinis and P. femorata may be responding differently, consequently resulting in their spatial (depth) separation. I will also discuss certain behavioral and biological adaptations which may (or, may not) help to reduce potential competition between the two species.

Salinity and Temperature

I have already suggested that P. affinis appears to have a preference for estuarine habitats. These conditions prevail in the shallows of numerous coastal lagoons during the open-water season. A review of the literature provides ample evidence that this species is adapted to brackish, estuarine conditions, apparently able to tolerate salinities below 6‰

reasonably well (Dunbar 1954; Segerstrale 1967; Zenkevitch 1963). In contrast, *P. femorata* is adapted to normal or somewhat lowered salinities, and does not survive at salinities below 6‰ (Segerstrale 1967; Zenkevitch 1963).

Salinity profiles obtained between July and August 1976 show a pronounced salinity stratification of lagoon waters after ice break-up and prior to general mixing of the water column (Fig. 3 a,b,c). During this time, the surface water is substantially diluted by fresh water derived from melting ice and river discharge. Salinities below 10‰, and even below 6‰, appear to be rather common in the upper 2-2.5 meter water strata. It is significant that *P. femorata* rarely penetrates within the 2.5 meter isobath (Fig. 2), since this is the general location of the halocline. The lowered surface salinities of the upper water strata, even if they exist for only a relatively short time prior to general mixing, are probably effective in restricting the migration of *P. femorata* into the lagoon shallows.

As the open-water season progresses, the salinity stratification of lagoon waters becomes much less pronounced (Figs. 3 and 4). With respect to the distribution of *P. affinis* in the various lagoons, it is significant to compare the nearly isohaline conditions of Elson Lagoon (18-22‰, Fig. 4) with those of Simpson Lagoon (12-13‰, Fig. 3,d). The overall salinity differences between these two lagoons probably reflect the lack of large river systems in the Elson Lagoon region, and the considerable influence of the Colville and Kuparuk rivers on Simpson Lagoon. If, as I have suggested, *P. affinis* shows an affinity for estuarine conditions, then the difference in the densities of *P. affinis* between these two lagoons (Table 7) may be partly related to the general availability of estuarine habitats within the lagoons.

Temperature is probably not an important ecological "isolating" factor for populations of *P. affinis* and *P. femorata*. *P. affinis* is cold-stenothermal, with an optimal temperature range between 8 and 12°C, and an upper thermal limit between 14 and 20°C (Segerstrale 1959). Bousfield (1958) suggested that it avoids the shallows of northern lakes when temperatures rise above 14.5°C. The summer temperature profiles (Figs. 3 and 4) indicate that the temperatures within the lagoon shallows are generally below or near optimum for this species. Although data on the temperature preferences of *P. femorata* are not available, I presume they

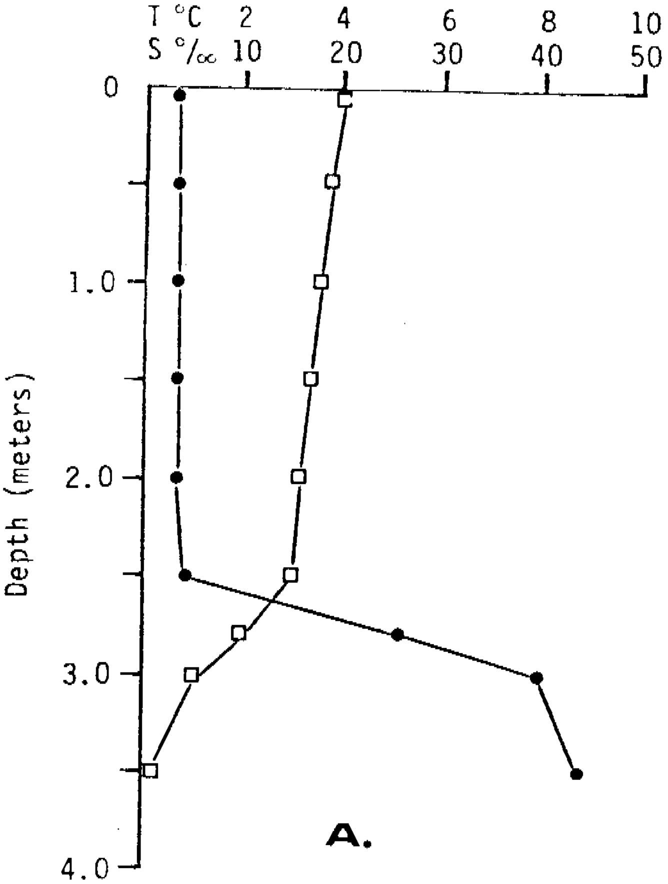
Figure 3.3 A-D. Salinity (●) - Temperature (□) profiles in Kaktovic Lagoon, Prudhoe Bay and Simpson Lagoon. Summer, 1976.

A. North Kaktovic Lagoon, 7/20/76.

B. Central Kaktovic Lagoon, 7/27/76.

C. Inner Prudhoe Bay, 7/31/76.

D. Central Simpson Lagoon, 8/4/76.


T °C 2 4 6 8 10
S ‰ 10 20 30 40 50
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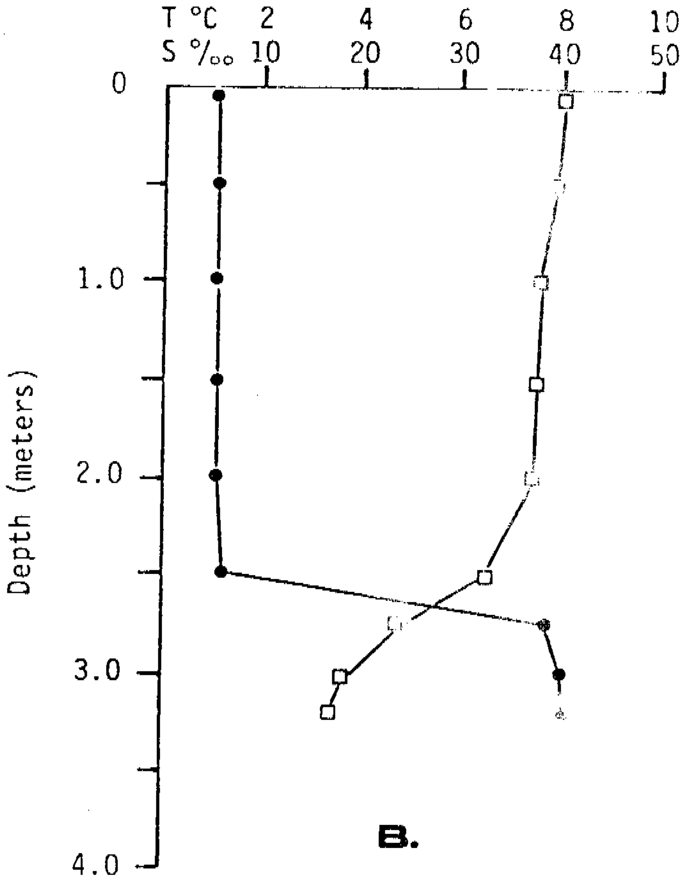
0
1.0
2.0
3.0
4.0

A.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S ‰ 10 20 30 40 50
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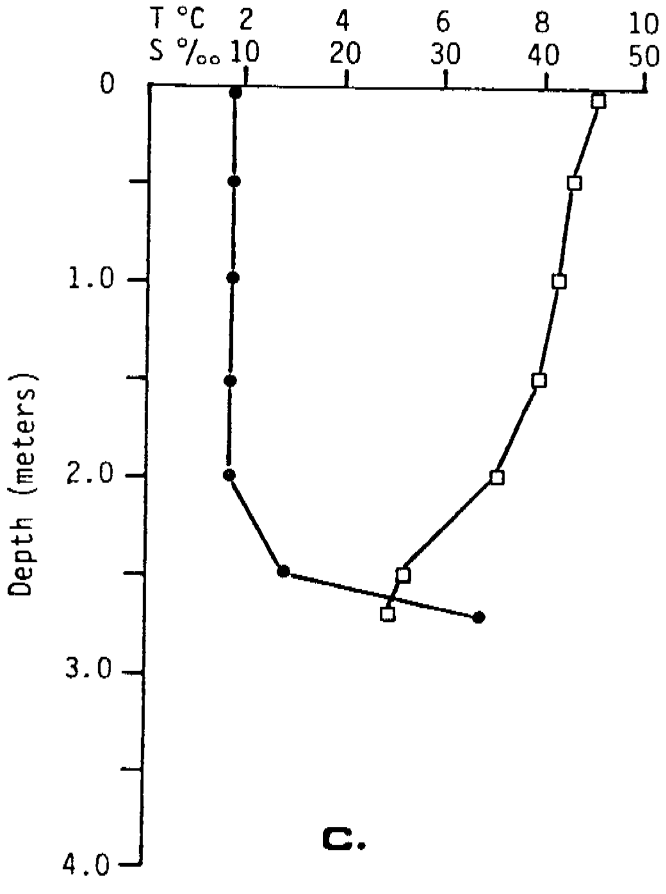
4.0

B.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S ‰ 10 20 30 40 50
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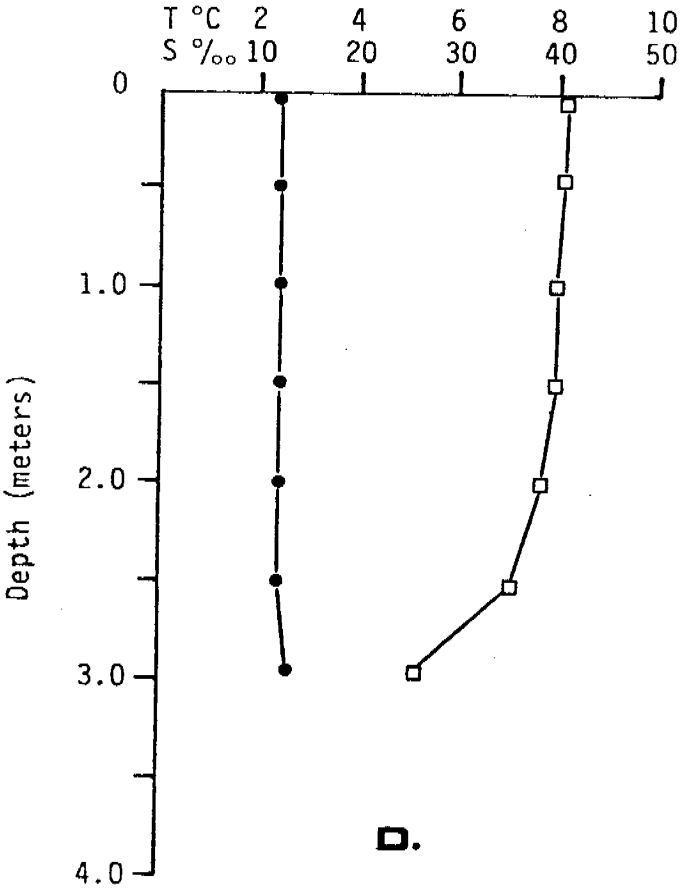
4.0

C.


T °C 2 4 6 8 10
S ‰ 10 20 30 40 50
Depth (meters)
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1.0
2.0
3.0
4.0

D.

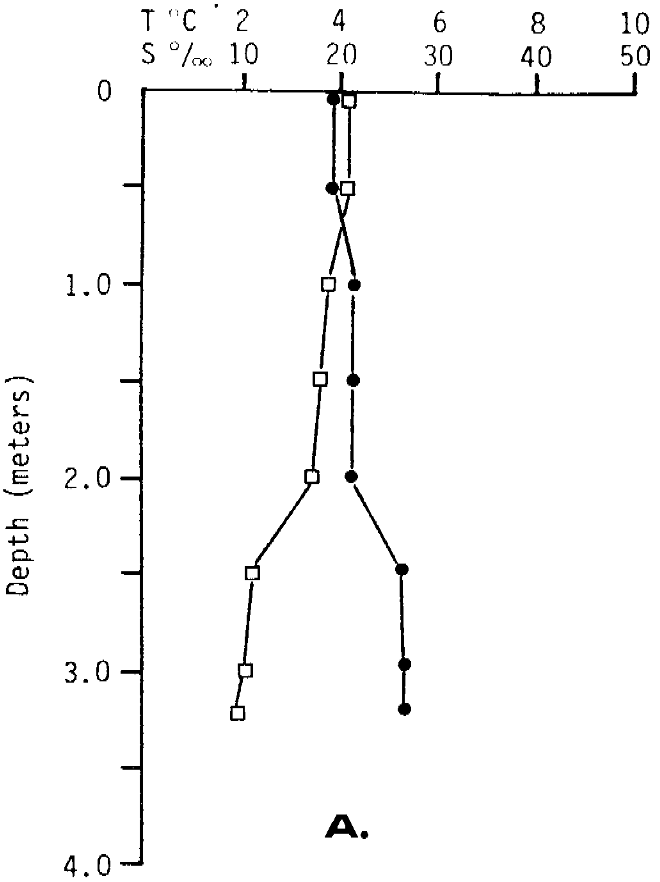
Figure 3.4 A-D. Salinity (●) - Temperature (□) profiles in Elson Lagoon, Summer 1976.

A. Elson Lagoon, West. (Pt. Barrow region) 8/11/76.

B. Elson Lagoon, Eluitkak Pass 8/11/76.

C. Elson Lagoon, Central. 8/16/76.

D. Elson Lagoon, East. 8/16/76.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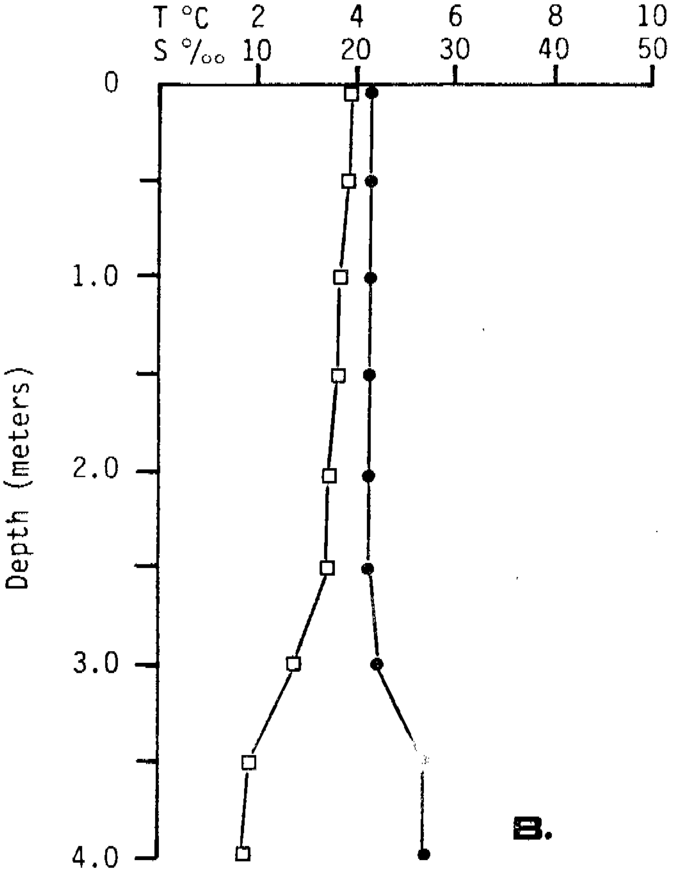
S ‰ 10 20 30 40 50
0
1.0
2.0
3.0
4.0
Depth (meters)

A.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1.0
2.0
3.0
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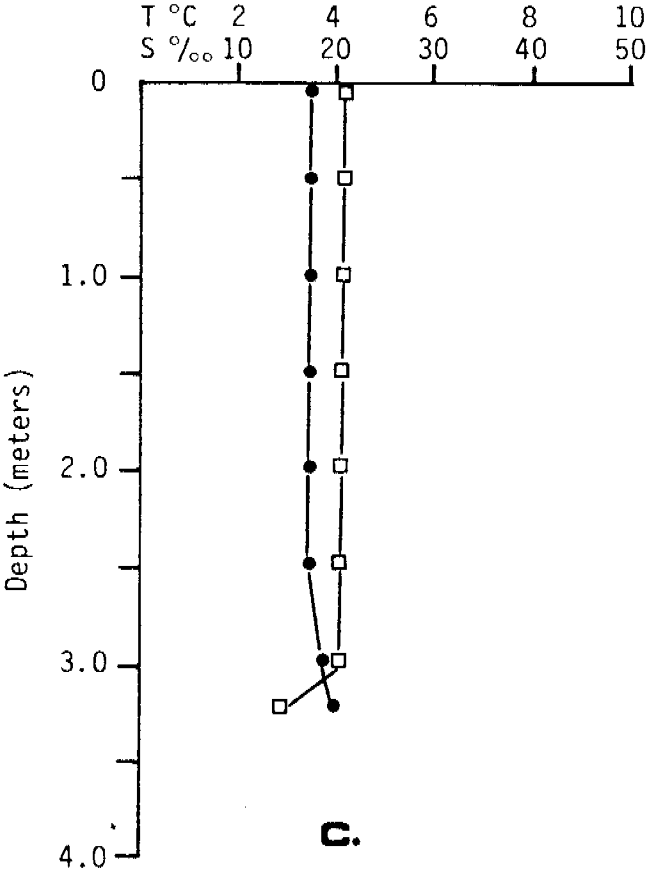
Depth (meters)

B.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S ‰ 10 20 30 40 50
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1.0
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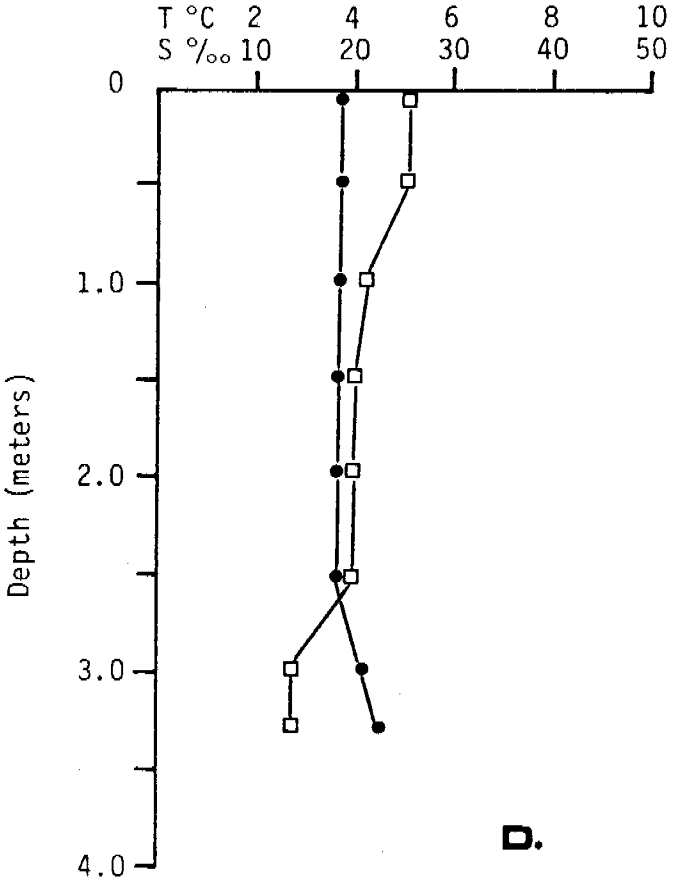
Depth (meters)

C.


T °C 2 4 6 8 10
S ‰ 10 20 30 40 50
0
1.0
2.0
3.0
4.0
Depth (meters)

D.

are not substantially different from those of P. affinis. Its restriction to deeper lagoon regions, and its occurrence in deeper offshore waters (Carey 1977; MacGinitie 1955) may indicate a somewhat lower optimum temperature preference.

Substratum

According to Segerstrale (1959), P. affinis lives mainly on soft bottoms, buried in the mud. Bousfield (1973) indicated that P. femorata burrows in muddy and sandy mud bottoms. Thorson (1957) reported that when the two species occur together in the same general area, P. affinis inhabits the shallow, sandier regions whereas P. femorata tends to prefer the deeper, siltier bottoms. The composition of the lagoon sediments shows a clear progression from coarse, sandy substrates in the shallows to mud or sandy mud at greater depths (Fig. 5). An analysis of the mud component of 20 lagoon sediment samples (1-4 meters water depth) revealed that silts constituted between 68 and 90% of the mud fraction, with a mean of approximately 80%. Similar substrate patterns were observed by Burrell et al. (1975) in Simpson Lagoon.

The depth distribution of lagoon sediments of varying composition clearly suggests that the depth separation of P. affinis and P. femorata is partly based on their preference for, and selection of, different substrates. This is in accordance with Thorson's observation. Croker (1967) observed similar differences in substrate preference among five sympatric species of haustoriid amphipods off the coast of Georgia. Furthermore, since the sediments at specific depths appear to be somewhat patchy (Fig. 5), it is possible that between 2 and 4 meters, where the populations of P. affinis and P. femorata overlap (Fig. 2, Table 3), P. affinis selects the coarser and P. femorata the finer patches. This may help reduce competition for space along isobaths at which the species co-occur.

Vertical Separation

Interspecific competition between burrowing species can partially be avoided if they occupy different depth strata within the sediments. Croker (1967) introduced two species of haustoriid amphipods, one a deep burrower the other a shallow burrower, into a dish with a shallow layer of sand. The species were thus forced to confront each other in a very narrow vertical

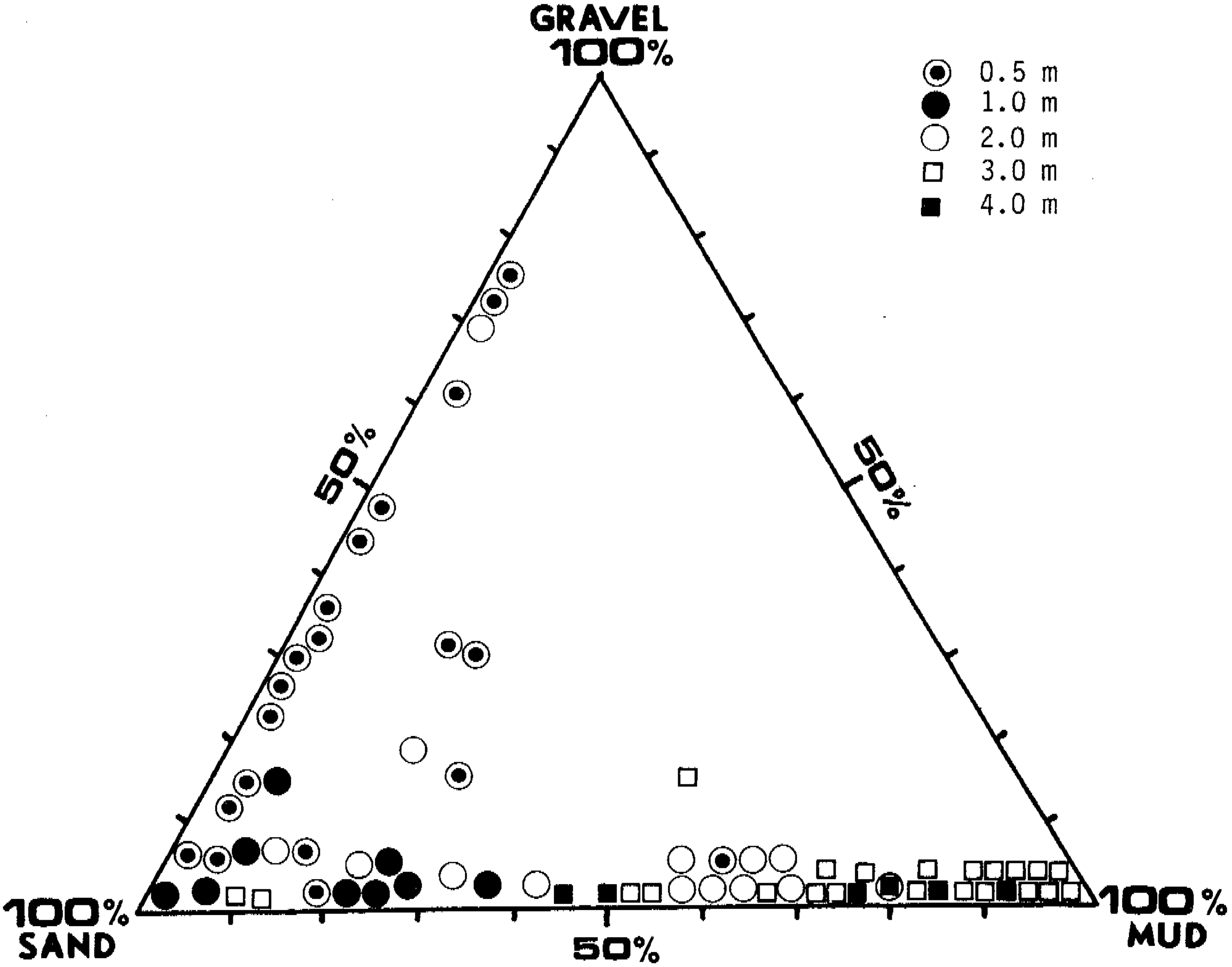


Figure 3.5. Composition of sediment samples collected with Ekman grab between 0.5 and 4.0 m in lagoon ecosystems of the Western Beaufort Sea, Summer 1976, 1977. Each point represents one sediment sample.

niche, and he observed that the deep burrower was constantly forced to come up out of the sand. The fact that populations of *P. affinis* and *P. femorata* overlap at depths (2-4 meters) at which other burrowing forms are very abundant, suggests that vertical separation between the various species, including *P. affinis* and *P. femorata*, is a distinct possibility. At present, there are no data on the burrowing habits of *P. affinis* and *P. femorata*.

Food

Differences in food preference and feeding strategies can reduce interspecific competition. Haustoriid amphipods are generally deposit or filter feeders (Bousfield, pers. comm.). Croker (1967) indicated that haustoriid amphipods generally ingest similar types of food. Although data on the food preferences of *P. femorata* appear to be lacking, *P. affinis* apparently feeds primarily on organic detritus and benthic and planktonic diatoms (Moore 1977; Segerstrale 1959). Larger specimens have been shown to consume oligochaetes (Moore 1977) and newly settled bivalve spat (Segerstrale 1973). The species apparently comforms to the opportunistic, omniverous feeding habits previously established for several other nearshore amphipod species (Schneider and Koch 1978, 1979).

Hutchinson (1959) suggested that when closely related sympatric species are dependent on the same types of food, the animals are often of different size, the smaller species consuming only the small food particles and the larger species feeding on both the small and the large particles. I do not believe, however, that the size difference between arcitc *P. affinis* and *P. femorata* is great enough for this food particle size-partitioning to play a significant role in reducing competition for food. Nevertheless, the opportunistic feeding habits of many arctic invertebrates, including *P. affinis* and most likely *P. femorata*, probably limit the intensity of interspecific competition for food, since the species are not dependent on specific food items. Barnard (1969) has suggested that the overall success of amphipods in widely varying habitats is partly attributable to their potential omniverous habits.

With respect to the lagoon environment it is, of course, possible that there are subtle, qualitative differences between the organic detritus in the shallows (particularly in estuarine-like regions) and the detritus that accumulates on the bottom at greater depths. *P. affinis*, especially the actively feeding juveniles which constitute a major portion of the summer standing stock, may prefer the detritus associated with the shallow, estuarine regions of coastal lagoons. This could contribute to the spatial separation between *P. affinis* and *P. femorata* during the summer.

Staggered Reproductive Peaks

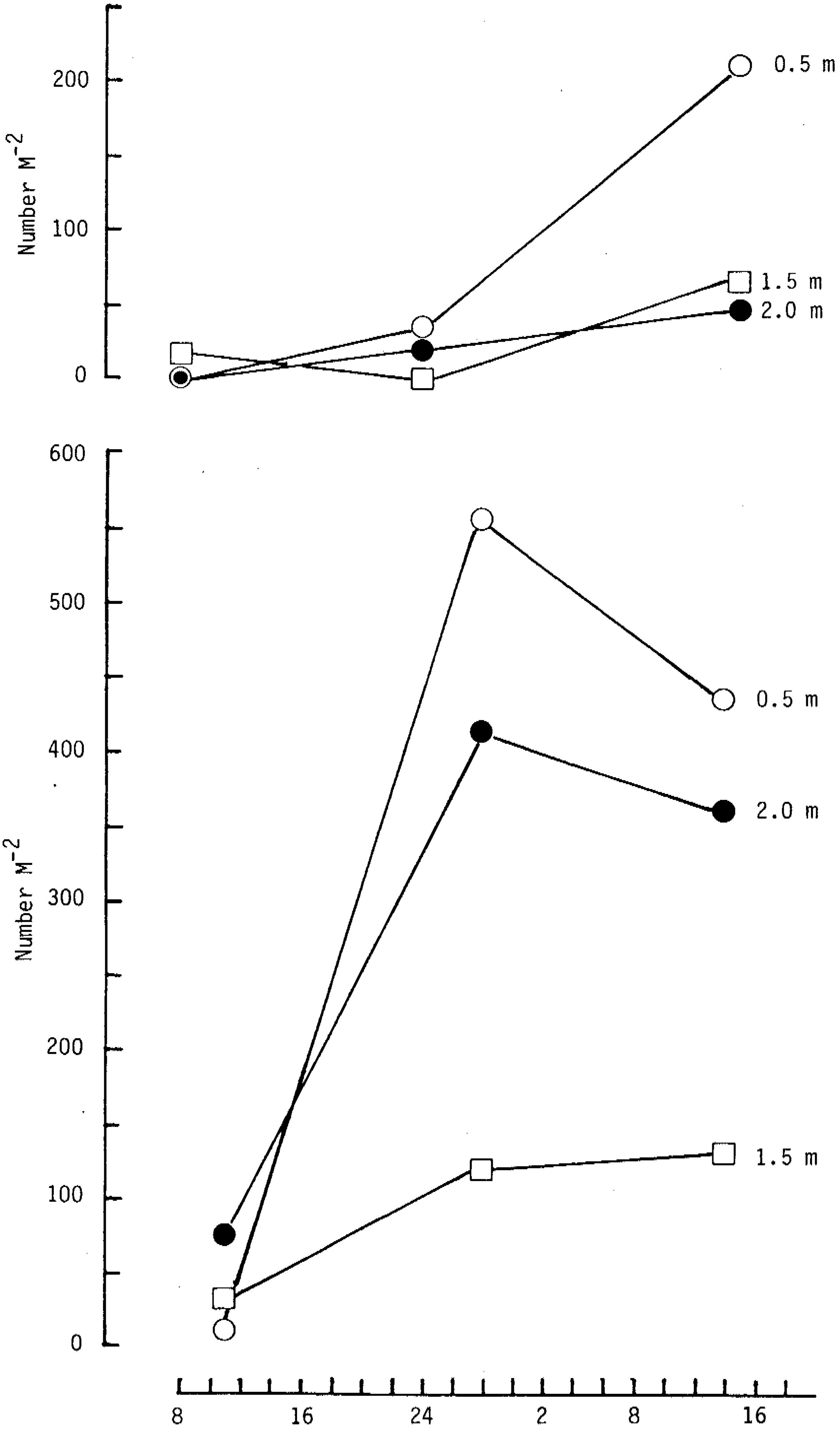
Related sympatric species often exhibit staggered peaks of reproductive activity, thereby assuring a temporal isolation of potentially competing life stages (Croker 1967; Hutchinson 1959). Evidence which I will present later suggests that *P. affinis* and *P. femorata* do not temporally stagger their reproductive phases, both species apparently recruiting young into their respective populations between spring and summer. Nevertheless, the two species appear to have solved the problem of overlap of potentially competing life stages, not by way of a temporal but rather via a significant spatial "isolation" of their populations. Although there are no data on the depth distribution of these species during the winter, their spatial separation during the summer is particularly significant since, at this time, their populations are dominated by actively feeding and growing juveniles and sub-adults.

Seasonal Fluctuations in the Population Density of *P. affinis*

During the summer of 1978, a number of sites (stations) were resampled throughout the summer to assess changes in the overall density and biomass of the inshore-nearshore benthic biota (see A. C. Broad, this report). At certain stations, the population densities of *P. affinis* showed pronounced variations between early July and mid-August (Figures 6 through 9). In general, the population densities increased as the season progressed. In their study of the Simpson Lagoon biota, Griffiths and Dillinger (1979) found that of all the amphipods they identified, only *P. affinis* showed significant seasonal differences in biomass. The biomass was low in early July, increased between mid-July and August, and then

Figure 3.6. Mean density (M^{-2}) of P. *affinis* in the mouth of the Putuligayuk River, inner Prudhoe Bay, at various depths and sampling dates during the summer of 1978. Each datum point represents the mean of 4 Ekman grab samples.

Figure 3.7. Mean density (M^{-2}) of P. *affinis* in western Prudhoe Bay (just west of ARCO causeway) at various depths and sampling dates during the summer of 1978. Each datum point represents the mean of 4 Ekman grab samples.



Number M^{-2}
200
100
0
0.5 m
1.5 m
2.0 m
Number M^{-2}
600
500
400
300
200
100
0
0.5 m
2.0 m
1.5 m
8
16
24
2
8
16
July 1978
August 1978

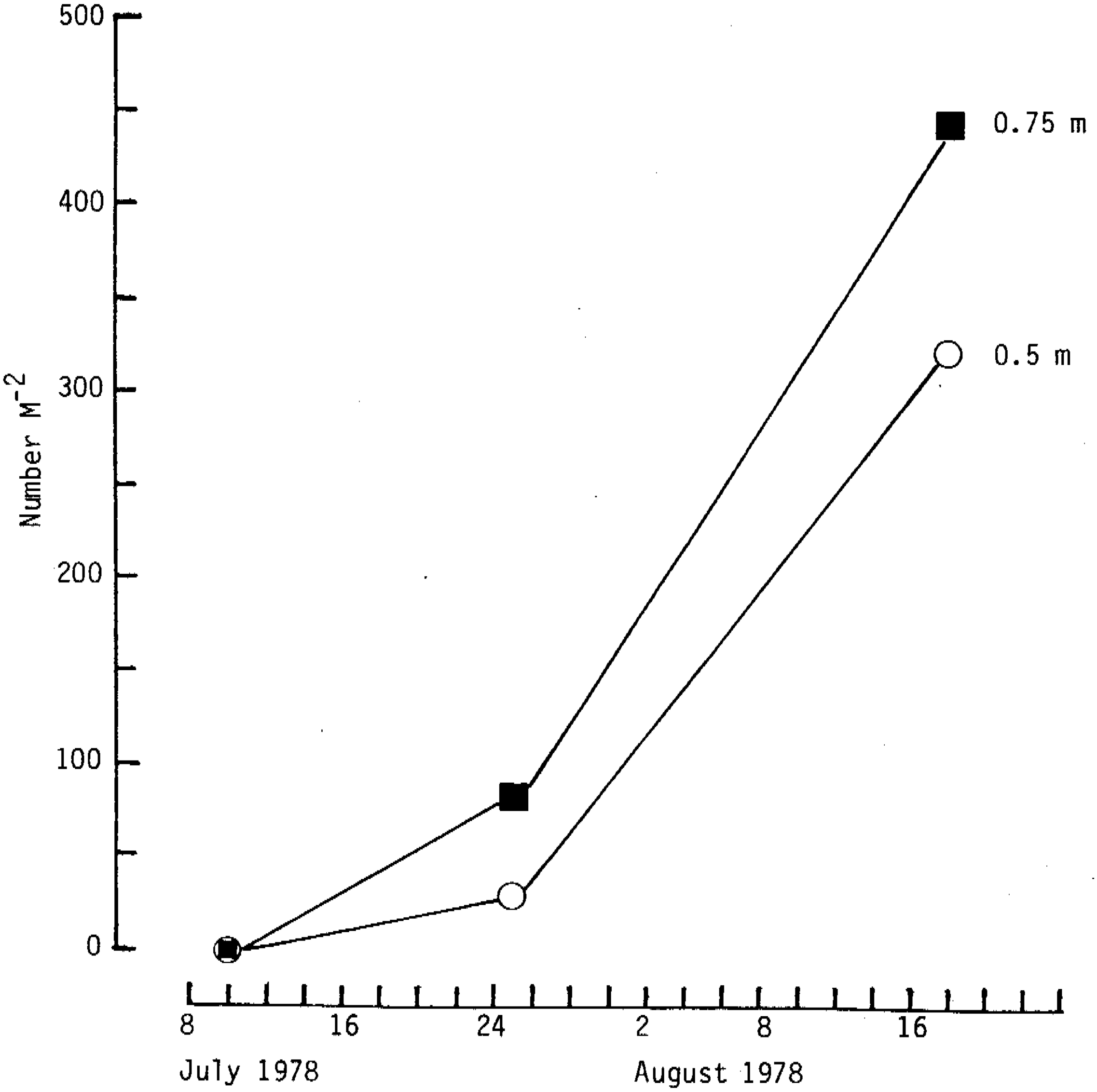


Figure 3.8. Mean density (M^{-2}) of P. affinis in the mouth of the Sagavanirktok River, near Prudhoe Bay, at various depths and sampling dates during the summer of 1978. Each datum point represents the mean of 4 Ekman grab samples.

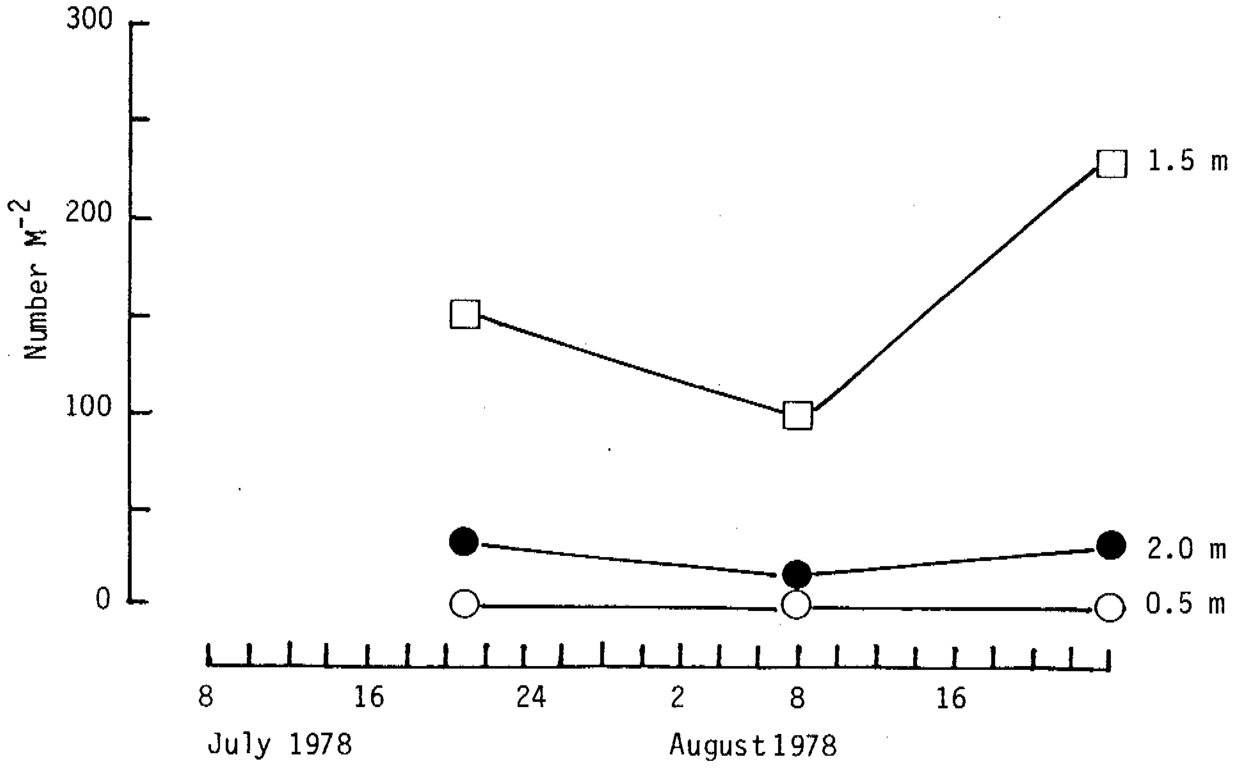


Figure 3.9. Mean density (M^{-2}) of P. affinis at station E59, Leffingwell Lagoon (see Fig. 1) at various depths and sampling dates during the summer of 1978. Each datum point represents the mean of 4 Ekman grab samples.

declined in late September. These general trends are also observable in Fibures 6 through 9, although September data are lacking.

The reasons for these patterns are not yet clear, but several possible explanations can be offered:

Recruitment of Young

Evidence I will present later suggests that the recruitment of young (release from female brood pouch) into the P. affinis population probably occurs mainly between early spring and early summer. However, some late-breeding females may not release young until later in the summer (July, early August), and I believe that such late recruitment of young may partially account for the mid-summer density peaks. Also, the growth of juveniles during the summer may contribute to a general increase in the population biomass in late summer, early fall.

Migration

Griffiths and Dillinger (1979) suggested that certain amphipods carry out current-assisted migrations into, out of and within Simpson Lagoon during the ice-free season. Feder and Schamel (1976) indicated that "local" populations of invertebrates along the Beaufort coast can recruit new individuals from immediately surrounding areas. During the summers of 1977 and 1978, numerous offshore stations (5 and 10 meters depth) were sampled by RU-356 (Table 8). The results indicate a complete absence of P. affinis in these offshore regions. This can be interpreted in several ways. Either offshore populations of P. affinis do, in fact, exist but carry out massive migrations into the lagoons during the summer, or they rarely penetrate into the deeper, offshore regions, remaining in the nearshore lagoon areas throughout the year. The latter case appears more likely. If offshore populations of P. affinis do exist but migrate into the lagoons during the summer, one would expect to find at least some remnants of these offshore populations during the summer. I do not believe, therefore, that the mid-summer lagoon density peaks of P. affinis are caused by extensive migrations from offshore regions into the lagoons.

It is significant, however, that the highest P. affinis densities and the most pronounced seasonal density fluctuations occurred in lagoon regions considerably influenced by freshwater discharge from nearby rivers.

Table 3.8. Mean densities (per square meter) of *P. affinis* and *P. femorata* collected with Smith McIntyre grab at 5 and 10 meters in the Western Beaufort Sea during the summers of 1977 and 1978. Sampling range in 1977 (Longitude): 143°08'24" - 156°27'12"; Sampling range in 1978 (Longitude): 146 41'24" - 150°25'00" (See Figure 1). N_{SA} = Number of samples taken; $\overline{N}_{PA}$ = mean number of *P. affinis*; $\overline{N}_{PF}$ = mean number of *P. femorata*; SE = standard error.

Year	Depth (M)	N_{SA}	$\overline{N}_{PA}M^{-2} \pm SE$	$\overline{N}_{PF}M^{-2} \pm SE$
1977 (Jul-Aug)	5	45	0	6 ± 2
	10	50	0	75 ± 21
1978 (Jul-Aug)	5	47	0	63 ± 18

P. affinis may be actively seeking out such estuarine-lagoon environments throughout the summer, migrating to these "favorable" habitats from adjacent inshore-nearshore regions.

Feder and Schamel (1976a) have suggested that fluctuations in nearshore concentrations of benthic invertebrates along the Beaufort coast may be a consequence of the translocation of organisms during storm surges. However, since *P. affinis* densities increased primarily in those lagoon regions where optimum conditions for that species appear to prevail, I suspect that an active rather than a passive distribution mechanism is involved.

Between early fall and mid-winter, mature adults of *P. affinis*, particularly the males, engage in pelagic excursions in preparation for mating in the water column (Segerstrale 1959, 1967). The males apparently die shortly after mating. These pelagic tendencies, and the death of early-mating males, may partially account for the decrease in the late-September biomass on the bottom of Simpson Lagoon reported by Griffiths and Dillinger (1979).

3. Predation

Segerstrale (1959) stressed the "economic importance" of *P. affinis* in the Baltic Sea, where it represents a significant food source for commercial fish such as cod and flounder, and for the large relict isopod, *Saduria entomon*. Along the coast of the Beaufort Sea, inshore lagoon regions appear to be important summer migratory pathways and feeding grounds for numerous species of anadromous fish (Craig and Griffiths 1978). *Saduria entomon* is a conspicuous component of the inshore lagoon benthos (Table 1). *P. affinis* undoubtedly falls prey to these animals, and such predation probably contributes to its density fluctuations and to its apparent decline in the fall.

Winter Distribution

There are virtually no data available on the winter distribution of populations of *P. affinis* and *P. femorata* within the coastal lagoons. In February, 1980, air lift samples from the western section of Elson Lagoon (3-3.5 meters depth) contained relatively high concentrations of *P. femorata*, but no *P. affinis* (D. E. Schneider, pers. comm.). The lack of *P.*

affinis in these samples is not surprising, since this species was also absent from 1976 summer samples taken in the same general area (Table 7). The presence of *P. femorata* in the winter lagoon samples indicates that it probably overwinters in the deeper parts of lagoons, where it is also found during the summer. Nevertheless, the presence of offshore populations of *P. femorata* during the summer (Table 8; Carey 1977) suggests at least the possibility of some seasonal migrations into and out of the lagoons.

As for *P. affinis*, their absence from offshore regions during the summer (Table 8) indicates that they are probably restricted to the nearshore coastal regions throughout the year. As I have suggested earlier, if *P. affinis* were to migrate offshore during the winter, one would expect to find some remnants of their offshore populations during the summer. I suspect, rather, that this species migrates into the sublittoral region of lagoons as the winter progresses. Thus, the low summer population densities in the deeper lagoon areas (Fig. 2, Table 3) probably represent the remnants of a winter sublittoral migration. Some form of winter migration on the part of *P. affinis* would seem to be almost a necessity since their preferred summer habitats, the lagoon shallows, become increasingly ice-stressed between September and May.

Assuming that *P. affinis* migrates into the lagoon sublittoral during the winter, competition with *P. femorata* would be expected to increase. There is, however, some evidence from other regions that adult males and females of both species, and in the case of *P. affinis* the juveniles as well, go into a period of feeding depression during the winter (Moore 1977; Segerstrale 1938, 1959, 1967). Segerstrale (1938) noted a pronounced reduction of the mandibular apparatus of males of both species shortly before the mating period in late fall, early winter. Females apparently undergo a progressive structural deterioration during the time of egg incubation between late fall and spring (Segerstrale 1938, 1967). MacGinitie (1955) noted that many arctic invertebrates appear to live primarily on high energy storage products (oils, fats, etc.) during the winter months. This may be true of *P. affinis* and *P. femorata*. Mature males and females would probably use these stored energy sources primarily for the production of reproductive products and for the general activity required in finding mates. Juveniles could channel some of this stored energy into growth.

It appears, therefore, that competition for food may not be a major problem for overlapping sublittoral populations of *P. affinis* and *P. femorata* during the winter. Competition for space on or in the lagoon bottoms could partially be avoided by (1) the increasing frequency of pelagic excursions by adult animals in preparation for mating, (2) selection of different substrates and, (3) possible vertical separation of the species within different depth strata of the sediments.

Size-Frequency Distributions and Reproductive Patterns

Pontoporeia affinis

The size-frequency distributions for *P. affinis* are presented in Figures 10-12. Animals were classified as either juveniles, males or females based on certain morphological, secondary sexual characteristics (Table 9). Generally, not enough material was available to establish seasonal changes in the size-frequency distributions at specific stations or locations. The distributions from various locations have been sequenced according to sampling date (Figures 10 and 11) to reveal changes in the general population structure throughout the summer. Figure 12 (a-c) presents a series of distributions from the same region (mouth of Sagavanirktok River), sampled on different dates during the summer; note, however, that distribution 12-c came from a different year (1975).

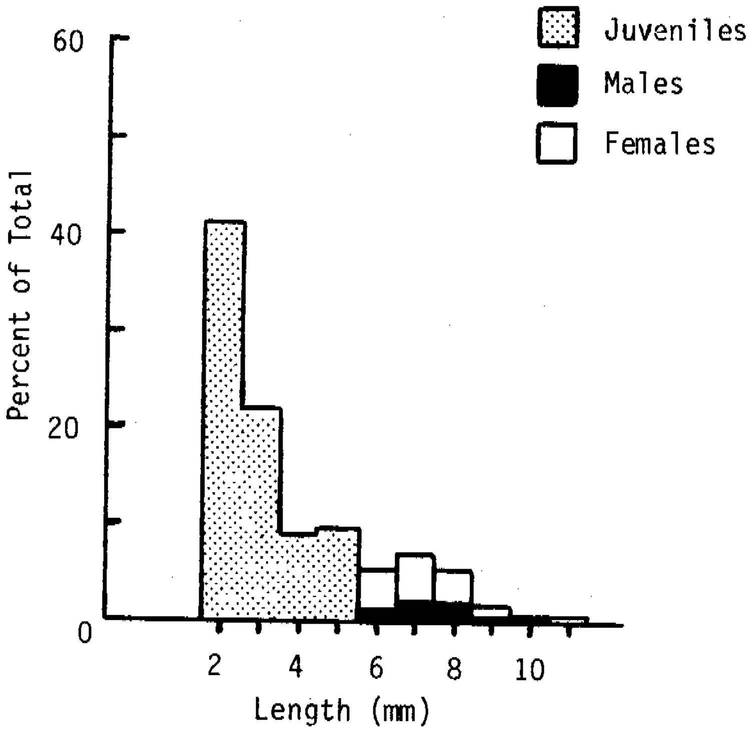
The use of widely scattered material to determine changes in the population structure presents a problem in that different populations may have been sampled. Despite this limitation, the data are still useful in establishing the reproductive patterns. Dunbar (1957) used material from various regions to establish the reproductive pattern and seasonal changes in the population size structure of the pelagic hyperiid amphipod, *Themisto* (=*Parathemisto*) *libellula*. The size-frequency distributions of *P. affinis* reveal the following general trends:

1. Between July and August, populations of *P. affinis* are dominated by juveniles and maturing adults
2. The size-frequency distributions appear to be bimodal, the lower mode (<6.0mm) representing the juveniles or 1st-year individuals, the upper mode (>6.0mm) representing primarily the sexually maturing, 2nd-year adults.

Table 3.9. Criteria used to distinguish juveniles, males and females of Pontoporeia affinis (PA) and Pontoporeia femorata (PF).

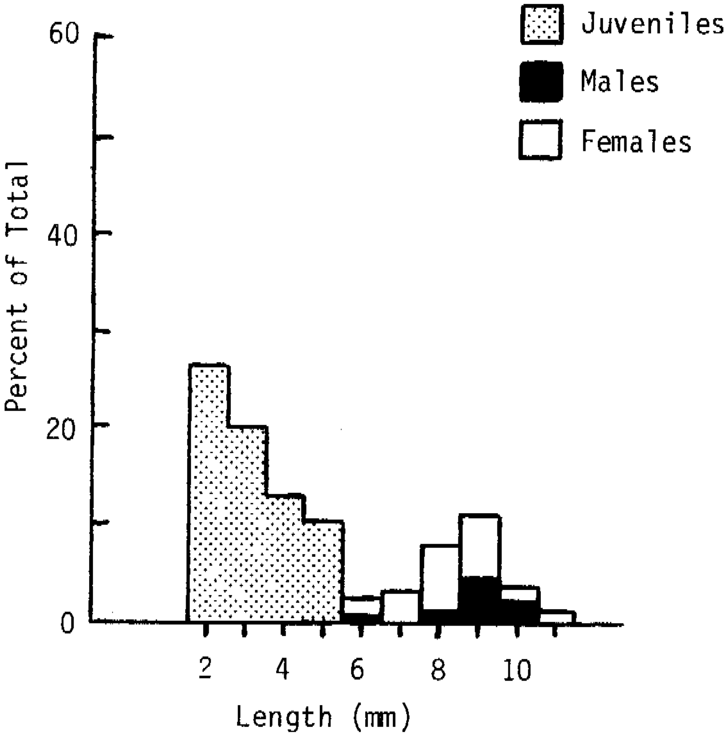
Category	Length (mm)	Morphological Characteristics
Juveniles	2.0 - 5.0 (PA) 2.0 - 6.0 (PF)	Immature individuals having no discernible secondary sexual characteristics
Males[a]	6.0 - 10.0 (PA) 7.0 - 13.0 (PF)	Second antennae considerably longer than those of females, with greater number of articulations; calceolate. In P. affinis, antenna 1 of males is also slightly longer than in females. No brood plates.
Females[b]	6.0 - 11.0 (PA) 7.0 - 10.0 (PF)	Second antennae only slightly longer than first and considerably shorter than second antennae of males. Second antennae not calceolate. Brood plates present on pereonite segments 2 to 5.

a, b Maximum length of males and females of both species reflects largest animals measured in samples



N = 384
Total dry weight (g) = 0.162
Dry weight of juveniles (2-5 mm) = 0.066 (40.7%)
Dry weight of adults (6-11 mm) = 0.096 (59.3%)
Sex ratio (6-11 mm) M/F = 0.51

Figure 3.10. Size-frequency distribution of P. affinis in Simpson Lagoon, 8/14/78. Depth, 3.0m. Smith McIntyre grab (4 samples).



N = 76
Total dry weight (g) = 0.055
Dry weight of juveniles (2-5 mm) = 0.013 (23.6%)
Dry weight of adults (6-11 mm) = 0.042 (76.4%)
Sex ratio (6-11 mm) M/F = 0.59

Figure 3.11. Size-frequency distribution of P. affinis at Station F0E (See Fig. 1), 8/24/78. Depth, 2.5 m. Smith McIntyre grab (3 samples).

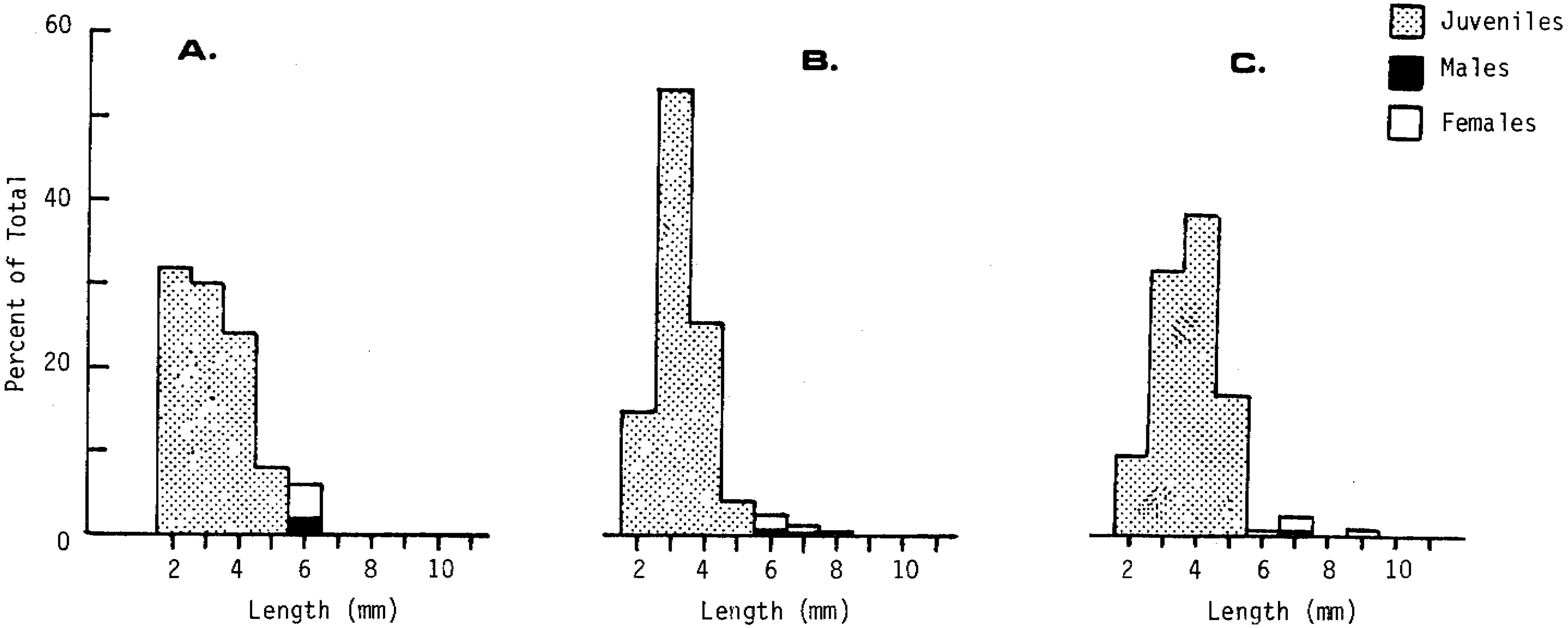


Figure 3.12 a-c. Size-frequency distribution of *P. affinis* in the mouth of the Sagavanirktok River, near Prudhoe Bay, 0.5-0.75 meters depth.

A. 7/25/78, Ekman grab (4 samples), N=50
B. 8/18/78, Ekman grab (4 samples), N-352
C. 8/28/75, Ekman grab (3 samples), N=344

3. Large, mature specimens (> 9 mm) are not abundant during the summer
4. Among the maturing animals, males are less abundant than females
5. As the summer progresses, shifts in the population structure become evident (compare Figures 10 and 11, Fig. 12a-b-c), suggesting growth

There were no ovigerous females, nor females carrying young, in any of the summer collections. None of the females had brood plates (oostegites) with marginal setae. Since the presence of marginal setae could be indicative of either recent release of young or reproductive "readiness," it seems that none of the females had shed young very recently or were ready to go into an immediate reproductive phase. I suspect, therefore, that the majority of summer females (and males) were the maturing animals of the 2nd-year class which would be expected to start breeding in the fall and winter. This is supported by the fact that large specimens (> 9 mm) were very uncommon. Since the maximum length of this species in arctic regions is between 11 and 14 mm (Dunbar 1954; Segerstrale 1959), the lack of such large specimens in the summer samples suggests that they have probably died, the males presumably shortly after mating and the females after the release of young (Segerstrale 1967). Females apparently produce only one brood during the winter of their second year, and then die (Segerstrale 1967).

The lack of ovigerous females and females carrying young, and the apparent domination of summer populations by smaller individuals (Figs. 10-12), suggest that the breeding period of this species is restricted primarily to the cold season, the main release of young occurring before July. Since the juveniles in July and August show a wide range of body lengths, the breeding phase probably extends over a relatively long period of time. The presence of 2 mm animals indicates that some late-breeding females do not release their young until the middle of summer (July, early August).

These findings are in general agreement with those from previous studies. Segerstrale (1959, 1967) summarized some of these results and reported that ovigerous females of shallow-water population of P. affinis have been found between October and May, and most of them release their young between March and April. However, he found spent females (recent release of young) as late as July in Finnish coastal waters, and suggested they were "delayed" members of the winter-breeding stock. Barnard (1959) reported female Gammarus wilkitzkii carrying hatched young in the middle of June. Steele and Steele (1970) found female Gammarus setosus still carrying young in July. They suggested that the low arctic temperatures probably delay the release of young until spring-early summer (presumably by lengthening the time of embryonic development), and that the timing of the release may be related to the spring algal bloom.

In all these species, breeding appears to occur primarily between fall and early winter, with maximum release of young between March and early summer. Griffiths and Dillinger (1979) established a similar reproductive pattern for Onisimus glacialis in Simpson Lagoon, but suggested that the presence of 3 mm animals in November indicated some summer-breeding activity as well. I do not know if this is true of lagoon populations of P. affinis, since data on the fall and winter population structure are entirely lacking. However, the existing evidence indicates that shallow-water populations of P. affinis breed exclusively between fall and spring, whereas deep-sea and deep-lake populations have been shown to exhibit a secondary breeding peak in summer (Segerstrale 1967; Green 1968).

The sex ratios of summer populations of P. affinis (Figs. 10 and 11) show a distinct dominance of females over males. This is not uncommon among amphipods. Segerstrale (1959) reported female-dominated populations of P. affinis from the inner Baltic. It is possible, however, that the males, and the larger animals in general, are not accurately represented in grab samples. As P. affinis males mature, they undergo a series of morphological changes in preparation for an essentailly pelagic existence during the winter breeding season (Segerstrale 1938, 1967). Maturing females also become better swimmers. Grab samples may, therefore, show a bias towards smaller individuals which tend to remain on or in the bottom sediments, while partially failing to capture larger animals capable of extended excursions into the overlying water column. Size-frequency distributions and sex ratios based solely on grab samples must, therefore, be viewed with caution.

If the juvenile component of the summer P. affinis population is represented fairly accurately in grab samples, then Figure 12a-c may reflect the manner in which the size-frequency structure of 1st-year individuals changes as the summer advances. Unfortunately, distribution 12-c came from a different year (1975). Assuming that these trends are fairly consistent from one year to another (an assumption that may not be valid), there is an indication of a progression of advancing sizes between July and August. Griffiths and Dillinger (1979) calculated the average change in the mean size of 1st-year individuals of Onisimus glacialis in Simpson Lagoon to be 0.8mm/30 days during the open-water season. They suggested that this was a fairly accurate estimate of "growth" for 1st-year individuals of that species. Nevertheless, changes in the population size structure are clearly not a function of growth alone. There are too many other variables (i.e., sampling error, possible new recruitment of young, mortality, size-selective predation) that can affect a size-frequency distribution at any particular time. I hesitate, therefore, to calculate "growth" from the size-frequency distributions in Figure 12a-c, although the relatively slow progression of advancing sizes between July and August may indicate that the overall "growth" of 1st-year individuals is not particularly rapid.

In summary, shallow-water populations of P. affinis in coastal lagoons of the Beaufort Sea show the following general reproductive patterns:

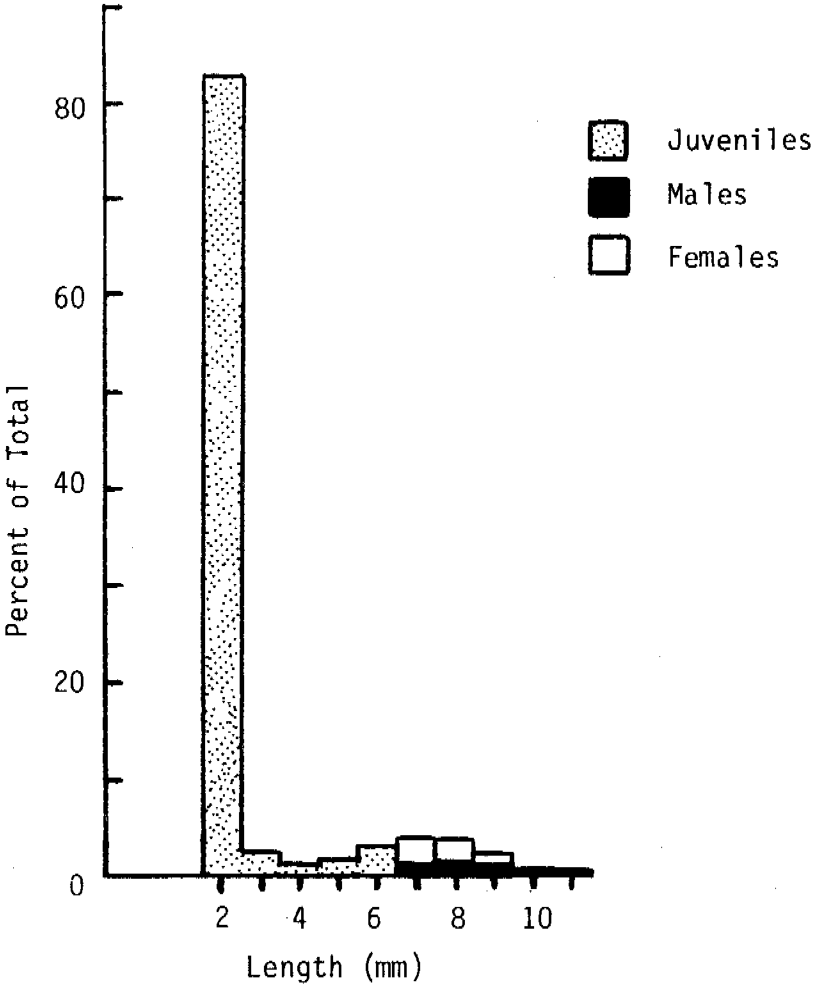
1. Breeding appears to be restricted primarily to the fall and winter seasons, with the major release of young occurring before July. Some late-breeding females do not release young until mid-summer.
2. The lack of large specimens, the relative abundance of juveniles and the bimodality of summer size-frequency distributions indicate that summer populations consist mainly of 1st-year individuals and 2nd-year maturing adults which will probably start to breed during the fall and winter.
3. Among the maturing adults, females are more abundant than males. The general paucity of maturing adults, in contrast to the relatively high proportion of juveniles, may reflect sampling error. Grabs may not adequately sample the more actively swimming adults.
4. The slow progression of advancing sizes of 1st-year individuals between July and August may be indicative of a relatively slow rate of "growth."
5. The size structure and composition of the summer population, and evidence from the available literature, suggest that a life span approaching 2 years seems most likely.

Pontoporeia femorata

The summer size-frequency distributions for P. femorata are presented in Figures 13-17. Animals were categorized as either juveniles, males or females based on the criteria in Table 9. As was the case for P. affinis, data from different locations and years had to be used to construct a series of size-frequency distributions. These have been sequenced chronologically (Figs. 13-17) to reveal changes in the overall patterns of the population size structure. Summer samples contained no ovigerous females or females carrying young, although one 8mm-female with setose brood plates was collected on 7/28/76 in Kaktovic Lagoon.

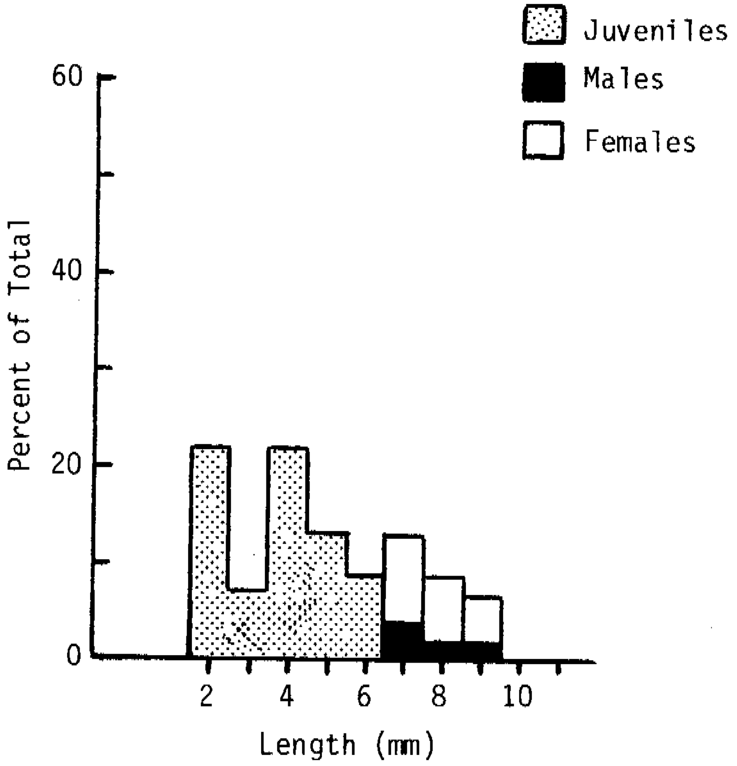
Segerstrale (1938; 1967) commented on the similarities between P. affinis and P. femorata with respect to their reproductive patterns and the morphological changes accompanying maturation. Most of the comments I made regarding P. affinis seem to apply to P. femorata as well. The following points summarize some aspects of the reproductive biology of P. femorata in the nearshore Beaufort Sea.

1. Between July and August, populations of P. femorata are dominated by juveniles and maturing adults (Figs. 13-17).
2. Although the size-frequency distributions are not as obviously bimodal as those of P. affinis, they essentially consist of a lower (< 6.0-6.5 mm) juvenile or 1st-year component, and an upper (> 6.0-6.5 mm) component of sexually maturing 2nd-year adults.
3. Large animals (> 9 mm) are not abundant in the summer. Since the maximum size of arctic P. femorata has been reported to be between 15 and 16 mm (Segerstrale 1938), the absence of large animals in summer probably indicates that they died after the winter-spring breeding period.
4. The absence of large adults, ovigerous females and females carrying young during the summer, coupled with the relative abundance of juveniles and small to medium-sized adults suggest that:
   a. breeding is restricted primarily to the cold season (Segerstrale 1938; 1967)
   b. release of young occurs mainly before July
   c. females probably produce only one brood and then die (Segerstrale 1938)
   d. the summer population consists of 1st-year individuals and 2nd-year maturing adults which will probably start to breed during the fall and winter months
5. The consistent presence of 2 mm animals throughout the summer (Figs. 13-17) indicates that some late-breeding females do not release their young until mid-summer. One 8 mm female with setose



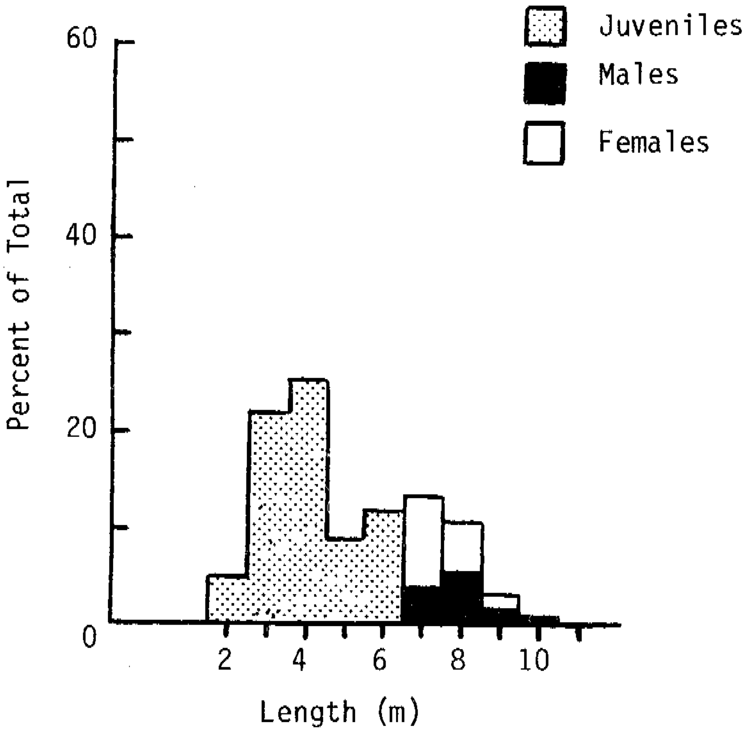
N = 616
Total dry weight (g) = 0.286
Dry weight of juveniles (2-6 mm) = 0.179 (62.5%)
Dry weight of adults (7-11 mm) = 0.107 (37.5%)
Sex ratio (7-11 mm) M/F = 0.73

Figure 3.13. Size-frequency distribution of P. femorata in Kaktovic Lagoon, (Barter Island), 7/20/76 - 7/28/76. Depth, 3.5 m. Ekman grab (5 samples).



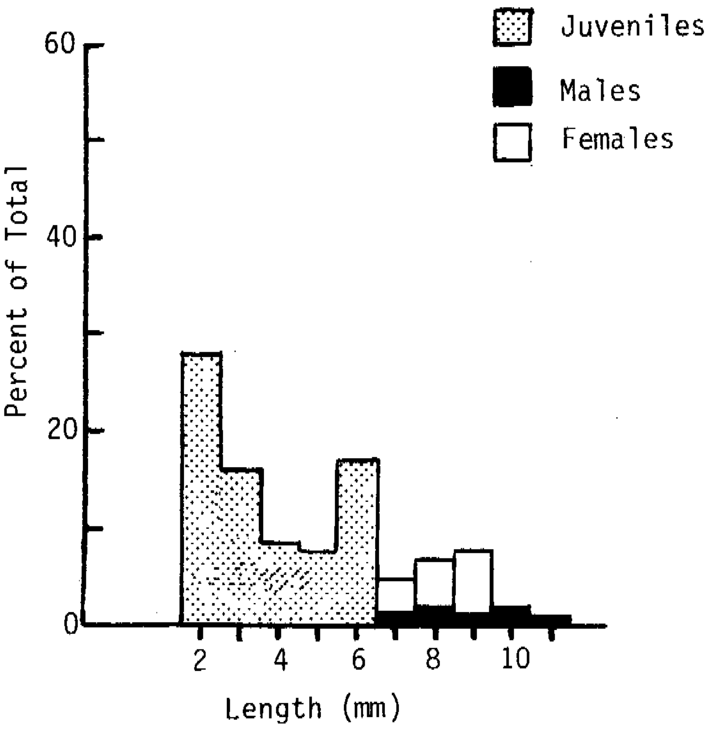
N = 46
Total dry weight (g) = 0.035
Dry weight of juveniles (2-6 mm) = 0.015 (42.9%)
Dry weight of adults (7-9 mm) = 0.020 (57.1%)
Sex ratio (7-9 mm) M/F = 0.44

Figure 3.14. Size-frequency distribution of P. femorata in Simpson Lagoon, 8/4/76. Depth, 2.3 m. Ekman grab (3 samples).



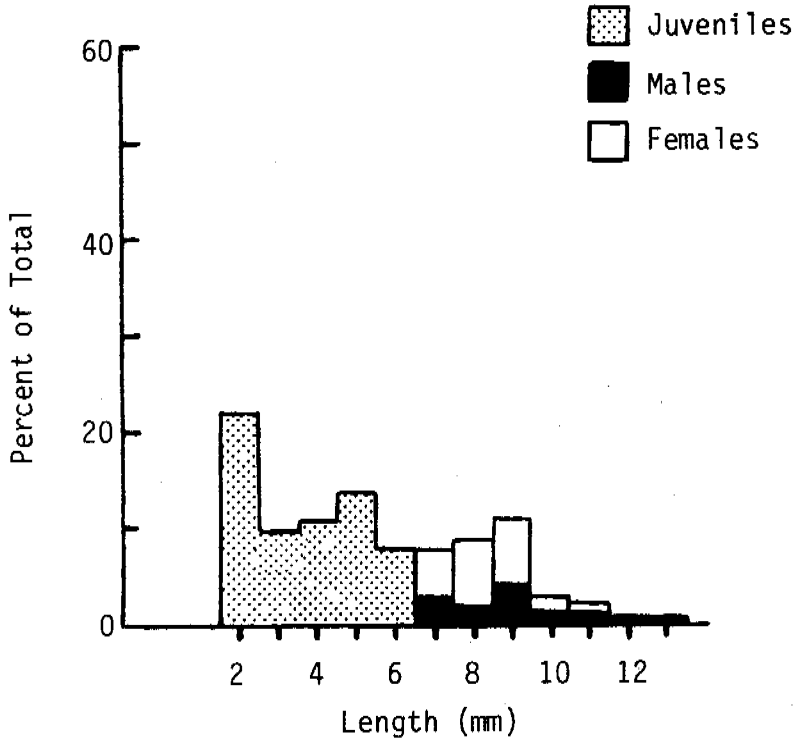
N = 258
Total dry weight (g) = 0.191
Dry weight of juveniles (2-6 mm) = 0.086 (45.0%)
Dry weight of adults (7-10 mm) = 0.105 (55.0%)
Sex ratio (7-10 mm) M/F = 0.86

Figure 3.15. Size-frequency distribution of P. *femorata* in Eluitkak Pass (Elson Lagoon), 8/11/76. Depth, 3.5 M. Ekman grab (6 samples).



N = 105
Total dry weight (g) = 0.088
Dry weight of juveniles (2-6 mm) = 0.040 (45.5%)
Dry weight of adults (7-11 mm) = 0.048 (54.5%)
Sex ratio (7-11 mm) M/F = 0.48

Figure 3.16. Size-frequence distribution of P. femorata at stations F1A, F0E (See Fig. 1), 8/24/78. Depth, 2.5 - 3.0 m. Smith McIntyre grab (5 samples).



N = 187
Total dry weight (g) = 0.191
Dry weight of juveniles (2-6 mm) = 0.055 (28.8%)
Dry weight of adults (7-13 mm) = 0.136 (71.2%)
Sex ratio (7-13 mm) M/F = 0.65

Figure 3.17. Size-frequency distribution of P. femorata at stations G0C, F4B (see Fig. 1), 8/25/78. Depth, 5 m. Smith McIntyre grab (6 samples).

brood plates was collected on 7/28/76 in Kaktovic Lagoon. Since the condition of the ovaries was not determined, the animal may either have been preparing to enter the reproductive phase (a situation which would imply summer breeding), or had recently released young.

6. Among the maturing adults, females are more abundant than males. The relatively high proportion of juveniles compared to adults probably reflects sampling error. Grabs may not adequately sample the more actively swimming larger animals.
7. The summer size-frequency distributions are highly variable from one location and date to another, making it impossible to detect any obvious chronological progression of advancing sizes throughout the summer.
8. Bousfield (1973) indicated an annual life cycle for _P. femorata_, but may have been referring to smaller (13 mm), non-arctic specimens. The larger size of arctic specimens (15-16 mm) and the apparently long time required for embryonic development at low arctic temperatures (Segerstrale 1938), suggest that arctic _P. femorata_ have a life span exceeding one year.

In February 1980, _P. femorata_ were collected with an air lift sampling technique in Elson Lagoon. Four specimens were made available to me for analysis, and the results are presented in Table 10. All the mature animals were females, and the largest was ovigerous. The eggs were in a relatively advanced stage of development and probably would have hatched in early March. The other two females were smaller, but based on the one 8 mm female with setose brood plates collected on 7/28/76, they should have been sexually mature. They did not show the structural deterioration (particularly of the gills) characteristic of females after they release their young. I suspect, therefore, that they had not yet entered the reproductive phase. Assuming that they were to do so within the next few months (March-April), then based on the duration of embryonic development in Finnish coastal waters (3-4 months, Segerstrale 1967), their young would not be released until July or August. This would explain the presence of small individuals throughout the summer (Figs. 13-17).

Segerstrale (1967) suggested that coastal populations of arctic _P. femorata_ breed primarily in late fall and winter, but that deep-sea populations also have a secondary breeding peak during the summer. MacGinitie (1955) collected several female _P. femorata_ between 155 and 245 meters water depth in the Beaufort Sea, September 1949. Of these specimens, one was ready to lay eggs, one was carrying eggs (early developmental

Table 3.10. Data on 4 specimens of P. femorata collected by air lift, under the ice, between 3 and 3.5 meters in Elson Lagoon. February 23, 1980. J = Juvenile, F = Female.

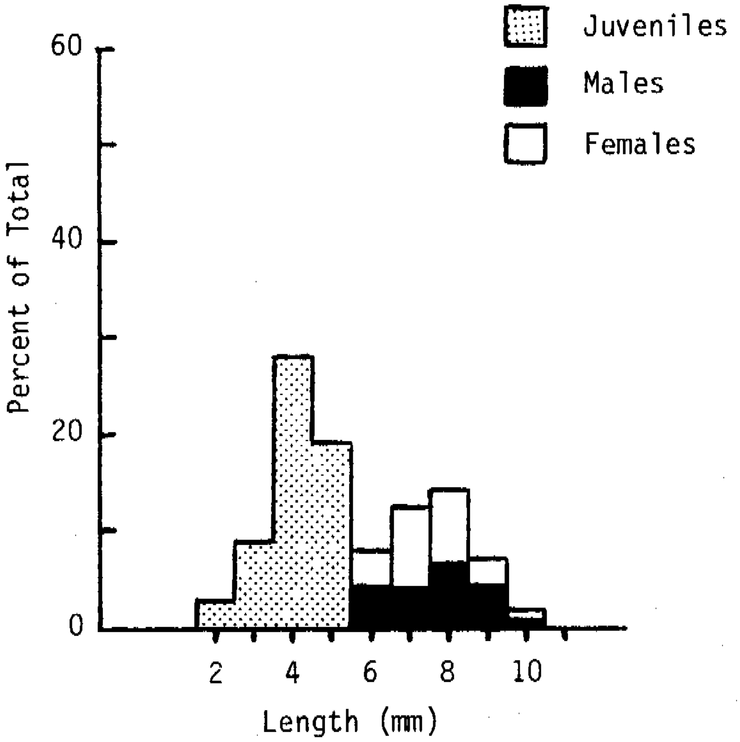
Length (mm)	Sex	Brood Pouch Development	Number of Eggs	Egg Differentiation
6.5	J	None	None	-----
7.8	F	Small, non-setose	None	-----
8.8	F	Small, non-setose	None	-----
9.8	F	Large, setose	17	Advanced; limb buds; embryo curvature distinct; eyes vaguely discernible in some.

stage) and several had recently lost their broods. This indicates summer-breeding activity within P. femorata populations in the deeper parts of the Beaufort Sea.

Size-Frequency Distributions Based on Epibenthic Dredge Catches

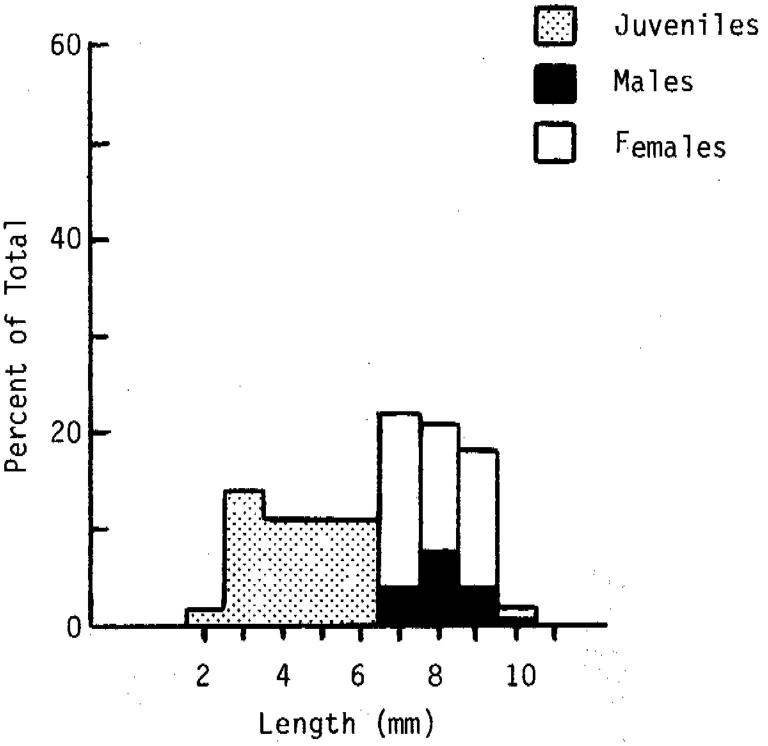
Earlier, I suggested the possibility that size-frequency distributions of P. affinis and P. femorata constructed from grab sample data may be biased towards the less actively swimming juveniles. A general comparison between distributions from epibenthic dredge collections (Figs. 18 and 19) and those from grab samples (Figs. 10-17) gives the immediate impression that the proportion of larger animals is considerably higher in the dredge samples. This is particularly evident when Figures 10 and 18 are compared, since these data came from the same location and were collected the same day. Despite the relatively large mesh size of the dredge net (slightly over 1 mm), I do not believe that the low abundance of 2 and 3 mm animals in the dredge catch (Fig. 18) represents a significant loss of smaller animals through the net. I suspect, rather, that animals of this size, having recently been released from the mother's brood pouch, are not yet capable of extended periods of swimming activity and are thus primarily confined to the bottom. Under these circumstances, they would be "under-sampled" by an epibenthic dredge and "over-sampled" by a grab. This has resulted in an almost complete reversal of the size structure of the juvenile component of the population (Figs. 10 and 18). The dredge caught a much higher proportion of the more actively swimming larger juveniles and maturing adults. Such discrepancies between sampling gears indicate the futility of trying to calculate "growth" from chronological changes in the population size structure based on one type of gear. At least, this seems to be the case for P. affinis and P. femorata. For these species, an accurate assessment of the population size structure at any given time depends upon critical examination of both bottom and epibenthic catches.

It is significant that, like the grabs, the epibenthic dredge catches did not contain overgerous females, females carrying young, or a significant number of animals larger than 9 mm. In this respect, they tend to support the general reproductive patterns of P. affinis and P. femorata outlineed in the previous sections of this report.



N = 238
Total dry weight (g) = 0.168
Dry weight of juveniles (2-5 mm) = 0.045 (26.8%)
Dry weight of adults (6-10 mm) = 0.123 (73.2%)
Sex ratio (6-10 mm) M/F = 0.86

Figure 3.18. Size-frequency distribution of P. affinis in Simpson Lagoon, 8/14/78. Depth, 3.4 m. Epibenthic dredge (150 m tow).



N = 182
Total dry weight (g) = 0.193
Dry weight of juveniles (2-6 mm) = 0.048 (24.9%)
Dry weight of adults (7-10 mm) = 0.145 (75.1%)
Sex ratio (7-10 mm) M/F = 0.47

Figure 3.19. Size-frequency distribution of P. femorata in Simpson Lagoon, 8/14/78. Depth, 3.4 m. Epibenthic dredge (150 m tow).

Recommended Further Research

1. Further in-depth ecological analysis of already existing data (RU 356) to define major differences in the biological structure and trophic organization between lagoon and non-lagoon habitats (i.e., ordination, cluster analysis, general data reduction and computer-oriented ecological analyses).

2. Further assessment of critical physical and biological parameters influencing the structure and organization of benthic communities in various coastal subsystems and habitats.

3. Identification of biologically important indicator species in various coastal habitats and at various depths, based on their abundance, biomass, motility-sessility, feeding strategies and general trophic status.

4. Winter sampling in both lagoon and non-lagoon habitats, at various depths, to establish more firmly the dynamics of biological flow between these coastal subsystems, the reproductive biology of important benthic species, winter feeding strategies and the overall impact of winter conditions (ice-stress) on the structure of coastal benthic communities.

5. Further assessment of the extent to which biological interactions (interspecific competition for food, space, etc., predation) determine the nature and extent of habitat-niche partitioning among the benthic biota of lagoon and non-lagoon ecosystems.

6. Relating specifically to the biology of, and interactions between, populations of _P. affinis_ and _P. femorata_:

   a. Salinity tolerance
   b. Substrate and food preferences, feeding stretegies
   c. Importance as a food source for fish and birds
   d. Space partitioning
   e. Winter migrations and reproductive biology
   f. Effects of oil-contaminated sediments on the burrowing behavior and general survival of both species (there is already some evidence suggesting that colonization of oil-contaminated sediments by _P. femorata_ is substantially curtailed; Atlas et al., 1978).

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Nearshore Samples in Selected Beaufort Sea Sites in 1978

A. C. Broad

INTRODUCTION

In 1977 and 1978 we sampled three times each summer at selected Beaufort (and, in 1977, Chukchi) Sea shore stations. The data from the 1977 eastern Beaufort Sea stations were presented in our 1979 annual report. In this section, we treat data collected in the Beaufort in 1978. Definition of lease areas made after the 1977 field season influenced the selection of sites sampled in 1978. We did not return to Nuvagapak Lagoon and Barter Island, adding instead stations on Flaxman Island and in the mouth of the Sagavanirktok River.

METHODS

Because prior (1975, 1976, and 1977) samples of infaunal benthos taken at depths of less than 0.5 m on Beaufort Sea and adjacent lagoon shores yielded very few animals, the 1978 sampling of seaward extensions of beach transects at Flaxman Island and in Prudhoe Bay was done at depths of 0.5 m, 1.5 m and 2.0 m. The shallowness of the Sagavanirktok delta made extension of the transect to 1.5 or 2.0 m impossible. Samples were taken at 0.5 m and 0.75 m (the deepest water encountered). In the Colville delta, stations were chosen along transects of river channels near the mouth. Each such station consisted of a single sampling location.

The methods employed were those we have used before. Infaunal benthos was sampled with a pole-mounted Ekman grab ($0.0231\,m^2$) and washed in the field in a 0.516 mm screen-bottomed pail. Motile, epibenthic organisms were caught in a WILDCO (No. 171) scrape/skid dredge with a 1.05 mm mesh bag. All washed samples were preserved in the field in 10% formalin and shipped to Bellingham where they were sorted, identified, weighed and subsequently preserved in propanol.

RESULTS

Summaries of the data obtained from Ekman grab and epibenthic dredge samples are presented in appended tables 4.1 to 4.24. The format of these tables is the same as that used to present the 1977 data, and the two years are, in some instances, directly comparable. The deeper (1.5 and 2.0 m) samples made in 1978 have no 1977 counterpart. As before, the reader is cautioned not to equate catches of the Ekman grab with those of the sled net, for the two methods are not comparable.

Our stations J2G, J2H, and J2I (tables 4.11 and 4.23) are on a transect across Kupigruak Channel very near the mouth in the eastern Colville delta. In 1977, the measured depth at these stations was 2.0, 3.0, and 2.0 m respectively. In 1978, three separate measurements at J2G were 0.4, 0.6, and 0.4 m. We measured the depth of water at station J2H in 1978 as 0.5 m at three separate times. Station J2I was 0.4 to 0.3 m deep in 1978. These three stations again comprised a complete transect of the channel. In 1977, our station J2D in the river just east of Anachlik Island was 2.0 m deep. In 1978 it was measured at 0.6, 0.75 and 0.3 m (also tables 4.11 and 4.23). There were differences in the depths noted at J2E and J2F (tables 4.12 and 4.24) in 1977 and 1978, but these were minor. Kupigruak Channel, however, had shallowed considerably in the year's interval, and the fauna was, perhaps accordingly, lower in both number of organisms and total mass (compare tables 4.11 and 4.23 to tables 2.7 and 2.14 from the 1979 report).

DISCUSSION

Certain general observations based on 1977 (and earlier) shoreline sampling in the Beaufort are borne out by the results of the 1978 samples. Infaunal benthos of the nearshore (0-2 m) region is low in diversity, number of individuals and total biomass, and this is most pronounced early in the Summer. Motile, epibenthic crustaceans, however, are at least as likely to be encountered early and in quite shallow water as they are farther from shore at somewhat greater depth. The current data and those from 1977 are consistent with annual repopulation of the nearshore by infaunal polychaetes and burrowing amphipods. Elsewhere in this report (see appendix 3) there is a discussion of the inferred behavior of two amphipod species derived in part from these data. Departure from the burrows may account for reduced numbers and biomass of amphipods at 0.5 and 1.5 m depths late in the Summer in many samples. The trends noted in most samples taken at 0.5 and 1.5 m, however, are not evident in the 2 m samples, and the inference is that the infauna is not destroyed annually at this depth. The usually larger average size of polychates encountered at 2 m implies older individuals in this more stable group as does the appearance of bivalve molluscs.

Samples of infaunal benthos made early in the open water season in the nearshore region, therefore, probably show a seasonal low in the biota. A corallary with some implications for exploitation of petroleum resources is that developments in this region such as artificial islands, grounded ice islands, or causeways have only the same direct biological consequences as has the annual ice. Secondary effects of impeded or deflected currents or routes of migration or other movements, of course, are separate. This generalization is particularly pertinent to river deltas where the infaunal benthos of the less-than 2 m deep water is particularly poor.

Table 4.1. Flaxman Island* - Benthic fauna in 1978. Data are from Ekmab grab samples taken on: A = 7/21, B = 8/8, and C = 8/25, and washed through a 0.516 mm screen. Number of samples is: A = 4, B = 4, C = 4. Samples were taken at:

STATION	N. LATITUDE	W. LONGITUDE	DEPTH (m)
E59	70° 10.9'	145° 59.0'	0.5

*Leffingwell Lagoon beach

TAXONOMIC CATEGORY	BIOMASS						NUMBER						mg/INDIVIDUAL		
	g/m²			%			n/m²			%					
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
POLYCHAETES															
OLIGOCHAETES		0.00						22			8			0.00	
ISOPODS															
AMPHIPODS	1.54	2.91	1.57	100	100	100	130	260	195	100	92	100	11.85	11.19	8.05
OTHER															
Σ	1.54	2.91	1.57	100	100	100	130	282	195	100	100	100			

Table 4.2. Flaxman Island * - Benthic fauna in 1978. Data are from Ekman grab samples taken on: A = 7/21, B = 8/8, and C = 8/25 and washed through a 0.516 mm screen. Number of samples is: A = 4 B = 4, C = 4. Samples were taken at:

STATION	N. LATITUDE	W. LONGITUDE	DEPTH (m)
E59	70° 10.9'	145° 59.0'	-1.5

*Leffingwell Lagoon shore

TAXONOMIC CATEGORY	BIOMASS						NUMBER						mg/INDIVIDUAL		
	g/m²			%			n/m²			%					
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
POLYCHAETES	0.46	0.96	0.08	12	9	2	562	682	98	30	38	9	0.82	1.41	0.82
OLIGOCHAETES															
ISOPODS		0.02			0			11			1			1.82	
AMPHIPODS[1]	3.35	10.07	4.81	86	91	98	1288	1093	952	68	61	88	2.60	9.21	5.05
OTHER	0.07	0.00	0.02	2	0	0	43	11	33	2	1	3	1.63	0.00	0.61
Σ	3.88	11.05	4.91	100	100	100	1893	1797	1083	100	101	100			

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[1] Pontoporeia, Gammarus, Onisimus

Table 4.3. Flaxman Island* - Benthic fauna in 1977. Data are from Ekman grab samples taken on: A = 7/21, B = 8/8, and C = 8/25, and washed through a 0.516 mm screen. Number of samples is: A = 4, B = 4, C = 4. Samples were taken at:

STATION	N. LATITUDE	W. LONGITUDE	DEPTH (m)
E59	70° 10.9	145° 59.0	2.0

*Leffingwell Lagoon beach

TAXONOMIC CATEGORY	BIOMASS						NUMBER						mg/INDIVIDUAL		
	g/m²			%			n/m²			%					
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
POLYCHAETES	3.05	2.31	4.46	27	51	15	1666	335	2188	67	38	69	1.83	6.90	2.04
OLIGOCHAETES	0.00		0.00	0		0	22		22	1		1	0.00		0.00
ISOPODS	0.11	0.25		1	6		11	11		0	1		10.00	22.73	
AMPHIPODS	5.10	1.93	6.57	44	43	22	671	541	649	27	61	21	7.60	3.57	10.12
OTHER[1]	3.26		19.44	28		64	108		303	4		10	30.19		64.16
Σ	11.52	4.49	30.47	100	100	101	2478	887	3162	99	100	101			

[1] Cyrotodaria kurriana

Table 4.4. Flaxman Island* - Benthic fauna in 1978. Data are from Ekman grab samples taken on: A = 7/21, B = 8/8, and C = 8/24, and washed through a 0.516 mm screen. Number of samples is: A = 4, B = 4, C = 4. Samples were taken at:

STATION	N. LATITUDE	W. LONGITUDE	DEPTH (m)
F05	70° 12.0'	146° 05.0'	0.5

*Beaufort Sea beach

TAXONOMIC CATEGORY	BIOMASS						NUMBER						mg/INDIVIDUAL		
	g/m^2			%			n/m^2			%					
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
POLYCHAETES															
OLIGOCHAETES															
ISOPODS															
AMPHIPODS	0.00	3.12	0.68	100	100	100	14	930	119	100	100	100	0.00	3.35	5.71
OTHER															
Σ	0.00	3.12	0.68	100	100	100	14	930	119	100	100	100			

Table 4.5. Flaxman Island* - Benthic fauna in 1978. Data are from Ekman grab samples taken on: A = 7/21; B = 8/8; and C = 8/24; and washed through a 0.516 mm screen. Number of samples is: A = 4, B = 4, C = 4. Samples were taken at:

STATION	N. LATITUDE	W. LONGITUDE	DEPTH (m)
F05	70° 12.0'	146° 05.0'	1.5

*Beaufort Sea beach

TAXONOMIC CATEGORY	BIOMASS						NUMBER						mg/INDIVIDUAL		
	g/m^2			%			n/m^2			%					
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
POLYCHAETES			0.01			0			21			11			0.48
OLIGOCHAETES															
ISOPODS		0.01	0.00		0	0		11	11		2	6		0.91	0.00
AMPHIPODS	1.22	6.16	2.17	100	100	100	119	433	151	100	98	83	10.25	14.23	14.37
OTHER															
Σ	1.22	6.17	2.18	100	100	100	119	444	183	100	100	100			

Table 4.6. Flaxman Island* - Benthic fauna in 1978. Data are from Ekamn grab samples taken on: A = 7/21, B = 8/8, and C = 8/24; and washed through a 0.516 mm screen. Number of samples is: A = 4, B = 4, C = 4. Samples were taken at:

STATION	N. LATITUDE	W. LONGITUDE	DEPTH (m)
F05	70°12.0	146°05.0	2.0

*Beaufort Sea beach

TAXONOMIC CATEGORY	BIOMASS						NUMBER						mg/INDIVIDUAL		
	g/m²			%			n/m²			%					
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
POLYCHAETES	0.05	0.00	0.05	5	0	3	43	11	33	23	6	10	1.16	0.00	1.52
OLIGOCHAETES															
ISOPODS			0.00			0			11			3			0.00
AMPHIPODS	0.83	1.61	1.78	88	100	97	119	184	281	65	94	86	6.97	8.75	6.33
OTHER	0.06			6.			21			11			5.45		
Σ	0.94	1.61	1.83	99	100	100	183	195	325	99	100	99			

Table 4.7. Sagavanirktok shore - Benthic fauna in 1978. Data are from Ekman grab samples taken on: A = 7/10, B = 7/20, and C = 8/18, and washed through a 0.516 mm screen. Number of samples is: A = 8, B = 8, C = 8. Samples were taken at:

STATION	N. LATITUDE	W. LONGITUDE	DEPTH (m)
H12	70° 20.7'	148° 12.3'	0.5 and 0.75

TAXONOMIC CATEGORY	BIOMASS						NUMBER						mg/INDIVIDUAL		
	g/m²			%			n/m²			%					
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
POLYCHAETES			0.02			1			6			0			3.33
OLIGOCHAETES	0.00	0.02	0.00		4	0	16	27	16	2	4	1	0.00	0.74	0.00
ISOPODS		0.02	0.04		4	2		6	11		1	0		3.33	3.64
AMPHIPODS[1]		0.22	2.21		49	97		271	2738		38	99		0.81	0.81
OTHER[2]	0.23	0.19		100.	42		898	411		98	57		0.26	0.46	
Σ	0.23	0.45	2.27	100	99	100	914	715	2771	100	100	100			

[1] Pontoporeia

[2] Chironomid larvae

Table 4.8. Prudhoe Shore - Benthic fauna in 1978. Data are from Ekman grab samples taken on: A = 7/8,11; B = 7/24,28; and C = 8/14,15; and washed through a 0.516 mm screen. Number of samples is: A = 8, B = 8, C = 8. Samples were taken at:

STATION	N. LATITUDE	W. LONGITUDE	DEPTH (m)
H28	70° 18.5'	148° 28.8'	0.5
H32	70° 22.6'	148° 32.6'	0.5

TAXONOMIC CATEGORY	BIOMASS						NUMBER						mg/INDIVIDUAL		
	g/m^2			%			n/m^2			%					
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
POLYCHAETES	0.00	0.04	0.22	0	2	8	5	119	238	2	12	23	0.00	0.34	0.92
OLIGOCHAETES	0.42	0.16	0.12	99	8	4	282	509	384	98	50	38	1.49	0.31	0.31
ISOPODS		0.29	0.26		14	9		33	22		3	2		8.79	11.82
AMPHIPODS		1.53	2.31		75	79		336	379		33	37		4.55	6.09
OTHER		0.02			1			27			3			0.74	
Σ	0.42	2.04	2.91	99	100	100	287	1024	1023	100	101	100			

Table 4.9. Prudhoe Shore = Benthic fauna in 1978. Data are from Ekman grab samples taken on: A = 7/8,11; B = 7/24,28; and C = 8/14,15; and washed through a 0.516 mm screen. Number of samples is: A = 8, B = 8, C = 6. Samples were taken at:

STATION	N. LATITUDE	W. LONGITUDE	DEPTH (m)
H28	70° 18.5	148° 28.8	1.5
H32	70° 22.6	148° 32.6	1.5

TAXONOMIC CATEGORY	BIOMASS						NUMBER						mg/ INDIVIDUAL		
	g/m^2			%			n/m^2			%					
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
POLYCHAETES	0.26	1.98	1.68	59	54	50	422	633	887	83	74	75	0.62	3.13	1.89
OLIGOCHAETES	0.00	0.00	0.00	0	0	0	49	98	116	10	11	10	0.00	0.00	0.00
ISOPODS	0.07		0.01	16		0	11		7	2		1	6.36		1.43
AMPHIPODS	0.11	1.38	1.64	25	38	49	27	125	166	5	15	14	4.07	11.04	9.88
OTHER		0.28			8			5			1			56.00	
Σ	0.44	3.64	3.33	100	100	99	509	861	1176	100	101	100			

Table 4.10. Prudhoe Shore - Benthic fauna in 1978. Data are from Ekman gram samples taken on: A = 7/8,11, B = 7/24,28, and C = 8/14,15, and washed through a 0.516 mm screen. Number of samples is: A = 8, B = 8, C = 8. Samples were taken at:

STATION	N. LATITUDE	W. LONGITUDE	DEPTH
H28	70° 18.5	148° 28.8	2.0
H32	70° 22.6	148° 32.6	2.0

TAXONOMIC CATEGORY	BIOMASS						NUMBER						mg/INDIVIDUAL		
	g/m^2			%			n/m^2			%					
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
POLYCHAETES	2.29	2.90	4.16	7	16	11	892	2273	1299	46	50	50	2.57	1.28	3.20
OLIGOCHAETES	0.07	0.69	0.14	0	4	0	278	1234	525	14	27	20	0.25	0.56	0.26
ISOPODS	0.10	0.48	4.22	0	3	11	11	43	27	1	1	1	9.09	11.16	156.30
AMPHIPODS	0.35	2.01	3.18	1	11	9	65	319	465	3	7	18	5.38	6.30	6.84
OTHER[1,2]	28.04[1]	11.92	25.36[2]	91	66	68	682	687	292	35	15	11	41.11[1]	17.39	86.84[2]
Σ	30.85	18.03	37.06	99	100	99	1928	4556	2608	99	100	100			

[1] Cyrtodaria kurriana (bivalve) and other

[2] Eucratea sp.

Table 4.11. Colville Delta - Benthic fauna in 1978. Data are from Ekman grab samples taken on: A = 7/16,17; B = 7/30; and C = 8/19,20; and washed through a 0.516 mm screen. Number of samples is: A = 14, B = 16, C = 16. Samples were taken at:

STATION	L. LATITUDE	W. LONGITUDE	DEPTH (m)*
J2D	70° 26.3'	150° 22.0'	0.6/0.75/0.3
J2G	70° 28.8	150° 24.5'	0.4/0.6/0.5
J2H	70° 29.0	150° 25.5	0.5/0.5/0.5
J2I	70° 29.2	150° 26.0	0.4/0.4/0.3

*A/B/C depth data

TAXONOMIC CATEGORY	BIOMASS						NUMBER						mg/ INDIVIDUAL		
	g/m^2			%			n/m^2			%					
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
POLYCHAETES	0.21	0.12	0.07	47	21	37	46	22	19	15	13	20	4.57	5.45	3.68
OLIGOCHAETES		0.00			0			5			3			0.00	
ISOPODS	0.18	0.36	0.02	40	64	11	9	11	11	3	7	11	20.00	32.73	1.82
AMPHIPODS	0.02	0.05	0.10	4	9	53	22	32	24	7	19	25	0.91	1.56	4.17
OTHER	0.04	0.03	0.00	9	5		238	95	43	76	58	44	0.17	0.32	0.00
Σ	0.45	0.56	0.19	100	99	101	315	165	97	101	100	100			

Table 4.12. Colville Delta - Benthic fauna in 1978. Data are from Ekman grab samples taken on: A = 7/16, B = 7/30, and C = 8/20, and washed through a 0.516 mm screen. Number of samples is: A = 8, B = 8, C = 8. Samples were taken at:

STATION	N. LATITUDE	W. LONGITUDE	DEPTH (m)*
J2E	70° 26.3	150° 21.8	2.3/2.5/2.1
J2F	70° 26.3	150° 21.7	3.3/3.5/3.1

*A/B/C depth data

TAXONOMIC CATEGORY	BIOMASS						NUMBER						mg/INDIVIDUAL		
	g/m²			%			n/m²			%					
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
POLYCHAETES	3.85	4.89	6.75	60	53	60	2629	3078	2478	67	65	71	1.46	1.59	2.72
OLIGOCHAETES	1.03	1.17	0.91	16	13	8	1174	1618	985	30	34	28	0.88	0.72	0.92
ISOPODS	1.36	3.19	3.61	21	34	32	54	43	32	1	1	1	25.19	74.19	112.81
AMPHIPODS	0.21	0.01	0.02	3	0	0	27	5	11	1	0	0	7.78	2.00	1.82
OTHER	0.01			0.			33			1			0.30		
Σ	6.46	9.26	11.29	100	100	100	3917	4744	3506	100	100	100			

Table 4.13. Flaxman Island* - Mobile, epibenthic fauna in 1978. Data are from 50 m tows of the sled net (see text for description of net) taken on: A = 7/21; B = 8/8; and C = 8/25. Number of samples is: A = 2; B = 2; and C = 2. Samples were taken at station E59; 70°10.9'N, 145°59.0'W; 0.5 m.

*Leffingwell Lagoon beach

TAXONOMIC CATEGORY	WET WEIGHT BIOMASS (mg)			NUMBER			mg/INDIVIDUAL		
	A	B	C	A	B	C	A	B	C
MYSIS LITORALIS		92.5	194.5		24.5	9.0		3.8	21.6
MYSIS RELICTA	10,849	71.5	788.0	445.5	15.0	52.0	24.4	4.8	15.2
CALANOIDA		121.5	1.0		1688.5	4.5		0.1	0.2
SADURIA ENTOMON	5		12.0	4.0		4.0	1.3		3.0
AMPHIPODS	7,574[1]	362.2	889.0	905.0[1]	48.0	217.5	8.4	7.5	4.1
OTHER	14	44.5	35.0	1.0	14.5	3.5	14.0	3.1	10.0
Σ	18,442	346.1	1919.5	1355.5	1790.5	290.5			

[1] Mostly *Onisimus glacialis*, *Gammarus setosa*

Table 4.14. Flaxman Island* - Mobile, epibenthic fauna in 1978. Data are from 50 m tows of the sled net (see text for description of net) taken on: A = 7/21; B = 8/8; and C = 8/25. Number of samples is: A = 2; B = 2; and C = 2. Samples were taken at stations E59; 70°10.9N, 145°59.0W; 1.5 m.

*Leffingwell Lagoon beach.

TAXONOMIC CATEGORY	WET WEIGHT BIOMASS (mg)			NUMBER			mg/INDIVIDUAL		
	A	B	C	A	B	C	A	B	C
MYSIS LITORALIS	22.0	1.5	28.5	0.5	0.5	5.0	44.0	3.0	5.7
MYSIS RELICTA	74.5		0.5	12.5		0.5	6.0		1.0
CALANOIDA			12.0			9.5			1.3
SADURIA ENTOMON		0.1			0.5			0.2	
AMPHIPODS[1]	466.5[1]	3.1	47.2	186.5	4.0	9.0	2.5	0.8	5.2
OTHER	5.0	11.1	42.0	6.5	3.0	2.0	0.8	3.7	21.0
Σ	568.0	15.8	130.2	206.0	8.0	26.0			

1. Mostly Onisimus glacialis

Table 4.15. Flaxman Island* - Mobile, epibenthic fauna in 1978. Data are from 50 m tows of the sled net (see text for description of net) taken on: A = 7/21; B = 8/8; and C = 8/25. Number of samples is: A = 2; B = 2; and C = 2. Samples were taken at station E59; 70°10.9'N, 145°59.0'W; 2.0 m.

*Leffingwell Lagoon beach

TAXONOMIC CATEGORY	WET WEIGHT BIOMASS (mg)			NUMBER			mg/INDIVIDUAL		
	A	B	C	A	B	C	A	B	C
MYSIS LITORALIS			43.0			9.0			4.8
MYSIS RELICTA	0.1			0.5			0.2		
CALANOIDA			96.0			92.0			1.0
SADURIA ENTOMON									
AMPHIPODS	23.0	1.2	9.5	9.5	2.0	3.0	2.4	0.6	3.2
OTHER	2.1	13.0	6.0	1.5	6.0	1.5	1.4	2.2	4.0
Σ	25.2	14.2	154.5	11.5	8.0	105.5			

Table 4.16. Flaxman Island* = Mobile, epibenthic fauna in 1978. Data are from 50 m tows of the sled net (see text for description of net) taken on: A = 7/21; B = 8/8; and C = 8/24. Number of samples is: A = 2; B = 2; and C = 2. Samples were taken at station F05; 70°12.0'N; 146°05.0'W; 0.5 m.

*Beaufort Sea beach

TAXONOMIC CATEGORY	WET WEIGHT BIOMASS (mg)			NUMBER			mg/INDIVIDUAL		
	A	B	C	A	B	C	A	B	C
MYSIS LITORALIS	0.0		17.0	1.0		2.5	0.0		6.8
MYSIS RELICTA	0.0	9.0		1.0	2.5		0.0	3.6	
CALANOIDA	32.0	0.0	2.0	35.5	1.5	1.0	0.9	0.0	2.0
SADURIA ENTOMON		0.5	14.0		0.5	0.5		1.0	28.0
AMPHIPODS	1591.5[1]	1350.0[3]	47.5	325.5[1]	264.5[3]	15.5	4.9	5.1	3.1
OTHER	76.0[2]		19.5	23.0		4.0	3.3		4.9
Σ	1699.5	1359.5	100.0	386.0	269.0	23.5			

1. Mostly Gammarus setosa
2. Plus 8.53g of Laminaria
3. Gammarus setosa and Halirages sp.

Table 4.17. Flaxman Island* - Mobile, epibenthic fauna in 1978. Data are from 50 m tows of the seld net (see text for description of net) taken on: A = 7/21; B = 8/8; and C = 8/24. Number of smaples is: A = 2; B = 2; and C = 2. Samples were taken at station F05; 70°12.0'N, 146°05.0'W; 1.5 m.

*Beaufort Sea beach

TAXONOMIC CATEGORY	WET WEIGHT BIOMASS (mg)			NUMBER			mg/INDIVIDUAL		
	A	B	C	A	B	C	A	B	C
MYSIS LITORALIS		4.5	6.0		2.0	1.5		2.3	4.0
MYSIS RELICTA	26.0[1]	443.5	100.5	22.5[1]	104.0	6.0	1.2	4.3	16.8
CALANOIDA	3.0	3.0		2.5	3.0		1.2	1.0	
SADURIA ENTOMON		1.0			0.5			2.0	
AMPHIPODS	45.1	101.6	18.7	9.5	55.5	7.0	4.8	1.8	2.8
OTHER	146.5[2]	14.0	1.0	62.0[2]	1.0	0.5	2.4	14.0	2.0
Σ	220.6	567.6	126.2	96.5	166.0	15.0			

1. *Mysis* sp.

2. Mostly *Corymorpha flammae* and *Perigonimus yoldiarcticae*

Table 4.18. Flaxman Island* - Mobile, epibenthic fauna in 1978. Data are from 50 m tows of the sled net (see text for description of net) taken on: A = 7/21; B = 8/8; and C = 8/24. Number of samples is: A = 2; B = 2; and C = 2. Samples were taken at station F05; 70°12.0'N, 146°05.0'W; 2.0 m.

*Beaufort Sea beach

TAXONOMIC CATEGORY	WET WEIGHT BIOMASS (mg)			NUMBER			mg/INDIVIDUAL		
	A	B	C	A	B	C	A	B	C
MYSIS LITORALIS									
MYSIS RELICTA	1385.5[1]	14.0	7.6	1024.5[1]	4.0	1.5	1.4	3.5	5.1
CALANOIDA	23.5	5.0		14	5.5		1.7	0.9	
SADURIA ENTOMON									
AMPHIPODS	49.7	15.6		17	2.5		2.9	6.3	
OTHER	280.5[2]		1.5	109.5[2]		0.5	1.6		3.0
Σ	1739.2	34.6	9.1	1165.0	12.0	2.0			

1. Mostly *Mysis* sp. (immature)

2. Mostly *Corymorpha flammae* and *Perigonimus yoldiarcticae*

Table 4.19. Sagavanirktok Delta - Mobile, epibenthic fauna in 1978. Data are from 50 m tows of the sled net (see text for description of net) taken on: A = 7/10; B = 7/25; and C = 8/18. Number of samples is: A = 4; B = 4; and C = 4. Samples were taken at station H12; 70°20.7'N, 148°12.3'W; 0.5 m and 0.75 m.

TAXONOMIC CATEGORY	WET WEIGHT BIOMASS (mg)			NUMBER			mg/INDIVIDUAL		
	A	B	C	A	B	C	A	B	C
MYSIS LITORALIS									
MYSIS RELICTA	0.3	2489.8	587.5	<0.3	1192.0	78.5	0.9	2.1	7.5
CALANOIDA			0.0			0.3			0.0
SADURIA ENTOMON	0.3	2.3	16.8	0.3	0.5	1.8	1.0	4.6	9.3
AMPHIPODS		31.6	108.1		10.0	29.5		3.1	3.7
OTHER	0.8	3.8	34.3[1]	2.5	4.5	0.5	0.3	0.8	68.6[1]
Σ	1.4	2527.5	746.7	3.1	1207.0	110.6			

1. *Myoxocephalus quadricornis*

Table 4.20. Prudhoe shore - Mobile, epibenthic fauna in 1978. Data are from 50 m tows of the seld net (see text for description of net) taken on: A = 7/8,11; B = 7/24,28; and C = 8/14,15. Number of samples is: A = 4; B = 4; and C = 4. Samples were taken at stations H28; 70°18.5N, 148°28.8'W; 0.5 m and H32; 70°22.8'N; 148°32.8'W; 0.5 m.

TAXONOMIC CATEGORY	WET WEIGHT BIOMASS (mg)			NUMBER			mg/INDIVIDUAL		
	A	B	C	A	B	C	A	B	C
MYSIS LITORALIS	29.5			59.3			0.5		
MYSIS RELICTA	297.3	92.6	2051.0	341.3	24.8	678.0	0.9	3.7	3.0
CALANOIDA	0.0	7.3	2.8	1.0	5.3	4.5	0.0	1.4	0.6
SADURIA ENTOMON	4.5	29.0	227.3	1.0	1.5	12.5	4.5	19.3	18.2
AMPHIPODS	369.3	20.3	129.1	60.5	3.5	21.3	6.1	5.8	6.1
OTHER	18.0	5.0	2.0	7.8	3.5	5.0	2.3	1.4	0.4
Σ	718.6	154.2	2412.2	470.9	38.6	721.3			

Table 4.21. Prudhoe Shore - Mobile, epibenthic fauna in 1978. Data are from 50 m tows of the sled net (see text for description of net) taken on: A = 7/8, 11; B = 7/24,28; and C = 8/14,15. Number of samples is: A = 4; B = 4; C = 4. Samples were taken at stations H28; 70°18.5'N, 148°28.8'W; 1.5 m
H32; 70°22.8'N, 148°32.8'W; 1.5

TAXONOMIC CATEGORY	WET WEIGHT BIOMASS (mg)			NUMBER			mg/INDIVIDUAL		
	A	B	C	A	B	C	A	B	
MYSIS LITORALIS			188.3			40.3			4.7
MYSIS RELICTA	142.8	43.5	286.0	37.5	21.5	59.3	3.8	2.0	4.8
CALANOIDA		6.0	5.5		4.0	4.8		1.5	1.1
SADURIA ENTOMON	955.8			171.5			5.6		
AMPHIPODS	165.3	47.5	18.8	15.3	13.5	3.8	10.8	3.5	4.9
OTHER	5.5	21.0	6.3	1.0	9.5	3.3	5.5	2.2	1.9
Σ	1269.4	118.0	504.9	225.3	48.5	111.5			

Table 4.22. Prudhoe Shore - Mobile, epibenthic fauna in 1978. Data are from 50 m tows of the sled net (see text for description of net) taken on: A = 7/8,11; B = 7/24,28; and C = 8/14,15. Number of samples is A = 4; B = 4; and C = 4. Samples were taken at stations H28; 70°18.5'N, 148°28.8'W; 2.0 m
H32; 70°22.8'N, 148°32.8'W; 2.0 m

TAXONOMIC CATEGORY	WET WEIGHT BIOMASS (mg)			NUMBER			mg/INDIVIDUAL		
	A	B	C	A	B	C	A	B	C
MYSIS LITORALIS		62.0	3126.5		24.8	617.8		2.5	5.1
MYSIS RELICTA	2570.8	24830.3	3184.5	198.8	11896.5	627.8	12.9	2.1	5.1
CALANOIDA		1.5	39.3		1.8	17.5		0.8	2.2
SADURIA ENTOMON	124.5			4.3			29.0		
AMPHIPODS	356.8	65.3	7.9	28.0	16.0	5.3	12.7	4.1	1.5
OTHER	78.6	3.5	12.5	0.8	1.5	2.5	98.3	2.3	5.0
Σ	3130.7	24962.6	6370.7	231.9	11940.6	1270.9			

Table 4.23. Colville Delta - Mobile, epibenthic fauna in 1978. Data are from 50 m tows of the seld net (see text for description of net) taken on: A = 7/16, 17; B = 7/30; and C = 8/19,20. Number of samples is: A = 8; B = 8; and C = 8. Samples were taken at stations:

J2D	70°26.3'N	150°22.0'W	0.6/0.75/0.3 m.*
J2G	70°28.8'N	150°24.5'W	0.4/0.6/0.4 m
J2H	70°29.0'N	150°25.5'W	0.5/0.5/0.5 m
J2I	70°29.2'N	150°26.0'W	0.4/0.4/0.3 m

*A/B/C depth data

TAXONOMIC CATEGORY	WET WEIGHT BIOMASS (mg)			NUMBER			mg/INDIVIDUAL		
	A	B	C	A	B	C	A	B	C
MYSIS LITORALIS									
MYSIS RELICTA	1.4	0.1	3.4	0.9	0.1	0.4	1.6	1.0	8.5
CALANOIDA									
SADURIA ENTOMON	59.8			0.9			66.4		
AMPHIPODS	40.9	1.8		3.5	0.1		11.7	18.0	
OTHER	0.2			0.8			0.3		
Σ	102.3	1.9	3.4	6.1	0.2	0.4			

Table 4.24. Colville Delta - Mobile, epibenthic fauna in 1978. Data are from 50 m tows of the sled net (see text for description of net) taken on: A = 7/16; B = 7/30; and C = 8/20. Number of samples is: A = 4; B = 4; and C = 4. Samples were taken at stations:

J2E	70°26.3'N	150°21.8'W	2.3/2.5/2.1 m*
J2F	70°26.3'N	150°21.7'W	3.3/3.5/3.1 m

*A/B/C depth data

TAXONOMIC CATEGORY	WET WEIGHT BIOMASS (mg)			NUMBER			mg/INDIVIDUAL		
	A	B	C	A	B	C	A	B	C
MYSIS LITORALIS									
MYSIS RELICTA	70.0	1.0	18.8	11.3	0.5	1.0	6.2	2.0	18.8
CALANOIDA									
SADURIA ENTOMON	15.3	169.8	53.0	1.3	18.5	0.5	11.8	9.2	106.0
AMPHIPODS	0.0	10.0	0.5	0.3	2.0	0.5	0.0	5.0	1.0
OTHER	5.1	19.3	4.0	3.3	16.8	3.8	1.5	1.1	1.1
Σ	90.4	200.1	76.3	16.2	37.8	5.8			

TROPHIC RELATIONSHIPS OF THE ARCTIC SHALLOW WATER MARINE ECOSYSTEM

by

D. E. Schneider

INTRODUCTION

Investigations of the trophic relationships of the shallow water Beaufort Sea ecosystem by RU-356 in 1977 and 1978 focused on the role of organic detritus, particularly peat derived from eroding tundra shoreines, as an energy source. Our experiments have shown that a number of species ingest peat fragments, but one amphipod, Gammarus setosus, is particularly active in processing this material. This species can apparently assimilate a surprisingly high proportion (65-75%) of the organic matter in coarse peat fractions (Schneider and Koch, 1979). Interestingly, peat from an eroding tundra bank that had not yet entered the marine ecosystem was not readily assimilated. G. setosus has also been shown to readily ingest fine sediments, but during 1978 we were not able to determine the amount of organic assimilation from this source. Our studies during the summer of 1979 were aimed at further elucidating the role of G. setosus in processing organic detritus. In particular we sought an explanation for the extremely high assimilation of peat organic matter. The ability of this species to assimilate organic matter from sediments was also investigated.

METHODS

Peat Assimilation Experiments

The procedures used for determining organic assimilation from peat were the same as those described in the last annual report (Schneider and Koch, 1979). Detailed procedures will not be repeated here except where they differ from those used last year, but a brief summary follows. The organic content of food (peat) and feces was determined as the weight loss upon ashing in a muffle furnace at 500°C for 2 hours. In some of our experiments discrete fecal pellets were not readily formed. Collection of fecal material in these cases was accomplished by transferring the amphipods to clean Millipore filtered (0.45μ) seawater in compartmented plastic boxes following a period of feeding. Fecal material was then recovered by suction filtration ($< 1/3$ atmosphere) on pre-ashed (475°C for one hour) and tared 2.4 cm Whatman GF/C glass fiber filters. These samples were then processed in the same manner that was used for peat samples collected on glass fiber filters. Organic assimilation was calculated using Conover's (1966) equation:

$$U' = \left[\frac{(F' - E')}{(1-E')\,F'}\right] \times 100$$

where U' is the percentage of assimilation, and F' and E' are the ash-free dry weight: dry weight ratios for ingested food and feces produced respectively. A detailed rationale has been presented for the use of this equation (Schneider and Koch, 1979). No gravimetric assimilation experiments were attempted this year because of the great difficulties in obtaining consistent results. Specific details of the peat assimilation experiments are presented in the next section along with the results.

Organic Assimilation from Sediments

The assimilation of organic material from fine sediments by <u>Gammarus setosus</u> was investigated using a wet oxidation method for organic content determinations. Small <u>G. setosus</u>, approximately 4-6 mg dry weight, were collected in the shore lead opposite the Naval Arctic Research Lab in early July. Three individuals were placed in each compartment of a 24 compartment plastic box in about 40 ml of Milipore filtered water from the shore lead (salinity < 1‰). The animals were allowed to clear their guts for 24 hours and fecal pellets were frequently removed to prevent reingestion. Fine surface sediments were collected by scraping a small vial across the sediment surface. The sediments were sieved through nitex screens and the fraction passing through a 63 μ screen was used for the experiment. A 5 ml aliquot of rapidly stirred suspension of the sediment was delivered with an automatic pipette to each compartment containing amphipods. An additional 12 aliquots were dispensed into vials for determination of the initial organic content of the sediment. Fecal pellets were recovered from the compartments after a 25 hour feeding period. The pellets from 3 compartments (i.e., the output from 9 animals) were pooled for organic content determinations.

Control sediment samples and recovered fecal pellets were suction filtered (< 1/3 atmosphere) onto pre-ashed (475^0 C for one hour) and tared Whatman FG/C glass fiber filters (2.4 cm), rinsed twice with 2 ml aliquots of Na_2SO_4 (45 g/ℓ) and dried in an oven at 70^0C for at least 12 hours. Sample dry weights were determined on a Cahn DTL electrobalance. The filters were then transferred to clean 30 ml beakers and the carbon content was determined using the dichromate wet oxidation method of Strickland and Parsons (1968). A 10 ml volume of oxidant was used in all cases. The extinction of each sample was read in a Hitachi-Perkin Elmer spectrophotometer (model 139) using a 1 cm light path cell. Two of the sediment and fecal pellet samples were ashed in a muffle furnace (500^0 C for 2 hours) before determining the carbon content. These served as controls to correct for any reactions of the oxidant not attributable to carbon.

^{14}C-Cellulose Oxidation

The ability of the amphibods Gammarus setosus and Onisimus litoralis to oxidize cellulose was investigated in a joint set of experiments with Don Shell (RU-357). The details and results of these experiments are presented in his annual report, but some reference to the results will be made in the discussion section of this report. In these experiments we incubated 2ℓ flasks of raw seawater, seawater plus amphipods, seawater plus peat, and seawater plus peat plus amphipods with about 120μg of ^{14}C-Cellulose. Evolution of $^{14}CO_2$ and incorporation of label into animal tissues was monitored at intervals throughout the experiments. In one experiment with G. setosus the amphipods were dissected to separate the gut from the remainder of the body for counting. Only total body counts were made for O. littoralis.

Antibiotic Treatment Experiments

A series of experiments was run to assess the role of microorganisms in the assimilation of peat by G. setosus. Three different antibiotic treatments were used:

1) Peat soaked in antibiotic for 2 days then fed to untreated amphipods.

2) Amphipods soaked in antibiotic for 2 days then fed untreated peat. The amphipods were fed peat during the first day of antibiotic treatment to encourage ingestion of the antibiotic, and were allowed to clear their guts on the second day of treatment.

3) Amphipods soaked in antibiotic for 2 days then fed peat that had also been soaked 2 days in antibiotic.

Control runs in which no antibiotics were used were run with each of the above experiments. The antibiotic solution was a mixture of neomycin-SO_4 and streptomycin-SO_4 each at 50 mg/ℓ in seawater. The procedures for determining organic assimilation of the peat were identical to those used in the other peat assimilation experiments.

Laminaria Assimilation Experiment

An experiment was set up to determine the ability of large (approximately 20-40 mg dry weight) and small (approximately 4-6 mg dry weight) *G. setosus* to assimilate organic matter from *Laminaria* fragments. Detached *Laminaria* fronds that had freshly drifted ashore were collected. Discs were punched from healthy regions of the fronds with a paper punch, and 10 discs were fed to each amphipod. Fecal pellets were collected after 24 hours of feeding. Both control batches of *Laminaria* discs and the fecal pellets were dried and ashed on glass fiber filters to determine organic content. The procedures were the same as previously described for peat assimilation experiments.

ATP Analysis

Attempts have been made to measure the ATP content of food and feces in assimilation experiments to provide an estimate of utilization of microbial biomass. Continued technical difficulties have been encountered in our attempts to perfect this method. The major problems have been inhibition of the enzyme system by some substance in the extracts and the lack of a suitably sensitive photodetection device. The levels of ATP in our systems apparently are too close to the resolution limit for our method when a liquid scintillation counter is used as the photodetector. I have therefore made the decision to discontinue experiments of this type.

RESULTS AND DISCUSSION

Organic Assimilation From Sediments

Gammarus setosus was found to ingest large quantities of fine silty sediments that had collected under the ice canopy (Schneider and Koch, 1979). An experiment was set up to determine whether G. setosus is capable of assimilating organic matter from those sediments. Table 5.1 shows the results of this experiment. The carbon content of sediment and feces was converted to the fraction of carbon before Conover's (1966) assimilation was calculated.

Table 5.1. Assimilation of organic material from sediments by Gammarus setosus. Mean values for carbon content ± S.E. are shown.

Sediment mgC/gm	n	Feces mgC/gm	n	Conover's % Assimilation
24.2 ± 0.84	9	17.0 ± 0.54	7	30.3

A t-test indicates that the difference in carbon content of the sediment and feces is significant ($p < .05$) so the positive value for % assimilation is meaningful. Therefore G. setosus is capable of deriving nutrition from feeding on bottom sediments. The nature of the organic material in these sediments is not known. Analysis of fecal pellets derived from feeding in the shore lead where the experimental animals were collected indicates that benthic diatoms and peat fragments may be important components (Schneider and Koch, 1979).

The assimilation efficiencies of other deposit feeders varies widely. Hargrave (1970) found that the deposit feeding freshwater amphipod Hyalella azteca only assimilated 6.5% of the organic matter in subsurface sediments and 14.9% of that in surface sediments. The presence of large quantities of cellulose and lignin-like substances in the lake sediment may account for the low efficiency. The higher efficiency seen in G. setosus may in part be due to its ability to assimilate peat fragments efficiently. Other values reported in the literature are 17.2% efficiency for a holothurian (Yingst,

1976) and 45% by the polychaete worm Pectinaria gouldii (Gordon, 1966). The efficiency found for G. setosus seems to fall somewhere near the middle of the range of values reported for other deposit feeders.

Organic Assimilation of Different Peat Size Fractions

The ability of G. setosus to assimilate organic matter from different size fractions of peat was investigated. Results of a similar experiment during the summer of 1978 indicated that only the coarsest particle sizes (> 1050μ) were efficiently assimilated. Verification of this trend by using another peat sample seemed desirable. In addition, two size classes of G. setosus, small (approximately 4-6 mg dry weight) and large (approximately 20-40 mg dry weight), were used in this experiment. Casual observations have suggested that small G. setosus feed more vigorously than large individuals and we felt that this might be reflected in their ability to assimilate peat organic matter.

The results in Table 5.2 indicate that both large and small G. setosus assimilated a very high proportion of peat organic matter in all fractions larger than 63 μ. Large individuals did not assimilate peat particles < 63 μ while small individuals were capable of utilizing this size class efficiently. The cause of this difference is not known. The results of this experiment differ from those reported last year (Schneider and Koch, 1979) in that a much wider range of particle sizes were assimilated in this experiment. No conclusive explanation can be offered for the difference. The peat samples used were different and since peat is not a particularly uniform substance, composition of the organic material in each size class may have differed. Nevertheless, it is again evident that G. setosus has unusual ability to assimilate organic matter from peat. The assimilation efficiency is far higher than would be expected if this amphipod was simply feeding on micro-organisms associated with the peat. Assimilation efficiences of the magnitude seen could only result from direct utilization of peat organic matter. To test this, the following experiment on oxidation of ^{14}C-cellulose was undertaken.

Table 5.2 Assimilation of different size fractions of peat from Elson Lagoon by large and small *Gammarus setosus*.

Peat Size Fraction	Peat % Organic	Feces % Organic	Conover's % Assimilation
> 1050 μ	66.2	23.4	84.4
425< x <1050 μ	65.8	21.8	85.5
202< x <425 μ	65.3	25.1	82.2
102< x <202 μ	60.6	25.4	77.9
63 < x <102 μ	39.7	21.4	58.6
< 63 μ	16.3	21.2	-38.2
1050	67.1	34.4	74.3
>425< x <1050 μ	69.2	25.4	84.8
202< x <425 μ	69.7	36.7	74.8
102< x <202 μ	65.7	21.0	86.1
63 < x <102 μ	48.7	10.4	87.8
<63 μ	16.2	8.4	52.6

^{14}C-Cellulose Oxidation

Although the detailed results of these experiments appear in Schell's (RU-357) annual report, a brief summary of our findings will be presented here. At 8°C, flasks that contained G. setosus released about 2.3 times as much $^{14}CO_2$ from ^{14}C-cellulose as the flask containing only seawater, and 3.4 times as much as the flask containing seawater and peat. At 0°C there was a 1.6 fold increase in $^{14}CO_2$ release in flasks containing G. setosus and peat compared to the flask containing only seawater and peat. The flasks containing Onisimus litoralis and peat showed almost the same $^{14}CO_2$ output as the flask containing only seawater and peat. Body counts exclusive of the gut for G. setosus indicate a net incorporation of ^{14}C into amphipod tissues. The results indicate that G. setosus is capable of oxidizing cellulose and incorporating carbon from this source into tissues. Onisimus litoralis apparently is unable to directly utilize cellulose.

Cellulase activity has been reported in a number of marine invertebrates (Yokoe and Yasumasu, 1964), but few studies have reported on the ability of these animals to assimilate cellulose. Foulds and Mann (1978) found that Mysis stenolepis assimilates sterile ^{14}C-cellulose with an efficiency of around 50%. Actually values as high as 60 to 75% were observed in some experiments. Our experiment did not permit us to calculate an assimilation efficiency for G. setosus feeding on cellulose. However the fact that cellulose is readily oxidized by this species coupled to the observations of high assimilation of peat organic matter suggests that G. setosus is able to directly utilize some of the refractory organic compounds in peat. Direct utilization of detrital carbon rather than having the energy flow through an intermediate microbial population should substantially increase the efficiency of energy flow for this species. Instead of having two trophic levels between the detritus and detritivore there may only be a single step (Foulds and Mann, 1978). In the arctic where primary production is very seasonal an increase in the efficiency of detrital food chains could be advantageous.

Antibiotic Treatment Experiments

Whether G. setosus produces its own cellulase activity or harbors a symbiotic gut microflora that can digest cellulose is not known. A series of experiments were set up to investigate this question. By inactivating the microbial populations on the peat and in the guts of the amphipods and subsequently determining the organic assimilation of peat, we hoped to elucidate the role of microbes in this process.

The results of these experiments shown in Table 5.3 are somewhat ambiguous. The first set of experiments run gave negative assimilations for both the control and the treated groups. The negative assimilation for the control group is highly unusual and represents the only case in a total of 7 experiments with 5-19 replicates per experiment where a negative assimilation with a coarse peat fraction has been observed. Furthermore, the assimilations of the other two control groups is lower than we have normally seen. In previous experiments the assimilation has ranged from about 60 - 85%. Nevertheless it appears that the antibiotic treatment of the amphipods and of both the amphipods and peat together may have reduced the ability to assimilate peat organic matter. The organic content of the food (peat) and feces is not significantly different for either of the antibiotic treated groups yet it is significantly different for the control groups. This suggests that a gut microflora may be involved in the ability of G. setosus to assimilate peat.

If a gut microflora is involved, a possible explanation for the low and even negative assimilation efficiencies in the control groups can be suggested. The amphipods used in these experiments had been stored in the laboratory for at least a month prior to being used. Fresh animals could not be obtained for the experiments because the field population had dispersed. During storage the amphipods were not fed regularly and it is possible that the populations of gut microbes had fallen to a low level. The amphipods used in the second and third experiments shown in Table 5.3 had been fed on peat for several days prior to the run. The positive but low assimilations in these groups could result from a partial buildup of the gut microbial populations that had not yet reached normal levels.

Table 5.3. The effect of antibiotic treatment on the ability of Gammarus setosus to assimilate organic matter from peat. Antibiotic treatment (neomycin - SO_4 and streptomycin - SO_4, 50mg/l) was for 48 hours. Asterisked feces % organic values are significantly different (t-test, $P < .05$) from the corresponding peat % organic values.

Treatment	Peat % Organic	Feces % Organic	Conover's % Assimilation
Control - no antibiotic	77.5	82.9*	-40.8
Antibiotic treated peat	72.5	76.9	-26.3
Control - no antibiotic	77.0	66.3*	41.2
Antibiotic treated amphipods	79.1	74.2	24.0
Control - no antibiotic	79.4	69.3*	41.4
Antibiotic treated peat and amphipods.	76.5	71.4*	23.3

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Arctic Saltmarsh Lakes

by

David T. Mason

The saltmarsh lakes of the Nearctic have rarely been studied. They were briefly treated by Hartz and Kruuse (1911) and later by Madsen (1936); the first authors compared them to the "Lo'er" of the Danish saltmarshes, while the latter reported studies of the marsh fauna. In this paper I describe lakes in a marsh at Arctic Circle Landing Strip (Lat. 66°26'26", Long. 161°52'08") which I have visited during the summers of 1976 through 1979.

They tiny lakes (1-3 m average dimension) are embedded in a continuous, gently sloping (0.0023 $m \cdot m^{-1}$) littoral meadow behind a long beach barrier that impounds the mouth of a _ca_. 75 km^2 wet tundra drainage. Both local vegetative growth and erosion may be seen in the marsh.

Moving downward, fewer species grow in the vegetative cover. The seaward limits of the principal higher plants of the marsh are apparently defined by periods of high soil water salinity (Mason, in prep.). The most halo-tolerant, _Puccinellia phryganodes_, fails to grow above about 35‰. (Soil solution salinities were determined by squeezing small plugs of soil with a culinary garlic press, and collecting the liquid on an A. O. Goldberg refractometer, especially calibrated for low temperature field use.) Across a soil salinity gradient from about 5 to 20‰ _Carex ramenskii_ grades into _C. subspathacea_. The lawn-like sward of these species along with _Pontentilla ogedii_ and _Stellaria humifusa_ is grazed occasionally by a passing reindeer herd and intensively by migrating geese, especially black brant. The boundaries of the pools which seen especially attractive to geese were composed mostly of these sedges and the grass, with especially luxuriant growth on the steep sides of the pools which are recessed 10-20 cm below the turf surface (Fig. 6.1). Nitrogen and phosphorus increase in soils towards the pools along with sodium and calcium (Table 6.1).

Figure 6.1. Surface profile and ice depths at PF Pond measured at several times during the summer season.

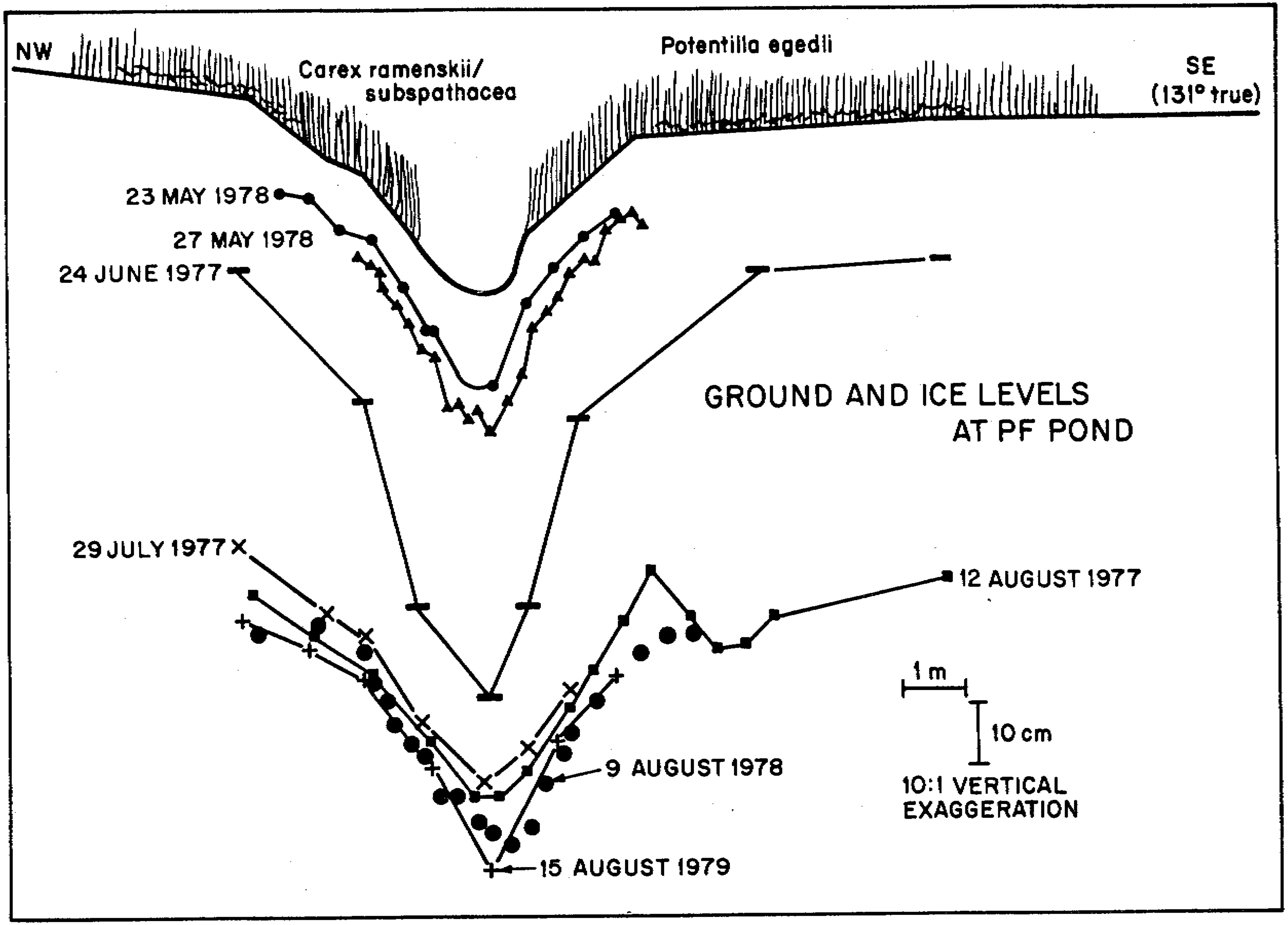

NW
Carex ramenskii/
subspathacea
Potentilla egedii
SE
(131° true)
23 MAY 1978
27 MAY 1978
24 JUNE 1977
GROUND AND ICE LEVELS
AT PF POND
29 JULY 1977
12 AUGUST 1977
1 m
10 cm
10:1 VERTICAL
EXAGGERATION
9 AUGUST 1978
15 AUGUST 1979

Table 6.1. Chemistry of Salt Marsh Surface Soils, Dried Weight Basis: Sampled 23 June 1977; Univ. of Alaska, Forest Soils Lab.

Transect Distance	0m High Marsh	18.8m Pond Mud	19.4m Wet Sedge Pond Margin	21.0m Meadow Near Pond	50 m Meadow	90 m Puccinellia
Na, mg/g	5.3	27.1	9.1	4.6	5.6	10.1
K "	1.4	2.2	2.4	2.6	2.9	4.0
Ca "	4.5	7.0	6.2	5.0	5.5	4.8
Mg "	4.5	5.5	6.5	7.5	7.8	8.5
P "	0.9	1.8	0.9	0.9	0.9	0.7
Kjeldahl-N (mg/g)	14	19	12	8.2	12	8.0
Fe "	4.8	5.5	1.5	2.4	2.2	2.2
Mn µg/g	95	95	120	155	207	225
Zn "	45	55	55	60	60	85

Meadow fertilization experiments over one growing season showed 40% greater growth of Carex ramenskii/subpathacea in response to 10 g added N (as nitrate) per square meter, as compared to adjacent unfertilized plants; and 30% greater growth in response to 10 g added P (as phosphate). A commercial mixed fertilizer (N-P-K levels of 32-9-13 gm^{-2}) produced 41% greater growth the first and 48% greater growth the second growing season after application. Underlying both the upland surface of relatively uniform 7 cm deep peaty soil (to 30 m 75% of dry weight is volatile at 500°C; then a linear decline occurs to 25% at 90 m) and the ponds as well is a layer of water-permeable fine silt-clay (only 10% of dry weight is volatile) that gradually tapers from 10 to 5 cm down the marsh. Beneath this are additional alternating bands of silt-clay and peat. The uppermost silt-clay layer dips with the surface terrain into the lake basins, becoming reduced as it drops below the groundwater level (Fig. 6.2). Rain and ground water move parallel to this silty layer towards the ponds and arrive with low redox potential at the pool margins just below the vegetation line. Groundwater may then ride out on wet sediments and the pond water surface where a layer of ferric oxides and presumably associated organic matter, phosphate, and metal ions forms (Stumm and Morgan 1970). Reduced soils (as evidenced by a transition to black iron sulfides) approach the surface at the margins of vegetation and salinity of both the surface and sub-surface peaty layers rises beneath the bonds (Fig. 6.2).

Soil salinity, in fact, rose at each lake intercepted by a transect of the marsh in 1978 (Fig. 6.3), a year when August showed a fifth of normal precipitation, and one that had followed a very dry summer which saw scores of tundra fires throughout the region. The summer of 1979 brought frequent rains to Kotzebue Sound (June had three times its normal rain.) and the salinity isopleths of the prior summers were pushed down the marsh some ten meters. (The sampling interval in 1979 did not reveal the fine structure of the pools.) In 1978 and again in 1979, core extracts and locally calibrated impedance-probe measures of salinity showed a linear increase (slopes averaged 0.04 o/oo cm^{-1}, the first year, and 0.56 the second; the difference significant at 93%) with depth, having a maximum salinity between 50 and 60 cm.

Along the same transect (Fig. 6.4) the ice surface underground deepened through season, especially below the ponds. (The albedo of the ponds, ca. 8%,

Figure 6.2. Profiles through a pond at 60 m on the salt marsh transect. The figure shows without vertical exaggeration the surface of the ground, the ice beneath, and a marker silt-clay layer. In addition the soil water salinity both above and below the silt-clay layer, as well as two vertical distributions of salinity, one in the pond and one characteristic of the meadow are indicated. The distribution of vegetation and the boundaries between oxidized and reduced (the orange to black color transition) are also shown.

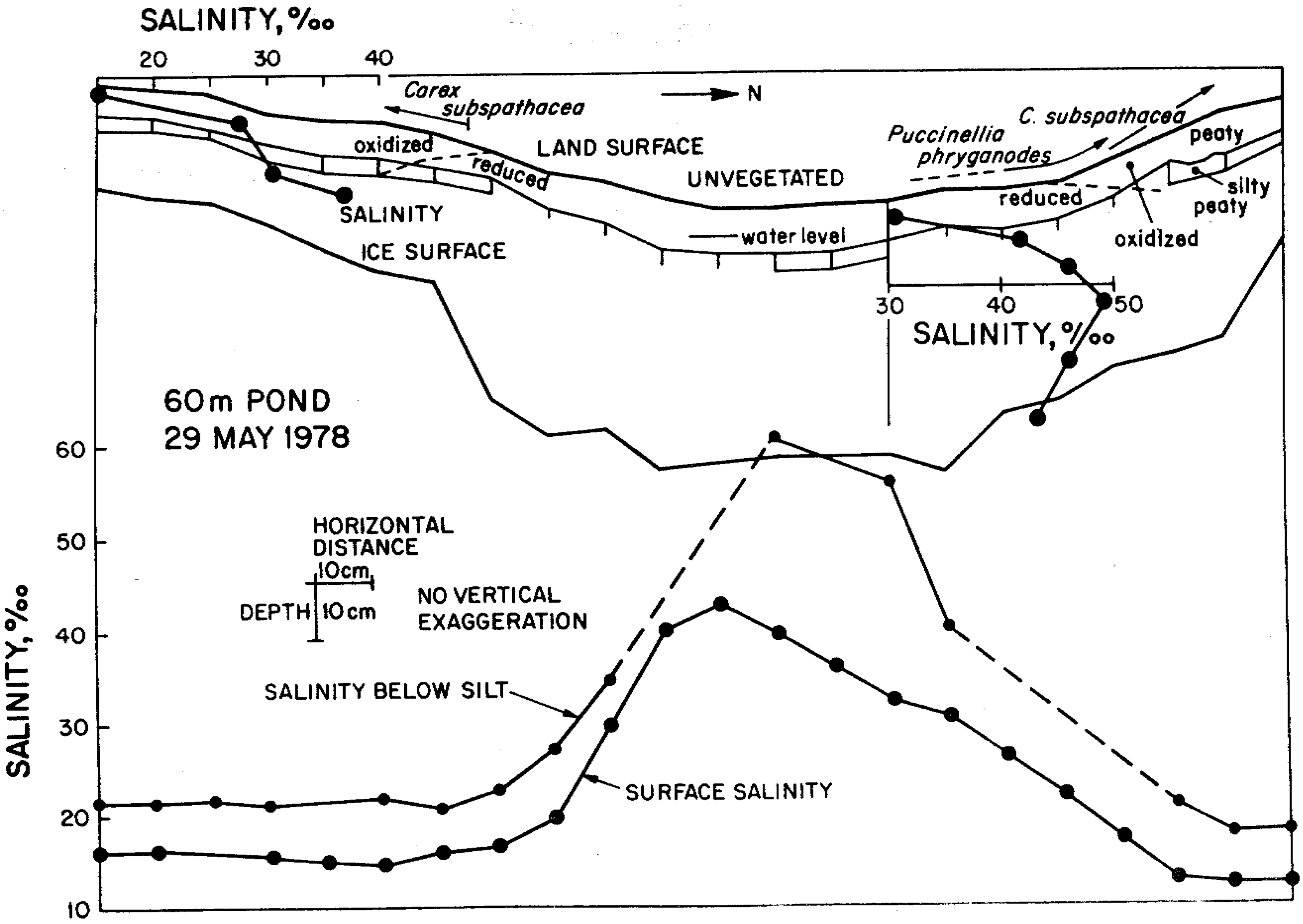
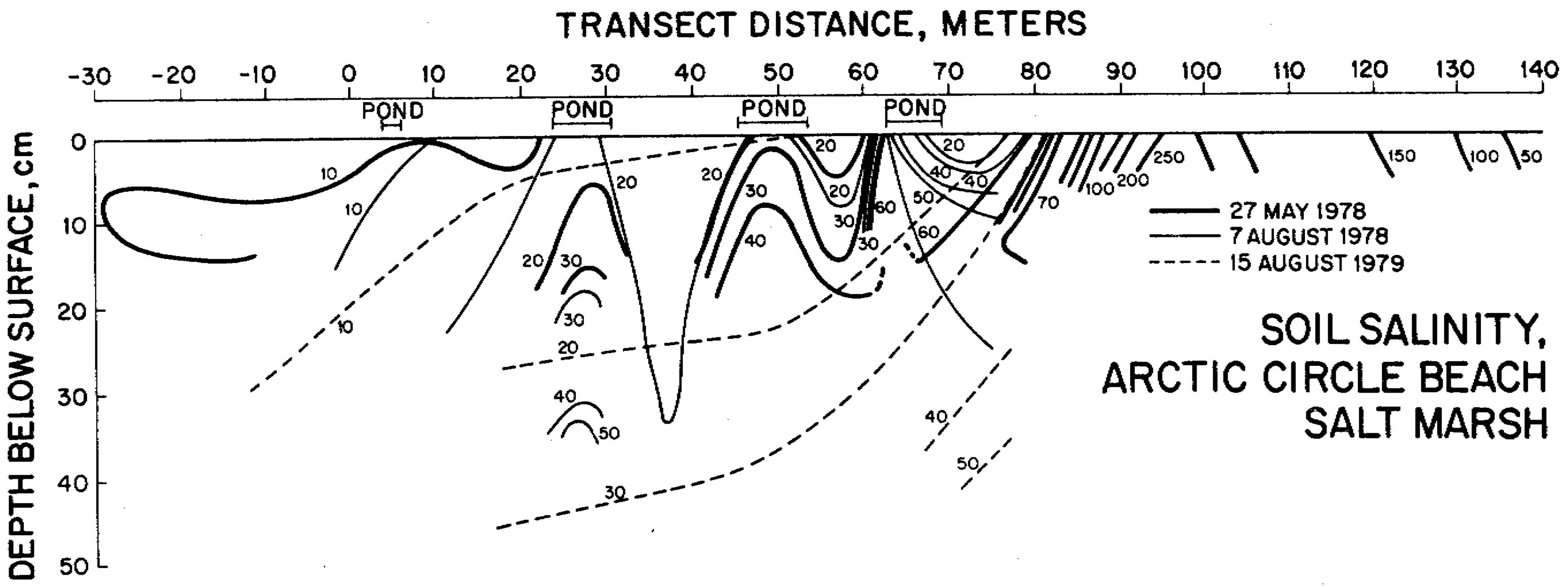
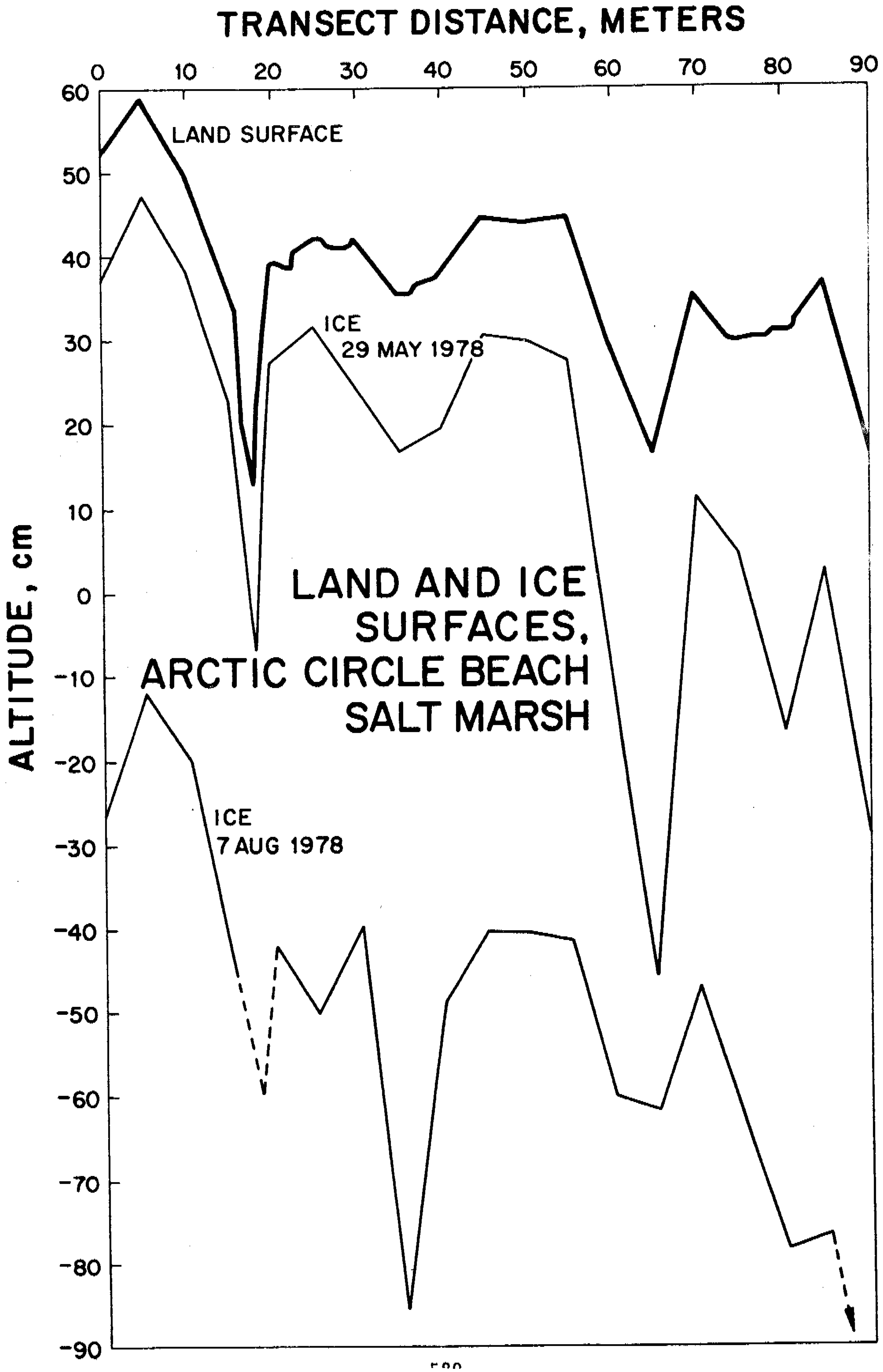

SALINITY, ‰
20
30
40
Carex subspathacea
N
C. subspathacea
Puccinellia phryganodes
peaty
oxidized
reduced
LAND SURFACE
UNVEGETATED
reduced
silty peaty
SALINITY
water level
oxidized
ICE SURFACE
30
40
50
SALINITY, ‰
60m POND
29 MAY 1978
60
50
40
30
20
10
HORIZONTAL DISTANCE
10cm
DEPTH
10cm
NO VERTICAL EXAGGERATION
SALINITY BELOW SILT
SURFACE SALINITY
SALINITY, ‰

Figure 6.3. Salinity isopleths along a transect of the salt marsh, normallized to a flat surface, at three different times. Between August 1978 and August 1979 considerable precipitation served to flush the salinity contours about 10 meters downward along the transect. Note that the 1978 measurements show clearly the concentrations of salts existing at the lake sites.



SOIL SALINITY,
ARCTIC CIRCLE BEACH
SALT MARSH

Figure 6.4. Ice depth profiles and the land surface of the salt marsh transect. Below the lakes the ice melts much deeper than it does beneath adjacent meadow. Altitude datum is "normal meterological high tide."


TRANSECT DISTANCE, METERS
0
10
20
30
40
50
60
70
80
90
ALTITUDE, cm
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
LAND SURFACE
ICE
29 MAY 1978
ICE
7 AUG 1978
LAND AND ICE
SURFACES,
ARCTIC CIRCLE BEACH
SALT MARSH

was one-third that of the adjacent meadow, 24%, as measured with a silicon photocell in August 1979 midday sun. Consequently more visible and near infra-red energy were absorbed by the pond than adjacent meadow. Thermal transmissibility is presumably less in the meadows because of the loose duff and aereated peat there.) At PF Pond the rate of ice melt was especially great through the zone 30-60 cm below the surface (Fig. 6.1). In August 1978 the groundwater sloped along the transect (0.0017 $m \cdot m^{-1}$) some 12 to 18 cm below the surface. Bailing of pit wells dug in 1978 (August) showed more rapid recharge in the higher marsh profiles reflecting the greater organic and water contents of the peats there. Four slugs of common salt placed 5-10 cm below the surface in May 1978 had dissolved and migrated into and beyond the two-meter-diameter grid used to detect them in August 1979. The marsh above the *Carex ram/sub* meadow appears to require an upland fresh-water source; shallow contemporary native wells (0.2 - 0.4 m deep) and hunting camp artifacts are associated with upper marsh communities rich in *Carex glareosa* and *Calamagrostis neglecta*. The water may arise from sources fed by snow and ice blown into the adjacent beach by the prevailing winter east winds.

OCHER COMMUNITY

The pond sediments are ocherous in color at the surface and derive in part from a precipitate that first forms as a film on the water surface, especially during times of receding pond levels. The oxidized iron produces a brittle, thin film that shows interference patterns making it seem "oily." It collapses under surface stress, sinking in loose strings to the bottom; there the deposits are flocculent and remain oxidized for several centimeters depth while covered with water. Once exposed to air, the ocher is dewatered and compacts to an oxidized layer only a few milimeters thick overlying black reduced material beneath.

A sample (15 Aug. 1979) of the oxidized ocher from PF Pond was composed of 35% (by volume) single-celled algae; two-thirds of this was a navicloid diatom, and one-third a palmelloid euglenid. Several other algae were present in small amounts along with occasional ciliates, bacteria, etc. (The plankton, preserved with acid Lugol's, and counted using Ütermohl phase-contrast techniques, contained only a few bacterial cells and naupliar crustaceans.) Occasional green blooms would occupy either small saline bottom seepages or, uncommonly, the whole pond; plankton samples of the latter (12 Aug. 1979) from a pond near the 50 m station contained 0.13 x 10^6 biflagellated euglenid cells ml^{-1}. Sulfur-precipitating bacteria were also occasionally abundant in the lower marsh in pycnoclinically isolated seepages, often in association with Vaucheria and Oscillatoria that form a coherent felt on the surface of more saline sediments. One such pocket contained 630 ppm (by volume) short rod-shaped bacteria with refractile sulfur inclusions.

A pair of similar ponds, 1.5 m in diameter near 10 m on the marsh transect was chosen for phosphate fertilization and control. Enough Na_2HPO_4 was added (11 Aug. 1977) to one to bring the concentration in the above-ground water of the pond to about 0.5 g $P \cdot l^{-1}$. A white precipitate formed immediately upon addition of the salt. Early (May) the next season the fertilized pond showed a developing bubbly mat of loating green filamentous algae and a plankton bloom; the mat was still present at the end of summer. In 1979 (12 August) the salinity of both ponds was 5 o/oo, the pH of both about 6.5, and both were 16°C at midday. There were no planktonic algae seen (Ütermohl), but comparable numbers of crustacean nauplii and bacteria were found in both ponds. Samples (14 August 1979) of the other, however, showed common ciliate protozoans and phytomonads but few euglenids or diatoms in the fertilized pond; in the ocher of the control pond ciliates were uncommon, phytomonads absent, and euglenids and diatoms common.

Dipteran larvae (chironomids, culicoids, and ephydrids) were abundant, feeding in the ocherous deposits of all ponds along the transect, and they were taken by predatory epineustic adult flies (family?) as well as common and actively feeding shorebirds. Once the sediments were exposed to the air, podurid collembolids may be locally abundant, feeding in great concentrations on the ocher. (Grey-black patches of collembolids feeding on ocher are a more common finding in higher arctic saltmarsh pools; only spiders have been observed preying on them.) Roaming the ocher surface were also common saldid hemipterans. These and the adult shore and predatory flies were also locally abundant on pond surfaces, especially on the partially decaying mats of floating green algae where the shore flies feed.

DISCUSSION

The data on ice surfaces and their melting, the salinity and plant nutrient patterns, and the responses of the vegetation to these, along with three summer's field observations, lead to the following hypothetical interpretation: Some initiating irregularity of surface retains occasionally flooding salty water; vegetation is inhibited by accumulating salt and the locale absorbs more solar energy, increasing summer temperatures and consequently evaporation and biotic decay. The water table dips toward the pond and lateral flows move anaerobic decay products of the peaty highlands lakeward.

The local ice surface below the developing pond recedes further than adjacent cooler regions: This a) increases the depth of the pond in summer through melt subsidence, and b) produces a high relief ice topography underground with ice-surface "pools" in the groundwater. The descending ice of autumn preferentially excludes salts downward towards an ice-surface sloping towards the thermal centers of the depressions.

Salts therefore accumulate at the pools: a) inhibiting but fertilizing the vegetation, thereby accentuating the vegetative margin; b) providing a warmer locus where oxygen solubility is decreased along with an increased demand for reducible electron sinks; c) lengthening the micro-biological season of the ponds because melting begins early while freezing is delayed by the thermodynamic competition the dissolved salts exert on the ice crystal for water molecules; d) selecting a euryhaline, eurythermal, tolerant biota which can escape some nutrient limitations of the marsh but must cope with high chemical competition for phosphate with the precipitated iron oxides.

Trophic interactions are focused onto the localized phosphorus on the actively sedimenting iron oxides. This favors small facultatively strongly motile primary producers with broad tolerances for oxygen content, electron pressure, salinity, temperature, and exposure to bright sun and frequent freezings. Dipteran larvae and collembolids exploit this concentration of organisms and probably re-work the volume of surface sediments several times a summer. Emergence and predation on larvae that feed breeding and migratory birds probably remove a relatively small part of the system's tightly held phosphorus.

The fluxes of fresh-water and salt seem to be primary mediators of the development of the marsh and its warm, concentrated lakes. I suspect that initiation and early development of a pond is self-perpetuating through the positive feedback interactions of the several controlling processes I have mentioned. Like the dust pits on permanent ice covers, these processes are probably naturally limited after some extension downward. Whether this limitation can be discovered in the noise of surface fluxes should challenge further studies.

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RECEPTORS-BENTHOS

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ANNUAL REPORT

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DISTRIBUTION, ABUNDANCE, COMMUNITY STRUCTURE, AND TROPHIC RELATIONSHIPS OF THE BENTHOS OF THE NORTHEASTERN GULF OF ALASKA FROM YAKUTAT BAY TO CROSS SOUND

AND

REPORT ON THE SUBMISSION OF BENTHIC INVERTEBRATE VOUCHER SPECIMENS

by

Dr. H. M. Feder, Principal Investigator
Assisted by S. C. Jewett
and S. G. McGee

March 1980

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DISTRIBUTION, ABUNDANCE, COMMUNITY STRUCTURE, AND TROPHIC RELATIONSHIPS OF THE BENTHOS OF THE NORTHEASTERN GULF OF ALASKA FROM YAKUTAT BAY TO CROSS SOUND

I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

The specific objectives of this investigation for the study area are: 1) a quantitative inventory census of dominant epifaunal invertebrates; 2) a description of spatial distribution patterns of selected epifaunal invertebrates; 3) where possible, assess spatial distribution and relative abundance of selected infaunal invertebrate species; and 4) observations of biological interrelationships, emphasizing trophic interactions, between selected segments of the benthic biota.

Trawls were made at 34 stations within the high priority area (area 1). Twenty-three additional stations were surveyed and considered to be untrawlable. Three stations at which the net was ripped were also considered untrawlable. Thus, all but two of the Priority 1 stations were at least surveyed. Van Veen grab samples were taken at 26 of the previously trawled stations in Priority area 1. In addition, five untrawlable stations in this area were similarly sampled. Pipe dredge samples were taken from 15 of the stations which were trawled and 11 of the untrawlable stations.

Trawls were taken from one station in Priority area 2 and three stations adjacent to this area, off Icy Bay; van Veen grab samples were taken at one of these and a pipe dredge sample was taken at another.

In Priority area 3, trawls were made at five stations. At one of these, van Veen grab samples and a pipe dredge were also taken.

Trawls were made at three stations in Yakutat Bay. Eleven additional stations were surveyed and considered to be untrawlable. Van Veen grab samples and a pipe dredge were taken from one of the stations which was trawled. Grab samples were also obtained at 11 other stations and pipe dredge samples were taken from an additional four.

Analysis of the trawl material from 45 stations resulted in a delineation of benthic invertebrates belonging to nine phyla, 20 classes, 73 families, 99 genera, and 133 species. It is probable that all species with numerical and biomass importance have been collected in the area of investigation and that only rare species will be added in future sampling.

Information on the feeding biology of 20 species on the NEGOA shelf, in addition to feeding data collected on other OCSEAP cruises, should enhance our overall understanding of benthic trophic relationships.

The impact of oil and gas development within the NEGOA region cannot be assessed or even implied at this time, but will be addressed in the Final Report.

II. INTRODUCTION

GENERAL NATURE AND SCOPE OF STUDY

The operations connected with oil exploration, production, and transportation in the northeast Gulf of Alaska (NEGOA) present a wide spectrum of potential dangers to the marine environment (see Olson and Burgess, 1967; Malins, 1977 for general discussion of marine pollution problems). Adverse effects on the marine environment of this area can neither be assessed nor predicted, unless background data are recorded prior to industrial development.

Insufficient long-term information about an environment, and the basic biology and recruitment of species in that environment, can lead to erroneous interpretations of changes in types and density of species that might occur if the area becomes altered (see Nelson-Smith, 1973; Pearson, 1971, 1972, 1975; Rosenberg, 1973 for general discussions on benthic biological investigations in industrialized marine areas). Populations of marine species fluctuate over a time span of from a few to 30 years, but such fluctuations are typically unexplainable because of the absence of long-term data (Lewis, 1970, and personal communication).

Benthic organisms (primarily the infauna but also sessile and slow-moving epifauna) are particularly useful as indicator species for a disturbed area because they tend to remain in place, typically react to long-range environmental changes, and by their presence, generally reflect the nature of the substratum. Consequently, the organisms of the infaunal benthos have frequently been chosen to monitor long-term pollution effects, and are believed to reflect the biological health of a marine area (see Pearson, 1971, 1972, 1975; Rosenberg, 1973 for discussion on long-term usage of benthic organisms for monitoring pollution; and Feder and Matheke, in press, for data and discussion on the infauna of NEGOA).

The presence of large numbers of epifaunal species of actual or potential commercial importance (crabs, shrimps, snails, finfishes) in NEGOA further dictates the necessity of understanding benthic communities since many commercial species feed on infaunal and small epifaunal residents of the benthos (see Zenkevitch, 1963 for a discussion of the interaction of commercial species and the benthos; also see appropriate discussion in Feder *et al.*, 1978a, b). Any drastic changes in density of the food benthos could affect the health and numbers of these commercially important species.

Experience in pollution-prone areas of England (Smith, 1968); Scotland (Pearson, 1972, 1975); and California (Straughan, 1971) suggests that at the completion of an initial study, selected stations should be examined regularly on a long-term basis to determine changes in species content, diversity, abundance and biomass. Such long-term data acquisition should make it possible to differentiate between normal ecosystem variation and pollutant-induced biological alteration. Intensive investigations of the benthos of the NEGOA are essential to understand the trophic interactions involved in this area and the changes that might take place once oil-related activities are initiated.

The benthic biological program in NEGOA (Feder, 1978) has emphasized development of an inventory of species as part of the examination by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of biological, physical and chemical components of shelf slated for oil exploration and drilling activity. In addition, a program designed to quantitatively assess assemblages (communities) of benthic species on the NEGOA shelf has expanded the understanding of distribution patterns of species there (Feder *et al.*, 1978a; Feder and Matheke, in press). Investigations connected with distribution, abundance, community structure, and trophic relationships of benthic species in Cook Inlet, two Kodiak Island bays, and the southeastern Bering Sea have recently been completed (Feder *et al.*, 1978a, b; Feder and Jewett, 1977). However, detailed information on the temporal and spatial variability of the benthic fauna is sparse.

The project considered in this Annual Report was designed to survey the benthic fauna, including feeding interactions, on the shelf of NEGOA in regions of potential oil and gas concentrations. Data were obtained on faunal composition and abundance to develop baselines to which future changes could be compared. Long-term studies on life histories and trophic interactions of important species should define aspects of communities and ecosystems potentially vulnerable to environmental damage, and should help to determine rates at which damaged environments can recover.

RELEVANCE TO PROBLEMS OF PETROLEUM DEVELOPMENT

Lack of an adequate data base elsewhere makes it difficult to predict the effects of oil-related activity on the subtidal benthos of the NEGOA. However, OCSEAP-sponsored research activities on the shelf should ultimately enable us to point to certain species or areas that might bear closer scrutiny once industrial activity is initiated. It must be emphasized that a considerable time frame is needed to comprehend long-term fluctuations in density of marine benthic species; thus, it cannot be expected that short-term research programs will result in predictive capabilities. Assessment of the environment must be conducted on a continuing basis.

As indicated previously, infaunal organisms tend to remain in place and, consequently, have been useful as indicator species for disturbed areas. Thus, close examination of stations with substantial complements of infaunal species is warranted (see Feder and Mueller, 1975; Feder and Matheke, in press; NODC data on file for examples of such stations). Changes in the environment at stations with relatively large numbers of species might be reflected by a decrease in diversity with increased dominance of a few species (see Nelson-Smith, 1973 for further discussion of oil-related changes in diversity). The potential effects of loss of species to the trophic structure on the NEGOA shelf cannot be assessed at this time, but the problem can be better addressed once benthic food studies resulting from recent projects are compared (Jewett and Feder, 1976; Feder *et al.*, 1978a; Feder and Jewett, 1977, 1978; Smith *et al.*, 1978; Feder and Jewett, 1980, in press).

Data indicating the effect of oil on subtidal benthic invertebrates are fragmentary (see Boesch *et al.*, 1974; Malins, 1977; Nelson-Smith, 1973 for reviews; Baker, 1976 for a general review of marine ecology and oil pollution), and virtually no data are available for the NEGOA shelf. Snow crabs (*Chionoecetes bairdi*) are conspicuous members of the shallow shelf of the Gulf of Alaska and this species supports a commercial fishery of considerable importance. Laboratory experiments with this species have shown that postmolt individuals lose most of their legs after exposure to Prudhoe Bay crude oil; obviously this aspect of the biology of the snow crab must be considered in the continuing assessment of this species (Karinen and Rice, 1974). Mecklenburg *et al.* (1976) examined the effects of Cook Inlet crude oil water soluble fractions on survival and molting of king crab (*Paralithodes camtschatica*) and coonstripe shrimp (*Pandalus hypsinotus*) larvae. Molting was permanently inhibited by exposing both larvae for 72 hours at a concentration of 0.8 to 0.9 ppm. Larvae that failed to molt died in seven days, although the contaminated water had been replaced with clean water. Although high concentrations of oil killed larvae in 96 hours; lower concentrations disrupted swimming and molting in the same period and also ultimately resulted in death. Little other direct data based on laboratory experiments are available for subtidal benthic species. Experimentation on toxic effects of oil on other common members of the subtidal benthos should be encouraged in future OCSEAP programs.

A direct relationship between trophic structure (feeding type) and bottom stability has been demonstrated by Rhoads (see Rhoads, 1974 for review). A diesel fuel spill resulted in oil becoming absorbed on sediment particles with resultant mortality of many deposit feeders on sublittoral muds. Bottom stability was altered with the death of these organisms, and a new complex of species became established in the altered substratum. The most common members of the infauna of the Gulf of Alaska and the Bering Sea are deposit feeders; thus, oil-related mortality of these species could result in a changed near-bottom sedimentary regime with subsequent alteration of species composition.

As suggested above, upon completion of initial baseline studies in pollution prone areas, selected stations should be examined regularly on a long-term basis. Also, intensive examination of the biology (e.g., age, growth, condition, reproduction, recruitment, and feeding habits) of selected species should afford obvious clues of environmental alteration.

III. CURRENT STATE OF KNOWLEDGE

Little was known about the biology of the invertebrate benthos of the Gulf of Alaska at the time OCS studies were initiated there. A compilation of some relevant data on the area was presented by Rosenberg (1972). Bakus and Chamberlain (1975) added some benthic biological data for a specific area south of the Bering Glacier; which were similar to those reported by Feder and Mueller (1975) in their OCS investigation. Some additional data based on trawl surveys conducted by the Bureau of Commercial Fisheries are available (Ronholt *et al.*, 1978); but much of the information on the invertebrate fauna is so general as to have little value. The International Pacific Halibut Commission (IPHC) conducts surveys in the Gulf of Alaska annually and records selected commercially important invertebrates but other, non-commercial species are ignored.

In late 1961 and early 1962 otter trawls were used by the Bureau of Commercial Fisheries in conjunction with the IPHC to survey the shellfishes and bottomfishes on the continental shelf and upper continental slope, in the Gulf of Alaska (Hitz and Rathjen, 1965). Invertebrates taken in these trawls were of secondary importance and only major groups and/or species were recorded, even though they comprised 27 percent of the total catch. These were grouped into the following categories: heart urchins (Echinoidea); snow crab (*Chionoecetes bairdi*); starfish (Asteroidea); dungeness crab (*Cancer magister*); scallop (*Pecten caurinus*); shrimps (*Pandalus borealis, P. platyceros, Pandalopsis dispar*); king crab (*Paralithodes camtschatica*); and miscellaneous invertebrates (shells, sponges, etc.). Heart urchins accounted for about 50 percent of the invertebrate catch and snow crab ranked second, representing about 22 percent. Approximately 20 percent of the total catch of invertebrates was composed of sea stars. Additional data on commercially important shellfish are available in Ronholt *et al.* (1976).

The benthic investigations of Feder and Mueller (1975), Jewett and Feder (1976), Feder *et al.* (1976) and Feder *et al.* (1977) were the first intensive quantitative and qualitative examinations of the benthic infauna and epifauna of the Gulf of Alaska. These also represented the initial examinations of trophic relationships involving some of the species in the area.

The present report represents an extension of the above investigations to an area in the northeastern Gulf of Alaska in which the invertebrate community has never been properly assessed. A determination of the distribution, relative abundance, and biomass of the benthic epifauna and infauna, as well as observations on food habits of selected species are being made.

IV. STUDY AREA

Sampling was conducted in the region of the northeastern Gulf of Alaska from Icy Bay to Cross Sound, extending outward to approximately the 300 m isobath. Stations were established on a grid (Fig. 1), which was an eastward extension of that used by Jewett and Feder (1976). The area surrounding each station, usually a rectangle 11 x 14 km, was designated as the station block. If bottom conditions prevented trawling at the predesignated station location, a trawl was attempted from any suitable location within the block. First priority was given to stations within the proposed sale No. 55 lease area (Priority area 1) (Fig. 2) and to a limited number of stations in Yakutat Bay. Second priority was given to those stations peripheral to and downstream from the lease area (Priority area 2) and the last priority was given to the remainder of the region upstream, toward Cross Sound (Priority area 3) (Fig. 2).

A second grid system was constructed for Yakutat Bay (Fig. 3). North-south lines at every five minutes of longitude were established. Stations were located along each of these lines at every 2.5 minutes of latitude. On alternate longitudinal lines, stations were shifted by 1.25 minutes of latitude from those of adjacent lines. For example, Station 1A was located at 59°41.0'N and 140°12.5'W. The surrounding station blocks were approximately 4.7 x 4.6 km.

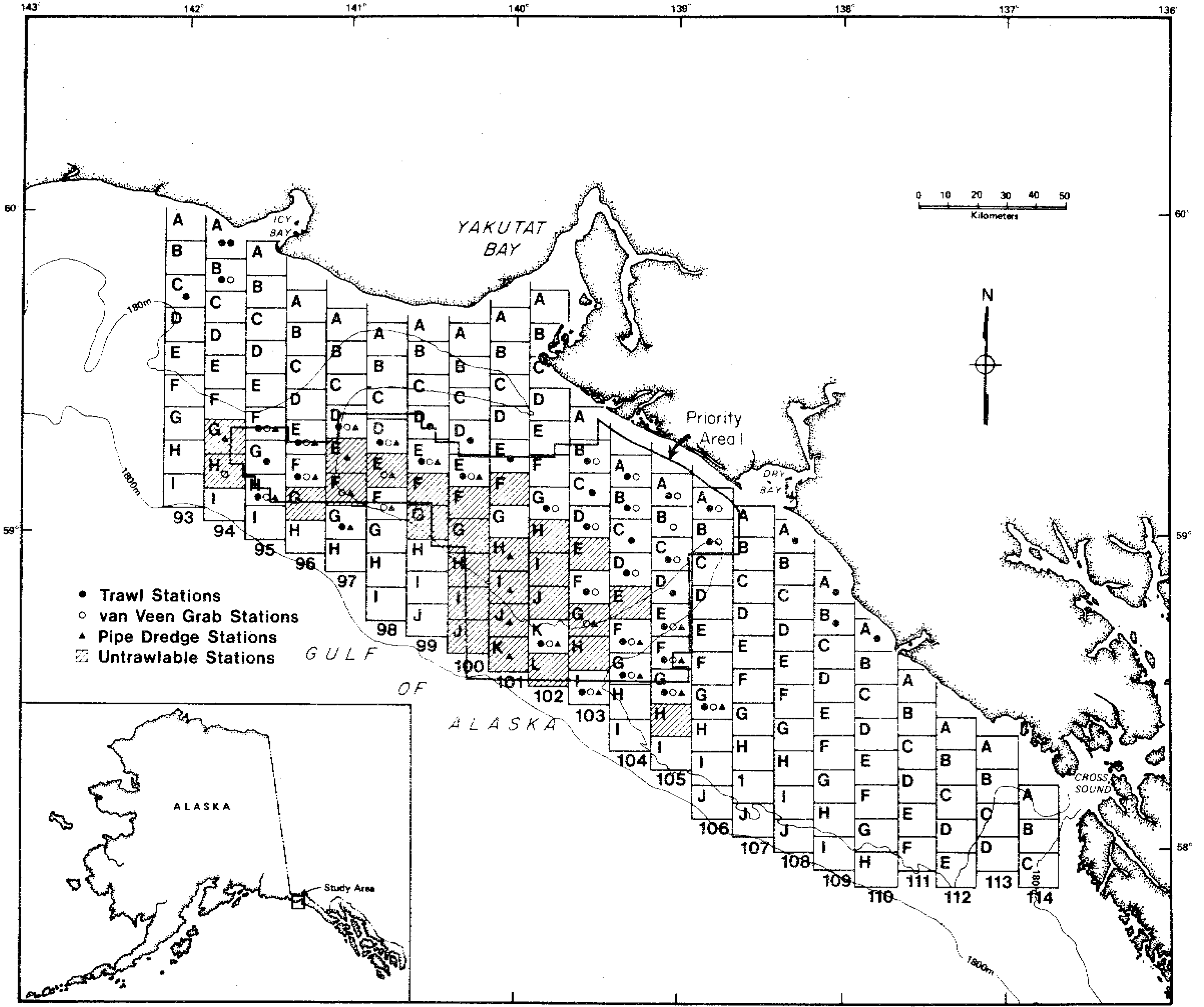

Figure 1. Northeastern Gulf of Alaska station grid occupied by the NOAA ship *Miller Freeman*, November 1979.

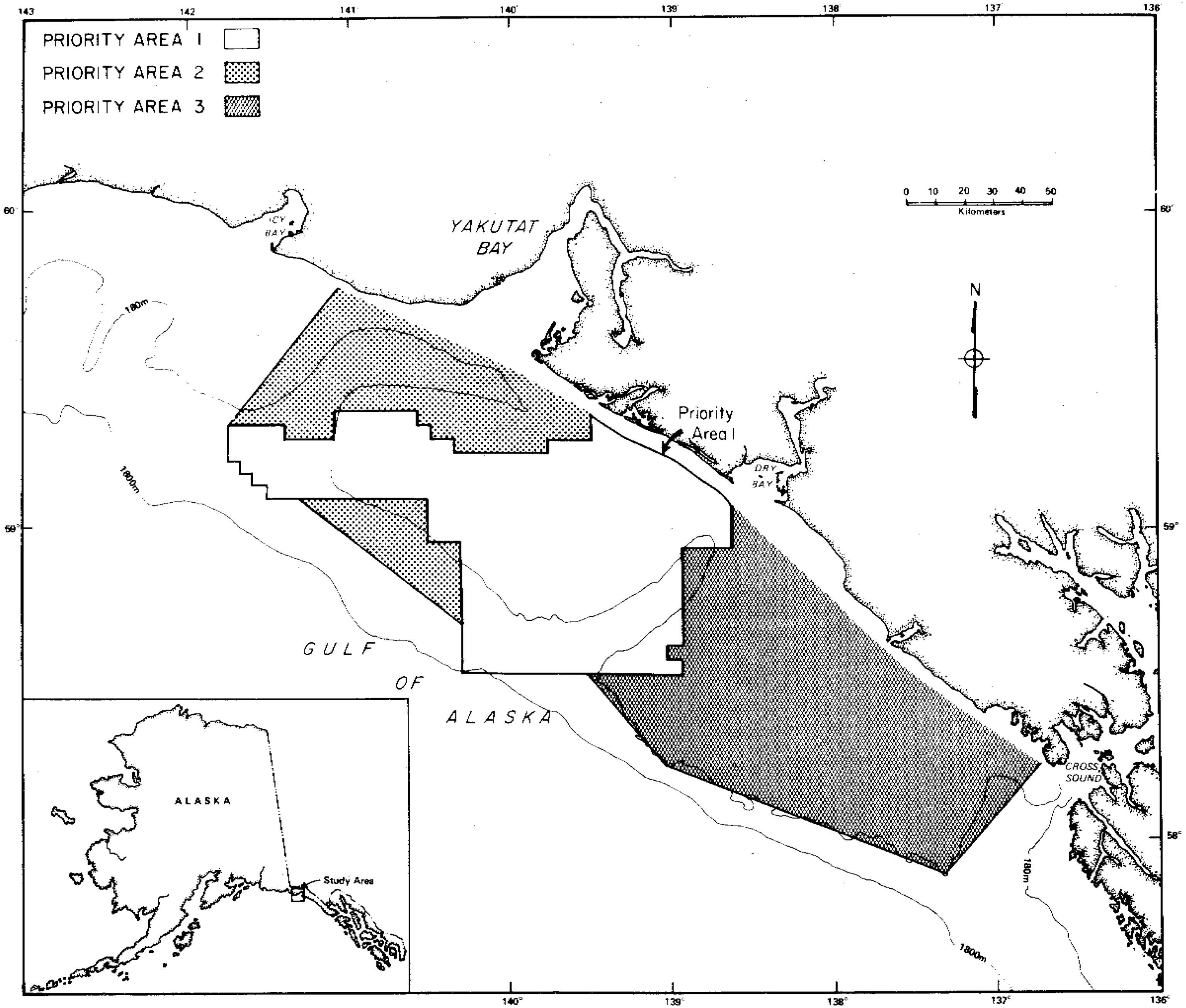

Figure 2. Priority sampling areas established in the northeastern Gulf of Alaska.

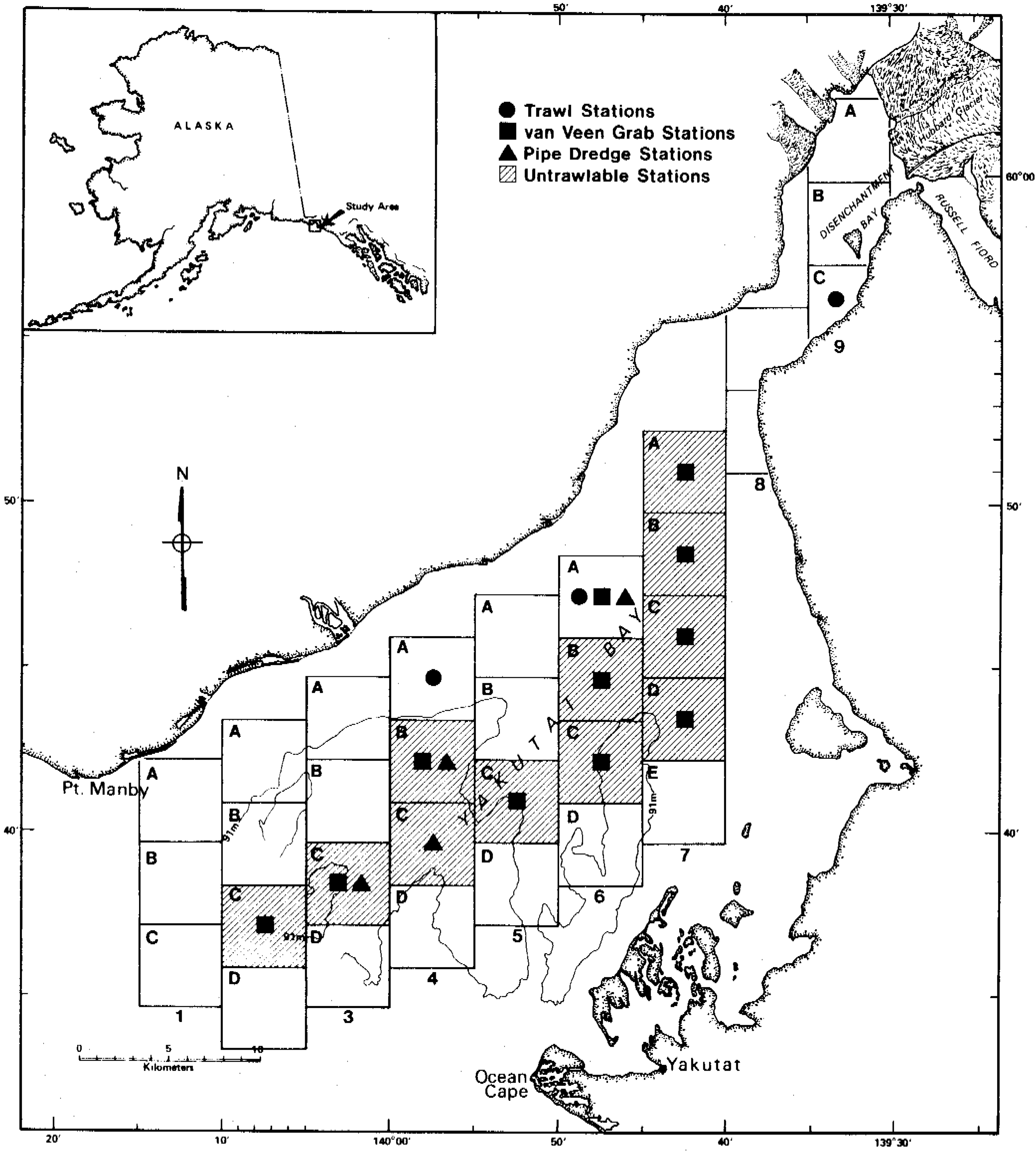

Figure 3. Yakutat Bay station grid occupied by the NOAA Ship *Miller Freeman*, November 1979.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Specimens were collected onboard the NOAA Ship *Miller Freeman*. Usually, one-half-hour tows were made at predetermined stations using a commercial size 400-mesh Eastern otter trawl with a 12.2 m horizontal opening. The lengths of some tows were shortened due to marginal bottom conditions, but never to less than 15 minutes.

All catches were sorted, weighed, counted, and given tentative identifications onboard ship, according to methodology developed in previous OCS investigations (Feder *et al.*, 1977). Aliquote samples of species of invertebrates were preserved in 10 percent neutral buffered formalin and labeled for verification at the Institute of Marine Science, University of Alaska. Tabulations of stomach contents from selected species of fishes and invertebrates were also carried out onboard. Analysis of this data was accomplished using the frequency of occurrence method. Contents of stomachs, or entire stomachs from some species, were preserved in 10 percent neutral buffered formalin and returned to the University of Alaska for more detailed analysis.

Samples of benthic invertebrates were also taken from selected stations by van Veen grab and pipe dredge according to methodology developed by Feder *et al.* (1977). These samples were usually from successfully trawled stations in order to aid in the stomach analysis of various species and provide additional information on small epifaunal and infaunal species not obtained in otter trawls. Pipe dredge and van Veen samples were also taken from some stations in Priority area 1, which were considered to be untrawlable. Five replicates from each van Veen station were usually taken. Pipe dredge and van Veen samples were routinely washed over a 1.0 mm mesh screen to remove fine sediment, and preserved in 10 percent neutral buffered formalin for later examination.

VI. RESULTS

The locations and depths of all successful tows are listed in Table I. Trawls were made at 34 stations in Priority area 1 (Fig. 1). Twenty-three additional stations were surveyed and considered to be untrawlable. Three stations at which the net was ripped were also considered untrawlable. Thus,

TABLE I

TRAWL STATIONS OCCUPIED IN THE NORTHEASTERN GULF OF ALASKA BY THE NOAA SHIP *MILLER FREEMAN*, NOVEMBER 1979

Station	Tow No.	Coordinates		Depth (m)
		Start	Finish	
Gulf Stations				
106G	1	58°29.6'N 138°56.3'W	58°30.1'N 138°53.3'W	86- 91
105G	2	58°33.1'N 139°00.3'W	58°32.2'N 139°02.4'W	111-113
105F	3	58°38.5'N 139°02.2'W	58°37.0'N 139°03.3'W	113-128
105E	4	58°46.5'N 139°04.4'W	58°45.0'N 139°03.9'W	223-242
104G	5	58°34.1'N 139°21.4'W	58°34.0'N 139°18.9'W	165-167
104F	6	58°42.3'N 139°17.1'W	58°41.6'N 139°19.6'W	247
103I	8	58°31.6'N 139°33.1'W	58°32.5'N 139°31.9'W	262-264
96F	12	59°12.8'N 141°20.0'W	59°13.8'N 141°17.4'W	351
97G	13	59°0.20'N 141°03.6'W	59°01.7'N 141°02.5'W	348
95H	14	59°08.6'N 141°33.2'W	59°10.0'N 141°33.8'W	326
95G	15	59°15.8'N 141°30.8'W	59°17.1'N 141°30.1'W	335-339
95F	16	59°21.8'N 141°30.8'W	59°21.4'N 141°33.3'W	185-187
96E	17	59°20.0'N 151°13.8'W	59°21.6'N 141°14.1'W	311-318
97D	18	59°23.9'N 141°06.0'W	59°22.9'N 141°06.9'W	284
98D	19	59°18.5'N 140°45.7'W	59°17.8'N 140°43.7'W	145-146
99D	21	54°24.9'N 140°34.1'W	59°24.9'N 140°37.0'W	139-143
99E	22	59°18.3'N 140°34.1'W	59°19.8'N 140°34.5'W	134-137
100E	23	59°11.6'N 140°14.7'W	59°10.7'N 140°17.3'W	123-126
100D	24	59°21.9'N 140°17.9'W	59°20.4'N 140°17.9'W	135-150
101E	25	59°16.1'N 140°00.7'W	59°17.7'N 140°01.5'W	139-146
103B	27	59°16.6'N 139°23.6'W	59°18.0'N 139°33.3'W	150-161
103C	28	59°05.3'N 139°30.6'W	59°06.3'N 139°28.3'W	115-117
104A	29	59°12.1'N 139°15.0'W	59°13.7'N 139°16.0'W	64- 68
104B	30	59°04.5'N 139°12.8'W	59°05.7'N 139°14.2'W	90- 92
106B	31	58°58.5'N 138°41.5'W	58°59.8'N 138°43.7'W	152
106A	32	59°06.2'N 138°49.3'W	59°06.7'N 138°52.6'W	55- 57
105A	33	59°08.0'N 139°05.7'W	59°08.9'N 139°08.7'W	70- 71
105B	34	59°03.8'N 138°59.6'W	59°03.9'N 139°02.7'W	84
105C	35	58°53.3'N 139°02.4'W	58°54.5'N 139°01.3'W	148-152
105D	36	58°50.1'N 138°59.2'W	58°49.5'N 138°57.3'W	209
94A	38	59°52.9'N 141°51.3'W	59°52.3'N 141°48.8'W	27- 29
94B	39	59°49.9'N 141°52.4'W	59°49.4'N 141°50.2'W	59
93C	40	59°50.3'N 142°00.9'W	59°40.1'N 141°58.1'W	66
102G	42	59°05.2'N 139°48.5'W	59°05.9'N 139°49.4'W	115
103D	43	59°02.4'N 139°30.1'W	59°01.4'N 139°27.6'W	113-115
103F	44	58°51.7'N 139°36.0'W	58°50.8'N 139°33.6'W	143-146
104D	45	58°53.2'N 139°15.9'W	58°54.1'N 139°18.7'W	119
104C	46	58°59.6'N 139°19.5'W	58°58.1'N 139°18.4'W	108-112
108A	47	58°59.5'N 138°23.3'W	58°58.2'N 138°21.3'W	62- 66
109A	48	58°49.2'N 138°06.2'W	58°50.5'N 138°07.9'W	110-117
109B	49	58°43.9'N 138°01.4'W	58°44.9'N 138°03.5'W	84
110A	50	58°40.2'N 137°51.9'W	58°41.4'N 137°53.4'W	59- 60

TABLE I

CONTINUED

Station	Tow No.	Coordinates		Depth (m)
		Start	Finish	
Yakutat Bay Stations				
6A	20	59°46.2'N 139°49.0'W	59°47.7'N 139°49.3'W	44- 57
9C	26	59°57.5'N 139°34.8'W	59°56.2'N 139°35.7'W	240-243
4A	37	59°42.8'N 139°57.4'W	59°44.2'N 139°54.8'W	88-104

all but two of the Priority area 1 stations were at least surveyed. Van Veen grab samples were taken at 26 of the previously trawled stations in Priority area 1. In addition, five untrawlable stations in this area were similarly sampled. Pipe dredge samples were taken from 15 of the stations which were trawled and 11 of the untrawlable stations.

Trawls were taken from one station in Priority area 2 and three stations adjacent to this area, off Icy Bay; van Veen grab samples were taken at one of these and a pipe dredge sample was taken at another.

In Priority area 3, trawls were made at five stations. At one of these, van Veen grab samples and a pipe dredge were also taken.

Trawls were made at three stations in Yakutat Bay. Eleven additional stations were surveyed and considered to be untrawlable. Van Veen grab samples and a pipe dredge were taken from one of the stations which was trawled. Grab samples were also obtained at 11 other stations and pipe dredge samples were taken from an additional four.

Trawl Program

All trawl samples have been processed, species identification and verification completed, and all data tabulated. A preliminary taxonomic analysis has delineated 9 phyla, 20 classes, 73 families, 99 genera, and 133 species of invertebrates from 45 stations.

The phyla Cnidaria, Mollusca, Arthropoda, and Echinodermata made up 88.7 percent, by weight, of all invertebrates recovered. The numbers, weights, and biomasses of the major epifaunal species in these groups are presented in Table II. These species alone accounted for over 80 percent of a total invertebrate biomass of 1.7 g/m^2.

Echinodermata, Arthropoda, and Mollusca were the dominant phyla represented in trawls from the northeast Gulf of Alaska; with 44, 38 and 24 species collected, respectively. These same groups made up 75.5 percent of the total invertebrate biomass in the following order: Arthropoda (27.5%), Echinodermata (27.0%), and Mollusca (21.0%). In terms of numbers of individuals, echinoderms were by far the most abundant group with 67.8 percent of the total count. Crustaceans were second with 16.1 percent, and molluscs were

TABLE II

NUMBERS, WEIGHT AND BIOMASS (g/m^2) OF THE MAJOR EPIFAUNAL SPECIES OF CNIDARIA, MOLLUSCA ARTHROPODA, AND ECHINODERMATA FROM THE NORTHEASTERN GULF OF ALASKA, NOVEMBER 1979

Phylum	Species[1]	Number of organisms	Wet weight (g)	Percent of total weight	Percent of phylum weight	Mean biomass per square meter ($\bar{x}$ g/m^2)
Cnidaria	Anthozoa	88	38041.0	1.50	11.37	0.02
	Actiniidae	92	26006.0	1.03	7.77	0.01
	Metridium senile	790	268800.0	10.60	80.36	0.17
	Total	960	332847.0	13.13	99.50	0.20
Mollusca	*Pecten caurinus*	2090	463360.0	18.28	86.96	0.30
	Fusitriton oregonensis	513	39522.7	1.52	7.42	0.02
	Rossia pacifica	119	11056.2	0.44	2.08	<0.01
	Total	2682	513938.9	20.24	96.46	0.33
Arthropoda (Crustacea)	*Pandalus jordani*	1533	13759.0	0.54	1.97	<0.01
	Lopholithodes foraminatus	97	59517.0	2.35	8.53	0.03
	Chionoecetes bairdi	1107	168022.4	6.63	24.08	0.11
	Cancer magister	993	422537.0	16.67	60.56	0.27
	Total	3730	663835.4	26.19	95.14	0.43
Echinodermata	*Solaster dawsoni*	99	116155.0	4.58	16.98	0.07
	Allocentrotus fragilis	1522	75752.0	2.99	11.07	0.04
	Strongylocentrotus sp.	5019	214230.0	8.45	31.32	0.14
	Strongylocentrotus droebachiensis	2393	164916.0	6.51	24.11	0.10
	Total	9033	571053.0	22.53	83.48	0.37

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[1] Species or lowest level of identification.

third with 11.1 percent of the total. Thus, the biomass was dominated by smaller numbers of relatively larger individuals.

The biomasses of the major phyla were usually dominated by a few species. For example, the genera *Allocentrotus* and *Strongylocentrotus* made up 66.5 percent of the biomass from echinoderms. The crabs, *Cancer magister*, *Chionoecetes bairdi*, and *Lopholithodes foraminatus* made up 93.2 percent of the biomass of arthropods. The biomass from *Pecten caurinus* was responsible for 87.0 percent of the total for molluscs.

The epifauna was generally diverse at most stations, but typically only a few individuals of each species were present per station. The average number of species per station was 14. Only 10 percent of the total number of species were present at more than 25 percent of all stations. Of these, only *C. bairdi*, *Fusitriton oregonensis*, *Solaster dawsoni*, *Allocentrotus fragilis*, and *L. foraminatus* were found in 40 percent or more of all trawls. The greatest biomass came from species which occurred at fewer than 25 percent of the stations.

Some species were distributed over the entire area while others were relatively localized or were prevalent only at near-shore stations. Large numbers of ophiuroids, particularly, *Ophiura sarsi* and *Ophiopholis* sp. occurred throughout the area, except in Yakutat Bay. For example, over 11,000 *O. sarsi* were found at Station 104A and over 500 *Ophiopholis* occurred at Station 95F. The weathervane scallop (*Pecten caurinus*) occurred only at near-shore stations in the vicinities of Icy Bay, Dry Bay, and Yakutat Bay. Representative stations were 93C, with 1093 individuals; 108A, with 736; and 4A with 90. Shrimps, particularly *Pandalus* spp. and *Pandalopsis dispar*, were more abundant in near-shore areas. The urchins, *Allocentrotus* sp. and *Strongylocentrotus* spp. were abundant only at offshore stations. For example, 600 and 900, respectively, of these two genera were present at Station 98D. At station 100E, 2200 *Strongylocentrotus* sp. were found. Dungeness crab (*Cancer magister*) was abundant only at Station 94A, where 833 individuals were found.

Feeding Studies

The analysis of stomach contents from two species of invertebrates and 18 species of fishes are presented in Tables III and IV. Ten of the species of fishes were members of the family Pleuronectidae. The percent frequency of occurrence for both the total number of stomachs and for only those which contained food were calculated. Major groups of contents are listed in Table III while Table IV contains all prey items, identified to the lowest taxon possible.

Five of the 18 species of fishes examined were mainly piscivorous; five preyed mainly on crustaceans; four consumed primarily brittle stars; and two consumed mainly polychaetes.

The arrowtooth flounder (*Atheresthes stomias*) primarily consumed small fishes such as walleye pollock (*Theragra chalcogramma*) and eulachon (*Thaleichthys pacificus*). Shrimps, including *Pandalus* spp., were second in frequency of occurrence. Pacific halibut (*Hippoglossus stenolepis*) preyed mainly on small fishes, including other pleuronectids, sculpins (Cottidae), and the Pacific sand lance (*Ammodytes hexapterus*). Second in frequency of occurrence among Pacific halibut were snow crabs (*C. bairdi*). The sablefish (*Anoplopoma fimbria*) also preyed primarily on other fishes, including pleuronectids, herring (*Clupea harengus*) and walleye pollock, and on jellyfish (Scyphozoa). Amphipods and other crustaceans were second in occurrence in sablefish. Spiny dogfish (*Squalus acanthias*) also preyed mainly on fishes, including pleuronectids, eulachon, and pricklebacks (Stichaeidae). Pandalidae and other shrimp were second in frequency of occurrence in this species.

Walleye pollock consumed mainly unidentified shrimp with amphipods and other small crustaceans occurring secondarily. The shortspine thornyhead (*Sebastolobus alascanus*) preyed almost entirely on shrimp, including Pandalidae and Hippolytidae. Rock sole (*Lepidopsetta bilineata*) preyed primarily on crustaceans, including snow crabs and gammarid amphipods. Brittle stars and polychaetes were second and third in frequency of occurrence, respectively. Pacific cod (*Gadus macrocephalus*) consumed mainly unidentified shrimp, with snow crab and cephalopods occurring slightly less frequently. Rougheye rockfish (*Sebastes aleutianus*) also preyed primarily on unidentified shrimp.

TABLE III

MAJOR GROUPS OF STOMACH CONTENTS FROM SELECTED FISHES AND INVERTEBRATES FROM THE NORTHEASTERN GULF OF ALASKA AND YAKUTAT BAY, NOVEMBER 1979

	Percent frequency of occurrence based on	
Stomach contents	Stomachs with food	Total stomachs
Fishes		
Atheresthes stomias	N = 120	N = 250
Empty (130)	-	52.0
Pisces (76)	63.3	30.4
Shrimp (35)	29.2	14.0
Other crustaceans (12)	10.0	4.8
Glyptocephalus zachirus	N = 195	N = 218
Polychaeta (142)	72.8	65.1
Amphipoda (66)	33.8	30.3
Shrimp (40)	20.5	18.4
Other crustaceans (25)	12.8	11.5
Empty (23)	-	10.5
Bivalves (16)	8.2	7.3
Hippoglossoides elassodon	N = 67	N = 92
Empty (78)	-	43.8
Ophiuroidea (62)	62.0	34.8
Shrimp (32)	32.0	18.0
Other crustacea (15)	15.0	8.2
Pisces (8)	8.0	4.5
Isopsetta isolepis	N = 54	N = 117
Empty (63)	-	53.8
Ophiuroidea (31)	57.4	26.5
Polychaeta (14)	25.9	12.0
Crustacea (11)	20.4	9.4
Parophrys vetulus	N = 67	N = 92
Polychaeta (50)	74.6	54.4
Empty (25)	-	27.2
Ophiuroidea (19)	28.4	20.7
Crustacea (12)	17.9	13.0
Bivalves (7)	10.4	7.6

TABLE III

CONTINUED

Stomach contents	Percent frequency of occurrence based on Stomachs with food	Percent frequency of occurrence based on Total stomachs
Microstomus pacificus	N = 74	N = 89
Ophiuroidea (66)	89.2	74.2
Mollusca (34)	46.0	38.2
Polychaeta (33)	44.6	37.1
Empty (14)	-	15.7
Crustacea (13)	17.6	14.6
Hippoglossus stenolepis	N = 49	N = 74
Pisces (29)	49.2	39.2
Empty (25)	-	33.8
Chionoecetes bairdi (18)	36.7	24.3
Other crustacea (11)	22.5	14.9
Ophiuroidea (5)	10.2	6.8
Cephalopoda (5)	10.2	6.8
Platichthys stellatus	N = 23	N = 37
Ophiuroidea (20)	87.0	54.1
Empty (14)	60.9	37.8
Mollusca (2)	8.7	5.4
Unid. remains (2)	8.7	5.4
Lepidopsetta bilineata	N = 26	N = 32
Crustacea (10)	38.5	31.3
Ophiuroidea (9)	34.6	28.1
Polychaeta (6)	23.1	18.8
Empty (6)	23.1	18.8
Pisces (4)	15.4	12.5
Psettichthys melanostictus	N = 4	N = 10
Empty	-	60.0
Pisces	100.0	40.0

TABLE III

CONTINUED

Stomach contents	Percent frequency of occurrence based on	
	Stomachs with food	Total stomachs
Anoplopoma fimbria	N = 57	N = 90
Empty (33)	-	36.7
Pisces (20)	35.1	22.2
Scyphozoa (15)	26.3	16.7
Amphipoda (14)	24.6	15.6
Other crustacea (9)	15.8	10.0
Cephalopoda (6)	10.5	6.7
Theragra chalcogramma	N = 39	N = 70
Empty (31)	-	44.3
Shrimp (22)	56.4	31.4
Amphipoda (13)	33.3	18.6
Other crustacea (8)	20.5	11.4
Pisces (5)	12.8	7.1
Gadus macrocephalus	N = 15	N = 15
Shrimp (12)	80.0	
Chionoecetes bairdi (9)	60.0	
Cephalopoda (9)	60.0	
Other crustacea (8)	53.3	
Pisces (3)	20.0	
Sebastolobus alascanus	N = 41	N = 50
Shrimp (37)	90.2	74.0
Empty (9)	-	18.0
Polychaeta (6)	14.6	12.0
Pisces (6)	14.6	12.0
Other crustaceans (5)	12.2	10.0
Squalus acanthias	N = 25	N = 43
Pisces (19)	76.0	44.2
Empty (18)	-	41.9
Shrimp (13)	52.0	30.2
Other (7)	28.0	16.3

TABLE III

CONTINUED

Stomach contents	Percent frequency of occurrence based on: Stomachs with food	Total stomachs
Invertebrates		
Pycnopodia helianthoides	N = 42	N = 70
Empty (28)	-	40.0
Gastropoda (19)	45.2	27.1
Ophiuroidea (19)	45.2	27.1
Bivalves (16)	38.1	22.9
Unid. remains (7)	16.7	10.0
Crustacea (6)	14.3	8.6
Cancer magister	N = 69	N = 77
Bivalves (68)	98.6	88.3
Diatoms (40)	58.0	52.0
Unid. material (31)	44.9	40.3
Crustacea (30)	43.5	39.0
Polychaeta (28)	40.6	36.4
Hydrozoa (10)	14.5	13.0
Ophiuroids (9)	13.0	11.7
Empty (8)	-	10.4

TABLE IV

STOMACH CONTENTS OF SELECTED FISHES AND INVERTEBRATES FROM THE NORTHEASTERN GULF OF ALASKA AND YAKUTAT BAY, NOVEMBER 1979

Stomach contents	Percent frequency of occurrence based on	
	Stomachs with food	Total stomachs
Fishes		
Atheresthes stomias	N = 120	N = 250
Empty (130)	-	52.0
Pisces (55)	45.8	22.0
Shrimp (21)	17.5	8.4
Theragra chalcogramma (walleye pollock) (19)	15.8	7.6
Euphausiacea (krill) (9)	7.5	3.6
Pandalidae (shrimps) (6)	5.0	2.4
Polychaeta (segmented worms) (3)	2.5	1.2
Chionoecetes bairdi (snow crab) (2)	1.7	0.8
Pandalus goniurus (humpy shrimp) (2)	1.7	0.8
Thaleichthys pacificus (eulachon) (2)	1.7	0.8
Pandalus jordani (ocean pink shrimp) (2)	1.7	0.8
Unid. remains (2)	1.7	0.8
Pandalus borealis (pink shrimp) (1)	0.8	0.4
Pandalopsis dispar (side-stripe shrimp) (1)	0.8	0.4
Eualus macrophthalma (shrimp) (1)	0.8	0.4
Crustacea (1)	0.8	0.4
Octopus sp. (1)	0.8	0.4
Rocks (1)	0.8	0.4
Glyptocephalus zachirus	N = 195	N = 218
Polychaeta (130)	66.7	59.6
Amphipoda (61)	31.3	28.0
Empty (23)	11.8	10.5
Shrimp (22)	11.3	10.1
Pandalidae (14)	7.2	6.4
Chionoecetes bairdi (12)	6.1	5.5
Unid. remains (9)	4.6	4.1
Bivalves (8)	4.1	3.7
Nucula tenuis (bivalve) (6)	3.1	2.8
Crangonidae (6)	3.1	2.8
Ophiuroidae (brittle stars) (4)	2.1	1.8
Aphrodita sp. (polychaete) (4)	2.1	1.8
Mysidae (4)	2.1	1.8

TABLE IV

CONTINUED

Stomach contents	Percent frequency of occurrence based on Stomachs with food	Percent frequency of occurrence based on Total stomachs
Sipuncula (peanut worms) (3)	1.5	1.4
Golfingia sp. (Sipuncula) (3)	1.5	1.4
Ampeliscidae (Amphipoda) (3)	1.5	1.4
Crustacea (3)	1.5	1.4
Cumacea (3)	1.5	1.4
Sternaspis scutata (polychaete) (2)	1.0	0.9
Terebellides stroemi (polychaete) (1)	0.5	0.5
Goniada annulata (polychaete) (1)	0.5	0.5
Travesia sp. (polychaete) (1)	0.5	0.5
Neohella sp. (amphipod) (1)	0.5	0.5
Anonyx sp. (amphipod) (1)	0.5	0.5
Isopoda (1)	0.5	0.5
Crangon septemspinosa (1)	0.5	0.5
Pinnixa sp. (pea crab) (1)	0.5	0.5
Pagurus ochotensis (hermit crab) (1)	0.5	0.5
Delolepis gigantea (giant wry mouth) (1)	0.5	0.5
Psephidia lordi (bivalve) (1)	0.5	0.5
Yoldia sp. (bivalve) (1)	0.5	0.5
Ophiura sarsi (1)	0.5	0.5
Hippoglossoides elassodon	N = 100	N = 178
Empty (78)	-	43.8
Ophiura sarsi (52)	52.0	29.2
Pandalidae (17)	17.0	9.5
Shrimp (13)	13.0	7.3
Ophiuroidea (12)	12.0	6.7
Chionoecetes bairdi (8)	8.0	4.5
Euphausiacea (6)	6.0	3.4
Stichaeidae (pricklebacks) (5)	5.0	2.8
Pisces (2)	2.0	1.1
Pandalopsis dispar (2)	2.0	1.1
Hippolytidae (2)	2.0	1.1
Lumpenus maculatus (daubed shanny) (1)	1.0	0.6
Caprellidae (amphipod) (1)	1.0	0.6
Gastropoda (1)	1.0	0.6
Yoldia sp. (1)	1.0	0.6
Amphipoda (1)	1.0	0.6

TABLE IV

CONTINUED

Stomach contents	Percent frequency of occurrence based on Stomachs with food	Percent frequency of occurrence based on Total stomachs
Isopsetta isolepis	N = 45	N = 117
Empty (63)	-	53.8
Ophiura sarsi (23)	42.6	19.7
Polychaeta (13)	24.1	11.1
Ophiuroidea (7)	13.0	6.0
Chionoecetes bairdi (5)	9.3	4.3
Unid. remains (3)	5.6	2.6
Amphipoda (2)	3.7	1.7
Pisces (2)	3.7	1.7
Diamphiodia periercta (ophiuroid) (1)	1.9	0.9
Aphrodita sp. (polychaete) (1)	1.9	0.9
Echiurus sp. (spoon worm) (1)	1.9	0.9
Crustacea (1)	1.9	0.9
Shrimp (1)	1.9	0.9
Isopoda (1)	1.9	0.9
Pagurus sp. (hermit crab) (1)	1.9	0.9
Nuculana fossa (bivalve) (1)	1.9	0.9
Lyonsia arenosa (bivalve) (1)	1.9	0.9
Parophrys vetulus	N = 67	N = 92
Polychaeta (51)	76.1	55.4
Empty (25)	-	27.2
Ophiuroidea (18)	37.3	19.6
Ophiura sarsi (13)	19.4	14.1
Amphipoda (12)	17.9	13.0
Unid. remains (6)	9.0	6.5
Bivalves (3)	4.5	3.2
Macoma sp. (1)	1.5	1.1
Psephidia lordi (1)	1.5	1.1
Nucula tenuis (1)	1.5	1.1
Yoldia sp. (1)	1.5	1.1
Crangon sp. (shrimp) (1)	1.5	1.1
Microstomus pacificus	N = 74	N = 89
Ophiuroidea (52)	70.3	58.4
Polychaeta (24)	32.4	27.0

TABLE IV

CONTINUED

Stomach contents	Percent frequency of occurrence based on	
	Stomachs with food	Total stomachs
Yoldia sp. (16)	21.6	18.0
Empty (15)	-	17.0
Amphipoda (11)	14.9	12.4
Ophiura sarsi (9)	12.2	10.1
Scaphapoda (9)	12.2	10.1
Nucula tenuis (8)	10.8	9.0
Diamphiodia craterodmeta (ophiuroid) (7)	9.5	7.9
Bivalves (6)	8.1	6.7
Sternaspis scutata (polychaete) (5)	6.8	5.6
Periploma alaskana (bivalve) (4)	5.4	4.5
Cadulus sp. (scaphapod) (4)	5.4	4.5
Nephtys sp. (polychaete) (3)	4.1	3.4
Polynoidae (polychaete) (3)	4.1	3.4
Owenia fusiformis (polychaete) (3)	4.1	3.4
Pista cristata (polychaete) (2)	2.7	2.3
Goniada annulata (polychaete) (2)	2.7	2.3
Lumbrineris sp. (polychaete) (2)	2.7	2.3
Yoldia myalis (2)	2.7	2.3
Caprellidae (2)	2.7	2.3
Ophiopholis aculeata (ophiuroid) (1)	1.4	1.1
Asychis dispanidentata (polychaete) (1)	1.4	1.1
Nicomachinae (polychaete) (1)	1.4	1.1
Myriochele heeri (polychaete) (1)	1.4	1.1
Ammotrypane alogaster (polychaete) (1)	1.4	1.1
Glyceridae (polychaete) (1)	1.4	1.1
Ampharitidae (polychaete) (1)	1.4	1.1
Nephtys cornuta franciscana (polychete) (1)	1.4	1.1
Etone longa (polychaete) (1)	1.4	1.1
Onuphis iridescens (polychaete) (1)	1.4	1.1
Chone cincta (polychaete) (1)	1.4	1.1
Terebellides stroemi (polychaete) (1)	1.4	1.1
Pectinidae (polychaete) (1)	1.4	1.1
Onuphis sp. (1)	1.4	1.1
Brada sp. (polychaete) (1)	1.4	1.1
Glycinde sp. (polychaete) (1)	1.4	1.1
Amphictene auricoma (polychaete) (1)	1.4	1.1
Prionospio malmgreni (polychaete) (1)	1.4	1.1
Sabellidae (polychaete) (1)	1.4	1.1

TABLE IV

CONTINUED

Stomach contents	Percent frequency of occurrence based on: Stomachs with food	Total stomachs
Golfingia sp. (1)	1.4	1.1
Rhyncocoela (proboscis worm) (1)	1.4	1.1
Nuculana fossa (1)	1.4	1.1
Odontogena borealis (bivalve) (1)	1.4	1.1
Cardiomya sp. (bivalve) (1)	1.4	1.1
Psephidia lordi (1)	1.4	1.1
Shrimp (1)	1.4	1.1
Crangonidae (1)	1.4	1.1
Diastylis sp. (cumacea) (1)	1.4	1.1
Heterophoxis occulaties (amphipod) (1)	1.4	1.1
Lysianassidae (amphipod) (1)	1.4	1.1
Ampeliscidae (amphipod) (1)	1.4	1.1
Velutina velutina (gastropod) (1)	1.4	1.1
Harpiniopsis excavata (amphipod) (1)	1.4	1.1
Byblis (Amphipoda) (1)	1.4	1.1
Oedicerotidae (Amphipoda) (1)	1.4	1.1
Chionoecetes bairdi (1)	1.4	1.1
Foraminifera (1)	1.4	1.1
Holothuroidea (1)	1.4	1.1
Ctenodiscus sp. (sea star) (1)	1.4	1.1
Anemone (1)	1.4	1.1
Nudibranchia (1)	1.4	1.1
Hippoglossus stenolepis	N = 49	N = 74
Empty (25)	-	33.8
Chionoecetes bairdi (18)	36.7	24.3
Pisces (14)	28.6	18.9
Pleuronectidae (flat fishes) (8)	10.2	6.8
Octopus sp. (4)	8.2	5.4
Ammodytes hexapterus (Pacific sand lance) (3)	6.1	4.1
Gamaridae (amphipod) (3)	6.1	4.1
Ophiura sarsi (3)	6.1	4.1
Ophiuroidea (2)	4.1	2.7
Cottidae (sculpins) (1)	2.0	1.4
Glyptocephalus zachirus (1)	2.0	1.4
Elassochirus sp. (hermit crab) (1)	2.0	1.4
Pagurus ochotensis (hermit crab) (1)	2.0	1.4

TABLE IV

CONTINUED

Stomach contents	Percent frequency of occurrence based on	
	Stomachs with food	Total stomachs
Hyas sp. (crab) (1)	2.0	1.4
Munida quadrispina (crab) (1)	2.0	1.4
Crangonidae (1)	2.0	1.4
Pandalus sp. (1)	2.0	1.4
Pandalus platyceros (spot shrimp) (1)	2.0	1.4
Isopoda (1)	2.0	1.4
Squid (1)	2.0	1.4
Actiniaria (sea anemone) (1)	2.0	1.4
Platichthys stellatus	N = 23	N = 37
Empty (14)	-	37.8
Ophiuroidea (10)	43.5	27.0
Ophiura sarsi (10)	43.5	27.0
Unid. remains (2)	8.7	5.4
Gastropoda (1)	4.3	2.7
Buccinum sp. (gastropod) (1)	4.3	2.7
Theragra chalcogramma (1)	4.3	2.7
Lepidopsetta bilineata	N = 26	N = 32
Empty (6)	-	18.8
Ophiura sarsi (5)	19.2	15.6
Ophiuroidea (4)	15.4	12.5
Chionoecetes bairdi (4)	15.4	12.5
Gammariidae (3)	11.5	9.4
Pisces (3)	11.5	9.4
Amphipoda (2)	7.7	6.3
Crangonidae (2)	7.7	6.3
Unid. remains (2)	7.7	6.3
Ammodytes hexapterus (1)	3.8	3.1
Travesia sp. (polychaete) (1)	3.8	3.1
Glycera capitata (polychaete) (1)	3.8	3.1
Spionidae (polychaete) (1)	3.8	3.1
Onuphis sp. (1)	3.8	3.1
Aphrodita sp. (1)	3.8	3.1
Polychaeta (1)	3.8	3.1
Rhynchocoela (1)	3.8	3.1
Anonyx sp. (1)	3.8	3.1

TABLE IV

CONTINUED

Stomach contents	Percent frequency of occurrence based on	
	Stomachs with food	Total stomachs
Psettichthys melanostictus	N = 4	N = 10
Empty (6)	-	60.0
Pisces (3)	75.0	30.0
Atheresthes stomias (1)	25.0	10.0
Anoplopoma fimbria	N = 57	N = 90
Empty (33)	-	36.7
Pisces (15)	26.3	16.7
Scyphozoa (jelly fish) (15)	26.3	16.7
Amphipoda (12)	21.0	13.3
Shrimp (10)	17.5	11.1
Euphausiacea (7)	12.3	7.8
Squid (3)	5.3	3.3
Hippoglossoides elassodon (2)	3.5	2.2
Pleuronectidae (2)	3.5	2.2
Gamariidae (2)	3.5	2.2
Gonatus sp. (cephalopod) (2)	3.5	2.2
Unid. remains (2)	3.5	2.2
Clupea harengus (herring) (1)	1.8	1.1
Theragra chalcogramma (1)	1.8	1.1
Pandalidae (1)	1.8	1.1
Pandalus goniurus (1)	1.8	1.1
Euphausia pacifica (krill) (1)	1.8	1.1
Thysanoessa inermis (krill) (1)	1.8	1.1
Cumacea (1)	1.8	1.1
Munida quadrispina (1)	1.8	1.1
Octopus sp. (1)	1.8	1.1
Ophiuroidea (1)	1.8	1.1
Theragra chalcogramma	N = 39	N = 70
Empty (31)	-	44.3
Shrimp (17)	43.6	24.3
Amphipoda (13)	33.3	18.6
Pisces (5)	12.8	7.1
Euphausiacea (5)	12.8	7.1
Pandalidae (3)	7.7	4.3

TABLE IV

CONTINUED

	Percent frequency of occurrence based on	
Stomach contents	Stomachs with food	Total stomachs
Eualus sp. (shrimp) (2)	5.1	2.9
Parathemisto pacifica (amphipod) (2)	5.1	2.9
Cumacea (2)	5.1	2.9
Unid. remains (2)	5.1	2.9
Thysanoessa sp. (1)	2.6	1.4
Gadus macrocephalus	N = 15	N = 15
Shrimp (11)	73.3	
Rocks (11)	73.3	
Chionoecetes bairdi (9)	60.0	
Munida quadrispina (6)	40.0	
Squid (5)	33.3	
Octopus sp. (4)	26.7	
Pisces (3)	20.0	
Crangonidae (2)	13.3	
Pandalus montagui (1)	6.6	
Hyas sp. (1)	6.6	
Rocinela sp. (isopod) (1)	6.6	
Echinodermata (1)	6.6	
Algae (1)	6.6	
Sebastolobus alascanus	N = 41	N = 50
Shrimp (23)	56.1	46.0
Empty (9)	-	18.0
Pandalidae (8)	19.5	16.0
Eualus sp. (5)	12.2	10.0
Polychaeta (5)	12.2	10.0
Hippolytidae (2)	4.9	4.0
Stichaeidae (2)	4.9	4.0
Zoarchidae (eel pouts) (2)	4.9	4.0
Pandalus borealis (1)	2.4	2.0
Pandalopsis dispar (1)	2.4	2.0
Eualus macrophthalma (1)	2.4	2.0
Cumacea (1)	2.4	2.0
Mysidae (1)	2.4	2.0
Neohella sp. (1)	2.4	2.0
Chionoecetes bairdi (1)	2.4	2.0

TABLE IV

CONTINUED

Stomach contents	Percent frequency of occurrence based on Stomachs with food	 Total stomachs
Polynoidae (1)	2.4	2.0
Yoldia sp. (1)	2.4	2.0
Octopus sp. (1)	2.4	2.0
Pisces (1)	2.4	2.0
Pleuronectidae (1)	2.4	2.0
Unid. material (1)	2.4	2.0
Crab (1)	2.4	2.0
Sebastes aleutianus	N = 8	N = 10
Shrimp (6)	75.0	60.0
Pisces (4)	50.0	40.0
Empty (2)	-	20.0
Mysidacea (1)	12.5	10.0
Squid (1)	12.5	10.0
Sebastes alutus		N = 10
Empty (10)		100.0
Sebastes paucispinis	N = 5	N = 6
Unid. remains (5)	100.0	83.3
Empty (1)	-	16.7
Squalus acanthias	N = 25	N = 43
Empty (18)	-	41.9
Pisces (10)	40.0	23.3
Pandalus jordani (4)	16.0	9.3
Thaleichthys pacificus (4)	16.0	9.3
Pleuronectidae (3)	12.0	7.0
Pandalidae (3)	12.0	7.0
Unid. remains (3)	12.0	7.0
Stichaeidae (2)	8.0	4.6
Atheresthes stomias (2)	8.0	4.6
Shrimp (2)	8.0	4.6
Hippolytidae (shrimp) (2)	8.0	4.6

TABLE IV

CONTINUED

Stomach contents	Percent frequency of occurrence based on	
	Stomachs with food	Total stomachs
Chionoecetes bairdi (2)	8.0	4.6
Octopus sp. (2)	8.0	4.6
Spirontocarus sp. (shrimp) (1)	4.0	2.3
Crangonidae (1)	4.0	2.3
Invertebrates		
Pycnopodia helianthoides	N = 42	N = 70
Empty (28)	-	40.0
Nuculana sp. (11)	26.2	15.7
Ophiuroidea (10)	23.8	14.3
Ophiura sarsi (9)	21.4	12.9
Unid. remains (7)	16.7	10.0
Mitrella gouldi (gastropod) (5)	11.9	7.1
Clinocardium ciliatum (bivalve) (4)	9.5	5.7
Buccinum polare (gastropod) (3)	7.1	4.3
Natica clausa (gastropod) (3)	7.1	4.3
Clinocardium californiense (3)	7.1	4.3
Aphrodita sp. (3)	7.1	4.3
Colus halli (gastropod) (2)	4.8	2.9
Neptunea lyrata (gastropod) (2)	4.8	2.9
Propebela sp. (gastropod) (2)	4.8	2.9
Chionoecetes bairdi (2)	4.8	2.9
Gastropoda (1)	2.4	1.4
Neptunea sp. (1)	2.4	1.4
Natica sp. (1)	2.4	1.4
Polinices pallida (gastropod) (1)	2.4	1.4
Pandora grandis (bivalve) (1)	2.4	1.4
Bivalve (1)	2.4	1.4
Musculus niger (bivalve) (1)	2.4	1.4
Clinocardium sp. (1)	2.4	1.4
Macoma sp. (1)	2.4	1.4
Gorgonocephalus caryi (basket star) (1)	2.4	1.4
Amphipoda (1)	2.4	1.4
Cancer sp. (1)	2.4	1.4
Pagurus ochotensis (1)	2.4	1.4
Holothuroidea (1)	2.4	1.4

TABLE IV

CONTINUED

Stomach contents	Percent frequency of occurrence based on Stomachs with food	Percent frequency of occurrence based on Total stomachs
Crangon sp. (1)	2.4	1.4
Plant material (1)	2.4	1.4
Cancer magister	N = 69	N = 77
Centric diatoms (40)	58.0	52.0
Bivalve (32)	46.4	41.6
Nuculana sp. (30)	43.5	39.0
Yoldia sp. (21)	30.4	27.3
Crustacea (18)	26.1	23.4
Unid. organic debris (16)	23.2	20.0
Unid. animal tissue (15)	21.7	19.5
Nephtyidae (polychaete) (14)	20.3	18.2
Polychaeta (10)	14.5	13.0
Hydroids (10)	14.5	13.0
Ophiuroidea (9)	13.0	11.7
Empty (8)	11.6	10.4
Crab (8)	11.6	10.4
Gastropoda (8)	11.6	10.4
Pisces (7)	10.1	9.1
Foraminifera (6)	8.7	7.8
Pennate diatoms (5)	7.2	6.5
Plant material (5)	7.2	6.5
Shrimp (4)	5.8	5.2
Capitellidae (polychaete) (4)	5.8	5.2
Lumbrineridae (polychaete) (3)	4.3	3.9
Nematoda (3)	4.3	3.9
Amphipoda (3)	4.3	3.9
Isopoda (3)	4.3	3.9
Flagellates (3)	4.3	3.9
Pandalidae (1)	1.4	1.3
Kinorhyncha (1)	1.4	1.3
Mitrella sp. (1)	1.4	1.3
Pinnixa sp. (1)	1.4	1.3
Clinocardium sp. (1)	1.4	1.3
Crangonidae (1)	1.4	1.3
Tindaria sp. (bivalve) (1)	1.4	1.3
Polyplacophora (chiton) (1)	1.4	1.3
Polynoidae (1)	1.4	1.3

TABLE IV

CONTINUED

Stomach contents	Percent frequency of occurrence based on Stomachs with food	Percent frequency of occurrence based on Total stomachs
Ampheretidae (polychaete) (1)	1.4	1.3
Cephalopoda (1)	1.4	1.3
Spionidae (polychaete) (1)	1.4	1.3
Pagurus sp. (1)	1.4	1.3

Unidentified fishes were second in frequency of occurrence in stomachs from this species.

The brittle star *Ophiura sarsi* was the most frequent prey of flathead sole (*Hippoglossoides elassodon*). Pandalid shrimp and other Crustacea, including snow crabs, were secondary in occurrence. Butter sole (*Isopsetta isolepis*) also consumed mainly *O. sarsi*. Unidentified polychaetes were second in frequency of occurrence in stomachs from this species. Brittle stars, including *O. sarsi*, were also the most frequent prey of Dover sole (*Microstomus pacificus*). Bivalves, including *Yoldia* sp. and *Nucula tenuis*, and scaphopods, including *Cadulus* sp. were secondary in occurrence. The starry flounder (*Platichthys stellatus*) was also found to prey almost entirely on ophiuroids, including *O. sarsi*. Gastropods and unidentified remains were second.

Rex sole (*Glyptocephalus zachirus*) were found to prey mainly on polychaete worms, including *Aphrodita* sp. and *Sternaspis scutata*. Amphipods were second in frequency of occurrence. Polychaetes were also found to be the most frequent prey of English sole (*Parophrys vetulus*). Ophiuroids, including *O. sarsi*, were second in frequency of occurrence in stomachs from this species.

There was some tendency toward a spacial distribution in food habits for some of the species mentioned above. Rock sole, flathead sole, and English sole, occurring at stations farther from shore, consumed mainly ophiuroids. At more near-shore stations these same species consumed a much greater diversity of prey, including amphipods, polychaetes, shrimp and small bivalves.

Benthic Infaunal Program

Selected van Veen grab and pipe dredge samples are currently being processed and will be included in the Final Report.

Pollutants on the Bottom

The frequency of occurrence of man-made debris is listed in Table V

TABLE V

FREQUENCY OF OCCURRENCE OF MAN-MADE DEBRIS ON THE NORTHEAST GULF OF ALASKA SEA FLOOR

Type of debris	Number of trawls in which debris was found	Percent of total N = 45
All types	11	24%
Metal	1	2%
Glass	1	2%
Plastic	10	22%
Rubber	1	2%

and a discussion of pollutants in the Gulf of Alaska will be included in the Final Report.

VII. DISCUSSION

Trawl Program

The overall biomass per unit area of 1.7 g/m^2 was considerably less than values obtained in previous OCSEAP studies for more western areas of the Gulf of Alaska and the southeastern Bering Sea. The biomass for the region from Montague Island to Yakutat Bay, taken in 1975, was 2.6 g/m^2 (Jewett and Feder, 1976). Biomass values for the Kodiak shelf area in 1978, ranged from approximately 3 to 4 g/m^2 (Feder and Jewett, in press). Values for the southeastern Bering Sea ranged from 3.3 to 5.0 g/m^2 for similar studies in 1975 and 1976 (Feder and Jewett, 1980). Thus, there appears to be an overall decrease in the epifaunal biomass of the Gulf of Alaska from west to east.

Further discussion of the trawl program results will be included in the Final Report.

Feeding Observations

Invertebrates

The sea star (*Pycnopodia helianthoides*) appeared to be an opportunistic generalist in food habits. Its diet was probably determined by the relative abundance of suitable prey species. *Pycnopodia helianthoides* from stations in the present study consumed mainly gastropods, brittle stars, and bivalves. The gastropods included *Mitrella gouldi*, *Natica* spp., *Buccinum polare*, and *Neptunea* spp. *Nuculana* sp. was the most common bivalve found and *Ophiura sarsi* was the common ophiuroid. These findings are similar to those of Jewett and Feder (1976) for a more western area of the Gulf of Alaska.

The dungeness crab (*Cancer magister*) fed primarily on bivalves, with crustaceans and polychaetes occurring less frequently. The dominance of *Nuculana* sp. and *Yoldia* sp. probably indicates an abundance of these bivalves at the same stations. This question should be resolved upon completion of the analysis of grab samples from these stations. The occurrence of diatoms in many of the stomachs examined was probably due to incidental ingestion with sediment. Other studies have also found *C. magister* to feed primarily on small bivalves and crustaceans (Feder and Paul, in press).

Additional feeding data on the snow crab (*Chionoecetes bairdi*) will be included in the Final Report.

A detailed discussion of the feeding observations in fishes will be included in the Final Report.

VIII. CONCLUSIONS

Trawl data and feeding data that have been analyzed to date broaden our knowledge of various aspects of the distribution, abundance, and general biology of the more important invertebrate components of the NEGOA shelf. Implicit in the current study is the vast amount of the survey region that was untrawlable and in some instances unsampleable.

Data was mainly obtained in Priority area 1; 34 trawl stations, 26 van Veen grab stations and 25 pipe dredge stations. These stations within Priority area 1 represent a reasonable nucleus around which a monitoring program can be developed.

The phyla Cnidaria, Mollusca, Arthropoda, and Echinodermata made up 88.7 percent of the invertebrate biomass. Important taxa within each phylum were *Metridium senile* (Cnidaria), *Pecten caurinus* (Mollusca), *Cancer magister* (Arthropoda), and *Strongylocentrotus* spp. (Echinodermata), respectively.

The feeding data compiled in this report, in conjunction with similar data compiled from other areas under OCSEAP studies, should better contribute to an understanding of the trophic role of these organisms in their respective ecosystems, and the impact of oil on these ecosystems.

Additional seasonal data are essential. It is only when such continuing information is available that a reasonable biological assessment of the effect of an oil spill can be made.

IX. NEEDS FOR FURTHER STUDY

Many of the species encountered in trawling operations are mobile i.e., undergo seasonal migrations. For this reason, it is important to obtain seasonal data on the distribution, abundance and biomass of organisms, as well as their trophic relationships. As a result of the current study the only data base for the designated area is during the month of November. If disturbances to the environment and ultimately to the organisms occurs during other months no data are available on those motile species for comparison. Therefore, if further study is conducted within the study area a seasonal approach is advised. Additionally, studies on the toxic effects of hydrocarbons on the biology of many of the commercially important and/or key ecologically important species should be initiated prior to petroleum exploration and development.

X. SUMMARY OF FOURTH QUARTER OPERATIONS

A. Ship or Laboratory Activities

1. No ship activity
2. Laboratory activity:
    a. Analysis of all trawl data was completed.
    b. Analysis of grab and dredge data was 50% completed.
    c. Analysis of fish and invertebrate stomach data was 80% completed.
    d. Submission of approximately 80% of the trawl and pipe dredge voucher specimens was completed.

B. Methods, Results and Discussion

1. The methods, results and discussion of work completed on the NEGOA project are included in Section I of this report.
2. The methods and results of the voucher specimen submission programs are included in Section II of this report.
3. During approximately 40% of the time in fourth quarter operations Stephen Jewett was involved in the submission of material for the OCSEAP-sponsored Bering Sea Book (Don Hood, editor). This precluded Mr. Jewett's full attention to current OCSEAP NEGOA and Kodiak studies.

C. Problems Encountered

During the November 1979 NEGOA cruise, aboard the NOAA Ship *Miller Freeman*, problems were encountered concerning gear inadequacy. The research proposal stated that "at least three 400-mesh Eastern otter trawls" be supplied by OCSEAP. Subsequent phone conversations with George Lapiene of OCSEAP-Juneau verified that two new trawl nets would be supplied by NMFS (Murray Hayes)-Seattle. Once the cruise began we realized that two well-worn nets had been supplied, rather than new ones. The used nets were easily torn and trawling on marginal bottom was precluded. As a result many of the 26 stations which were deemed untrawlable may have been trawled if we had more or stronger gear.

D. Milestones

1. Approximately 1900 samples of benthic invertebrate voucher taxa from various OCSEAP studies were submitted to the California Academy of Science. Final Report due October 1980.
2. The Final Report on the epifauna of three bays (Port Etches, Zaikof Bay and Rocky Bay) of Prince William Sound was completed and submitted March 1980.
3. Final phases of separate Final Reports for Cook Inlet and Kodiak Island are nearly complete. Submission of reports is expected to be no later than 30 April 1980.

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SECTION II

SUBMISSION OF BENTHIC INVERTEBRATE VOUCHER SPECIMENS

I. INTRODUCTION

Since 1975 benthic organisms have been collected during the course of OCSEAP investigations in various bodies of water on Alaska's Continental Shelf. Data on the distribution, abundance and biomass of these infaunal and epifaunal species were obtained through the use of trawls, grabs, and dredges and has been submitted or are in the submission process to NODC (actual data) and OCSEAP (Final Reports). In order to comply with the request to provide voucher specimens of benthic samples collected during the course of these investigations a voucher specimen submission program was initiated. The specimens, to be archived at the California Academy of Science (CAS), in addition to the deposited NODC and OCSEAP data, will provide a data base against which future investigations can be compared.

II. STUDY AREAS

The areas where benthic collections occurred were: (1) southeastern Bering Sea (Feder *et al.*, 1978; Feder *et al.*, 1979a, Feder and Jewett, 1980; (2) Cook Inlet (Feder *et al.*, 1979b); (3) northeastern Bering Sea and southeastern Chukchi Sea (Feder and Jewett, 1977a, 1978); (4) Ugak and Alitak bays of Kodiak Island (Feder and Jewett, 1977b,c); (5) Kodiak Island region, inclusive of Izhut and Kiliuda bays (Feder *et al.*, 1979c; Feder and Jewett, in press); (6) the embayments of Prince William Sound-Port Etches, Zaikof Bay and Rocky Bay (Feder *et al.*, 1979b; Feder and Hoberg, 1980); and (7) the northeastern Gulf of Alaska from Yakutat Bay to Cross Sound (Present Report - Section I).

III. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

The sources, methods and rationale of data collection are discussed in the respective reports submitted to OCSEAP (see II. Study Area in this section for references). Most vouchered specimens were preserved in 40 percent isopropyl alcohol. Specimens were carefully packed and submitted to CAS *via* Dr. William Eschmeyer and Miss Susan Marelli. A complete listing of the samples with pertinent data and copies of the original data printouts accompanied the specimens.

IV. RESULTS

A total of 1880 samples of invertebrate taxa have been submitted to CAS to date. Table I contains a listing of the number of taxa submitted by area, date and gear type. Additional voucher specimens will be shipped within the next few months.

TABLE I

NUMBER OF VOUCHERED BENTHIC INVERTEBRATE TAXA SUBMITTED TO CALIFORNIA ACADEMY OF SCIENCE

No. Vouchered Taxa	Sampling Area	Collection Date	Sampling[1] Gear
707	SE Bering Sea	Aug-Oct 1975 Mar-Jun 1976	OT-PD
27	Cook Inlet	Oct 1976	CD
129	Cook Inlet	Oct 1976	OT-AT
357	Cook Inlet	Oct 1976	PD
14	Cook Inlet	Apr 1976	PD
413	NE Bering Sea- SE Chukchi Sea	Sep-Oct 1976	OT
89	Ugak-Alitak bays	Jun-Aug 1976 Mar 1977	OT
30	Kodiak Island Shelf	Jun-Jul 1978	PD
114	Izhut-Kiliuda Bay	Apr-Aug, Nov 1978 Mar 1979	OT-AT

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[1] OT = otter trawl
AT = Agassiz trawl
PD = pipe dredge
CD = clam dredge

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ANNUAL REPORT
1 April 1979 - 31 March 1980
Research Unit #006

The distribution, abundance, diversity and productivity of the western Beaufort Sea benthos.

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1 April 1980

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I. Summary of Objectives, Conclusions, and Implications with Respect to OCS Oil and Gas Development.

Extensive exploration and development for oil and gas on the Alaskan and Canadian continental shelf have the potential to significantly influence the marine environment of the Beaufort Sea. It is impossible with our present knowledge to accurately predict the consequences of petroleum development on the marine benthos.

The past and continuing goal of this project has been to acquire the knowledge of the ecology of benthic invertebrate faunas of the Beaufort Sea continental shelf necessary to evaluate the consequences of offshore oil and gas development. The distribution and abundance of the fauna has been examined in detail with studies of the spatial and temporal variability of these. These data will provide a baseline against which future changes in the benthic environment and community structure can be evaluated. Of current importance are: (1) the definition of temporal changes in sublittoral community structure, (2) the determination of the life histories and secondary production estimates of dominant and ecologically important species, (3) the description of the benthic food web, (4) the investigation of the biological interrelationships between the benthic community and the underice biota, and (5) the study of the ecology of benthic invertebrates important as prey organisms to the marine mammals, birds, and fishes. Now that broad ecological patterns of benthic invertebrates on the Beaufort Sea shelf are becoming fairly well known, it is imperative to define the dynamic processes maintaining temporal and spatial structure.

II. Introduction

A. General nature and scope of the study.

The present benthic ecological studies on the continental shelf include functional process-oriented research that is built upon an accumulated base of descriptive information on the invertebrate organisms and environmental measurements within the Beaufort Sea. Seasonal changes in the numerical abundance and biomass of the large macro-infauna (>1.0 mm) are being examined at stations across the shelf. The benthic food web and its relationship to bird, fish and mammalian predators and the relationships between the epontic ice algal community and the benthic community beneath are under investigation. Research on the interrelationships between the underice epontic community and the associated sedimentary biota has been undertaken.

Concentrated study of the Beaufort Sea continental shelf benthic invertebrates was not initiated until the early 1970's. As very little was known about the fauna at the beginning of the exploration and developmental phases of the petroleum fields on the Alaskan North Slope, the early research involved basic survey work on the 1971 and 1972 U.S. Coast Guard oceanographic cruises (WEBSEC-71 and WEBSEC-72). Initial processing and analysis of bottom grab samples, otter trawls, and bottom photographs were sponsored by the Oceanographic Section of the National Science Foundation through a grant to the Principal Investigator.

When NOAA, under sponsorship of BLM, initiated environmental assessment research around the continental shelves of Alaska, Oregon State University participated in the benthic program in the Beaufort Sea. A combination NSF and NOAA/BLM research project supported several approaches and phases of research. Detailed analysis of benthic communities and identification of the total polychaete worm fauna over a wide range of depths was accomplished under the National Science Foundation's auspices. Further continental shelf survey sampling was then continued under the OCSEAP with the cooperation of the Coast Guard and their Beaufort Sea icebreaker program. With NOAA's interest and logistics support, seasonal sampling and study of temporal changes in the continental shelf communities could be accomplished for the first time.

During the first year of operation a major objective of Task Order #4 for RU #6 was to summarize the literature and unpublished data. The majority of this information came from the work-up of the samples and the analysis of the data already on hand at Oregon State University as a result of the WEBSEC investigations. The objectives for Task Order #5 under the present research contract for RU #6 emphasize the delineation of the benthic food web and the description of the coastal benthos. Efforts to characterize the composition of the Beaufort Sea fauna at the species level are continuing as this is a critical step toward understanding the dynamics of the benthic ecosystem. Detailed studies on temporal changes in the continental shelf benthic communities continued. An examination of the nearshore epontic community and its role in the ecology of the Beaufort Sea is now being actively pursued.

Research is currently being undertaken in cooperation with other scientists which is oriented toward understanding the processes that maintain the nearshore and lagoonal ecosystems. Of particular interest is the source of carbon that fuels the heterotrophic organisms living within the system. In lower latitude oceanic waters most of the carbon fixed by photosynthesis is ultimately derived from the phytoplankton, but in coastal waters much of the organic material may be land-derived. Water acts as a three dimensional reservoir and transporter of organic carbon through a complex cycle that involves the interactions of numerous marine organisms. The benthos as an ecological group depend to a large extent on detritus that falls down to them. In the ice-covered waters of the Arctic, the epontic diatoms on the undersurface of the sea ice is an added source of carbon to the system (Horner, 1976), and in shoal waters benthic algae add to the primary production (Matheke and Horner, 1974). In the coastal Beaufort Sea and its bordering lagoons, detrital peat from coastal erosion may also add carbon to the system.

The underice diatom bloom is known to exist in coastal waters in the Chukchi Sea off Barrow, AK (Horner and Alexander, 1972), in the Eskimo Lakes region (Grainger, 1975), and in Stefansson Lagoon. Though its areal extent either in coastal waters or offshore over the continental shelf is not known, it has been suggested that these epontic diatoms could be an important energy source within the southern Beaufort Sea ecosystem (Clasby, et al., 1973). It is most pertinent to note that Schell (RU #537) recently measured substantial concentrations of chlorophyl on the undersurface of Beaufort Sea ice to distances of 100 n mi offshore (personal communication). The existence of the algal epontic community in oceanic waters in the Beaufort Sea suggests that primary production in this community is indeed energetically important to the total Beaufort Sea ecosystem. Although no direct measurements have been made, the pennate diatoms may fall to the sea floor upon ice melt in June (Matheke and Horner, 1974) thus providing a supplementary route for organic carbon to reach the benthos.

Various organisms become associated with the ice-sea water interface as the diatom bloom progresses through the months of April, May and June (Horner, 1976). Nematode worms are most abundant but harpacticoid copepods, amphipods and polychaete larvae have been observed on the underice surface. The coastal amphipod Onisimus affinis, an important member of the demersal fish food chain, has been reported as migrating up to the epontic community presumably to feed (Percy, 1975).

The degree of linkage between the underice epontic community and the benthic community beneath is not known. There is no direct evidence that this "upside down benthic community" is important in the energetics of the bottom communities themselves (Horner, 1966; Hameedi, 1978), but it has been hypothesized that the sinking of detritus and diatom cells from the epontic community could provide a sizeable downward organic input to the underlying benthic communities. The vertical migration of benthic fauna up to the ice undersurface could provide another significant source of energy-rich organics to certain faunal groups.

The research project (RU #6W) on the interactions of the benthic community and the underice epontic community is now providing the necessary background data to prove whether direct fluxes of food materials and organisms exist between the two surfaces.

B. Specific Objectives

1. Conclude synthetic analyses of benthic communities across the Beaufort Sea continental shelf with concentration on nearshore synthesis.

   a. Document zoogeographic zonation and faunal community clustering of the Beaufort lease region, so as to put into regional context both the current sale area and future proposed Beaufort Sea lease sales. Make correlative studies to determine the major features of the physical, chemical and biological environment that appear to have an effect on faunal distributions and abundances. Where possible, map the distribution of numerically dominant species and the prey species important in the food web.

b. Document the benthic food web as far as possible for the lease zone environments. Summarize the distribution, abundance and ecology of key prey species.

c. Analyze the temporal variation of benthic communities across the continental shelf on the OCS Pitt Point Station Transect. Define the recruitment, growth, life histories and reproductive activity of numerical dominant species as far as possible, and extrapolate to determine rough estimates of the rate of recovery from disturbance of characteristic benthic invertebrate species.

Justification

Ecological trends give the over-view of the ecology of the benthic fauna that provides interpreations of the environmental and biological causes of the distributional and abundance patterns.

Foodweb studies are important in establishing the routes by which energy elements and pollutants are transferred from one trophic level to another. Such studies are necessary to identify the keystone species and important feeding areas on the Beaufort Sea continental shelf.

The total and average data from the year-round benthic samples at five standard stations on the Pitt Point Transect across the Beaufort Sea continental shelf strongly indicate that the communities undergo seasonal reproductive cycles. Data on the reproductive activity and population size structure of individual species throughout the year are essential to determine if the fauna may be more sensitive to oil-related pollution problems at some particular season. As the free or brooded larval phase of benthic invertebrate reproductive cycles is considered a very critical stage, life histories of the dominant and key food web species must be considered to estimate risks involved.

2. Define the interrelationships between the epontic ice algal community and the benthic community beneath as far as possible in conjunction with RU's 359 and 537.

   a. Compare the fauna associated with the under-ice surface with that of the sediment surface and statistically analyze to determine if the benthos might be actively grazing on the epontic algal cells or preying on other associated fauna.

   b. Measure the downward flux of particulate organic carbon to determine if the ice algal community provides a potential food source to the *in situ* benthic organisms.

   c. Study the mechanism of vertical migration of benthic fauna to the under-ice surface and, if feasible, determine if there is a direct association between certain vagile benthic species and the under-ice epontic community.

Justification

It has come to the attention of NOAA/BLM-OCSEAP that further year-round information is needed on the oceanographic and ecological processes taking place in the coastal waters of the Beaufort Sea. As exploratory and production drilling will take place in the lagoons and possibly offshore of the barrier islands out to 20 meters depth, studies are needed to determine if the winter-spring months are biologically quiescent or whether organisms may be active and/or vulnerable to the oil-related activities during the ice-covered months of the year.

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C. Relevance to Problems Associated with Petroleum Development.

Extensive exploratory and production drilling for petroleum on the Alaskan and Canadian continental shelf has the potential to significantly influence the marine benthic environment and its associated biota. It is still not possible to accurately predict either the long or short term consequences of oil and gas development on the marine invertebrate benthos and the benthic food web. However, the addition of recent descriptive baseline data on species distribution, composition and abundance will allow refined estimates of the variability within the benthic community which occurs both through space and time. It is these estimates which are necessary in sorting out the naturally-occurring changes in the biota from those induced by the future development of the petroleum industry.

III. Current State of Knowledge

Since 1971, when intensive sampling of the benthos of the southwestern Beaufort Sea was initiated, numerous collections have been made in an effort to define the broad ecological patterns exhibited by the bottom invertebrate organisms. These data have been submitted as part of the Final Report of NOAA/BLM-OCSEAP Contract No. 03-5-022-68, Task Order No. 4 submitted to NOAA by the Benthic Ecology Group at Oregon State University under Dr. Andrew G. Carey, Jr., in Quarterly and Annual Reports for Task Order No. 5 of RU #6, and in several publications (Carey, Ruff, Castillo and Dickinson, 1974; Carey and Ruff, 1977; Montagna and Carey, 1978; Bilyard and Carey, 1979.)

Both temporal and spatial variability have been addressed, but the processes involved in maintaining these are not known. In some areas the scoring of the sea floor by ice gouging appears to increase the patchiness of the large infauna (Carey et al., 1974 and Carey and Ruff, 1977). It is suggested that the temporal variability of the outer continental shelf communities are seasonal and caused by reproductive cycles, but the data available to test this hypothesis are still being examined (Carey, Ruff and Montagna, unpublished M.S.).

Benthic invertebrates that are important as food sources to marine mammals and birds have been designated by other research groups (RU's 230, 232, 172 and 196), and the ecology of these particular prey species is being elucidated. Research is continuing on the benthic food web, and its structure and rates are under active investigation.

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IV. Study Area

The Beaufort Sea is an integral part of the Arctic Ocean (Coachman and Aagaard, 1974). Normally the sea ice melts and is advected seaward during July and August in the southern fringe of the sea over the continental shelf. This is a response to regional wind stresses which are variable from year to year. For example, in some years the polar pack ice can remain adjacent to the coastline throughout the entire season. The extent of ice cover during the sunlit summer months affects wind mixing of surface waters and the penetration of light into the water column. These factors affect the onset and intensity of phytoplankton production which is highly variable and of low magnitude (Horner, 1976; Clasby, Alexander and Horner, 1976). The keels of sea ice pressure ridges ploughing through the sediments cause significant disturbance of the benthic environment in water depths between 20 and 40 meters (Barnes and Reimnitz, 1974; Reimnitz and Barnes, 1974). They gouge the bottom as they are transported across the inner shelf by the Beaufort Sea gyral circulation and by wind stress.

Generally the bottom water masses of the southwestern Beaufort Sea are stable, and except for the shallow coastal zone, differ little in thermohaline characteristics throughout the year (Coachman and Aagaard, 1974). However, the outer shelf region from Point Barrow to about 150°W is influenced by Bering-Chukchi water that is advected as a subsurface layer and moves around Point Barrow throughout the year in pulses controlled in part by atmospheric pressure gradients (Hufford et al., 1977). Coastal upwelling was observed in the Barter Island region on the shelf near 143°W during the summer of 1971 when the pack ice had moved relatively far offshore (Mountain, 1974).

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V. Sources, Methods and Rationale of Data Collection

In general, two areas of continuing benthic ecological research are: (1) the further accumulation of data from existing samples to document zoogeography, delineate the key prey species, and define the recruitment, growth, life histories and reproductive activity of the characteristic benthic invertebrate species; and (2) the examination of the epontic ice algal community to determine its character and to gain an understanding of the relationships between the epontic and the benthic communities.

The existing benthic samples derive from numerous field efforts conducted throughout the Beaufort Sea since 1971. The majority are Smith-McIntyre 0.1 m^2 grab samples which have been washed through a 0.5 mm aperature sieve and sorted at Oregon State University. The infaunal organisms from these grabs form the basis for large-scale studies on the total benthic community structure, and for defined looks at growth and life histories of selected species. Through analysis of the faunal information derived from these samples, it is possible to more accurately estimate the natural spatial and temporal variability occurring within the invertebrate populations, and to sort these out from externally induced perturbations.

The current work on the epontic community is necessary in understanding the role of the benthos in the arctic ecosystem. The degree of linkage between the under-ice and sedimentary communities must be elucidated, as these links may be important in supplying energy to the benthos or in providing cues to trigger reproductive episodes in certain invertebrates.

VI - VIII. Results, Discussion and Conclusion

The results, discussions and conclusions for the 1979/1980 reporting year are combined into sections which correspond to the various areas of ongoing research.

A. Winter Studies: Sea ice epontic community - benthic faunal community interactions.

Research has been initiated on the interrelationships between the underice epontic community and the benthic community associated with the sediments beneath the ice canopy. Preliminary research undertaken in Stefansson Sound during the spring of 1979 was aimed at the determination of the relative abundances and taxonomic similarities of the substrate fauna on the two surfaces. The small macrofauna and the meiofauna were quantitatively categorized by major taxa. For the initial pilot study, the harpacticoid copepods were used as an indicator group of organisms for detailed comparisons of taxonomic similarities.

Methods

Samples of the ice undersurface and sediments beneath and the deployment of particle collectors and vertical migration traps were accomplished in March and May of 1979 in Stefansson Sound (Figure 1). The meiofauna and small macrofauna on the undersurface of the sea ice was sampled by 3.5 cm diameter plastic core tubes (Table 1). The core tubes were corked at the lower end and were pushed by SCUBA diver up through the softer ice as far as they could be pushed so as to seat them firmly against the hard ice structure. A flat trowel was maneuvered over the mouth as a temporary closure while the core was withdrawn from the ice. A cork was pushed into the tube. It was then placed in the diver's carrying bag, and the operation was repeated. During the May field effort a box-type scraper was used to sample ten centimeter wide by one meter long transects in an effort to cover a greater area (see Table 4 in NOAA-OCSEAP 29 September 1979 Quarterly Report by RU #006 for a comparison). The larger samples did contain the expected higher numbers of organisms for the desired rigorous statistical treatment.

Sediment cores for collecting meiofauna and small macrofauna were taken from the sediments beneath the ice samples with modified 28.5 mm diameter plastic syringe barrels (Table 2). With the tip removed from the syringes, these units were operated as small piston corers with the use of the plunger. Both the ice and sediment samples were preserved in 10% buffered formalin.

The vagile, large macrofauna were sampled by hand nets and vertical migration traps (Figure 1). Owing to low densities, no fauna could be collected from the sediments or ice by the SCUBA divers. The vertical migration traps (VMT) retained organisms in the upper section that faced the surface on the bottom of the ice. The migration traps were constructed in two sizes, 1 meter in diameter and 28 cm in diameter. The basic design involved an upward facing cone funnel and a downward-facing one that led into a separated central trap section. The large VMT consisted of a one meter diameter stainless steel ring with a 1.0 mm NYTEX net funnel lashed to it and to a 28 cm plastic funnel at the smaller end. The plastic funnel in turn led into a 16 oz plastic jar with a rubber stopper providing a positive seal. The small trap consisted of the plastic funnels and plastic jar trap ends. An anchor weight and foam floats completed the traps. They were positioned by the divers to float equidistant from sediment and ice surfaces.

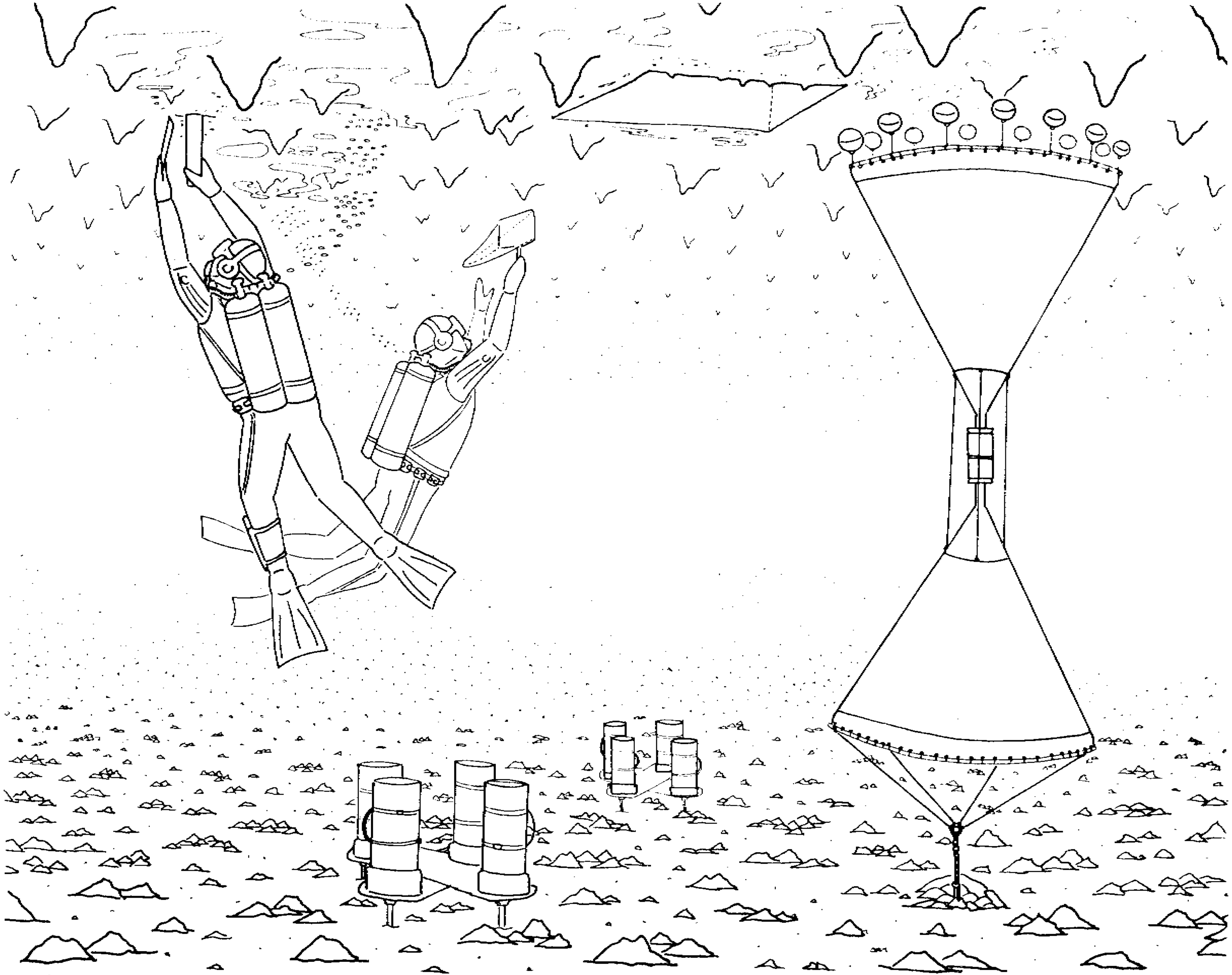

Figure 1. Illustration of Stefansson Sound sampling site showing <u>in situ</u> particle collectors, a large vertical migration trap, an ice corer and a diver-operated sweep net.

Table 1. Mean densities and standard errors for invertebrate organisms collected in Stefansson Sound in March and May, 1979, from the undersurface of the ice.

	March 1979 $\bar{X} \pm SE/9.62cm^2$ (N=17)	May 1979 $\bar{X} \pm SE/9.62cm^2$ (N=9)
polychaete larvae	5.2±1.2	0
nauplii	1.7±0.5	0.2±0.2
Calanoida	0.6±0.3	0
Cyclopoida	0	0.6±0.2
Harpacticoida	0.1±0.1	0.2±0.2
Rotifera	0.1±0.1	0
Nematoda	0.1±0.1	3.3±0.8

Table 2: Mean densities and standard errors for meiofaunal groups collected with 6.12 cm^2 sediment corers in March and May 1979.

	March 1979 $\bar{X} \pm SE/10cm^2$ (N=10)	May 1979 $\bar{X} \pm SE/10cm^2$ (N=10)
Nematoda	542.0±102.0	504.0±116.0
Kinorhyncha	1.1± 0.5	1.1± 0.4
Nemertinea	0.3± 0.5	0
Polychaeta	19.0± 5.7	17.0± 4.4
Amphipoda	0.2± 0.2	0
Harpacticoida	24.0± 3.6	28.0± 4.4
Tanaidacea	0.3± 0.2	6.5± 2.6
Ostracoda	6.5± 1.0	5.5± 1.5
Cumacea	0	0.7± 0.4
Isopoda	0	0.2± 0.2
Acarina	0.3± 0.2	0
nauplii	11.0± 3.1	3.9± 1.5
Pelecypoda	0	0.2± 0.2
Gastropoda	0	0.2± 0.2
Priapulida	0	0.2± 0.2
Anthozoa	0	0.2± 0.2

The third approach toward the determination of the interactions between the benthic and ice substrate communities involved the collection of large particles falling to the sediments. Eight cyclindrical particle traps were deployed in sets of four in frames placed on the bottom by SCUBA divers. The PVC plastic cylinders had a diameter of ∿13 cm and a height of ∿40 cm with an aspect ratio of 3:1. These traps were deployed filled with cold filtered seawater and with plastic caps in place. Only after full deployment and a suitable time for clearance of the water column of disturbed sediments were the caps removed and the collection period begun.

Deployment time was 5 days in March and 4 days in May. During this trial period, purified salt cakes were utilized to provide a stable and dense liquid as a preservative in the cylinders. This minimal approach to preservation may not have been adequate, although outside data suggest that bacterial growth and metabolic rates are at low levels during the winter-spring months.

Sampling for this winter studies subproject was undertaken in and adjacent to the Boulder Patch in Stefansson Sound. Dive Site 11 (70°19.7'N, 147°34.1'W) was used as the dive hole and the area of research during March, 1979, while an adjacent area 200 meters away was utilized during the May operations. This region has a scattered cover of boulders that support a large growth of kelp and associated organisms. The soft sediment cover is thin and patchy, and what patches there are lie next to boulders. In the dive site 11 area, large areas of the soft sediments appear to have been eroded away exposing a consolidated Pleistocene clay beneath.

The temperature and salinity at the two dive sites showed differences in the water column from the bottom to the top in May (Table 3). Measurements made with an in situ salinometer indicated higher salinities at the lower part of the water column, but there were fluctuations from one day to the next. The temperatures were also variable, suggesting that water with different characteristics was advected into the region over a one day period. Upon return to the laboratory the instrument was calibrated. It checked out at the appropriate temperatures and salinities. Extensive field measurements will be made with the salinometer during the 1980 field season. These data will be used to confirm the above information.

There were several types of sea ice present in the area under study in 1979. The major portion of ice contained an horizon of ice-laden "slush" ice beneath a frozen layer that was incorporated within the ice column (Reimnitz, Barnes and Dunton, unpublished manuscript). Normal congelation was present and was sometimes of less thickness when it formed at leads in the ice. The March faunal samples were taken from a "slush" surface, while the May samples came from clean congelation ice on which an ice algal community was established.

Results

At both sampling periods the epontic faunal community was found to be sparse in number and depauperate in species compared to the communities in the sediments beneath (Tables 1, 2 and 4). Numerical densities were 100 to 1,000 times less on the bottom surface of the ice, and only two species of harpacticoid copepods were collected there. In contrast, 28 species of harpacticoids were identified from the sediment samples. The two harpacticoid species, Halectinosoma neglectum and Pseudobradya sp. B were found on both surfaces, although H. neglectum was more abundant on the bottom surface of the ice. The one other copepod species collected from the ice was Cyclopina gracilis, a cyclopoid. This species was abundant in the ice algal community in May but not present in the slush ice in March.

Table 3. Salinity-temperature data for May 1979 at the ice algal community studies dive site. Data taken with a Kahlsico *in situ* salinometer. The ice algal studies dive site was 200 meters from Dive Site #11 (70°19.7'N, 147°34.1'W) in Stefansson Sound.

A. Dive Site #11. 5/19/79

Depth(m)	Sal.°/oo	Temp.C°
Surface	31.4	-2.0
1	23.5	-2.0
Ice 2	26.0	-2.0
3	31.2	-2.0
4	31.4	-2.0
5	31.4	-2.0
Bottom (6)	31.4	-2.0

B. Dive Site #11. 5/20/79

Depth(m)	Sal.°/oo	Temp.C°
Surface	25.5	-1.2
1	26.0	-1.2
Ice 2	26.3	-1.8
3	33.0	-1.9
4	33.2	-1.9
5	33.2	-1.8
Bottom (6)	33.1	-1.6

C. Ice algal studies dive site. 5/20/79

Depth(m)	Sal.°/oo	Temp.C°
Underice 3	29.5	-2.0
Bottom (6)	15.5	-1.3

Table 4. Harpacticoid copepod summary for ice and sediment cores taken in March and May 1979.

	March 1979		May 1979	
Species	Sediment Cores X SE/10cm^2 (N=10)	Ice Cores X SE/1000cm^2 (N=6)	Sediment Cores X SE/10cm^2 (N=10)	Ice Cores X SE/1000cm^2 (N=6)
Ectinosomatidae				
Halectinosoma neglectum	0.2±0.2	16±11	0.2±0.2	0.7±0.4
Halectinosoma sp. E	0.2±0.2	–	–	–
Halectinosoma sp. F	4.0±0.8	–	6.6±2.4	–
Halectinosoma sp. G	0.7±0.3	–	–	–
Bradya typica	2.3±0.7	–	10.1±2.2	–
Pseudobradya sp. B	0.2±0.2	–	0.2±0.2	0.3±0.3
Pseudobradya sp. C	0.2±0.2	–	0.2±0.2	–
Tachidiidae				
Danielssenia stefanssoni	1.8±0.4	–	1.0±1.0	–
Harpacticidae				
Harpacticus flexus	0.2±0.2	–	–	–
Tisbidae				
Tisbe sp. A	–	–	0.2±0.2	–
Zosime sp. A	–	–	0.2±0.2	–
Diosaccidae				
Stenhelia nuwukensis	0.3±0.3	–	0.7±0.4	–
Stenhelia sp. C	0.3±0.3	–	–	–
Stenhelia sp. E	–	–	0.3±0.3	–
Stenhelia sp. P	0.2±0.2	–	–	–
Amphiascoides sp. A	0.3±0.3	–	0.8±0.4	–
Paramphiascella fulvofasciata	1.6±0.6	–	–	–
Haloschizopera sp. A	–	–	3.7±1.4	–
Ameiridae				
Ameira sp. A	5.4±1.5	–	1.8±0.6	–
Ameirid B	–	–	0.3±0.3	–
Cylindropsyllidae				
Cylindropsyllid A	–	–	0.2±0.2	–
Cletodidae				
Cletodes tenuipes	0.7±0.3	–	0.2±0.2	–
Cletodes sp. A	0.2±0.2	–	–	–
Cletodes sp. B	0.2±0.2	–	–	–
Rhizothrix sp. A	0.3±0.3	–	0.2±0.2	–
Eurycletodes sp. A	0.2±0.2	–	–	–
Laophontidae				
Echinolaophonte brevispinosa	0.2±0.2	–	0.2±0.2	–
Laophontid A	–	–	0.2±0.2	–
Cyclopoida				
Cyclopina gracilis	–	–	–	24±11

Conclusions

The meiofaunal community associated with the undersurface of the sea ice seems to be distinct from that of the sediments beneath. Though the harpacticoid species are found associated with both the sediments and ice, there were only two species present. The cyclopoid copepods were more abundant and were of one species. This may also be a substrate-seeking species. Because of the general composition of the ice meiofaunal community, it appears to be a substrate community. Further research is necessary to determine the stability, spatial variability and the food web interactions of this group of organisms.

B. Biological Characteristics of the Nearshore (5-25 m) Beaufort Sea Bivalves

Nearshore bivalve molluscs in the western Beaufort Sea encompass a wide variety of feeding types, habitat orientation and larval development (Table 5). The following will be an initial look at these biological characteristics. The four numerically dominant bivalves *Axinopsida orbiculata* (33.4%), *Portlandia arctica* (21.6%), *Liocyma fluctuosa* (12.4%), and *Macoma calcarea* (7.6%) will be emphasized.

Habitat type

Epifauna

True epifaunal bivalves are poorly represented in the five to twenty meter zone of the Beaufort Sea. Only four species (*Arctinula greenlandica*, *Serripes groenlandicus*, *Pandora glacialis*, and *Crenella descussata*) comprising less than 9% of the total bivalve numbers were found to have a solely epifaunal existence. The glass scallop, *A. greenlandica*, has a greatly reduced foot and no external siphons which restrict burrowing and infaunal feeding. *A. greenlandica*, *S. groenlandicus*, and *P. glacialis* are all free living epifauna with no attachment to the substrate. *C. decussata* on the other hand develops a permanent or semi-permanent byssus which allows the mussel to remain fixed in the area. *Pandora* has been studied in captivity and has never been observed to burrow (Figure 2A). As in *Arctinula*, this species has a non-burrowing foot and very short siphons. *S. groenlandicus*, a member of the cockle family, has a well developed foot but is only a superficial burrower (Figure 2B) due to highly reduced siphons.

Two additional species, *Hiatella arctica* and *Montacuta dawsoni* have been observed in both epifaunal and infaunal orientations. *H. arctica* can be a rock borer or use its byssus for an epifaunal substrate attachment (Figures 2C and 2D). *M. dawsoni* has limited burrowing ability and might be commensally associated with epifaunal echinoderms.

Infauna

The vast majority of the nearshore pelecypod molluscs are members of the infauna. Two distinct types of infaunal bivalves are present, 1) deep burrowers and 2) shallow burrowers.

The deep burrowing forms are dominated by the active *Macoma* species (Figure 2E). *Macoma calcarea* is the most abundant species of the genus in the shallow water zone. *M. calcarea* has a highly developed foot which can be used for both vertical and horizontal burrowing. The long, separated siphons of the *Macoma* species allow a deep, infaunal orientation. The only other deep burrowing species is *Mya pseudoarenaria* (Figure 2F). This bivalve was present in low numbers at only three of the seventeen stations sampled. Adult *M. pseudoarenaria* is the deepest burrowing form found in the Beaufort Sea and is unable to re-burrow if taken from its deep infaunal position.

The bulk of the bivalves (>70%) fall into the shallow burrowing category. *Axinopsida orbiculata*, the most abundant species, generally lies less than 5 mm from the sediment surface (Figure 3A). This species has a long, bulbous foot which is especially efficient for quick burrowing. The protobranch family Nuculanidae comprised of *Portlandia*, *Nuculana* and *Yoldia* is well represented in

Table 5 . Biological characteristics of pelecypod molluscs by station from the R/V ALUMIAC cruise (Aug.-Sept. 1976). Summarized are station sediment type, species habitat, (E = epifauna, IN = infauna), species feeding type (D = deposit feeder, F = filter feeder), species larval development (L = lecithotrophic, P = planktotrophic, B = brooder) and numbers of individuals.

	Habitat Type	Feeding Type	Larval Type	Number of Individuals
Point Barrow - 25 m (BRB-25)				
Clayey silt				
<u>Nucula</u> <u>bellotii</u>	IN	D	L	1
<u>Yoldia</u> <u>myalis</u>	IN	D	L	3
<u>Axinopsida</u> <u>orbiculata</u>	IN	F	L	1
<u>Macoma</u> <u>calcarea</u>	IN	D/F	P	47
<u>Hiatella</u> <u>arctica</u>	E/IN	F	P	3
Point Barrow - 20 m (BRB-20)				
Clayey silt				
<u>Mya</u> <u>pseudoarenaria</u>	IN	F	P	3
<u>Macoma</u> <u>calcarea</u>	IN	D/F	P	12
Point Barrow - 15 m (BRB-15)				
Clayey silt				
<u>Serripes</u> <u>groenlandicus</u>	E	F	P	1
<u>Macoma</u> <u>calcarea</u>	IN	D/F	P	4
Point Barrow - 10 m (BRB-10)				
Silty sand				
<u>Yoldia</u> <u>hyperborea</u>	IN	D	L	5
<u>Yoldia</u> <u>myalis</u>	IN	D	L	3
<u>Axinopsida</u> <u>orbiculata</u>	IN	F	L	45
<u>Montacuta</u> <u>dawsoni</u>	E/IN	D/F	B	32
<u>Mysella</u> <u>planata</u>	?	?	B	6
<u>Serripes</u> <u>groenlandicus</u>	E	F	P	11
<u>Macoma</u> <u>moesta</u>	IN	D/F	L	13
<u>Macoma</u> <u>calcarea</u>	IN	D/F	P	5
<u>Liocyma</u> <u>fluctuosa</u>	IN	F	L	88
<u>Mya</u> <u>pseudoarenaria</u>	IN	F	P	7
<u>Hiatella</u> <u>arctica</u>	E/IN	F	P	4
Point Barrow - 5 m (BRB-5)				
Sand				
<u>Axinopsida</u> <u>orbiculata</u>	IN	F	L	1
<u>Montacuta</u> <u>dawsoni</u>	E/IN	D/F	B	1
<u>Serripes</u> <u>groenlandicus</u>	E	F	P	41
<u>Liocyma</u> <u>fluctuosa</u>	IN	F	L	1

Table 5. (continued)

	Habitat Type	Feeding Type	Larval Type	Number of Individuals
Pitt Point - 25 m (PPB-25)				
Silty clay				
Nucula bellotii	IN	D	L	10
Portlandia arctica	IN	D	L	183
Portlandia lenticula	IN	D	L	3
Nuculana radiata	IN	D	L	4
Arctinula greenlandica	E	F	L	2
Macoma moesta	IN	D/F	L	1
Macoma calcarea	IN	D/F	P	8
Liocyma fluctuosa	IN	F	L	1
Hiatella arctica	E/IN	F	P	1
Pingok Island - 15 m (PIB-15)				
Sandy clay				
Nucula bellotii	IN	D	L	1
Portlandia arctica	IN	D	L	44
Nuculana radiata	IN	D	L	1
Crenella decussata	E	F	L	1
Arctinula greenlandica	E	F	L	12
Astarte montagui	IN	F	L	71
Macoma calcarea	IN	D	P	9
Macoma inflata	IN	D	L	2
Liocyma fluctuosa	IN	F	L	48
Mya pseudoarenaria	IN	F	P	1
Pandora glacialis	E	F	L	9
Lyonsia arenosa	IN	F	L	3
Thracia devexa	IN	F	L	5
Pingok Island - 10 m (PIB-10)				
Clayey sand				
Nucula bellotii	IN	D	L	1
Portlandia arctica	IN	D	L	126
Portlandia intermedia	IN	D	L	5
Arctinula greenlandica	E	F	L	1
Axinopsida orbiculata	IN	F	L	214
Montacuta dawsoni	E/IN	D/F	B	1
Macoma moesta	IN	D	L	5
Macoma calcarea	IN	D	P	1
Liocyma fluctuosa	IN	F	L	4
Pandora glacialis	E	F	L	5
Lyonsia arenosa	IN	F	L	2
Pingok Island - 5 m (PIB-5)				
Clayey sand				
Portlandia intermedia	IN	D	L	2

Table 5. (continued)

	Habitat Type	Feeding Type	Larval Type	Number of Individuals
Narwhal Island - 15 m (NIB-15)				
Clayey sand - gravel and rocks				
Nucula bellotii	IN	D	L	1
Portlandia frigida	IN	D	L	4
Crenella decussata	E	F	L	1
Arctinula greenlandica	E	F	L	7
Axinopsida orbiculata	IN	F	L	7
Astarte montagui	IN	F	L	1
Macoma moesta	IN	D/F	L	1
Macoma calcarea	IN	D/F	P	3
Macoma inflata	IN	D/F	L	2
Pandora glacialis	E	F	L	7
Thracia devexa	IN	F	L	1
Narwhal Island - 10 m (NIB-10)				
Clayey sand				
Portlandia arctica	IN	D	L	1
Arctinula greenlandica	IN	F	L	5
Axinopsida orbiculata	IN	F	L	23
Macoma moesta	IN	D/F	L	1
Macoma calcarea	IN	D/F	P	2
Liocyma fluctuosa	IN	F	L	19
Narwhal Island - 5 m (NIB-5)				
Sand and gravel				
Hiatella arctica	E/IN	F	P	1
Barter Island - 25 m (BAB-25)				
Clayey silt - silty clay				
Nucula bellotii	IN	D	L	6
Portlandia arctica	IN	D	L	50
Portlandia frigida	IN	D	L	1
Portlandia lenticula	IN	D	L	2
Nuculana radiata	IN	D	L	1
Arctinula greenlandica	E	F	L	31
Axinopsida orbiculata	IN	D	L	1
Macoma moesta	IN	D/F	L	7
Barter Island - 20 m (BAB-20)				
Clayey silt and peat				
Nucula bellotii	IN	D	L	11
Portlandia arctica	IN	D	L	35
Portlandia lenticula	IN	D	L	1
Nuculana radiata	IN	D	L	1
Nuculana pernula	IN	D	L	2
Crenella decussata	E	F	L	1
Arctinula greenlandica	E	F	L	22
Axinopsida orbiculata	IN	F	L	152
Macoma moesta	IN	D/F	L	13
Macoma loveni	IN	D/F	L	1
Pandora glacialis	E	F	L	3
Thracia devexa	IN	F	L	1

Table 5. (continued)

	Habitat Type	Feeding Type	Larval Type	Number of Individuals
Barter Island - 15 m (BAB-15)				
Clay silt, silty clay				
Portlandia arctica	IN	D	L	29
Arctinula greenlandica	E	F	L	1
Axinopsida orbiculata	IN	F	L	193
Montacuta dawsoni	E/IN	D/F	B	2
Macoma moesta	IN	D/F	L	16
Macoma calcarea	IN	D/F	P	44
Liocyma fluctuosa	IN	F	L	68
Pandora glacialis	E	F	L	17
Lyonsia arenosa	IN	F	L	8
Barter Island - 10 m (BAB-10)				
Clayey silt, silty sand				
Portlandia arctica	IN	D	L	4
Axinopsida orbiculata	IN	F	L	25
Montacuta dawsoni	E/IN	D/F	B	2
Macoma moesta	IN	D/F	L	3
Macoma calcarea	IN	D/F	P	33
Liocyma fluctuosa	IN	F	L	16
Lyonsia arenosa	IN	F	L	4
Barter Island - 5 m (BAB-5)				
Sand, silty sand, silty clay				
Portlandia arctica	IN	D	L	4
Axinopsida orbiculata	IN	F	L	16
Macoma moesta	IN	D/F	L	2
Liocyma fluctuosa	IN	F	L	2
Cyrtodaria kurriana	E/IN	F	?	10

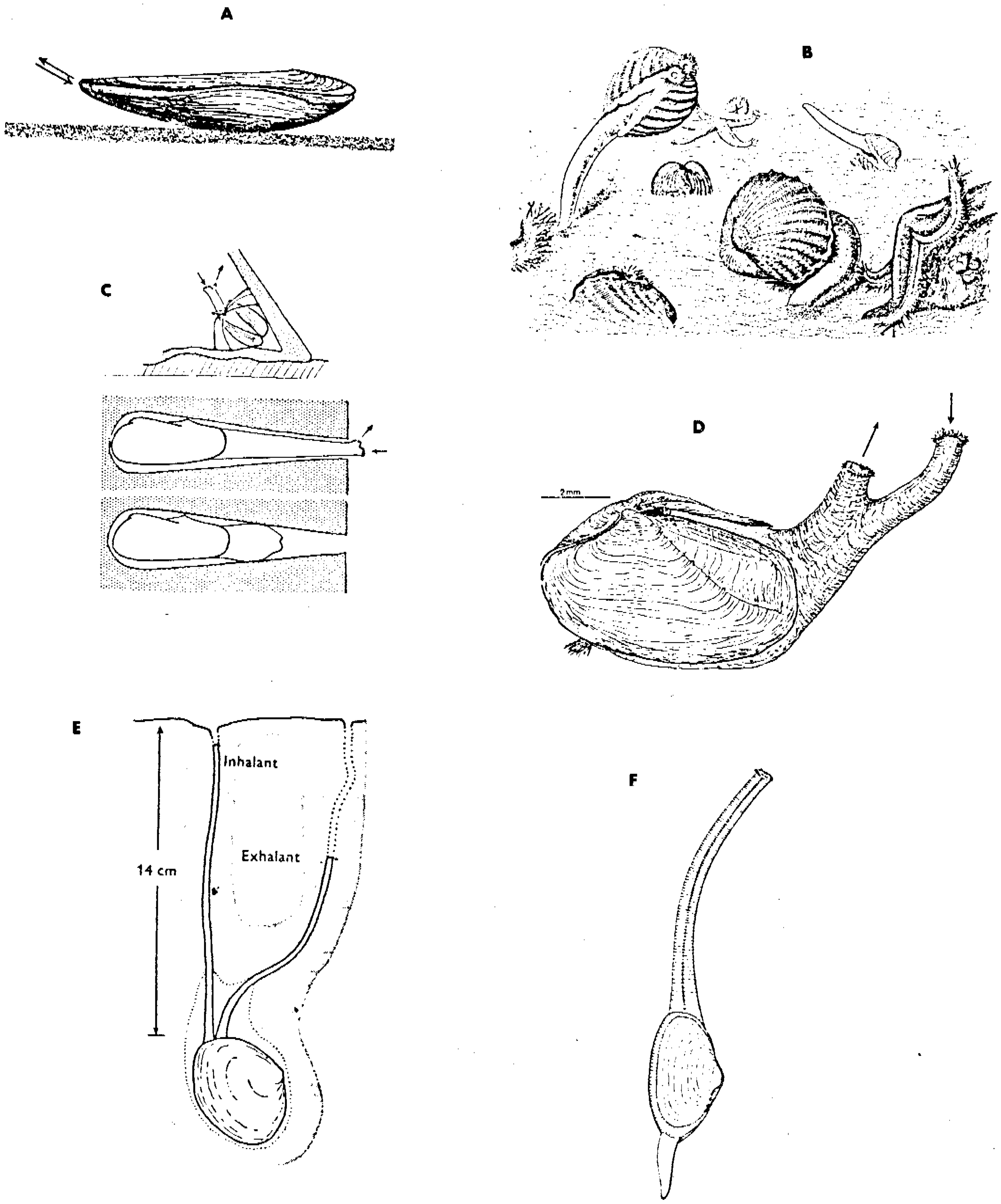

Figure 2: A. The epifaunal bivalve Pandora (from Allen). B. A generalized cockle in epifaunal position (by Thorson). C. Nestling and boring behavior of Hiatella (from Yonge after Russell-Hunter). D. Detail of Hiatella arctica (from Yonge). E. A generalized Macoma with long separated siphons (from Barnes after Hughes). F. The deep burrowing Mya (from Yonge).

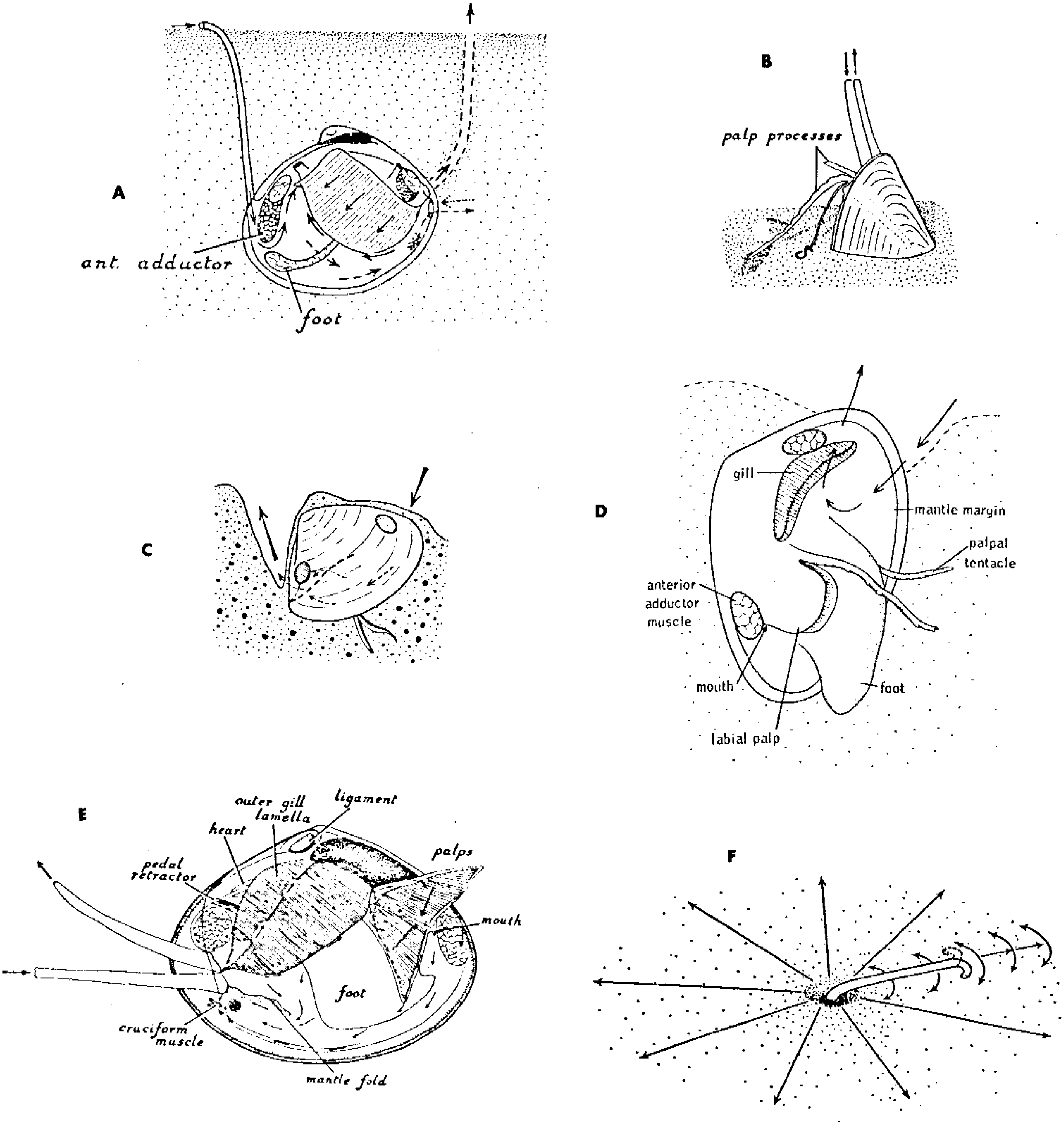

Figure 3: A. Axinopsida in shallow feeding position (by Allen). B. A member of the Nuculanidae in the vertical feeding position (from Yonge after Drew). C. The shallow burrower Nucula (from Yonge). D. The feeding structure of a generalized protobranch (from Barnes after Yonge). E. Feeding and respiratory structures of Macoma (from Yonge). F. The "vacuum cleaner" inhalent siphon of Macoma (from Barnes after Hughes).

the nearshore shallow infauna. Portlandia arctica and other arctic nuculanids are thought to burrow vertically in the sediment with the siphons, palp processes and posterior portion of the shell exposed (Figure 3B). Nucula bellotii is the only other protobranch pelecypod present at the nearshore stations. N. bellotii slowly moves just beneath the sediment surface assisted by a large foot and developed palp processes (Figure 3C). The venus clam, Liocyma fluctuosa, is a shallow burrower with a strong hatchet-shaped foot and moderately short siphons.

Feeding Type

Deposit feeders

The protobranch bivalves Nucula, Nuculana, Portlandia and Yoldia are the most primitive of the deposit feeders. They orient themselves vertically in the sediment with the posterior portion of the shell slightly above or just below the sediment surface (Figures 3B, 3C, 3D). The primary feeding structures of the protobranch pelecypods are the palp processes which are considered to be extensions of the mouth. The palp processes are extended into the organic rich sediment during feeding. The mucus covered processes collect dispositional material and transport the food and sediment to the labial palps with strong ciliary action. The labial palps serve as sorting mechanism which separates the heavy sediment particles from the organic food particles. The lighter organic particles are continually sorted by cilia from the labial palps to the mouth. The sediment is carried in the opposite direction on the palps and is rejected as pseudofeces in the mantle cavity. Protobranchs generally inhabit organic-rich, soft sediments due to this restricted feeding method.

The other major group of deposit feeders is represented by the Macoma species. The bivalves of the genus Macoma have separated siphons which are divided into a long inhalent and a short exhalent siphon (Figure 3E). The long inhalent siphon acts very much like a vacuum cleaner which pulls in the organic-rich detrital material on the sediment surface (Figure 3F). This feeding mode acts as a very efficient method of extracting large amounts of detritus from the less exploited sediment-water interface. The Macoma species also have the ability to filter feed when there are large amounts of organic material in the water (phytoplankton blooms, etc.). This allows a more efficient use of the food resources during different times of the year.

Filter feeders

The advanced lamellibranch bivalves (filter feeders) include the majority of the molluscs present in the nearshore region. Axinopsida orbiculata, Liocyma fluctuosa, Pandora glacialis, Arctinula greenlandica and many others are all members of this group. The primary feeding structures of the lamellibranchs are highly modified gills (ctenidia). The ctenidium (also a respiratory structure) in filter feeders is lengthened and folded which increases the available surface area. Water is transported to the ctenidia by the inhalent siphon and moved along the ctenidia surface by ciliary action. The ctenidia act as a very fine sieve which filters out potential food and transports the mucus covered particles to the mouth. Most lamellibranchs exploit phytoplankton and particulate organics as a food source. The majority of the nearshore filter feeders are shallow burrowers or members of the epifauna.

Larval Development

Three types of bivalve larval development occur in the study area: 1) planktotrophic, 2) internal brooder and 3) lecithotrophic. Of the thirty species present four are planktotrophic, two are internal brooders and the remaining twenty-four species are lecithotrophic.

Macoma calcarea, *Hiatella arctica*, *Mya pseudoarenaria*, and *Serripes groenlandicus* are the only species with planktotrophic larvae. These species develop small eggs (<100μ) which produce larvae that are dependent on plankton as a food source. The four species have an early spawning period which may occur in conjunction with ice break-up and the phytoplankton bloom.

The two montacutid species, *Montacuta dawsoni* and *Mysella planata* are the only known internal brooders in the 5-25 m zone. The eggs of these two species are thought to be fertilized in a brooding chamber in the mantle cavity of adults. The larvae develop in the brood chamber and are released in the juvenile bottom stage.

The species with lecithotrophic larvae dominate the nearshore region. *Axinopsida*, *Portlandia* and *Liocyma* are included in this group. These species are characterized by large yolky eggs (from 120 to 220 microns) which develop with a short or completely absent planktonic stage. Most of the larval development occurs in the benthic habitat. The large egg provides most of the necessary nutrition during this period. The spawning period of the lecithotrophic species seems to occur in July, August and September.

Sampling and Species Accumulation

Five samples were collected with a 0.1 m^2 Smith-McIntyre grab at each station location. After initial washing and preservation, all mollusc fauna retained on a 1.0 mm screen were identified. Figures 4 and 5 represent the species accumulation for the mollusc fauna of the shallow Beaufort Sea. For each of the 17 stations sampled, 5 sample grabs result in the species accumulation curve becoming asymptotic, suggesting an unbiased representation of the total mollusc fauna at that station.

Species Richness

Patterns in the numbers of species and individuals for the 17 stations and 85 samples collected between 5 and 25 m in the Beaufort Sea were examined. Table 6 summarizes the data, and includes the calculated expected number of species ([E(S)] (Hulbert, 1971) and standard deviation of E(S) (Heck, van Belle and Simberloff, 1975) for equivalent numbers of individuals (n). The empirical effect of differing sample sizes of individuals on species numbers and measures of species diversity (Sanders, 1968) is accounted for by E(Sn) allowing for unbiased comparisons of species richness. Earlier the relationship between the number of samples and number of new species, species accumulation, was considered. This relationship indicated that 5 sample grabs at one station were sufficient in most instances for the species accumulation curve to become asymptotic (Figure 4 and 5). Since 5 grabs represent the best estimate of total mollusc fauna from a site, comparisons between stations were considered the most accurate indicator of patterns in mollusc species richness.

Figure 4. Species accumulation curves for the mollusc fauna sampled at 17 stations between 5-25 m in the Beaufort Sea.

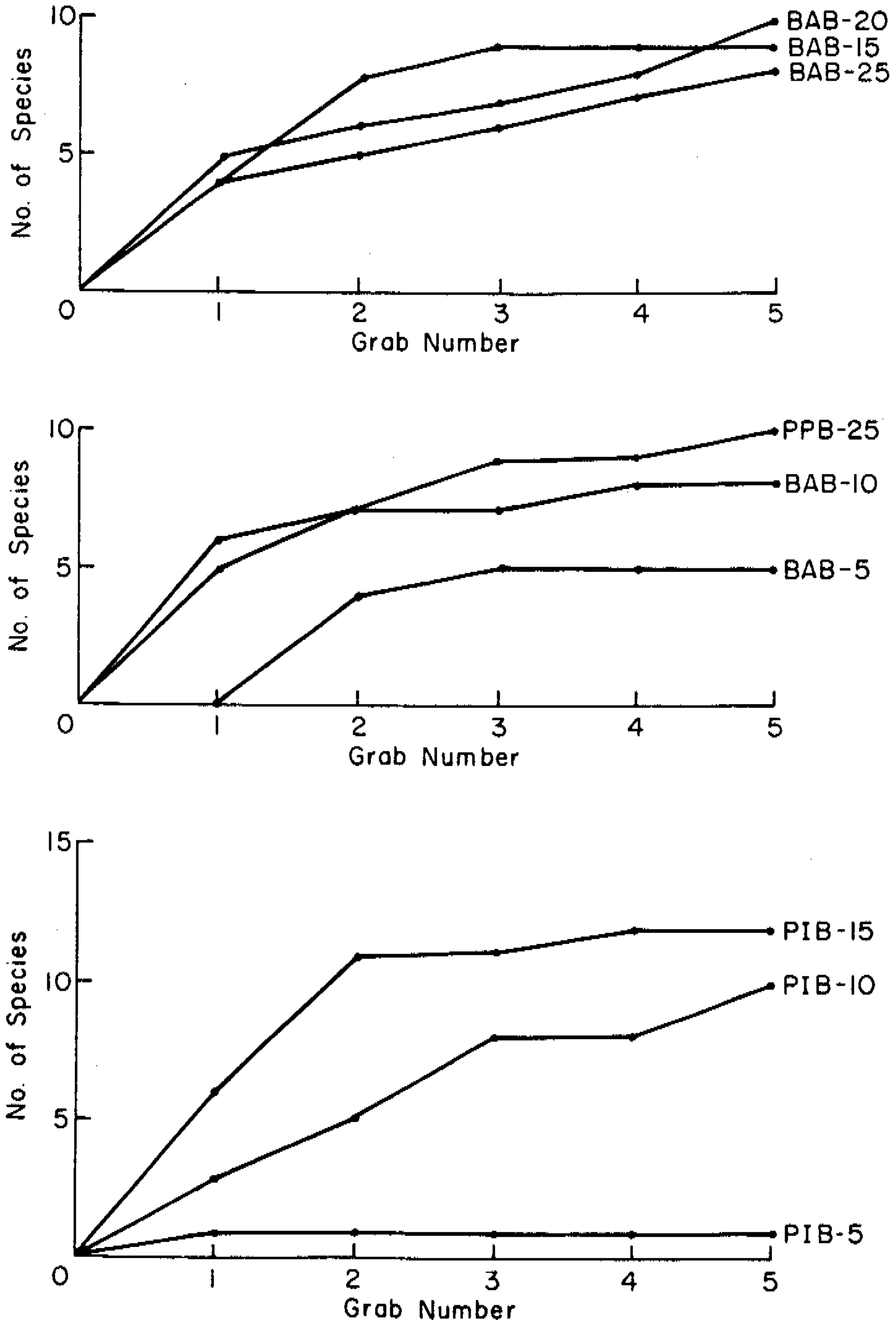

Figure 5. Species accumulation curves for the mollusc fauna sampled at 17 stations between 5-25 m in the Beaufort Sea.

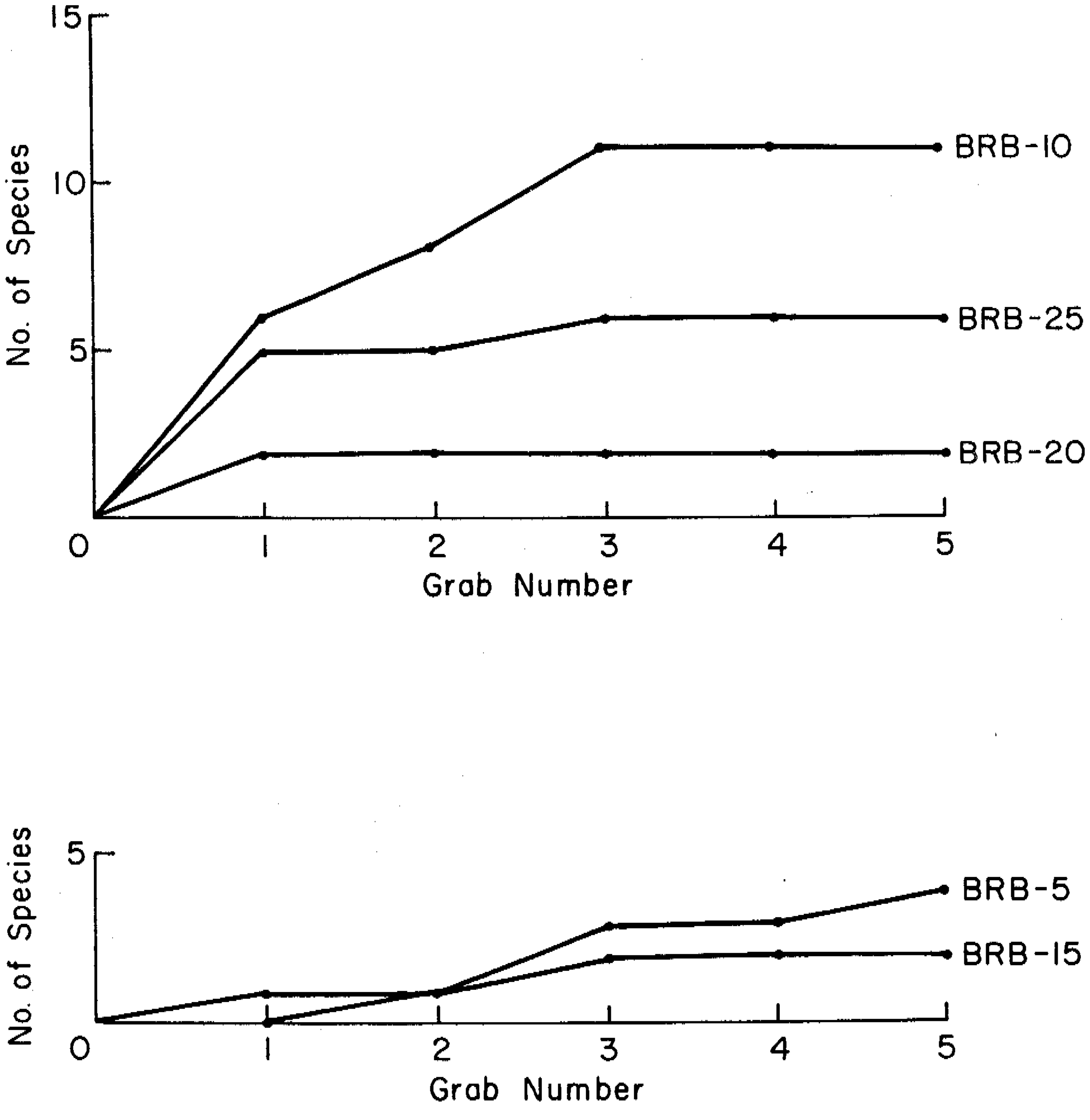

Table 6. Comparative bivalve data for nearshore Beaufort Sea - number of individuals, number of species, and number of experted species at sample sizes of 30 and 50 individuals (Hulbert, 1971; Heck, van Belle and Simberloff, 1975).

Station	Sample	No. of Individuals	No. of Species	Expected No. of Species (N=30)	Expected No. of Species (N=50)
BAB-05	1479	0	0		
	1480	10	4		
	1481	2	2		
	1482	5	2		
	1483	17	5		
Station	Total	34	5		
BAB-10	1473	14	5	4.98(±0.14)	
	1475	5	4		
	1476	26	5		
	1477	11	5		
	1478	31	5	5.00(±0.00)	
Station	Total	87	7	5.94(±0.83)	6.69(±0.51)
BAB-15	1467	29	4		
	1468	119	7	5.32(±0.89)	6.11(±0.70)
	1469	55	4	3.91(±0.29)	3.99(±0.02)
	1470	92	6	5.33(±0.65)	5.77(±0.43)
	1471	83	7	5.58(±0.76)	6.19(±0.69)
Station	Total	378	9	6.04(±0.89)	6.73(±0.75)
BAB-20	1461	16	5		
	1462	16	4		
	1463	10	3		
	1464	21	5		
	1466	181	10	4.92(±1.15)	6.14(±1.16)
Station	Total	244	12	5.82(±1.12)	6.93(±1.19)
BAB-25	1455	22	4		
	1456	23	4		
	1457	19	6		
	1459	7	3		
	1460	28	5		
Station	Total	99	8	5.25(±0.99)	6.25(±0.96)
BRB-05	1389	10	1		
	1390	5	1		
	1392	10	3		
	1393	10	1		
	1394	9	2		
Station	Total	44	4	3.04(±0.79)	
BRB-10	1384	32	6	5.88(±0.34)	
	1385	83	7	5.86(±0.84)	6.63(±0.56)
	1386	71	10	8.31(±0.99)	9.54(±0.59)
	1387	17	8		
	1388	16	7		
Station	Total	219	11	7.76(±1.23)	9.20(±1.07)

Table 6 . (continued)

Station	Sample	No. of Individuals	No. of Species	Expected No. of Species (N=30)	Expected No. of Species (N=50)
BRB-15	1377	0	0		
	1378	2	1		
	1379	3	2		
	1381	0	0		
	1382	0	0		
Station Total		5	2		
BRB-20	1371	15	2		
	1372	0	0		
	1374	0	0		
	1375	0	0		
	1376	0	0		
Station Total		15	2		
BRB-25	1365	28	5		
	1366	10	3		
	1367	11	1		
	1368	5	2		
	1369	3	1		
Station Total		57	6	4.63(±0.89)	5.73(±0.47)
NIB-05	1437	1	1		
	1439	0	0		
	1440	0	0		
	1441	0	0		
	1442	0	0		
Station Total		1	1		
NIB-10	1450	1	1		
	1451	1	1		
	1452	28	5		
	1453	3	2		
	1454	20	5		
Station Total		53	7	5.75(±0.86)	6.88(±0.33)
NIB-15	1443	4	4		
	1445	8	5		
	1446	5	2		
	1447	3	1		
	1448	15	8		
Station Total		35	12	10.27(±0.74)	
PIB-05	1419	1	1		
	1420	0	0		
	1421	1	1		
	1423	0	0		
	1424	0	0		
Station Total		2	1		

Table 6 . (continued)

Station	Sample	No. of Individuals	No. of Species	Expected No. of Species (N=30)	Expected No. of Species (N=50)
PIB-10	1425	46	3	2.65(±0.48)	
	1426	64	5	3.41(±0.85)	4.34(±0.70)
	1427	110	5	3.16(±0.78)	3.75(±0.78)
	1429	101	7	4.06(±1.02)	5.11(±1.00)
	1430	100	7	3.71(±1.02)	4.75(±1.06)
Station Total		422	10	3.42(±1.02)	4.23(±1.18)
PIB-15	1432	22	6		
	1433	54	11	8.31(±1.18)	10.62(±0.57)
	1434	30	6	6.00(±0.00)	
	1435	51	9	7.12(±1.03)	9.00(±0.00)
	1436	50	9	7.19(±1.02)	9.00(±0.00)
Station Total		207	13	7.15(±1.22)	8.52(±1.22)
PPB-25	1281	54	6	3.78(±1.07)	5.63(±0.56)
	1282	24	5		
	1283	31	3	3.00(±0.00)	
	1284	39	4	3.67(±0.51)	
	1285	69	7	5.12(±1.02)	6.43(±0.45)
Station Total		217	10	3.97(±1.14)	5.11(±1.16)

Actual numbers of species observed between stations were relatively low in comparison to other benthic taxa sampled in the Beaufort Sea (Ruff, pers. comm.). Along with the limited area sampled, 5 to 25 m, this would suggest few recognizable differences in numbers of species between stations. To test this, variation in E(Sn) was examined for both a depth and latitudinal gradient. Results of both parametric and non-parametric analysis of variance substantiate the impression of no significant difference in the numbers of species between stations for either depth or transect (latitudinal) groups (Table 7). These results are reinforced due to the increase in experimental error from employing two one-way analyses instead of a two-way design, a procedure necessitated by the unbalanced data set. Failure to reject the null hypothesis of no difference in species numbers either by depth or transect with increased Type I error is therefore a very conservative test. Any difference in species richness for the region could exist on scales smaller than the sampling regime or in a manner less systematic than by depth or latitude. Preliminary sediment results suggest a highly heterogeneous environment making both sample scale and systematic explanations possible.

Compositional Similarity

Deterministic

The distribution of mollusc species was examined for the 17 stations and 31 species sampled in an attempt to identify 'biologically meaningful groups.' Similarities between pairwise comparisons of all stations and species were calculated using Jaccard (1908), Dice (1945) and Menzies (1973) indicies. Results for these indicies correlated well with each other as do various measures of similarity reported in the literature (Goodall, 1966; Sepkoski and Rex, 1974). The similarity values between stations or species were then clustered by a single-linkage algorithm (Anderberg, 1973). Trellis diagrams for both species and station clusterings using the Jaccard index of similarity were constructed (Figure 6 and 7). For the station by station comparison based on species composition (Figure 6) it appears there are only two groups that form at similarity values greater than 0.5: BAB-25, BAB-20, PPB-25, NIB-15 and BAB-15, BAB-10, PIB-10, NIB-10, BAB-05. Species associations were more complex, three groups being identifiable at similarities greater than 0.5: 008-111, 028-010 and 018-217. The largest of these groups, 018-217, seems to be divided into three smaller subgroups. Species identification for the coded values and possible groupings are shown in Table 8.

Results of the station and species clusterings are unclear. It is possible to suggest a deeper-water mollusc fauna for the region studied based on the two groups generated for the station similarities, but there is no test of this hypothesis. The same is true for the proposed species associations. The nature of similarity techniques and clustering strategies (Simberloff and Connor, 1979) makes an objective interpretation of the station or species groups unclear.

Probablistic

A major difficulty with the use of most similarity indicies, and the clustering/ordination techniques which employ them, has been the lack of a null hypothesis against which results may be tested (Connor and Simberloff, 1978; Raup and Crick, 1979). This difficulty was evident in the last section where station or species groups must be judged as representing real differences in distributions on purely arbitrary criteria. The credibility of these groups rests on the differences in the Jaccard index, or any other, having objective

Table 7. Parametric and non-parametric analysis of variance for the number of mollusc species between 5 and 25 m in the Beaufort Sea.

Comparison	Variables	Test	F	χ^2	P
By Station	$E(S_{30})$ By Depth	ANOVA	2.417		.1061
		K-W		7.899	.095
	$E(S_{50})$ By Depth	ANOVA	3.206		.0523
		K-W		6.737	.150
	$E(S_{30})$ By Transect	ANOVA	0.261		.8974
		K-W		1.394	.845
	$E(S_{50})$ By Transect	ANOVA	0.405		.8013
		K-W		1.510	.825

Figure 6. Station clustering for mollusc fauna based on Jaccard similarities.

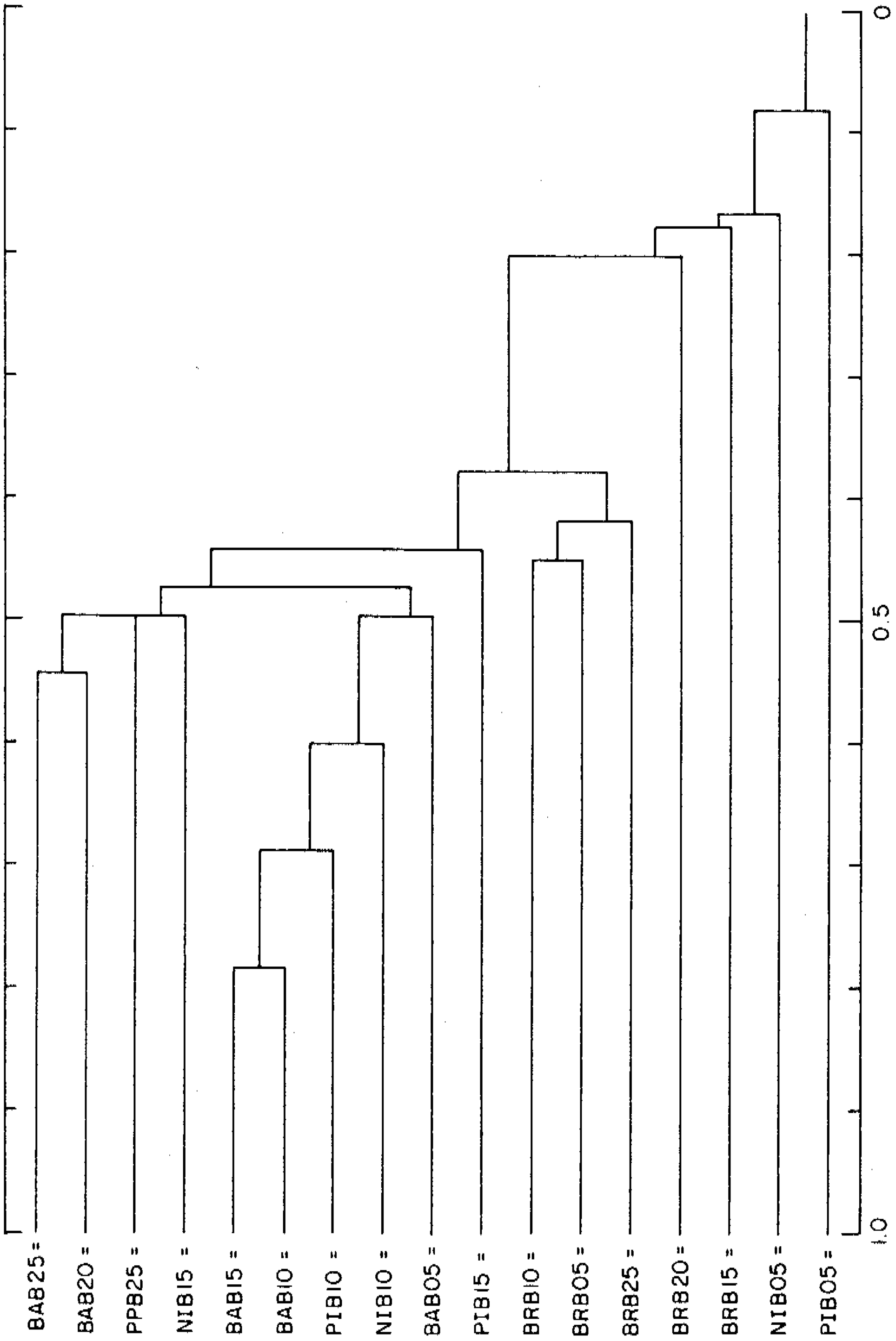

Figure 7. Species clustering for the mollusc fauna based on Jaccard similarities

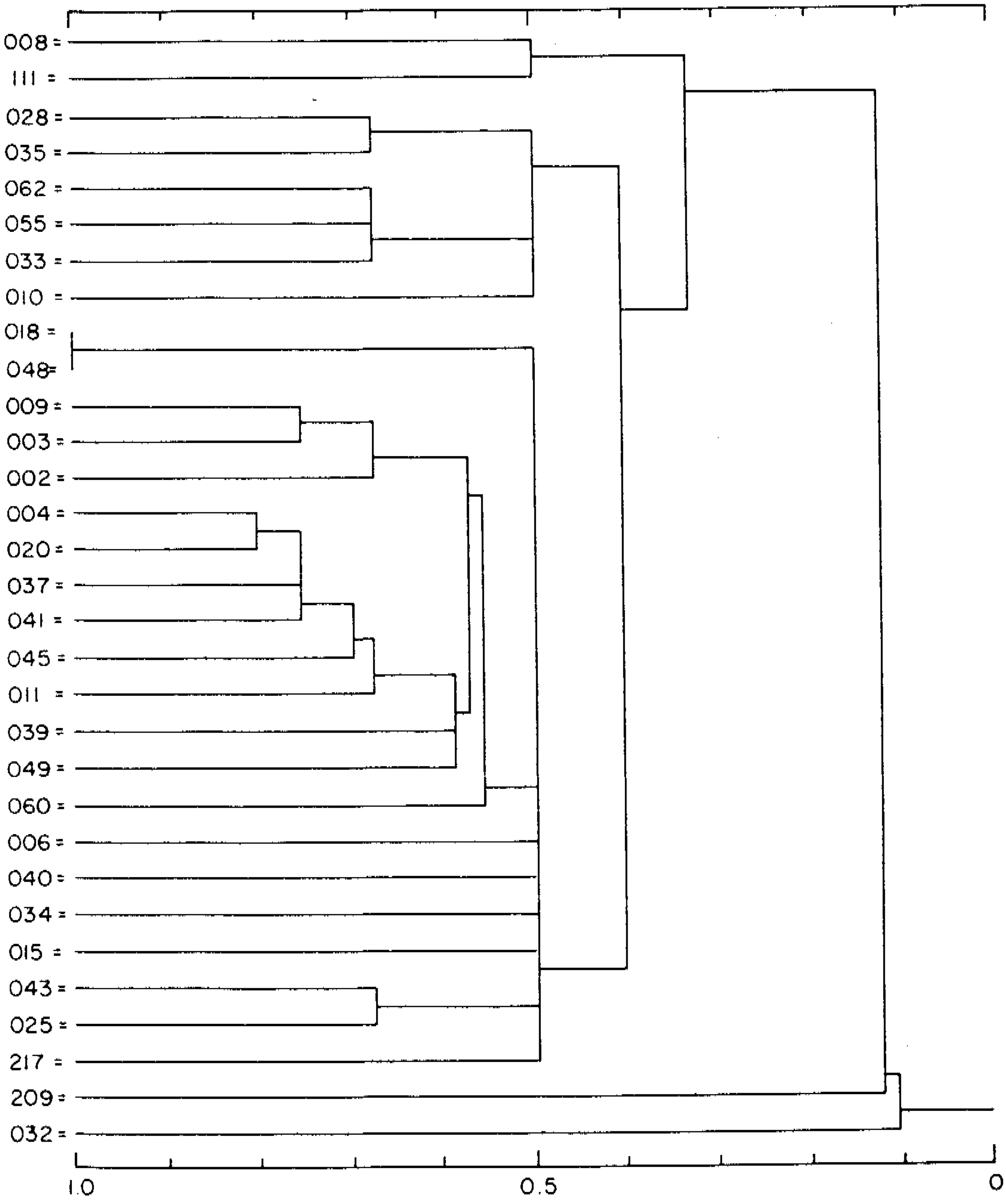

Table 8. Species groups and identification from Figure 7 constructed using Jaccard similarities and a single-linkage clustering algorithm

Group I	
008	*Portlandia intermedia*
111	*Macoma inflata*
Group II	
028	*Serripes groenlandicus*
035	*Mysella planata*
062	*Yoldia myalis*
055	*Mya pseudoarenaria*
033	*Hiatella arctica*
010	*Yoldia hyperborea*
Group III	
060	*Montacuta dawsoni*
006	*Portlandia frigida*
040	*Macoma loveni*
034	*Lyonsia arenosa*
015	*Crenella decussata*
043	*Thracia devexa*
025	*Astarte montagui*
Subgroup 1	
009	*Portlandia lenticula*
003	*Nuculana radiata*
002	*Nuculana pernula*
Subgroup 2	
018	*Musculus niger*
048	*Thyasira gouldii*
Subgroup 3	
004	*Portlandia arctica*
020	*Arctinula greenlandicus*
037	*Pandora glacialis*
041	*Macoma moesta*
045	*Axinopsida orbiculata*
011	*Nucula bellotii*
039	*Macoma calcarea*
049	*Liocyma fluctuosa*
Misc.	
209	*Boreacola vadossa*
032	*Cyrtodaria kurriana*

meaning. This objective meaning cannot be demonstrated (Connor and Simberloff, 1978, Simberloff and Connor, 1980). The arbitrary nature of similarity indicies and clustering/ordination strategies has led to the proposal of numerous alternative approaches to viewing compositional similarity, many based on a probabilistic hypothesis (Harper, 1977; Simberloff, 1978; Raup and Crick, 1979).

The null hypothesis proposed to account for the distribution of mollusc species among stations was the same Null Hypothesis I of Connor and Simberloff (1978). As stated, the observed number of species in common between two stations is no different than would be expected if the species composition of the stations was determined by randomly assigning species from a 'common pool.' To test this null hypothesis it is assumed that a common species pool for the area of interest can be defined, and that each species from that pool is equally likely to be found at any station. The first assumption, definition of a species pool, can be minimized by consideration of the species accumulation curves for the shallow water region (Figure 4 and 5). A total of 36 species represents the extant mollusc fauna of the region. Although this ignores possible immigrants from outside the area, it is not felt this greatly biases the results (Walters, in prep.). Assuming that these 36 species are equally likely to inhabit any station in the region is a simplistic, if not unrealistic, assumption. Since non-probabilistic indicies of similarity make this assumption for presence/absence data, results of the probabilistic index represent a baseline for comparison (Simberloff, 1978).

Table 9 lists the results for the pairwise comparison of all shallow water stations. The upper half of the matrix are values of the observed number of species in common (OBS), the expected number in common under the null hypothesis (EXP), and the normalized test statistic (OBS-EXP/SD_e (standard deviation of the expected)). An asterisk indicates whether observed values are significantly different than expected as determined by the test statistic. The lower half of the matrix are values of the Jaccard index calculated between stations, an asterisk indicating greater than or equal to 0.50. A summary of the pairwise station comparisons is presented in Table 10, results partitioned into depth and latitudinal groups as well as an overall comparison for the region.

A conservative test of the null hypothesis that species distributions are the result of stochastic persistence and dispersal would be to assume that 50% of the possible pairwise station comparisons would show expected values greater than observed and 50% would show expected values less than observed (Connor and Simberloff, 1978). A χ^2 test of this (Table 10) indicates that the null hypothesis should be rejected for the mollusc species of the shallow water Beaufort Sea, although in 74% of all comparisons observed numbers of species in common are not significantly different ($P<0.05$) from expected. Reasons for rejection of the null hypothesis can be directly related to the original assumptions of definable species' pool and equiprobable species' dispersal (Connor and Simberloff, 1978). Perhaps more important than rejection of the null hypothesis for the entire region is an understanding of the large percentage (74%) of comparisons that resulted in no significant difference between observed and expected values. To address this, stations were grouped by depth or latitude as was done earlier for a consideration of species richness. Results of between depth or latitude groups were then compared (Table 10). χ^2 tests between depth groups resulted in rejection of the null hypothesis for 3 of the 5 station depths. Tests between transects resulted in rejection of the null hypothesis for only the BAB comparisons. Combined with the results of the overall regional comparison, it appears that only a small percentage of the stations examined have similar species contents greater than would be expected if the mollusc fauna of the region was randomly distributed.

Table 9: Compositional similarity of mollusc species for the 17 shallow water Beaufort Sea stations. The upper triangular half matrix consist of observed, expected (in parentheses), and OBS-EXP/SD, asterisks indicating these comparisons significantly greater than expected (P<.05)* lower triangular matrix are Jaccard similarities, asterisks indicating those comparisons ≥0.5.

	BAB-05	BAB-10	BAB-15	BAB-20	BAB-25	PIB-05	PIB-10	PIB-15	BRB-05	BRB-10	BRB-15	BRB-20	BRB-25	NIB-05	NIB-10	NIB-15	PPB-25
BAB-05	-- -- --	4 (0.97) 3.64*	4 (1.25) 3.02*	3 (1.67) 1.34	3 (1.11) 2.16*	0 (0.14) -.40	4 (1.81) 2.17*	2 (1.53) 0.49	2 (0.69) 1.79	3 (1.53) 1.52	0 (0.28) -.58	1 (0.14) 2.49*	1 (0.83) 0.21	0 (0.14) -.40	4 (0.97) 3.64*	3 (1.67) 1.34	3 (1.81) 1.18
BAB-10	0.50 *	-- -- --	7 (1.75) 5.03*	3 (2.33) 0.59	3 (1.56) 1.44	0 (0.19) -.49	7 (2.53) 3.87*	4 (2.14) 1.68	3 (0.97) 2.43*	5 (2.14) 2.58*	1 (0.39) 1.11	1 (0.19) 2.04*	2 (1.17) 0.93	0 (0.19) -.49	5 (1.36) 3.82*	4 (2.33) 1.47	4 (2.53) 1.27
BAB-15	0.40	0.78 *	-- -- --	5 (3.00) 1.61	4 (2.00) 1.83	0 (0.25) -.58	9 (3.25) 4.54*	6 (2.75) 2.68*	3 (1.25) 1.92	5 (2.75) 1.85	1 (0.50) 0.83	1 (0.25) 1.73	2 (1.50) 0.51	0 (0.25) -.58	6 (1.75) 4.08*	6 (3.00) 2.42*	6 (3.25) 2.17*
BAB-20	0.21	0.19	0.31	-- -- --	7 (2.67) 3.63*	0 (0.33) -.71	7 (4.33) 1.94	6 (3.67) 1.77	1 (1.67) -.67	2 (3.67) -1.26	0 (0.67) -1.01	1 (0.33) 1.41	2 (2.00) -.00	0 (0.33) -.71	4 (2.33) 1.47	8 (4.00) 2.96*	8 (4.33) 2.66*
BAB-25	0.30	0.25	0.31	0.54 *	-- -- --	0 (0.22) -.53	5 (2.89) 1.74	4 (2.44) 1.33	1 (1.11) -.13	2 (2.44) -.38	0 (0.44) -.77	1 (0.22) 1.87	2 (1.33) 0.71	0 (0.22) -.53	4 (1.56) 2.44*	6 (2.67) 2.80*	7 (2.89) 3.38*
PIB-05	0.00	0.00	0.00	0.00	0.00	-- -- --	1 (0.36) 1.33	0 (0.31) -.66	0 (0.14) -.40	0 (0.31) -.66	0 (0.06) -.24	0 (0.03) -.17	0 (0.17) -.45	0 (0.03) -.17	0 (0.19) -.49	0 (0.33) -.71	0 (0.36) -.75
PIB-10	0.29	0.54	0.69	0.39	0.31	0.08	-- -- --	7 (3.97) 2.25*	3 (1.81) 1.18	5 (3.97) 0.76	1 (0.72) 0.41	1 (0.36) 1.33	3 (2.17) 0.77	0 (0.36) -.75	6 (2.53) 3.00*	8 (4.33) 2.66*	7 (4.69) 1.64
PIB-15	0.14	0.29	0.43	0.35	0.27	0.00	0.41	-- -- --	1 (1.53) -.54	3 (3.36) -.28	1 (0.61) 0.61	0 (0.31) -.66	3 (1.83) 1.12	0 (0.31) -.66	4 (2.14) 1.68	7 (3.67) 2.52*	7 (3.97) 2.25*
BRB-05	0.25	0.33	0.27	0.06	0.08	0.00	0.20	0.07	-- -- --	5 (1.53) 3.58*	1 (0.28) 1.50	0 (0.14) -.40	1 (0.83) 0.21	0 (0.14) -.40	2 (0.97) 1.23	1 (1.67) -.67	1 (1.81) -.80
BRB-10	0.23	0.38	0.33	0.10	0.12	0.00	0.26	0.16	0.45	-- -- --	2 (0.61) 2.16*	1 (0.31) 1.51	5 (1.83) 3.03*	1 (0.31) 1.51	4 (2.14) 1.68	3 (3.67) -.50	3 (3.97) -.72
BRB-15	0.00	0.13	0.10	0.00	0.00	0.00	0.07	0.08	0.17	0.18	-- -- --	0 (0.06) -.24	1 (0.33) 1.28	0 (0.06) -.24	1 (0.39) 1.11	1 (0.67) 0.51	1 (0.72) 0.41
BRB-20	0.20	0.14	0.11	0.08	0.13	0.00	0.08	0.00	0.00	0.09	0.00	-- -- --	0 (0.17) -.45	0 (0.03) -.17	1 (0.19) 2.04*	1 (0.33) 1.41	1 (0.36) 1.33
BRB-25	0.10	0.18	0.15	0.13	0.17	0.00	0.19	0.21	0.10	0.42	0.14	0.00	-- -- --	1 (0.17) 2.24*	2 (1.17) 0.93	3 (2.00) 0.94	2 (2.17) -.15
NIB-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.17	-- -- --	0 (0.19 -.49	0 (0.33) -.71	0 (0.36) -.75
NIB-10	0.50	0.56	0.60	0.27	0.36	0.00	0.43	0.29	0.20	0.29	0.13	0.14	0.18	0.00	-- -- --	5 (2.33) 2.35*	5 (2.53) 2.14*
NIB-15	0.21	0.27	0.40	0.50	0.43	0.00	0.47	0.44	0.06	0.15	0.08	0.08	0.20	0.00	0.36	-- -- --	7 (4.33) 1.94
PPB-25	0.20	0.25	0.38	0.47	0.50 *	0.00	0.37	0.41	0.06	0.14	0.07	0.08	0.12	0.00	0.33	0.39	-- -- --

Table 10: Summary of results obtained under the null hypothesis for comparison of observed (OBS) and expected (EXP) values of the number of mollusc species shared between stations. X^2 values and significance given for test of observed values evenly distributed above and below expected values

Station Comparison	No. of Pairwise Comparisons	OBS>EXP	OBS>EXP (P<.05)	OBS<EXP	OBS<EXP (P<.05)	OBS=EXP (P<.05)	X^2	P
By Depth								
5x5-25m	58	23	8(14%)	35	0	50(86%)	2.48	>.05
10x5-25m	58	47	20(34%)	11	0	38(66%)	22.34	<.001
15x5-25m	58	41	15(26%)	17	0	43(74%)	9.93	<.01
20x5-25m	31	19	6(19%)	12	0	25(81%)	1.58	>.05
25x5-25m	45	32	11(24%)	13	0	34(76%)	8.02	<.01
By Transect								
BABxBAB-PPB	70	52	23(33%)	18	0	47(67%)	16.51	<.001
PIBxBAB-PPB	45	25	9(20%)	20	0	36(80%)	0.56	>.05
BRBxBAB-PPB	70	43	9(13%)	27	0	61(87%)	3.66	>.05
NIBxBAB-PPB	45	27	14(24%)	18	0	31(56%)	1.80	>.05
PPBxBAB-PPB	16	11	5(31%)	5	0	11(69%)	2.25	>.05
All Stations	136	89	35(26%)	47	0	101(74%)	12.97	<.001

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C. Beaufort Sea Nearshore Polychaetes

The feeding modes, mechanisms, and locomotory capabilities of the polychaetous annelids collected in 1976 in nearshore waters (5-25 m) from the R/V ALUMIAK are under current investigation. This total data set encompasses nearly 17,000 individuals which include 99 polychaete species taken at 21 separate stations (105 grab samples) between Point Barrow and Barter Island. For the sake of manageability, only the seven most abundant species are being examined from three shallow-water areas along the coast (Pt. Barrow region, Pitt Point, and off Barter Island). These seven species encompass about two thirds of the total polychaete collection, and their distribution in the three nearshore regions is shown in Table 11.

Minuspio nr cirrifera
family - SPIONIDAE
discreetly motile surface deposit feeder
4883 specimens examined - 28.7% of the total collection

This small spionid feeds from surface deposits using a pair of ciliated palps to select appropriately sized and organic rich particles from the substrate (Fauchald and Jumars, 1979). The particles are transported along the palps to prostomial tracts where they are either channeled to the mouth or rejected over the lip. This species resides in a mud tube during feeding, but it is capable of leaving the tube and rebuilding elsewhere when environmental conditions deteriorate (Fauchald and Jumars, 1979).

Cistenides hyperborea
family - PECTINARIIDAE
motile sub-surface deposit feeder
1768 specimens examined - 10.4% of the total collection

The pectinariids are characterized by stout, stiff paleal setae which are used to burrow into mud or silty sediments. These worms reside in open-ended sand tubes oriented head-down with the posterior narrow opening of the tube projecting above the sediment surface. Cistenides is a selective deposit feeder, preferring organic-encrusted particles, flocculent organic aggregates, faecal pellets (Whitlatch, 1974) or small infaunal organisms (Schäfer, 1972). Although this species is motile, it appears that the amount of movement is dictated by the environmental conditions. A high degree of mobility is observed when these worms encounter coarse, well aerated, food-poor sediments, while little or no motion is seen in areas where the substrates are fine-grained, oxygen-poor but nutrient-rich (Fauchald and Jumars, 1979).

Ampharete vega
Family - AMPHARETIDAE
sessile surface deposit feeder
1103 specimens examined - 6.5% of the total collection

Ampharete vega is a tube-dwelling surface deposit feeder which uses short ciliated tentacles to pick up food particles. This worm is sessile, living in a permanent mucus-lined tube which projects at an angle above the substrate, allowing the worm to spread its feeding tentacles across the sediments. Examination of the gut contents of similar ampharetid species has revealed a diet of unicellular algae, larval invertebrates, and detritus (Fauvel, 1897; Hessle, 1925).

Although A. vega is sessile, there is some evidence that the worm can move into different areas through a process of continuous horizontal tube building

Table 11. The numerical abundance of seven polychaete species in the shallow water regions (5-25m) off Point Barrow, Pitt Point and Barter Island in the Beaufort Sea.

	Point Barrow	Pitt Point	Barter Island
Minuspio nr *cirrifera*	7	784	768
Cistenides hyperborea	1754	8	6
Ampharete vega	2	270	267
Tharyx sp.	49	136	558
Chone sp.	19	289	142
Spio theeli	198	545	4
Micronephthys minuta	191	109	301

(Fauvel, 1897; Fauchald and Jumars, 1979). This form of locomotion may be initiated by a low food available as an effort to reach a more hospitable environment.

Tharyx sp.

family - CIRRATULIDAE
mobile surface deposit feeder
910 specimens examined - 5.4% of the total collection

This cirratulid is constructed on a plan similar to that of Minuspio, with a pair of ciliated feeding palps used to select particles from the surface of the sediments. This species is motile and is often found in muddy crevices, beneath rocks or in algal holdfasts (Kennedy, 1978).

Chone sp.

family - SABELLIDAE
sessile filter feeder
832 specimens examined - 4.9% of the total collection

In general, the sabellids are tubicolous polychaetes which have the prostomium and peristomium modified into a ciliated tentacular crown. These worms are selective feeders, preferring small invertebrates, larvae, and unicellular organisms such as diatoms and dinoflagellates which are filtered from the water column (Fauchald and Jumars, 1979). Observations indicate that some species are also capable of sweeping the surface of the surrounding sediments (Day, 1967).

Members of the subfamily Fabriciinae, including Chone sp., are capable of movement when necessary. Aquarium observations show that these worms can move across the sediment in a posterior-end first mode, and can construct tubes in new locations (Day, 1967; Lewis, 1968).

Spio theeli

family - SPIONIDAE
discreetly motile surface deposit feeder
749 specimens examined - 4.4% of the total collection

This species is very similar in both structure and functioning to the previously discussed spionid and cirratulid species.

Micronephthys minuta

family - NEPHTYIDAE
motile carnivore
680 specimens examined - 4.0% of the total collection

Micronephthys is a small predator which is adapted for burrowing through muds and silts, and is capable of very rapid movements (Pettibone, 1963). This species is equipped with an eversible proboscis bearing soft terminal papillae and a pair of chitinized, hooked jaws. Usual prey items include small molluscs, crustaceans, and other polychaetes (Fauchald and Jumars, 1979).

Discussion

The above seven species comprise approximately 65% of the total polychaete fauna collected from the shallow Beaufort Sea (5-25 m) between Point Barrow and Barter Island. Of these, four species (Minuspio nr cirrifera, Ampharete vega, Tharyx sp., and Spio theeli) are recognized as selective surface deposit feeders, one species (Chone sp.) is classified as a selective filter feeder, one species (Cistenides hyperborea) is a selective sub-surface deposit feeder, and one species (Micronephthys minuta) is a carnivore. It should be noted that evidence exists which suggests that Chone sp. is also capable of selective surface deposit feeding. Also of interest is the observation that Cistenides, the subsurface feeder, occurs almost exclusively at the Barrow station (taken to the west of the point) and is virtually absent from the Beaufort Sea proper. It can be stated, then, that in the Beaufort Sea nearshore benthic environment, selective surface deposit feeding is the dominant feeding mode exhibited by the polychaetous annelids, with carnivory playing a much less significant role. This is indicative of an environment where there are inputs of organics from the overlying water column, and/or where the sedimentary detritus provides a substrate for active bacterial growth.

All of the species examined exhibit some degree of motility. Even the two species which are normally classified as sessile (Ampharete vega and Chone sp.) are able to move some distance laterally, either by tube extension or by reconstruction of a new tube elsewhere. It appears, then, that a premium is placed on a locomotory capability indicating an environment which may periodically become inhospitable for the nearshore polychaete species.

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D. Size Frequency Determinations

1. Size frequency measurements of the pelecypod mollusc *Nucula bellotii*.

The height and length of the bivalve *Nucula bellotii* has been measured for specimens taken in OCS cruises 1 through 7 (Table 12). A preliminary look at the data shows probable differences in size class structure in the three standard Pitt Point benthic stations (Figure 8). The intermediate station, Pitt Point - 55 m, has been used for more detailed analysis. Figure 9 represents the change and size structure over time for PPB-55.

2. Size frequency measurements on polychaetous annelids.

Length measurements have been initiated on four species of polychaetes, including:

Micronephthys minuta	-	a soft-substrate carnivore
Pholoe minuta	-	a hard-substrate carnivore
Terebellides stroemi	-	a surface deposit feeder
Sternaspis scutata	-	a sub-surface deposit feeder

These species were selected for having broad distributions across the Beaufort Sea continental shelf, for being fairly abundant and for representing a cross-section of the various feeding types.

In the laboratory effort to measure specimens of *Micronephthys minuta*, it was found to be much easier to measure just the anterior portion rather than try to straighten out the individuals for total length measurements. It has been determined that the length of the first 12 setigers in *M. minuta* is proportional to the total worm length (Figure 10), and the 12 setiger measurement will be used for future analyses of this species. Similar methods will be employed for the other polychaete species if statistically significant anterior length:total length relationships are found.

Table 12. Size frequency measurements in millimeters for the pelecypod mollusc <u>Nucula bellotii</u> from cruises OCS-1 through OCS-7. s denotes specimens from the 0.5 mm-1.0 mm fraction; q denotes quartered subsamples; h denotes half subsamples.

Cruise Station	SMG #	Height	Length	Height	Length	Height	Length	Height	Length	Height	Length
OCS-1											
PPB-25	1082	7.4	9.4	3.1	4.1						
	1082s	0.7	0.7	0.6	0.7	1.1	1.4				
	1083	3.7	4.6	1.6	2.1	4.1	5.4				
	1084	5.8	7.2	3.8	4.8						
	1084s	0.8	0.9	0.6	0.7	0.9	1.1				
	1085	4.4	5.4	4.9	6.6						
PPB-55	1088	1.7	2.2	1.1	1.3	2.2	3.0				
	1090	2.7	3.4	3.2	6.9						
	1091	1.6	2.0	2.6	3.4						
	1092	6.0	7.7	1.0	1.3						
	1092sq	0.6	0.7	0.7	0.8						
PPB-100	1093	5.9	7.9	0.8	1.0	1.0	1.4	1.4	1.8	1.6	1.9
		1.5	1.8	1.7	2.0	1.9	2.4	2.7	3.5	1.0	1.3
		1.9	2.3	1.5	2.0	0.9	1.2	2.4	2.8		
	1093sq	0.8	0.9								
	1094	2.1	2.8								
	1094s	0.9	1.2	1.4	1.2	0.7	1.0	0.6	0.7	1.1	1.3
		1.4	1.8								
	1095	8.7	11.0	2.6	3.3	1.3	1.6	1.6	2.1	0.8	1.1
	1095sq	1.0	1.4	1.0	1.3						
	1096	9.3	11.7	1.4	1.8	1.3	1.7	2.0	2.4		
	1096sq	0.9	1.1	0.7	1.0	0.6	0.8	0.7	0.8		
OCS-2											
PPB-25	1098	1.1	1.4	2.4	3.0						
	1099	5.4	6.6								
	1099s	0.7	0.8								
	1101	8.4	10.2	7.0	8.7						
	1102	2.8	2.9								
	1104	6.6	7.8								
	1107	4.1	4.8	6.6	7.9	5.1	6.5				
PPB-40	1118	2.2	2.9								
	1120	2.7	3.4	3.0	3.7						

Table 12. (continued)

PPB-55	1121	4.1	5.2								
	112.sq	0.6	0.7								
	1122	4.1	5.7	3.0	3.8						
	1123	1.4	1.8	4.7	5.7						
	1123sq	0.6	0.7								
	1126	4.1	5.1	2.2	2.5	7.0	8.5	6.7	7.9		
	1127	4.3	5.5								
	1130	1.2	1.4	1.8	2.2	1.7	2.2				
	1130sq	0.7	0.8								
PPB-70	1108	3.8	4.4	4.2	5.3	4.3	5.3	1.5	1.9	3.0	3.9
	1109	2.7	3.6	0.7	0.9	0.9	1.2	0.9	1.0	3.0	3.9
		4.0	5.1								
	1110	5.6	7.3	1.9	2.6	2.2	2.6				
	1111	1.5	2.1	5.6	7.3	2.3	2.8	1.5	1.7		
	1114	2.0	2.4	4.1	5.1	1.4	1.8	5.6	6.9		
PPB-100	1131	2.9	3.4	1.4	1.7	1.6	2.0	1.3	1.7	1.8	2.2
		1.8	2.4	1.1	1.4	1.8	2.3				
	1131sq	1.0	1.2								
	1132	1.5	1.8	2.7	3.7	1.4	2.0				
	1133	1.6	1.8	3.5	4.0	1.4	1.7	3.0	4.0	3.9	5.2
		1.8	2.2								
	1133sq	1.2	1.5								
	1134sq	0.5	0.7	1.1	1.4						
	1135	2.8	3.7	1.8	2.2						
	1136	0.7	0.9	0.8	1.1	1.1	1.4	1.0	1.2	3.8	4.9
	1137	1.2	1.5	1.4	1.8	0.8	1.0	2.2	2.8		
	1138	2.6	3.3	1.7	2.2	2.6	3.1	3.2	4.3	6.2	8.0
	1139	2.4	3.1								
	1139s	1.1	1.5	0.9	1.1	0.9	1.0				
	1140	2.1	2.7	1.6	1.9	1.5	2.0				
	1140sq	1.0	1.2								
OCS-3											
PPB-25	1141s	0.6	0.8								
	1142s	1.1	1.3								
	1143s	0.7	0.9								
	1146s	0.9	1.1	0.6	0.7	0.6	0.7				
	1150s	0.8	1.0								
PPB-55	1152	3.1	3.8	3.2	4.1						
	1153	3.3	4.2	0.6	0.8	0.5	0.6	0.5	0.7	0.6	0.7
		0.5	0.6								
	1154	4.2	5.6	5.4	7.2	5.9	7.5				
	1156s	0.6	0.8	0.6	0.8	1.3	1.6	0.9	1.0	0.8	1.0
		0.7	0.8	0.6	0.8						

Table 12. (continued)

	1157	4.2	5.0	1.4	1.8						
	1158sq	0.9	1.2	0.8	1.0						
	1159sq	0.5	0.7								
PPB-100	1161sh	0.7	1.0								
	1162sq	1.0	1.4								
	1163	3.4	4.4	1.4	1.7	0.9	1.2	0.8	0.9	0.8	1.0
		0.9	1.1	0.9	1.2	6.2	8.1				
	1165	0.7	0.8	1.5	1.8	1.8	2.4	1.2	1.5	2.6	3.6
	1166sq	1.2	1.4								
	1170	1.0	1.5	1.8	2.5	2.8	3.6	1.0	1.4	1.5	2.0
		1.4	1.8	0.8	1.0	1.0	1.2	1.4	1.8	3.7	4.6
OCS-4											
PPB-25	1281	10.0	11.3								
	1282	8.5	9.8	7.2	7.0	4.0	4.5	2.1	2.5	7.5	8.8
	1284	9.2	10.2	4.8	5.2						
	1285	3.5	3.6	5.6	7.0						
	1360s	0.6	0.7								
	1361s	0.6	0.8	0.6	0.7	0.8	0.9				
	1363s	0.8	1.0								
	1364s	0.8	0.9	1.0	1.2						
PPB-40	1354	0.8	0.9	1.0	1.2	0.9	1.1	0.6	0.9		
PPB-55	1330sq	0.7	0.9	0.6	0.6	0.8	1.0	0.6	0.6	0.7	0.8
	1331	2.0	2.5	1.9	2.4	5.1	6.5	1.4	1.8		
	1333	2.3	2.9								
	1334	1.5	1.9	0.9	1.0						
	1335sq	0.8	0.9	0.6	0.7						
	1336sq	0.6	0.7	0.7	0.8	1.0	1.0	0.6	0.8		
	1338	1.3	1.5	2.4	3.1						
	1339	8.8	9.2	2.1	2.5						
	1340sq	1.0	1.2	0.7	0.8	0.7	0.9	1.0	1.1	1.0	1.1
		0.6	0.7	0.8	1.0						
	1341sq	0.8	0.9	1.0	1.2	0.6	0.7	0.6	0.7		
	1342	4.2	5.1	2.0	2.4	1.4	1.8				
	1343	3.3	4.0	2.9	3.7	2.6	3.3	3.0	4.0	5.2	6.8
		7.4	8.3								
	1345	7.0	8.9	2.2	2.6	7.3	9.5				
	1347	3.3	4.1	4.4	4.7						
	1348	0.8	0.9	1.0	1.1	0.7	0.9	0.6	0.8	3.0	3.3
	1349	3.2	4.1	1.3	1.7	3.9	4.8				
	1350	9.2	11.8	0.7	0.8	3.4	4.0	0.7	0.9	4.6	5.8
		1.9	2.1	1.0	1.2						
	1351	1.6	1.9								
PPB-100	1318sq	0.7	1.0								
	1319	0.8	0.9	1.3	1.7						
	1319sq	0.7	0.8	1.0	1.2	0.9	1.1	0.8	1.0	0.8	1.0

Table 12. (continued)

	1320sq	1.4	1.6								
	1321	7.7	9.8	4.2	5.0	5.2	6.6	4.4	5.4		
OCS-5											
BRB-25	1365	1.6	2.1								
PIB-10	1430	2.5	3.0								
NIB-15	1445	3.8	4.0								
BAB-25	1456	3.0	3.7	1.7	2.1						
	1457	1.4	1.8								
	1455	1.8	2.4	1.8	2.2	2.4	2.9				
BAB-20	1464	7.0	8.8	7.0	8.9	2.0	2.3	3.2	4.0		
	1466	9.3	11.3	2.4	3.2	4.4	5.7	6.0	7.6	2.6	3.4
OCS-6											
PPB-25	1500s	1.0	1.2	0.6	0.7	0.7	0.8				
	1501s	0.8	1.0								
	1502s	0.7	0.8								
	1503s	1.0	1.3								
PPB-55	1495sq	1.2	1.3								
	1496sq	0.9	1.0	0.7	0.8	0.6	0.6	0.8	1.0	0.6	0.7
	1498sq	0.6	0.7								
	1499s	0.8	1.0	0.7	0.8						
PPB-100	1490sq	1.0	1.0	1.2	1.4						
	1492sq	0.6	0.8								
OCS-7											
PPB-25	1562	7.3	8.8	3.8	4.9						
	1565	6.6	8.8								
PPB-40	1549	2.4	2.9	2.5	2.9						
	1550	3.3	4.2	3.7	4.9						
	1552	8.8	9.2	1.8	1.9						
	1556	1.4	1.8	1.4	1.8						
PPB-55	1541	0.9	1.1	0.7	0.8	1.3	1.5	3.5	4.4	2.3	3.2
		5.7	7.4								
	1542	1.8	2.7	3.4	4.5						
	1543	7.0	9.4	0.9	1.3	0.8	1.0	2.6	3.9		
	1545	2.4	3.0								
	1546	1.3	1.4	1.5	1.8	3.6	4.5	1.8	2.5	1.9	2.2
PPB-70	1570	3.8	4.9	1.0	1.3	1.1	1.3	4.8	5.4		
	1571	5.4	6.6	2.6	3.2	1.3	1.6	1.0	1.4		
	1572	6.4	7.2	2.8	3.2	1.6	1.9				
	1573	1.1	1.3	3.1	3.9	1.8	2.2	3.7	4.2		
	1574	5.2	6.6	4.8	5.3	4.7	6.2				
PPB-100	1575	10.2	11.8	1.5	2.0	5.0	5.7	2.2	2.7	2.8	3.8
		3.8	5.0	1.7	2.3	2.3	2.9				

Table 12. (continued)

	1576	2.3	2.6	1.7	2.3	5.0	5.5	2.3	3.1	1.2	1.6
		1.7	2.1								
	1577	2.8	3.7	1.9	2.5	4.8	6.2	2.2	2.6	1.4	1.7
	1578	1.0	1.3	1.4	1.8	1.7	2.2	2.0	2.4	1.6	2.2
		1.8	2.3	1.8	2.5	3.2	4.1	2.4	3.1	1.9	2.3
	1579	0.7	0.9	0.8	1.0	0.8	1.0	1.0	1.2	0.9	1.1
		1.4	1.8								
Sta.37(25m)	1631	6.2	8.8	1.7	1.9	3.2	5.8				
Sta.38(55m)	1638	1.8	2.0								
	1640	1.3	1.5	1.4	1.7	1.3	1.6	1.4	1.7	2.0	2.2
	1641	6.0	6.6	1.3	1.6	1.3	1.6				

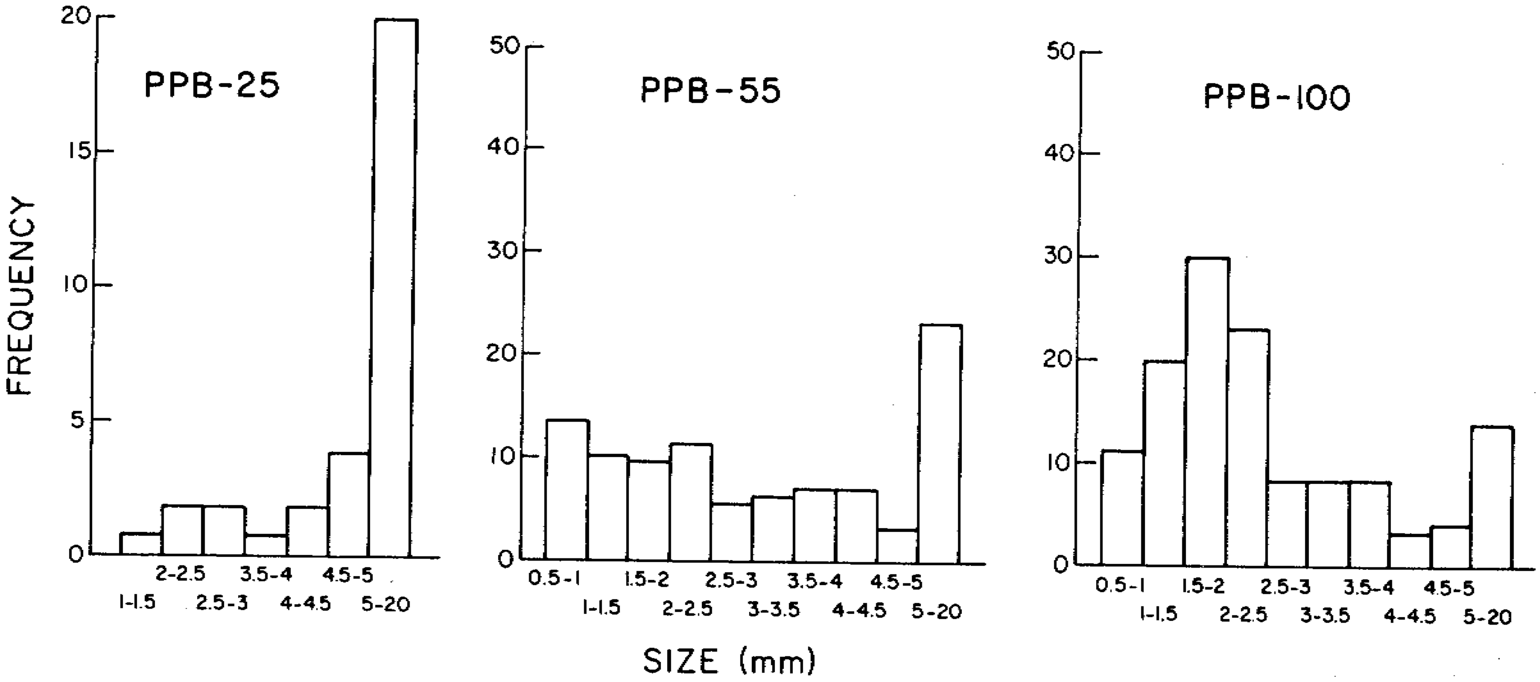


Figure 8. Size (length) frequencies for Nucula bellotii at the three standard benthic stations from cruises OCS 1, 2, 3, 4 and 7.

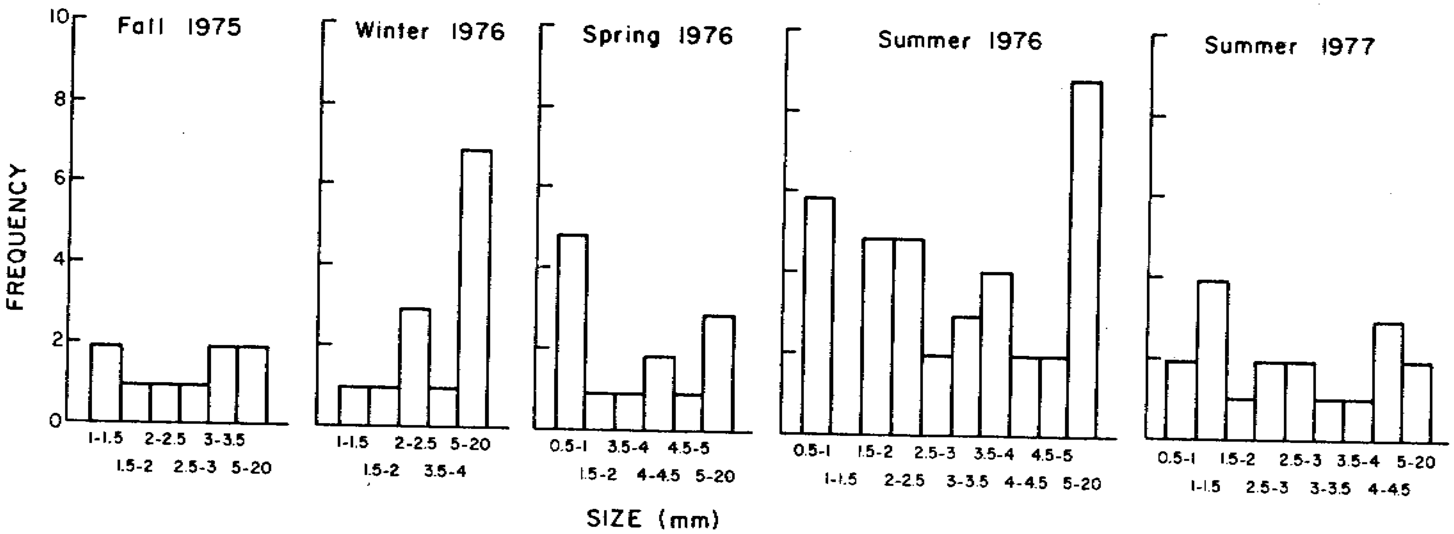


Figure 9. Size frequencies for the bivalve *Nucula bellotii* from the Pitt Point transect at 55 meters (PPB-55). Size was determined by total shell length in millimeters.

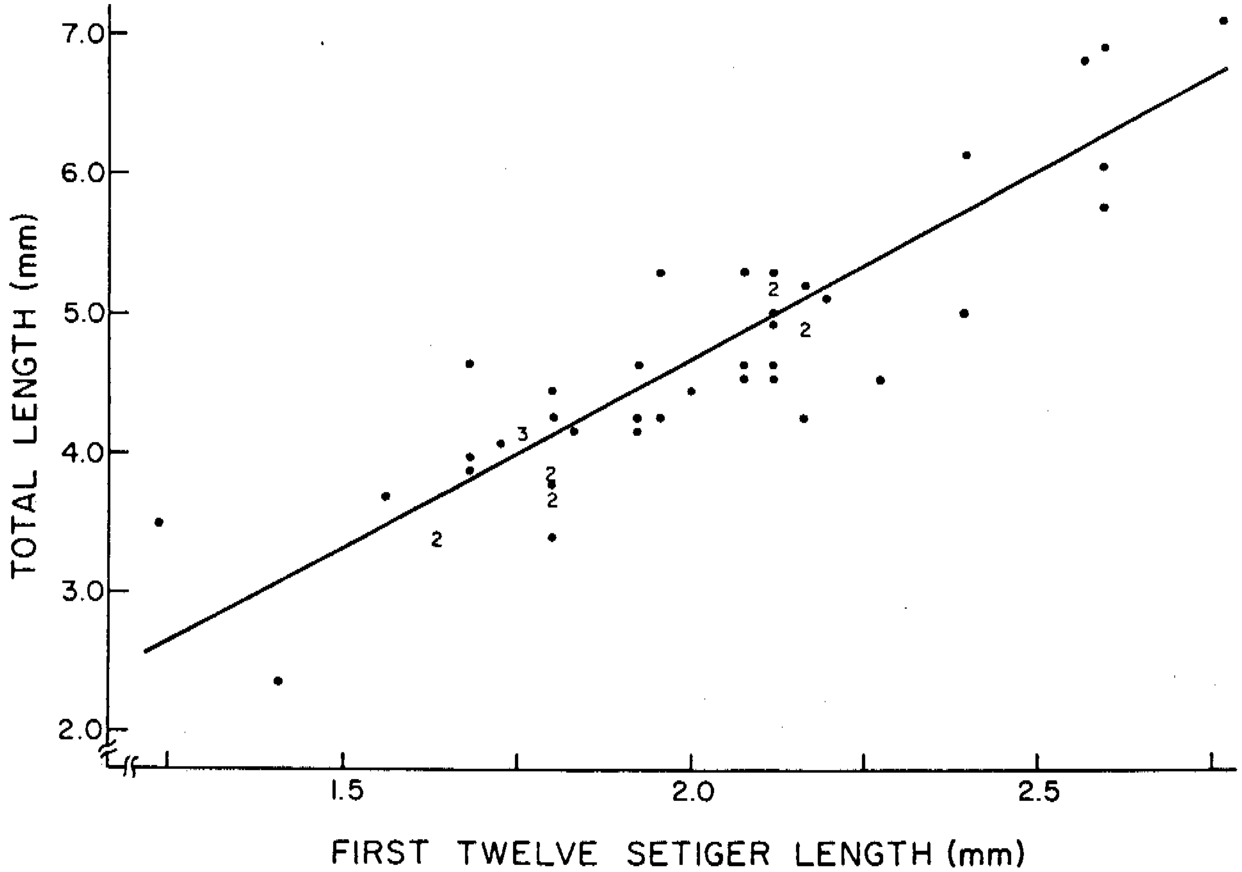


Figure 10. Relationship of first twelve setiger length to total worm length in the polychaete *Micronephthys minuta* ($r=0.89$, $F=196.88$, $P<0.0$).

E. OCS Species Voucher Specimens

1. Pelecypod Molluscs

Voucher specimens for thirty-seven species of pelecypod molluscs identified by Paul H. Scott of the OSU benthic ecology group have been sent to the California Academy of Sciences. The specimens have been accessioned into the museum (CAS Acc. No. 1979-X:29) and are currently being catalogued. The voucher species names and specimen numbers are outlined in Table 13.

2. Polychaetous Annelids

A total of 56 polychaete species from 26 families identified from the nearshore R/V ALUMIAK samples are being readied for shipment to the CAS museum (Table 14). An additional 43 species from this material are rare or undescribed, and for the present are being retained at OSU.

Table 13.

Pelecypod voucher specimens sent to California Academy of Sciences

Species	Smith/McIntyre grab number	Specimens
Nucula bellotii	1436-11	1
Nucula bellotii	1462-11	2
Nuculana minuta	1546-18	1
Nuculana pernula	1630-15	1 + 1 pair valves
Nuculana radiata	1102	1 pair valves
Portlandia arctica	1434-13	11 + valves
Portlandia frigida	1448-13	2
Portlandia lenticula	1639-15	7 + 3 valves
Yoldia hyperborea	1378-07	1 broken pair valves
Yoldia myalis	1374-08	1 broken pair valves
Bathyarca glacialis	1643-14	1
Crenella decussata	1448-13	1
Dacrydium vitreum	1646-14	7 + 2 pair _ 3 valves
Musculus corrugatus	1637-16	1
Musculus discors	1089	2
Musculus niger	1085	2 valves
Arctinula greenlandica	1456-09	5 + 2 pair valves
Axinopsida orbiculata	1454-11	6
Thyasira equalis	1624-13	6 + 2 pair valves
Thyasira gouldii	1093	4
Mysella planata	1342-14	1
Cyclocardia crebricostata	1123-19	1
Astarte crenata	1647-14	2 valves
Astarte borealis	1339-16	1
Astarte montagui	1577-15	6
Clinocardium ciliatum	1545-16	1
Serripes groenlandicus	1107-12	1 matched pair + 1 valve
Macoma calcarea	1470-15	18
Macoma loveni	1557-12	1
Macoma moesta	1334-14	2
Liocyma fluctuosa	1386-10	19 + 1 pair valves
Mya pseudoarenaria	1475-10	1 pair valves
Hiatella arctica	1437-07	1
Pandora glacialis	1468-13	6
Lyonsia arenosa	1469-12	2 matched pair + 2 valves
Periploma aleutica	1578-11	1
Thracia devexa	1647-14	1 pair valves
Cuspidaria glacialis	1641-16	1

Table 14. Polychaete species to be shipped as voucher specimens to the California Academy of Sciences.

Family:	Species:
AMPHARETIDAE	*Ampharete vega* *Ampharete acutifrons* *Lysippe labiata* *Amphicteis sundevalli*
APISOBRANCHIDAE	*Apistobranchus tullbergi*
CAPITELLIDAE	*Capitella capitata* *Heteromastus filiformis*
CIRRATULIDAE	*Chaetozone setosa* *Tharyx* sp.
COSSURIDAE	*Cossura longocirrata*
dorvilleidae	*Schistomeringos caecus*
FLABELLIGERIDAE	*Brada villosa*
HESIONIDAE	*Nereimyra aphroditoides*
LUMBRINERIDAE	*Lumbrineris minuta*
MALDANIDAE	*Clymenura polaris* *Microclymene acirrata* *Praxillella practermissa*
NEPHTYIDAE	*Micronephthys minuta* *Nephtys longosetosa* *Nephtys ciliata*
OPHELIIDAE	*Ophelina cylindricaudata* *Ophelina acuminata* *Ophelina groenlandica*
ORBINIIDAE	*Scoloplos armiger* *Scoloplos acutus*
PARAONIDAE	*Tauberia gracilis*
PECTINARIIDAE	*Cistenides hyperborea*
PHYLLODOCIDAE	*Anaitides groenlandica* *Eteone longa* *Mystides borealis*
POLYNOIDAE	*Antinöella sarsi* *Arcteobia anticostiensis* *Melaenis loveni*

Table 14. (continued)

Family:	Species:
SABELLIDAE	*Chone* sp.
	Euchone papillosa
	Laonome broyeri
SCALIBREGMIDAE	*Scalibregma inflatum*
SIGALIONIDAE	*Pholoë minuta*
SPHAERODORIDAE	*Sphacrodoropsis minuta*
	Sphacrodoropsis biserialis
SPIONIDAE	*Marenzellaria wireni*
	Minuspio nr *cirrifera*
	Prionospio steenstrupi
	Pygospio elegans
	Spio filicornis
	Spio theeli
	Polydora caulleryi
	Polydora quadrilobata
	Polydora socialis
STERNASPIDAE	*Sternaspis scutata*
SYLLIDAE	*Exogone dispar*
TEREBELLIDAE	*Artacama proboscidea*
	Proclea graffii
	Polycirrus medusa
	Laphania boecki
TRICHOBRANCHIDAE	*Terebellides stroemi*

F. Data Management

The increase in the need to store and retrieve large amounts of information has provided the selective pressure for the evolution of database management systems. Mainly derived for industrial and business applications, database systems are well suited for the management of scientific information. Software packages are currently available that are specifically designed for the scientific user and the structure of the information that he/she might accumulate. One such package, SIR (Scientific Information Retrieval), is available at Oregon State University. It has been determined, for reasons outlined below, to convert all benthic data currently stored and maintained by an inhouse record management system to be managed by the SIR database system. Representations of the two systems are shown in Figure 11.

Advantages/Disadvantages

There exists both general and specific reasons for conversion from the current inhouse system, hereafter referred to as GRS (Gish Record System), to a database system. A number are enumerated in Table 15. The general reasons include the arguments for having a database management system at all. These reasons include the ability to implement new and one-of-a-kind requests easily and quickly, elimination of data duplication and inconsistency, programming/data independence and structuring that provides for future applications, ease of data maintenance, and sophisticated retrieval and reporting. Disadvantages to implementation, cost, complexity, recovery difficulty and increased vulnerability are answered specificall by the intended database system. SIR is online and fully maintained by the Oregon State University Computer Center so cost is not an issue. The structure and backup procedures of SIR address the complexity, recovery and vulnerability issues. Specific advantages of SIR include its online, interactive programming facility, the ability to generate complex reports in a hierarchical manner consistent with the structure of the database, statistical interfacing with SPSS and BMDP, and its self-documenting nature.

GRS is a record management system, and as such does not provide for the integrated addressing of data. Its disadvantages are many including continued program maintenance, the need for systematic processing of data records with no random access capability, excessive use of direct access storage necessitating tape processing only, binary data storage, incomplete documentation, complex programming for specific reporting, complex and batch oriented update procedures, and multiple file processing increasing data duplication and inconsistencies. GRS does not allow for possible processing of data subsets and requires complete file I/O for either report or update facilities. Its advantage is in its ability to provide machine readable data records.

SIR Structure

SIR is a hierarchical or tree-like database system. Perhaps the most primitive of management systems above sequential record storage, it is well suited to biological information storage and retrieval. The SIR database consists of 5 files maintained by the software. These are the schema definition or codebook file which contains the structure of the database, the detail file or database documentation, procedure file containing retrieval and reporting programs written under the interactive editor, the data file with the stored data, and a backup procedure file. In a hierarchical system, one record is said to "own" many other records as below:

Figure 11. Diagramatic representation of GRS and SIR data management systems.

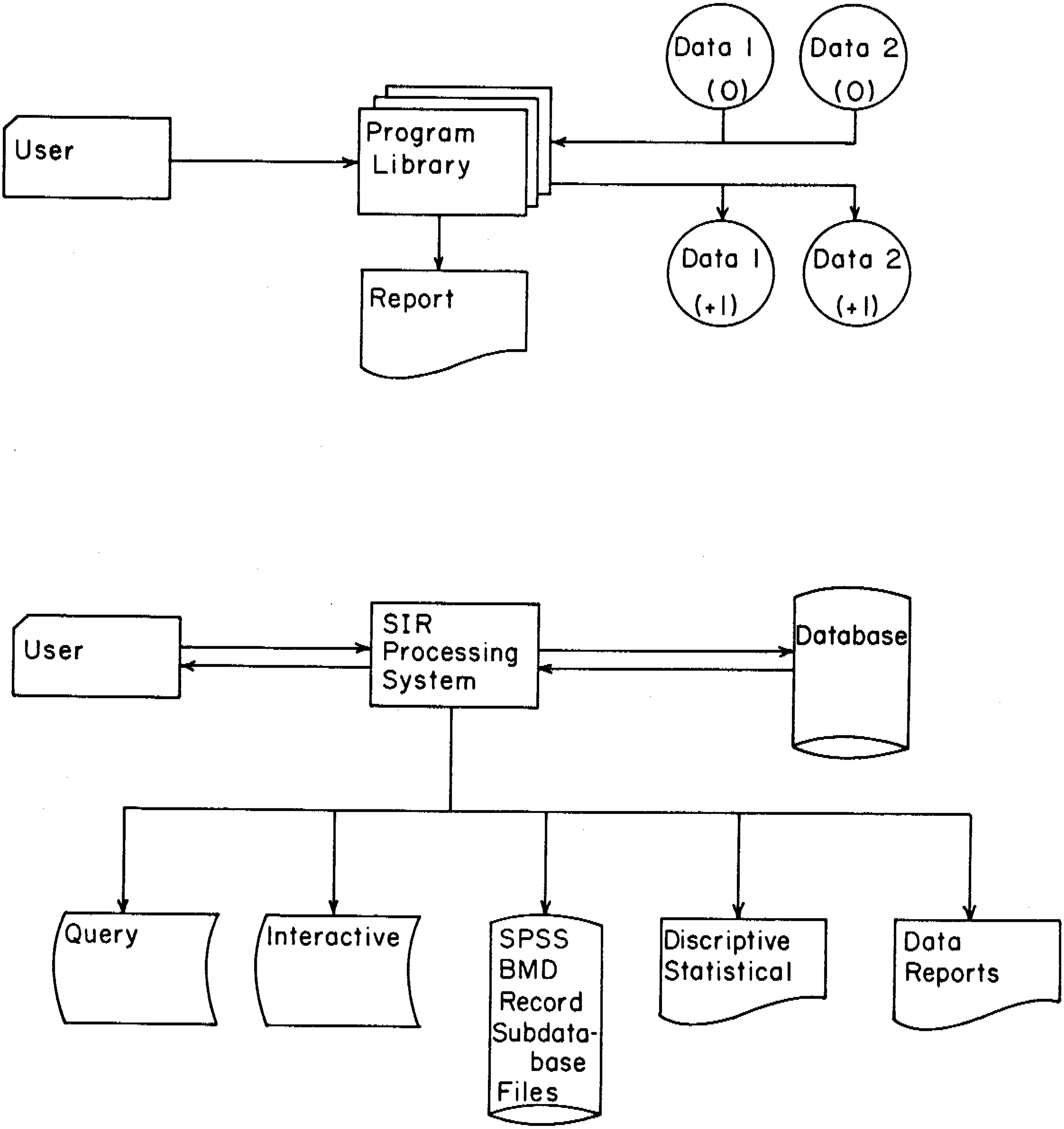
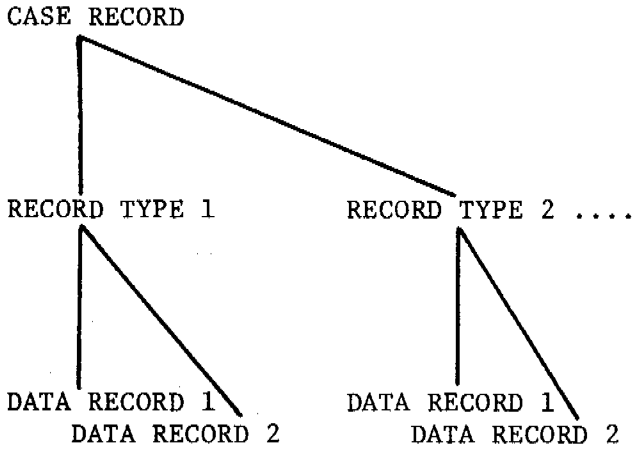


Table 15. A comparison of SIR, a database management system, and GRS, the current record management system.

	SIR	GRS
1.	Data processed as an integrated whole indirectly by the application system	Fortran program "systems" interact separately with 2 data files and individual records
2.	New and one-of-a-kind user requests easily implemented	Major programming and testing effort needed for each request - no programming overlap
3.	Reduction in data duplication	Two data files which lack integrity - data items disagree
4.	Programming/data independence	Strict program/data structure - a change to one requires a change in the other
5.	Selective data processing - decreased reporting costs	Complete processing of data file even for subset reports
6.	Ease of database update	Requires complete rewrite of data files for update
7.	Order independent for data entry and retrieval	Strict record order and field within record structure - only sequential processing possible
8.	Ease of data management - self documenting	Confused and incomplete documentation - complex management procedures



The proposed structure to accomodate information collected from benthic systems is below:

POSITIONAL DATA (case record including primary key along with latitude, longitude, date, cruise ship, etc.)

PHYSICAL DATA (records containing temperature, sediment type, etc. for each possible sample subsample)

BIOLOGICAL DATA (data records on each species with name, phyla, numbers, etc.)

This structure provides complete flexibility to accomodate future studies directed at gathering benthic data.

Conversion

Conversion of data now stored under GRS was undertaken after completion of a pilot project designed to test the behaviour of SIR as well as provide an interactive database system to handle the OSU benthic museum. Completion of the museum project further indicated the ease and effectiveness of SIR to handle biological data. Currently online update and reporting procedures are being implemented to facilitate user access to needed museum information. Programming of the arctic benthic data schema has been completed as well as the conversion program itself to transfer GRS formated records to SIR format structure. During the testing of the conversion program numerous data inconsistencies were identified. Corrections of these conflicting values are proceeding before implementation of SIR.

IX. Summary of January-March 1980 Quarter (RU #006 and #006W).

A. Ship or Laboratory Activities

1. Ship or Field Trip Schedule

No field efforts were undertaken this quarter.

2. Scientific Personnel

a. Andrew G. Carey, Jr.	Principal Investigator Associate Professor
Responsibilities:	Coordination, evaluation, analysis, and reporting
b. R. Eugene Ruff	Research Assistant Unclassified
Responsibilities:	Species list compilation, sample processing, reference museum curation, polychaete systematics, field collection, and laboratory management
c. Paul Scott	Research Assistant Unclassified
Responsibilities:	Sample processing, data summary, molluscan systematics and field collection
d. Keith Walters	Research Assistant Unclassified
Responsibilities:	Data management, statistical analysis; field collection.
e. Douglas Cronin	Part-time Student Assistant
Responsibilities:	Sample processing, general laboratory assistance (now on leave, Spring Quarter)

3. Methods

a. PPB temporal variability studies

1) Appropriate dominant species of bivalve molluscs and polychaetous annelids have been chosen for detailed studies of species population dynamics at the 1975-76 OCS Seasonal Stations off Pitt Point.

2) Techniques for measurement of the individuals have been evaluated, and measurements by a dissecting microscope ocular micrometer have been initiated.

b. Sea ice epontic community-benthic community interactions, Stefansson Sound.

1) Techniques for the study of particle flux measurements and processes are under evaluation.

4. Sample localities

   a. Stefansson Sound
   b. OCS lease area, Beaufort Sea
   c. OCS Transect Line - Pitt Point (PPB)

5. Data collected and analyzed

   a. Coastal bivalve molluscan data have been analyzed by quantitative statistical techniques (see Results-Discussion-Conclusion section B of Annual Report).
   b. OCS Pitt Point Transect polychaetes have been partially identified (Table 16). Dominant species have been selected for species population dynamics studies (see Results-Discussion-Conclusions sections C and D of Annual Report).
   c. The accumulation of harpacticoid copepod data from the Pitt Point transect line has been completed for stations PPB-25, PPB-55, and PPB-100 for the OCS cruises 1-7 (Table 17). The specimens from both the 1.00 mm and the 0.50 mm size fractions have been identified. In all, about 1500 individuals distributed among 25 species have been examined, and the reproductive state and cohort class of each has been determined. The dominant species are *Pseudocervinia magna*, *Paranannopus echinipes*, *Halectinosoma neglectum*, *Halectinosoma sarsi*, *Bradya typica*, and *Paramphiascopsis giesbrechti*.

B. Problems encountered/recommended changes

Data accumulation lag.

Owing to the departure of a Biological Research Assistant (P.M. Montagna), RU #006's capability to identify a wide taxonomic range of fauna has decreased. Dependency on outside specialists for primary identifications and verification of previously identified material creates significant delays and/or complete data gaps. Supplementary funding of RU #006 for work-up of previous Chukchi Sea samples would add to our taxonomic capability and significantly increase efficiency in the laboratory by providing support for one additional research assistant with demonstrated ability with crustacean systematics.

Table 16. Polychaete identifications for cruises OCS-1 through OCS-6 at station PPB-25.

PPB-25 Polychaete Identifications

	Family	Genus, species	Number
OCS-1			
SMG 1082			
	Sternaspidae	*Sternaspis scutata*	12
	Cirratulidae	*Chaetozone setosa*	1
		Tharyx (?) sp.	31
	Sabellidae	*Chone* sp.	2
	Lumbrineridae		1
	Nephtyidae	*Micronephthys minuta*	15
		Nephtys ciliata	1
	Paraonidae	*Allia* sp. A	3
		Allia sp. (?)	1
		Tauberia gracilis	1
	Phyllodicidae	*Anaitides groenlandica*	1
	Polynoidae	*Arcteobia anticostiensis*	1
	Opheliidae	*Ophelina cylindricaudatus*	1
	Cossuridae	*Cossura longocirrata*	7
	Orbiniidae	*Scoloplos acutus*	2
	Dorvilleidae	*Schistomeringos caecus*	1
	Capitellidae	*Capitella capitata*	2
		un ID	1
	Apistobranchidae	*Apistobranchus tullbergi*	1
SMG 1083			
	Sternaspidae	*Sternaspis scutata*	8
	Cirratulidae	*Chaetozone setosa*	2
		Tharyx (?) sp.	12
	Nephtyidae	*Micronephthys minuta*	19
		Nephtys ciliata	1
	Paraonidae	*Allia* sp. A	4
	Opheliidae	un ID	1
	Cossuridae	*Cossura longocirrata*	5
	Orbiniidae	*Scoloplos acutus*	2
	Phyllodocidae	*Eteone longa*	1
SMG 1084			
	Sternaspidae	*Sternaspis scutata*	25
	Cirratulidae	*Chaetozone setosa*	1
		Tharyx (?) sp.	10
	Lumbrineridae		1
	Nephtyidae	*Micronephthys minuta*	28
	Paraonidae	*Allis* sp. A	2
		Allia sp. B	2
		Tauberia gracilis	3
		un ID	1
	Opheliidae	un ID	1
	Cossuridae	*Cossura longocirrata*	1
	Capitellidae	***Heteromastus filiformis***	1
	Sphaerodoridae	*Sphaerodoropsis biserialis*	1

Table 16. (continued)

PPB-25 Polychaete Identifications

	Family	Genus, species	Number
OCS-1			
SMG 1085			
	Sternaspidae	*Sternaspis scutata*	8
	Cirratulidae	*Tharyx* (?) sp.	7
	Nephtyidae	*Micronephthys minuta*	22
	Paraonidae	*Allia* sp. A	3
		Tauberia gracilis	1
	Polynoidae	*Antinoella sarsi*	1
	Cossuridae	*Cossura longocirrata*	1
	Capitellidae	*Capitella capitata*	1
SMG 1087			
	Sternaspidae	*Sternaspis scutata*	3
	Cirratulidae	*Tharyx* (?) sp.	12
	Sabellidae	*Chone* sp.	3
	Nephtyidae	*Micronephthys minuta*	4
	Paraonidae	*Allia* sp. A	1
		Allia sp. B	1
		un ID	2
	Opheliidae	*Ophelina acuminata*	1
	Cossuridae	*Cossura longocirrata*	5
	Capitellidae	*Heteromastus filiformis*	1
	Apistobranchidae	*Apistobranchus tullbergi*	1
	Spionidae	*Minuspio cirrifera*	1

Table 16. (continued)

PPB-25 Polychaete Identifications

	Family	Genus, species	Number
OCS-2			
SMG 1098			
	Sternaspidae	Sternaspis scutata	2
	Cirratulidae	Chaetozone setosa	9
		Tharyx (?) sp.	22
	Nephtyidae	Micronephthys minuta	11
		Nephtys ciliata	2
	Phyllodocidae	Eteone longa	1
	Flabelligeridae	Brada villosa	2
	Paraonidae	Allia sp. A	8
		Tauberia gracilis	1
	Terebellidae	Artacama proboscidea	1
	Spionidae	Prionospio steenstrupi	2
	Cossuridae	Cossura longocirrata	1
	Apistobranchidae	Apistobranchus tullbergi	1
SMG 1100			
	Cirratulidae	Chaetozone setosa	11
		Tharyx sp.	11
	Nephtyidae	Micronephthys minuta	2
		Nephtys ciliata	2
	Paraonidae	Allia sp. A	7
		Tauberia gracilis	2
	Spionidae	Prionospio steenstrupi	1
	Cossuridae	Cossura longocirrata	1
	Apistobranchidae	Apistobranchus tullbergi	1
	Orbiniidae	Scoloplos acutus	1
	Lumbrineridae		1
	Polynoidae	Antinoella sarsi	1
SMG 1103			
	Cirratulidae	Chaetozone setosa	1
		Tharyx (?) sp.	10
	Paraonidae	Allia suecica	1
		Allia sp. A	5
		Tauberia gracilis	1
	Cossuridae	Cossura longocirrata	9
	Capitellidae	Capitella capitata	1

Table 16, (continued)

PPB-25 Polychaete Identifications

	Family	Genus, species	Number
OCS-2			
SMG 1104			
	Sternaspidae	*Sternaspis scutata*	2
	Cirratulidae	*Chaetozone setosa*	6
		Tharyx (?) sp.	37
	Nephtyidae	*Micronephthys minuta*	23
		Nephtys ciliata	3
	Paraonidae	*Allia* sp. A	30
		Allia sp. B	2
		Tauberia gracilis	1
		Allia sp.	2
	Terebellidae	*Artacama proboscidea*	1
	Phyllodocidae	*Eteone longa*	1
	Spionidae	*Prionospio steenstrupi*	5
		Minuspio cirrifera	1
	Cossuridae	*Cossura longocirrata*	7
	Apistobranchidae	*Apistobranchus tullbergi*	2
	Orbiniidae	*Scoloplos acutus*	3
	Opheliidae	*Ophelina cylindricaudatus*	1
SMG 1105			
	Sternaspidae	*Sternaspis scutata*	3
	Cirratulidae	*Chaetozone setosa*	7
		Tharyx (?) sp.	46
	Nephtyidae	*Micronephthys minuta*	23
		Nephtys ciliata	2
	Paraonidae	*Allia* sp. A	40
		Allia sp. B	11
		Tauberia gracilis	2
	Terebellidae	un ID	1
	Spionidae	*Prionospio steenstrupi*	3
		un ID	2
	Cossuridae	*Cossura longocirrata*	15
	Apistobranchidae	*Apistobranchus tullbergi*	4
	Capitellidae	*Capitella capitata*	2
	Scalibregmidae	*Scalibregma inflatum*	1
	Dorvilleidae	*Ophryotrocha* sp.	1

Table 16. (continued)

PPB-25 Polychaete Identifications

	Family	Genus, species	Number
OCS-3			
SMG 1141			
	Sternaspidae	*Sternaspis scutata*	11
	Nephtyidae	*Micronephthys minuta*	24
		Nephtys ciliata	3
	Cirratulidae	*Tharyx* sp.	30
	Paraonidae	*Allia* sp. A	18
		Tauberia gracilis	2
	Terebellidae	un ID	1
	Apistobranchidae	*Apistobranchus tullbergi*	1
	Spionidae	*Minuspio cirrifera*	2
		Prionospio steenstrupi	6
	Opheliidae	*Ophelina cylindricaudatus*	4
	Lumbrineridae		5
	Cossuridae	*Cossura longocirrata*	4
	Orbiniidae	*Scoloplos acutus*	3
	Dorvilleidae	*Dorvillea* sp.	1
	Sabellidae	*Chone* sp.	2
	Capitellidae	*Heteromastus filiformis*	1
	Sigalionidae	*Pholoe minuta*	2
	Polynoidae	*Antinoella sarsi*	2
SMG 1142			
	Nephtyidae	*Micronephthys minuta*	2
		Nephtys ciliata	1
		Un ID	2
	Cirratulidae	*Tharyx* (?) sp.	3
	Paraonidae	*Allia* sp. A	1
	Spionidae	*Minuspio cirrifera*	1
		Prionospio steenstrupi	1
	Opheliidae	*Ophelina cylindricaudatus*	1
	Dorvilleidae	*Schistomeringos caecus*	1
	Spirorbidae	*Spirorbis granulatus*	3
SMG 1143			
	Sternaspidae	*Sternaspis scutata*	2
	Cirratulidae	*Tharyx* sp.	10
	Nephtyidae	*Micronephthys minuta*	
		Nephtys ciliata	2
	Paraonidae	*Allia* sp. A	4
		Tauberia gracilis	2
	Spionidae	*Minuspio cirrifera*	1
		Prionospio steenstrupi	1
	Cossuridae	*Cossura longocirrata*	2
	Dorvilleidae	*Schistomeringos caecus*	3
	Sigalionidae	*Pholoe minuta*	1
	Lumbrineridae		1

Table 16. (continued)

PPB-25 Polychaete Identifications

	Family	Genus, species	Number
OCS-3			
SMG 1146			
	Sternaspidae	*Sternaspis scutata*	8
	Cirratulidae	*Chaetozone setosa*	2
		Tharyx (?) sp.	29
	Nephtyidae	*Micronephthys minuta*	12
		Nephtys ciliata	4
	Paraonidae	*Allia* sp. A	10
		Tauberia gracilis	1
		un ID	1
	Spionidae	*Minuspio cirrifera*	1
		Prionospio steenstrupi	1
	Cossuridae	*Cossura longocirrata*	3
	Opheliidae	*Ophelina cylindricaudatus*	1
	Trichobranchidae	*Terebellides stroemi*	2
	Terebellidae	un ID	1
	Orbiniidae	*Scoloplos acutus*	1
	Phyllodocidae	*Eteone longa*	1
	Sabellidae	*Chone* sp.	1
	Dorvilleidae	*Schistomeringos caecus*	2
	Capitellidae	*Capitella capitata*	1
		Heteromastus filiformis	1
	Lumbrineridae		2
SMG 1149			
	Sternaspidae	*Sternaspis scutata*	13
	Cirratulidae	*Chaetozone setosa*	2
		Tharyx (?) sp.	35
	Nephtyidae	*Micronephthys minuta*	5
		Nephtys ciliata	4
	Paraonidae	*Allia* sp. A	16
		Tauberia gracilis	4
	Spionidae	*Minuspio cirrifera*	1
		Prionospio steenstrupi	2
	Trichobranchidae	*Terebellides stroemi*	5
	Pectinariidae	*Cistenides hyperborea*	1
	Flabelligeridae	*Brada villosa*	2
	Sigalionidae	*Pholoe minuta*	1
	Orbiniidae	*Scoloplos acutus*	1
	Capitellidae	*Heteromastus filiformis*	1
	Sabellidae	*Chone* sp.	1
	Lumbrineridae		2

Table 16. (continued)

PPB-25 Polychaete Identifications

	Family	Genus, species	Number
OCS-4			
SMG 1281			
	Nephtyidae	*Micronephthys minuta*	12
		Nephtys ciliata	2
	Pectinariidae	*Cistenides hyperborea*	1
	Opheliidae	*Ophelina acuminata?*	1
	Apistobranchidae	*Apistobranchus tullbergi*	2
	Cossuridae	*Cossura longocirrata*	7
	Sabellidae	*Chone* sp.	1
	Paraonidae	*Allia* sp. A	5
		Allia sp. B	4
		Tauberia gracilis	1
	Terebellidae	*Artacama proboscidea*	4
	Capitellidae	*Capitella capitata*	5
	Cirratulidae	*Chaetozone setosa*	2
		Tharyx (?) sp.	16
	Lumbrineridae	*Lumbrineris minuta*	1
SMG 1282			
	Nephtyidae	*Micronephthys minuta*	43
		Nephtys ciliata	1
	Sternaspidae	*Sternaspis scutata*	2
	Scalibregmidae	*Scalibregma inflatum*	1
	Orbiniidae	*Scoloplos acutus*	3
	Phyllodocidae	*Eteone longa*	1
	Sphaerodoridae	*Sphaerodoropsis biserialis*	5
	Apistobranchidae	*Apistobranchus tullbergi*	14
	Cossuridae	*Cossura longocirrata*	5
	Sabellidae	*Chone* sp.	1
	Paraonidae	*Allia* sp. A	46
		Allia sp. B	22
		Tauberia gracilis?	1
	Spionidae	*Minuspio* nr. *cirrifera*	2
		Prionospio steenstrupi	2
	Terebellidae	*Artacama proboscidea*	7
	Capitellidae	*Capitella capitata*	3
		Heteromastus filiformis	7
	Cirratulidae	*Chaetozone setosa*	40
		Tharyx (?) sp.	33
SMG 1283			
	Nephtyidae	*Micronephthys minuta*	3
		Nephtys ciliata?	1
		Nephtys discors	1
	Scalibregmidae	*Scalibregma inflatum*	1
	Opheliidae	*Ophelina cylindricaudatus*	1
	Phyllodocidae	*Eteone longa*	1
	Sphaerodoridae	*Sphaerodoropsis* cf. *biserialis*	1
	Apistobranchidae	*Apistobranchus tullbergi*	1

Table 16. (continued)

PPB-25 Polychaete Identifications

	Family	Genus, species	Number
OCS-4			
SMG 1283 (continued)			
	Cossuridae	*Cossura longocirrata*	4
	Sigalionidae	*Pholoe minuta*	2
	Hesionidae	*Nereimyra aphroditoides*	1
	Polynoidae	*Antinoella sarsi*	1
	Spionidae	*Polydora socialis*	1
	Terebellidae	*Artacama proboscidea*	1
		Proclea graffii	1
	Ampharetidae	*Ampharete acutifrons*	1
	Capitellidae	*Capitella capitata*	1
	Cirratulidae	*Tharyx* (?) sp.	3
	Lumbrineridae	*Lumbrineris minuta*	1
SMG 1284			
	Nephtyidae	*Micronephthys minuta*	4
		Nephtys ciliata	1
	Pectinariidae	*Cistenides hyperborea*	2
	Opheliidae	*Ophelina cylindricaudatus*	1
	Cossuridae	*Cossura longocirrata*	1
	Sigalionidae	*Pholoe minuta*	1
	Polynoidae	*Antinoella sarsi*	1
	Paraonidae	*Allia* sp. A	17
	Terebellidae	*Artacama proboscidea*	2
	Cirratulidae	*Tharyx* (?) sp.	13
	Lumbrineridae	*Lumbrineris minuta*	1
SMG 1285			
	Nephtyidae	*Micronephthys minuta*	32
		Nephtys ciliata	1
		un ID	2
	Sternaspidae	*Sternaspis scutata*	3
	Pectinariidae	*Cistenides hyperborea*	1
	Orbiniidae	*Scoloplos acutus*	1
	Sphaerodoridae	*Sphaerodoropsis* cf. *biserialis*	1
	Apistobranchidae	*Apistobranchus tullbergi*	2
	Cossuridae	*Cossura longocirrata*	2
	Paraonidae	*Allia* sp. A	1
		Allia sp. B	8
		Tauberia gracilis	2
	Terebellidae	*Artacama proboscidea*	4
	Capitellidae	*Heteromastus filiformis*	1
	Cirratulidae	*Tharyx* (?) sp.	20
		Chaetozone setosa	2

Table 16. (continued)

PPB-25 Polychaete Identification

	Family	Genus, species	Number
OCS-6			
SMG 1500			
	Sternaspidae	*Sternaspis scutata*	4
	Cirratulidae	*Chaetozone setosa*	1
		Tharyx sp.	15
	Nephtyidae	*Micronephthys minuta*	10
	Paraonidae	*Allia* sp. A	2
		Tauberia gracilis	12
	Trichobranchidae	*Terebellides stroemi*	4
	Cossuridae	*Cossura longocirrata*	2
	Orbiniidae	*Scoloplos acutus*	3
	Scalibregmidae	*Scalibregma inflatum*	1
	Spionidae	*Prionospio steenstrupi*	1
	Opheliidae	*Ophelina cylindricaudatus*	3
		Ophelina acuminata	1
	Oweniidae	*Myriochele heeri*	1
	Dorvilleidae	*Schistomeringos caecus*	1
	Capitellidae	*Heteromastus filiformis*	5
		Barantolla americana	1
	Polynoidae	*Melaenis loveni*	1
		Antinoella sarsi	1
		un ID	1
	Sabellidae	*Jasmineira* sp.?	1
	Lumbrineridae	*Lumbrineris*	7
SMG 1501			
	Sternaspidae	*Sternaspis scutata*	5
	Cirratulidae	*Chaetozone setosa*	2
		Tharyx sp.	23
	Nephtyidae	*Nephtys ciliata*	2
		Micronephthys minuta	4
	Paraonidae	*Allia* sp. A	1
		Tauberia gracilis	6
	Pectinariidae	*Cistenides hyperborea*	1
	Trichobranchidae	*Terebellides stroemi*	3
	Ampharetidae	*Ampharete acutifrons*	1
		Lysippe labiata	3
	Cossuridae	*Cossura longocirrata*	1
	Orbiniidae	*Scoloplos acutus*	3
	Spionidae	*Prionospio steenstrupi*	2
	Opheliidae	*Ophelina cylindricaudatus*	3
	Phyllodocidae	*Anaitides groenlandica*	2
	Maldanidae	*Maldane sarsi*	1
	Lumbrineridae	*Lumbrineris*	3

Table 16. (continued)

PPB-25 Polychaete Identification

	Family	Genus, species	Number
OCS-6			
SMG 1502			
	Sternaspidae	*Sternaspis scutata*	6
	Cirratulidae	*Tharyx* sp.	20
	Nephtyidae	*Micronephthys minuta*	2
		Nephtys ciliata	3
	Paraonidae	*Allia suecica*	1
		Allia sp. A	2
		Tauberia gracilis	4
	Trichobranchidae	*Terebellides stroemi*	5
	Cossuridae	*Cossura longocirrata*	2
	Orbiniidae	*Scoloplos acutus*	1
	Scalibregmidae	*Scalibregma inflatum*	1
	Magelonidae	*Magelona* sp.	1
	Spionidae	*Prionospio steenstrupi*	3
	Opheliidae	*Ophelina cylindricaudatus*	2
	Ampharetidae	*Lysippe labiata*	1
	Terebellidae	un ID	2
	Flabelligeridae	*Brada villosa*	3
	Apistobranchidae	*Apistobranchus tullbergi*	1
	Pectinariidae	*Cistenides hyperborea*	1
	Sigalionidae	*Pholoe minuta*	2
	Polynoidae	un ID	1
	Maldanidae	*Maldane sarsi*	1
	Pilargiidae	*Ancistrosyllis* ??	1
	Lumbrineridae		2
SMG 1503			
	Sternaspidae	*Sternaspis scutata*	7
	Cirratulidae	*Tharyx* sp.	13
	Nephtyidae	*Micronephthys minuta*	3
		Nephtys ciliata	3
	Paraonidae	*Allia* sp. A	3
		Tauberia gracilis	6
		Paraonis sp.	2
	Trichobranchidae	*Terebellides stroemi*	3
	Pectinariidae	*Cistenides hyperborea*	2
	Cossuridae	*Cossura longocirrata*	2
	Orbiniidae	*Scoloplos acutus*	2
	Spionidae	*Prionospio steenstrupi*	2
	Opheliidae	*Ophelina cylindricaudatus*	4
	Phyllodocidae	*Anaitides groenlandicus*	3
	Magelonidae	*Magelona* sp.	fragments only
	Maldanidae	*Maldane sarsi*	1
	Capitellidae	*Heteromastus filiformis*	1
	Lumbrineridae		4

Table 16. (continued)

PPB-25 Polychaete Identification

	Family	Genus, species	Number
OCS-6			
SMG 1504			
	Sternaspidae	Sternaspis scutata	8
	Cirratulidae	Chaetozone setosa	1
		Tharyx sp.	28
	Nephtyidae	Micronephthys minuta	3
		Nephtys ciliata	3
	Paraonidae	Allia sp. A	2
		Tauberia gracilis	7
		Paraonis sp.	2
	Trichobranchidae	Terebellides stroemi	1
	Ampharetidae	Lysippe labiata	1
	Orbiniidae	Scoloplos acutus	1
	Spionidae	Prionospio steenstrupi	1
		Minuspio cirrifera	2
		un ID	1
	Opheliidae	Ophelina cylindricaudatus	1
	Phyllodocidae	Eteone longa	1
	Magelonidae	Magelona sp.	1
	Sabellidae	un ID	1
	Maldanidae	Maldane sarsi	fragments only
	Capitellidae	Heteromastus filiformis	1
	Lumbrineridae		4

Table 17. Harpacticoid copepod species from seasonal stations along the Pitt Point Transect.

OCS-1	Helo	30 Oct. 75
71°21.6'N	152°35'W	PPB-100

SMG 1096-12 102 m

1	Cerviniidae	Pseudocervinia magna	1♀
1	Tisbidae	Tisbe furcata	1♀ gravid
1	Harpacticidae	Harpacticus superflexus	1♀
3			

OCS-2	Helo	12 Mar. 76
71°9.5'N	152°47.5'W	PPB-25

SMG 1102 27.4 m

1	Cerviniidae	Pseudocervinia magna	1♀

SMG 1104 27.4 m

1	Cerviniidae	Pseudocervinia magna	1♀

OCS-2	Helo	13 Mar. 76
71°9.2'N	152°47.5'W	PPB-70

SMG 1108 73 m

1		Pseudocervinia magna	1♀

SMG 1109 73 m

8		Pseudocervinia magna	7♀, 1 juv.

SMG 1111 73 m

1	Ectinosomidae	Bradya typica	1♀

SMG 1114 73 m

1		Pseudocervinia magna	1♀

OCS-2	Helo	19 Mar. 76
71°26.5'N	152°38.7'W	PPB-100 99 m

SMG 1131

5	Cerviniidae	Pseudocervinia magna	5♀
4	Diosaccidae	Paramphiascopsis giesbrechti	3♀, 1G♀
1	Thalastridae	Parathalestris jacksoni	1G♀
1		Cervinia langi	1♀
11			

OCS-2 (cont.)	Helo	19 Mar. 76
71°26.5'N	152°38.7'W	PPB-100 99 m

SMG 1132

1	Diosaccidae	Paramphiascopsis giesbrechti	1♀

SMG 1135

1	Ectinosoma	Bradya typica	1♀

SMG 1136

1	Diosaccidae	Paramphiascopsis giesbrechti	1♀

SMG 1137

1	Cletodidae	Parananopus echinatus	1♀
2	Cerviniidae	Pseudocervinia magna	2♀
2	Diosaccidae	Paramphiascopsis giesbrechti	1♀, 1G♀
1	Ectinosomidae	Bradya typica	1♀
2	Cyclopoida	Dermatomyzon nigripes	2♀
8			

SMG 1138

2	Cerviniidae	Pseudocervinia magna	2♀
1	Ectinosomidae	Bradya typica	
3			

SMG 1139

1	Diosaccidae	Paramphioscopsis giesbrechti	1♂

SMG 1140

1	Cerviniidae	Pseudocervinia magna	1♀
2	Diosaccidae	Paramphiascopsis giesbrechti	1♀, 1G♀
3			

OCS-2	Helo	15 Mar. 76
71°11.0'N	152°50.0'W	PPB-40 35.5 m

SMG 1115

1	Diosaccidae	Paramphiascopsis giesbrechti	1♀

OCS-2 Helo 18 Mar. 76
71°17.6'N 152°41.5'W PPB-55 58 m

SMG 1121

1	Diosaccidae	Paramphiascopsis giesbrechti	1♀
4	Cerviniidae	Pseudocervinia magna	4♀
5			

SMG 1122

1	Ectinosomidae	Halectinosoma sp. A	1♀

SMG 1123

2	Cerviniidae	Pseudocervinia magna	2♀
3	Diosaccidae	Paramphiascopsis giesbrechti	2♀, 1♂ disected
5			

SMG 1126

1	Thalestridae	Thalestris frigida	1♀

SMG 1130

1	Cerviniidae	Pseudocervinia magna	1♀
1	Harpacticidae	Harpacticus superflexus	1♀
2	Diosaccidae	Paramphiascopsis giesbrechti	1♀, 1G♀
1	Diosaccidae	Amphiascus minuta like	1♀ one female has longer terminal caudal segment, curious looking, narrower body
5			

OCS-3 Helo 17 May 76
71°11.8'N 152°53.0'W PPB-25 28.3 m

SMG 1143

1	Cerviniidae	Pseudocervinia magna	1♀
1	Diosaccidae	Paramphiascopsis giesbrechti	1♀
2			

OCS-3 Helo 20 May 76
71°19.0'N 152°38.5'W PPB-55
SMG 1151

2	Cerviniidae	Pseudocervinia magna	2♀
1	Diosaccidae	Typhlamphiascus lamellifer	1G♀
1	Harpacticidae	Zaus sp. A	1♀
1	Ectinosomidae	Halectinosoma sp. B	1♀
1	Tisbidae	Zosime sp. A	1G♀
6			

OCS-3 (cont.)	Helo	20 May 76
71°19.0'N	152°38.5'W	PPB-55 54.6 m

SMG 1155

1	Diosaccidae	Paramphiascopsis giesbrechti	1♂

SMG 1156

2	Diosaccidae	Paramphiascopsis giesbrechti	1♀, 1G♀
1	Ameridae	Sarsameira sp.	

SMG 1158

11	Cerviniiade	Pseudocervinia magna	11♀
5	Cletodidae	Paranannopus echinapes	5♀
1	Cletodidae	Argestes mollis	1♀
1	Ectinosomidae	Bradya typica	1♀
18			

SMG 1159

2	Cerviniidae	Pseudocervinia magna	2♀
5	Cletodidae	Paranannopus echinapes	3♀, 2 juv.
1	Cletodidae	Argestes mollis	1♀
2	Cletodidae	Eurycletodes arcticus	2♀
1	Diosaccidae	Paramphiascopsis giesbrechti	1♀
1	Diosaccidae	Amphiascus minutus	1♀
3	Ectinosomidae	Bradya typica	3♀
15			

OCS-3	Helo	26 May 76
71°19.0'N	152°37.5'W	PPB-70 70 m

SMG 1171

1	Cerviniidae	Pseudocervinia magna	1♀

SMG 1173

1	Cyclopoida	Euryte longicaudata	1♀
1	Cyclopoida	Neopontis angularis	1♀
1	Ectinosomidae	Halectinosoma neglectum	1♀
3		Paramphiascopsis giesbrechti	2G♀, 1♀
1	Ameiridae	Sarsameira elongata	1G♀
1	Cyclopodidae	Cyclopoida lichomolgidae	1G♀
1	Diosaccidae	Typlamphiascus lamellifer	1♂
9			

SMG 1174

1	Diosaccidae	Paramphiascopsis giesbrechti	1♀

OCS-3 71°13.0'N		Helo 152°42.0'W	27 May 76 PPB-40 37 m
SMG 1189			
2	Diosaccidae	Typhlamphiascus lamellifer	1G♀, 1♀
SMG 1190			
2	Ectinosomidae	Halectinosoma sp. A	2♀

OCS-3 70°50.8'N		Helo 146°58.0'W	1 June 76 NIB-55 52 m
SMG 1193			
1	Cerviniidae	Pseudocervinia magna	1♀
SMG 1194			
2	Cerviniidae	Pseudocervinia magna	2♀

OCS-3 70°43.5'N		Helo 152°36.0'W	1 June 76 NIB-40
SMG 1198			
4	Cerviniidae	Cervinia langi	4♀
4		Pseudocervinia magna	4♀
8			
SMG 1199			
1	Cerviniidae	Cervinia langi	1♀
1	Cletodidae	Mesocletodes monensis (I.C. Thompson, 1893)	1♀
1		Pseudocervinia magna	
3			

OCS-4 1°22.4'N		Glacier 152°06.1'W	31 Aug. 76 PPB-70 69 m
SMG 1329			
1	Harpacticidae	Harpacticus superflexus	1♀

OCS-4	Glacier	31 Aug. 76
71°18.1'N	152°32.2'W	PPB-55 55 m

SMG 1330

3	Cerviniidae	Pseudocervinia magna	3♀
1	Diosaccidae	Typhlamphiascus lamellifer	1♀
4			

SMG 1335

4	Cletodidae	Paranannopus echinipes	4♀
1	Cletodidae	Eurycletodes serratus	1♀
5			

SMG 1336

1	Cletodidae	Paranannopus echinipes	1♀
1	Cerviniidae	Cervinia synarthra	1♀
2			

SMG 1340

1	Cerviniidae	Pseudocervinia magna	1♀
1	Harpacticidae	Harpacticus superflexus	1♀
2			

SMG 1341

1	Cletodidae	Paranannopus echinipes	1♀

OCS-1 Helo 26 Oct. 75
71°08.7'N 152°39.9'W PPB-25 25 m

SMG 1082_s-08

19	Cerviniidae	Pseudocervinia magna	15♀, 1♂, 3C_4
1	Cletodidae	Paranannopus echinipes	1G♀ (∿8 eggs)
28	Harpacticidae	Harpacticus superflexus	28♀
76	Tisbidae	Tisbe sp.	74♀, 2G♀ (many small eggs)
2	Harpacticidae	Zaus sp. A	1♀, 1♂
1	Peltidiidae	Paralteutha	1♀
8	Ectinsomatidae	Bradya typica	8♀
1	Diosaccidae	Paramphiascopsis giesbrechti	1G♀ (6 eggs)
2	Diosaccidae	Stenhelia nuwukensis	2♀
2	Tachidiidae	Danielssenia stefanssoni	1♀, 1G♀ (1 egg?)
1	Diosaccidae	Robertsonia	1♀
1	Ameiridae	Pseudomeira birulai	1♀
14	Ectinosomidae	Halectinosoma neglectum	13+, 1G+ (∿40 eggs)
3	Ectinosomidae	Halectinosoma sarsi	2♀, 1C
8	Cerviniidae	Cervinia langi	8♂
176			

SMG 1083

19	Cerviniidae	Pseudocervinia magna	16♀, 1C_4, 2C_4 ♂
22	Tisbidae	Tisbe	17♀, 5G♀
4	Harpacticidae	Harpacticus superflexus	3♀, 1C
2	Harpacticidae	Zaus sp. A	1♀, 1G♀
1	Diosaccidae	Paramphiascopsis giesbrechti	1♀
10	Ectinosomatidae	Bradya typica	10♀
2	Ectinosomatidae	Halectinosoma neglectum	1♀, 1C
3	Ectinosomatidae	Halectinosoma sarsi	2♀, 1♂
1	Ectinosomatidae	Halectinosoma mixtum	1♀
4	Cerviniidae	Cervinia langi	4♂
68			

SMG 1084_s-08

13	Cerviniidae	Pseudocervinia magna	10♀, 1C_4, 1C_3, 1C_4 ♂
43	Tisbidae	Tisbe sp.	33♀, 8G♀, 2C
3	Harpacticidae	Harpacticus superflexus	3♀
3	Cletodidae	Paranannopus echinipes	1♀, 1G♀(14 eggs), 1C
1	Diosaccidae	Stenhelia nuwukensis	1C
10	Ectinosomatidae	Bradya typica	10♀
6	Ectinosomatidae	Halectinosoma neglectum	4♀, 2G♀
2	Ectinosomatidae	Halectinosoma sarsi	2♀
6	Cerviniidae	Cervinia langi	6♂

OCS-1 (cont.) Helo 26 Oct. 75
71°08.7'N 152°39.9'W PPB-25 25 m

SMG 1085_s - 07

5	Cerviniidae	Pseudocervinia magna	3♀, 1♂, $1C_3$
5	Harpacticidae	Harpacticus superflexus	5♀
46	Tisbidae	Tisbe	28♀, 18G♀
1	Thalestridae	Thalestris frigida	1C
1	Ectinosomatidae	Bradya typica	1♀
4	Ectinosomatidae	Halectinosoma neglectum	4♀
62			

SMG 1087_s - 07

6	Cerviniidae	Pseudocervinia magna	6♀
66	Tisbidae	Tisbe	47♀, 18G♀, 1C
7	Harpacticidae	Harpacticus superflexus	7♀
1	Harpacticidae	Harpacticus uniremis	1♀
1	Thalestridae	Thalestris frigida	1♀
1	Diosaccidae	Stenhelia nuwukensis	1♀
12	Ectinosomatidae	Halectinosoma neglectum	8♀, 4G♀
3	Ectinosomatidae	Halectinosoma mixtum	3♀
1	Cerviniidae	Cervinia langi	1♂ (3 setae on exopod)
88			

OCS-1 Helo 28 Oct. 75
71°19.1'N 152°34'W PPB-55 59 m

1.00 mm fraction	SMG 1088_a - 09			
1♀	4	Cerviniidae	Pseudocervinia magna	2♀, $1C_4$, $1C_3$
1♀	4	Harpacticidae	Harpacticus superflexus	4♀
16♀	17	Tisbidae	Tisbe	12♀, 5G♀
-	1	Cletodidae	Paranannopus echinipes	1♀
-	1	Diosaccidae	Paramaphiascopsis giesbrechti	1C
1♀	10	Ectinosomatidae	Halectinosoma neglectum	8♀, 1G♀, $1C_4$
-	1	Ectinosomatidae	Halectinosoma sarsi	1 juv ♂
-	3	Ectinosomatidae	Bradya typica	2♀, 1C♂
-	2	Tachiididae	Danielssenia stefanssoni	2♀
1♀		Diosaccidae	Typhlamphiascus lamellifer	
-	1	Cerviniidae	Cervinia langi	1♂

Per .1 m^2

17	P. magna
17	H. superflexus
69	T. furcata
4	P. echinipes
4	P. giesbrechti
41	H. neglectum
4	H. sarsi
12	B. typica
8	D. stefanssoni
1	T. lamellifer
4	C. langi

	OCS-1		Helo	28 Oct. 75
	71°19.1'N		152°34'W	PPB-55 59 m
1.00 mm fraction	SMG 1089 - 07			
1♀	2	Harpacticidae	Harpacticus superflexus	2♀
-	6	Tisbidae	Tisbe	5♀, 1G♀
-	1	Cletodidae	Paranannopus echinipes	1♀
-	2	Ectinosomatidae	Halectinosoma neglectum	1G♀, (1♀?)

Per .1 m^2

9	H. superflexus
24	Tisbe sp.
4	P. echinipes
8	H. neglectum

OCS-1	Helo	28 Oct. 75
71°19.1'N	152°34'W	PPB-55 59 m

SMG 1090_a - 08

3	Cerviniidae	Pseudocervinia magna	3♀
5	Tisbidae	Tisbe sp.	4G♀, 1♀
5	Harpacticidae	Harpacticus superflexus	5♀
1	Cletodidae	Paranannopus echinipes	1♀
1	Diosaccidae	Paramphiascopsis giesbrechti	1♀
1	Ectinosomidae	Bradya typica	$1C_4$
1	Ectinosomidae	Halectinosoma sarsi	1♀
4	Ectinosomidae	Halectinosoma sarsi	1♀
1	Cerviniidae	Cervinia langi	1♂

Per .1 m^2

12	P. magna
20	Tisbe sp.
20	H. superflexus
4	P. echinipes
4	P. giesbrechti
4	B. typica
4	H. sarsi
16	H. neglectum
4	C. langi

OCS-1 Helo 28 Oct. 75
71°19.1'N 152°34'W PPB-55 59 m

SMG 1091_a - 10

2	Cerviniidae	Pseudocervinia magna	1♀, $1C_3$
7	Tisbidae	Tisbe sp.	2G♀, 5♀
6	Harpacticidae	Harpacticus superflexus	6♀
1	Thalestridae	Thalestris frigida	1♀
1	Cletodidae	Paranannopus echinipes	1♀
4	Cletodidae	Argestes mollis	4♀
2	Diosaccidae	Paramphiascopsis giesbrechti	1G♀ (4 eggs), $1C_4$
1	Ectinosomidae	Bradya typica	1♀
2	Ectinosomidae	Halectinosoma neglectum	2♀
1	Ectinosomidae	Halectinosoma sarsi	1♀
1	Ectinosomidae	Halectinosoma mixtum	1♀

Per .1 m^2

8	P. magna
28	Tisbe sp.
24	H. superflexus
4	T. frigida
4	P. echinipes
16	A. mollis
8	P. giesbrechti
4	B. typica
8	H. neglectum
4	H. sarsi
4	H. mixtum

OCS-1	Helo	28 Oct. 75
71°19.1'N	152°34'W	PPB-55 59 m

SMG 1091_a - 10

2	Cerviniidae	Pseudocervinia magna	1♀, $1C_3$
7	Tisbidae	Tisbe sp.	2G♀, 5♀
6	Harpacticidae	Harpacticus superflexus	6♀
1	Thalestridae	Thalestris frigida	1♀
1	Cletodidae	Paranannopus echinipes	1♀
4	Cletodidae	Argestes mollis	4♀
2	Diosaccidae	Paramphiascopsis giesbrechti	1G♀(4 eggs), $1C_4$
1	Ectinosomidae	Bradya typica	1♀
2	Ectinosomidae	Halectinosoma neglectum	2♀
1	Ectinosomidae	Halectinosoma sarsi	1♀
1	Ectinosomidae	Halectinosoma mixtum	1♀

Per .1 m^2

8	P. magna
28	Tisbe sp.
4	T. frigida
4	P. echinipes
16	A. mollis
8	P. giesbrechti
4	B. typica
8	H. neglectum
4	H. sarsi
4	H. mixtum

	OCS-1 71°19.1'N	Helo 152°34'W	28 Oct. 75 PPB-55 59 m

1.00 mm fraction SMG 1092_a - 08

2♀	5	Tisbidae	Tisbe sp.	3♀, 2G♀
-	2	Harpacticidae	Harpacticus superflexus	2C4
-	1	Cletodidae	Paranannopus echinipes	1♀
-	2	Diosaccidae	Paramphioscopsis giesbrechti	2♀
-	3	Ectinosomidae	Halectinosoma neglectum	2♀, 1G♀

Per .1 m^2

22	Tisbe sp.
8	H. superflexus
4	P. echinipes
8	P. giesbrechti
12	H. neglectum

	OCS-1 71°21.6'N		Helo 152°35.0'W	30 Oct. 75 PPB-100 102 m
1.00 mm fraction	SMG 1093_a - 08			
11♀	7	Cerviniidae	Pseudocervinia magna	5♀, $2C_3$
12G♀, 12♀	21	Tisbidae	Tisbe sp.	5G♀, 16♀
5♀	3	Harpacticidae	Harpacticus superflexus	3♀
11♀, $1C_4$	4	Cletodidae	Paranannopus echinipes	4♀
2G♀, 3♂	8	Diosaccidae	Typhlamphiascus lamellifer	3o , 4♀, 1G♀ (24 eggs
-	1	Cletodidae	Heteropsyllus rostratus similis	1♀
1♀	7	Ectinosomidae	Bradya typica	3♀, 1♂ , $2C_4$, 1J♂
2G♀, 14♀	22	Ectinosomidae	Halectinosoma neglectum	21♀, $1C_4$
-	1	Ectinosomidae	H. mixtum	1♀
1♀		Thalestridae	Thalestris frigida	
4♀	1	Tachidiidae	Danielssenia fusiformis	1♀

Per .1m^2

29	P. magna
108	Tisbe
17	H. superflexus
28	P. echinipes
37	T. lamellifer
4	H. rostratus
29	B. typica
104	H. neglectum
4	H. mixtum
1	T. frigida
8	D. fusiformis

OCS-1	Helo	30 Oct. 75
71°21.6'N	152°35.0'W	PPB-100 102 m

SMG 1094_s - 08

1	Cerviniidae	Pseudocervinia magna	1♀
11	Tisbidae	Tisbe sp.	9♀, 2G♀
2	Harpacticidae	Harpacticus superflexus	2♀
2	Thalestridae	Thalestris frigida	2♀
5	Cletodidae	Paranannopus echinipes	5♀
3	Diosaccidae	Typhlamiascus lamellifer	3♀
3	Ectinosomidae	Halectinosoma neglectum	3♀
3	Ectinosomidae	Halectinosoma sarsi	3♀

OCS-1	Helo	30 Oct. 75
71°21.6'N	152°35.0'W	PPB-100 102 m

SMG 1095_a - 08

-	Cerviniidae	Pseudocervinia magna	-
1	Tisbidae	Tisbe sp.	1♀
1	Harpacticidae	Harpacticus superflexus	1♀
1	Thalestridae	Thalestris frigida	1♀
2	Cletodidae	Paranannopus echinipes	2♀
-	Diosaccidae	Typhlamaphiascus lamellifer	-
1	Diosaccidae	Bradya typica	1♀

Per .1 m^2

1	P. magna
4	Tisbe sp.
4	H. superflexus
5	T. frigida
8	P. echinipes
1	T. lamellifer
4	B. bypica

OCS-1	Helo	30 Oct. 75
71°21.6'N	152°35.0'W	PPB-100 102 m

SMG 1096_a - 07

-	Cerviniidae	Pseudocervinia	-
3	Tisbidae	Tisbe	3♀
1	Harpacticidae	Harpacticus superflexus	1♀
1	Peltidiidae	Parateutha	1o
3	Cletodidae	Parananopus echinipes	3♀
1	Diosaccidae	Typhlamphiascus lamellifer	1♀
1	Tachidiidae	Danielssenia fusiformis	1♂
1	Cyclopoida	Cyclopoid A	

Per .1 m^2

1	P. magna
13	Tisbe
5	H. superflexus
4	Paralteutha
12	P. echinipes
4	T. lamellifer
4	D. fusiformis

OCS-1	Helo	30 Oct. 75
71°21.6'N	152°35'W	PPB-100 102 m

SMG 1097_s -07

1	Cerviniidae	Pseudocervinia magna	1♀
3	Tisbidae	Tisbe sp.	2♀, 1G♀
4	Thalestridae	Thalestris frigida	4♀
1	Cletodidae	Paranannopus echinipes	1♀
1	Diosaccidae	Typhlamphiascus lamellifer	1♀
1	Ectinosomatidae	Halectinosoma neglectum	1♀

OCS-2	Helo	12 Mar. 76
71°9.5'N	152°47.5'W	PPB-25 27.4 m

SMG 1099_s -06

24	Certiniidae	Pseudocervinia magna	7♀, 1♂ , $12C_4$, $3C_3$, $1C_4$♂
1	Harpacticidae	Zaus B	1♀
1	Cletodidae	Parananopus echinipes	1♀
1	Ectinosomatidae	Halectinosoma sarsi	1♀
5	Ectinosomatidae	Bradya typica	4♀, 1G♀
1	Cerviniidae	Cervinia longi	1♂
2	Cyclopoidae	Cyclopaid A	

OCS-2 Helo 12 Mar. 76
71°9.5'N 152°47.5'W PPB-25 27.4 m

SMG 1100_s -07

1	Cerviniidae	Pseudocervinia magna	$1C_4$
1	Harpacticidae	Zaus sp. B	1♀
1	Ectinosomidae	Bradya typica	1♀

OCS-2 Helo 12 Mar. 76
71°9.5'N 152°47.5'W PPB-25 27.4 m

SMG 1107$_s$ -05

1	Cerviniidae	Cervinia langi	1♂
1	Diosaccidae	Stenhelia proxima	1♀

OCS-2	Helo	18 Mar. 76	
71°17.6'N	152°41.5'W	PPB-55	58 m

1.00 mm fraction

SMG 1121_a - 08

1♀, $2C_4$	7	Cerviniidae	Pseudocervinia magna	4+, $2C_4$, $1C_4$♂
$1C_4$	1	Cerviniidae	Cervinia langi	$1C_4$
-	2	Diosaccidae	Typhlamphiascus lamellifer	1♀, 1♂
1♀	-	Diosaccidae	Paramphiascopsis giesbrechti	-
-	2	Ectinosomatidae	Bradya typica	2♀

Per .1 m^2

30	P. magna
5	C. langi
8	T. lamellifer
1	P. giesbrechti
8	B. typica

OCS-2 Helo 18 Mar. 76
71°17.6'N 152°41.5'W PPB-55 58 m

1.00 mm fraction	SMG 1123_a -08			
2♀	2	Cerviniidae	Pseudocervinia magna	2♀
-	1	Cerviniidae	Cervinia langi	1♀
-	1	Cletodidae	Rhizothrix	1♀
-	3	Cletodidae	Eurycletodes arcticus	3♀
-	1	Ectinosomidae	Halectinosoma neglectum	1♀
-	1	Diosaccidae	Typhlamphiascus confusus	1G♀ (14 eggs)
2♀, 1♂	-	Diosaccidae	Paramphiascopsis giesbrechti	-

Per .1 m^2

10	P. magna
4	C. langi
4	Rhizothrix
12	E. arcticus
4	H. neglectum
4	T. confusus
3	P. giesbrechti

	OCS-2 71°17.6'N		Helo 152°41.5'W	18 Mar. 76 PPB-55 58 m
1.00 mm fraction	SMG 1126_a -08			
-	6	Cerviniidae	Pseudocervinia magna	1♀, $1C_4$, $2C_3$, $2C_2$
1♀	-	Thalestridae	Thalestris frigida	-

Per .1 m^2.

24	P. magna
1	T. frigida

OCS-2 71°17.6'N		Helo 152°41.5'W	18 Mar. 76 PPB-55 58 m

SMG 1128_a - 06

1	Cletodidae	Argestes mollis	$1C_4$

Per .1 m^2

4	A. mollis

OCS-2 Helo 18 Mar. 76
71°17.6'N 152°41.5'W PPB-55 58 m

1.00 mm fraction	SMG 1130_a - 08			
1♀	7	Cerviniidae	Pseudocervinia magna	4♀, $2C_4$, $1C_2$
1G♀(4 eggs) 1♀, $1C_4$	5	Diosaccidae	Paramphiscopsis giesbrechti	2♀, 1G♀ (4 eggs), $2C_4$
1♀	-	Harpacticidae	Harpacticus superflexus	-

Per .1 m^2

29	P. magna
23	P. giesbrechti
1	H. superflexus

OCS-2 Helo 19 Mar. 76
71°26.5'N 152°38.7'W PPB-100 99 m

1.00 mm fraction	SMG 1131$_a$ -07			
3♀, 2C_4	4	Cerviniidae	Pseudocervinia magna	3♀, 1C_4
1♀	-	Cerviniidae	Cervinia langi	
-	1	Ectinosomatidae	Bradya typica	1♀
-	1	Ectinosomatidae	Halectinosoma neglectum	1♀
3♀, 1G♀ (4 eggs)	-	Diosaccidae	Paramphiascopsis giesbrechti	
1G♀	-	Thalestridae	Parathalestris jacksoni	

Per .1 m^2

17	P. magna
1	C. langi
4	B. typica
4	H. neglectum
4	P. giesbrechti
1	P. jacksoni

OCS-2 71°26.5'N	Helo 152°38.7'W	19 Mar. 76 PPB-100 99 m

SMG 1133_a - 08

4	Cerviniidae	Pseudocervinia magna	3♀, $1C_4$

Per .1 m^2

16	P. magna

OCS-2 71°26.5'N		Helo 152°38'N	19 Mar. 76 PPB-100 99 m
SMG 1134_a - 06			
1	Cerviniidae	Pseudocervinia magna	1♀

Per .1 m^2

4	P. magna

	OCS-2		Helo	19 Mar. 76
	71°26.5'N		152°38'W	PPB-100 99 m
1.00 mm fraction	SMG 1139_a - 07			
-	1	Diosaccidae	Typhlamphiascus confusus	1G♀, (14 eggs)
1♂	-	Diosaccidae	Paramphiascopsis giesbrechti	

Per .1 m^2

4	T. confusus
1	P. giesbrechti

	OCS-2		Helo	19 Mar. 76
	71°26.5'N		152°38'W	PPB-100 99 m
1.00 mm fraction	SMG 1140_a - 07			
1♀	2	Cerviniidae	Pseudocervinia magna	1♀, $1C_4$
1♀, 1G♀ (4 eggs)	-	Diosaccidae	Paramphiascopsis giesbrechti	

Per .1 m^2

9	P. magna
2	P. giesbrechti

OCS-3	Helo	17 May 76
71°11.8'N	152°53.0'W	PPB-25 28.3 m

SMG 1141_s - 07

54	Cerviniidae	Pseudocervinia magna	24♀, $18C_4$, $12C_3$
8	Cerviniidae	Cervinia langi	8o
2	Cletodidae	Parananopus echinipes	2♀
1	Ectinosomatidae	Halectinosoma sarsi	1♀
5	Ectinosomatidae	Bradya typica	5♀
6	Cyclopoida	Cyclopoid A	6♀

OCS-3 Helo 17 May 76
71°11.8'N 152°53.0'W PPB-25 28.3 m

SMG 1142_s - 07

31	Cerviniidae	Pseudocervinia magna	16♀, 1♂, $13C_4$, $1C_3$
3	Cerviniidae	Cervinia langi	3♂
2	Cletodidae	Paranannopus echinipes	2♀
1	Ectinosomatidae	Halectinosoma sarsi	1♀

	OCS-3		Helo	17 May 76
	71°11.8'N		152°53.0'W	PPB-25 28.3 m
1.00 mm fraction	SMG 1143_s - 07			
1♀	12	Cerviniidae	Pseudocervinia magna	6♀, $4C_4$, $2C_3$
-	2	Cerviniidae	Cervinia langi	2♂
-	1	Ectinosomatidae	Halectinosoma sarsi	1♀
1♀	-	Diosaccidae	Paramphiascopsis giesbrechti	-

Per .1 m^2

13	P. magna
2	C. langi
1	H. sarsi
1	P. giesbrechti

OCS-3 Helo 17 May 76
71°11.8'N 152°53.0'W PPB-25 28.3 m

SMG 1146_s - 05

57	Cerviniidae	Pseudocervinia magna	33♀, 14C_4, 9C_3, 1♂
3	Cerviniidae	Cervinia langi	3♂
3	Cletodidae	Paranannopus echinipes	3♀
1	Ectinosomatidae	Halectinosoma sarsi	1♀
2	Ectinosomatidae	Bradya typica	2♀

OCS-3	Helo	17 May 76
71°11.8'N	152°53.0'W	PPB-25 28.3 m

SMG 1150$_s$ - 05

7	Cerviniidae	Pseudocervinia magna	3♀, $3C_4$, 1♂

OCS-3
71°19.0'N

Helo
152°38.5'W

17 May 76
PPB-55 54.6m

SMG 1156 Quarter fractions

1.00 mm fraction	A-08	B-08	C-10	D-09		
-	4♀,$1C_2$	1♀,$1C_4$,$1C_2$	2♀,$1C_4$	1♀	Cerviniidae	Pseudocervinia magna
-	7♀	4♀,$2C_4$	5♀,2♂		Cletodidae	Paranannopus echinipes
-	2♀	1♀	1♀		Cletodidae	Argester mollis
-	2♀	-	-		Laophontidae	Echinolaophonte brevispinis
1G♀,1♀ (4 eggs)	1G♀,$1C_4$,1♂ (4 eggs)	1G♀,2♀,2♂ (4 eggs)	1♀,1♂	2G♀,1♂ (4 eggs)	Diosaccidae	Paramphiascopsis giesbrechti
-	1♂,$1C_3$	1♀	1♀,1♂	1♀,1♂	Diosaccidae	Typhlamphiascus lamellifer
1♀	1♀	-	-		Ameiridae	Sarsameira sp.
-	1♀	1♀	-	$1C_4$	Ectinosomatidae	Halectinosoma sarsi
-	-	1♀	-	2♀	Ectinosomatidae	Bradya typica
-	-	1♀	-		Diosaccidae	Pseudomesochra longifurcata
-	-	-	1♂		Cerviniidae	Cervinia langi
-	-	-	-	1♀	Cletodidae	Heteropsyllus rostratus similis
-	1♀				Cyclopoida	

Per .1 m^2

12	P. magna
29	P. echinipes
4	A. mollis
2	E. brevispinosa
15	P. giesbrechti
7	T. lamellifer
2	Sarsameira sp.
3	H. sarsi
3	B. typica
1	P. longifurcata
1	C. langi
1	H. rostratus similis

	OCS-3		Helo	20 May 76
	71°19.0'N		152°38.5'W	PPB-55 54.6 m
1.00 mm fraction	SMG 1158_a - 08			
11♀(USNM)	2	Cerviniidae	Pseudocervinia magna	2♀
-	2	Cletodidae	Paranannopus echinipes	2♀
1♀	-	Cletodidae	Argestes mollis	
1♀	1	Ectinosomatidae	Bradya typica	1C_4
-	1	Ectinosomatidae	Halectinosoma mixtum	1♀
-	1	Tisbidae	Tisbe sp.	

Per .1 m^2

19	P. magna
8	P. echinipes
1	A. mollis
5	B. typica
4	H.
4	Tisbe sp.

OCS-3 Helo 20 May 76
71°19.0'N 152°38.5'W PPB-55 54.6 m

1.00 mm fraction	SMG 1159_a - 10			
1♀,$1C_3$	3	Cerviniidae	Pseudocervinia magna	2♀,$1C_3$
2♀,$1C_4$	-	Cletodidae	Paranannopus echinipes	
2♀	-	Cletodidae	Rhicothrix	
$1C_4$	-	Cletodidae	Argestes mollis	
2♀	-	Cletodidae	Eurycletodes arcticus	
1♀,$1C_4$	1	Diosaccidae	Paramphiascopsis giesbrechti	1♀
-	1	Diosaccidae	Typhlamphiascus lamellifer	1G♀(12 eggs)
3♀	-	Ectinosomatidae	Bradya typica	
-	1	Diosaccidae	Pseudomeschra longifurcata	1♀

Per .1 m^2	
14	P. magna
3	P. echinipes
2	Rhizothrix
1	A. mollis
2	E. arcticus
6	P. giesbrechti
4	T. lamellifer
3	B. typica

OCS-3	Helo	20 May 76
71°19.0'N	152°38.5'N	PPB-55 54.6 m

1.00 mm fraction	SMG 1160_a - 08			
3♀	3	Cerviniidae	Pseudocervinia magna	2♀,$1C_4$
2♀	-	Cletodidae	Paranannopus echinipes	-
2♂	3	Diosaccidae	Paramphiascopiss giesbrechti	1♀,2♂
1G♀	-	Diosaccidae	Typhlamphiascus lamellifer	
2♀	-	Ectinosomatidae	Bradya typica	

Per .1 m^2

15	P. magna
2	P. echinipes
14	P. giesbrechti
1	T. lamellifer
2	B. typica

	OCS-3		Helo	21 May 76
	71°20.5'N		162°36.0'W	PPB-100 101 m
1.00 mm fraction	SMG 1161$_{a\&b}$			
1C$_2$	-	Cerviniidae	Pseudocervinia magna	
1♀	-	Cletodidae	Paranannopus echinipes	
2♀	-	Diosaccidae	Paramphiascopsis giesbrechti	

	OCS-3		Helo	21 May 76
	71°20.5'N		162°36.0'W	PPB-100 101 m
1.00 mm fraction	SMG 1162$_a$ - 09			
2C$_4$	-	Cerviniidae	Pseudocervinia magna	
5♀	1	Cletodidae	Paranannopus echinipes	1♀
3♀,1G♀ (4 eggs)	-	Diosaccidae	Paramphiascopsis giesbrechti	
2♀	-	Ectinosomidae	Bradya typica	

Per .1 m^2

2	P. magna
9	P. echinipes
3	P. giesbrechti
2	B. typica

OCS-3		Helo	21 May 76
71°20.5'N		151°36.0'W	PPB-100 101 m

1.00 mm fraction	SMG 1166_a - 07			
-	1	Cerviniidae	Cervinia langi	1♂
1♀	-	Cerviniidae	Pseudocervinia magna	
1♀	-	Cletodidae	Paranannopus echinipes	
-	1	Ectinosomatidae	Halectinosoma sarsi	1♀
3♀	-	Diosaccidae	Paramphiascopsis giesbrechti	

Per .1 m^2

4	C. langi
1	P. magna
1	P. echinipes
4	H. sarsi
3	P. giesbrechti

	OCS-3 71°20.5'N		Helo 152°36.0'W	21 May 76 PPB-100 101 m
1.00 mm fraction	SMG 1168 - 09			
1♀	1	Cletodidae	Rhicothrix	1♀
2♀	-	Cletodidae	Paranannopus echinipes	
1♀	-	Cletodidae	Eurycletodes arcticus	
2♀,1G♀ (4 eggs)	-	Diosaccidae	Paramphiascopsis giesbrechti	
1♀	-	Ectinosomatidae	Bradya typica	
1♀	-	Ectinosomatidae	Halectinosoma sarsi	

Per .1 m^2

5	Rhizothria
2	P. echinipes
1	E. arcticus
3	P. giesbrechti
1	B. typica
1	H. sarsi

	OCS-3 71°20.5'N	Helo 152°36.0'W	21 May 76 PPB-100 101 m
1.00 mm fraction	SMG 1169_a		
1♀	-	Cerviniidae	Pseudocervinia magna
5♀	-	Cletodidae	Paranannopus echinipes
1♀	-	Cletodidae	Eurycletodes arcticus
1♀	-	Diosaccidae	Paramphiascopsis giesbrechti
1♀	-	Ectinosomatidae	Bradya typica

	OCS-4 71°22.6'N		GLACIER 152°23.1'W	30 August 76 PPB-100 92 m
1.00 mm fraction	SMG 1318_a - 10			
-	1	Cerviniidae	Pseudocervinia magna	$1C_4$
3♀	1	Cletodidae	Parananopus echinipes	1♀
3♀	6	Harpacticidae	Harpacticus superflexus	
-	2	Cyclopoida	Neopantius angula	2♀
-	1	Cyclopoida	?	1♀
1♀	-	Cyclopoida	Euryte longicaudata	-

Per .1 m^2

4	P. magna
7	P. echinipes
27	H. superflexus

OCS-4	GLACIER	30 August 76
71°22.5'N	152°22.6'W	PPB-100 90 m

1.00 mm fraction	SMG 1319_a - 10			
1♀	2	Cletodidae	Paranannopus echinipes	1♀, $1C_2$
-	2	Cletodidae	Heteropsyllus rostratus similis	2♀
-	4	Harpacticidae	Harpacticus superflexus	4♀
-	2	Tisbidae	Tisbe sp.	$2C_4$
-	2	Diosaccidae	Paramphiascopsis giesbrechti	2♀
-	9	Ectinosomatidae	Bradya typica	5♀, $2C_4$, $1C_3$, 1♂
-	3	Ectinosomatidae	Halectinosoma neglectum	3♀
	3	Cyclopoida	Neopontius angularis	3♀

Per .1 m^2

9	P. echinipes
8	H. rostratus similis
16	H. superflexus
8	Tisbe
8	P. giesbrechti
36	B. typica
12	H. neglectum

OCS-4	GLACIER	30 August 76
71°22.5'N	152°22.6'W	PPB-100 88 m

1.00 mm fraction	SMG 1320$_a$ - 09			
1♀	1	Cerviniidae	Pseudocervinia magna	1C$_2$
1♀	-	Cletodidae	Parananopus echinipes	
4♀	1	Harpacticidae	Harpacticus superflexus	1♀
-	1	Ectinosomatidae	Halectinosoma neglectum	1♀
1♀	-	Ectinosomatidae	Bradya typica	
1♀	-	Diosaccidae	Paramphiascopsis giesbrechti	
2	3	Cyclopoida	Neopontius angularis	2♀,1♂

Per .1 m^2

5	P. magna
1	P. echinipes
8	H. superflexus
4	H. neglectum
1	B. typica
1	P. giesbrechti

	OCS-4 71°22.4'N		GLACIER 152°21.9'W	30 August 76 PPB-100 84 m
1.00 mm fraction	SMG 1322_a - 10			
1♀	5	Harpacticidae	Harpacticus superflexus	5♀
-	2	Cletodidae	Paranannopus echinipes	1♀,1C_2
-	1	Cletodidae	Eurycletodes serratus	1G♀(18 eggs)
-	2	Diosaccidae	Paramphiascopsis giesbrechti	1♂,1C_4
-	4	Ectinosomatidae	Bradya typica	3♀,1C_4
-	1	Ectinosomatidae	Halectinosoma neglectum	1♀
-	1	Tisbidae	Tisbe	
	1♀	Cyclopoida	Neopontius argularis	
	3♀	Cyclopoida	Paranthessius?	
		Cyclopoida		

Per .1 m^2

21	H. superflexus
8	P. echinipes
4	E. serratus
8	P. giesbrechti
10	B. typica
4	H. neglectum
4	Tisbe

	OCS-4 71°22.4'N		GLACIER 152°21.5'W	30 August 76 PPB-100 83 m
1.00 mm fraction	SMG 1323$_a$ - 08			
-	1	Cletodidae	Paranannopus echinipes	1♀
1♀	4	Harpacticidae	Harpacticus superflexus	4♀
-	4	Ectinosomatidae	Bradya typica	1G♀,3♀
-	1	Ectinosomatidae	Pseudobradya	1♀
-	1	Tisbidae	Tisbe sp.	1♀
-	1	Thalestridae	Dactylopodia glacialis	1♀
1♀	-	Ameiridae	Proameira dubia	-
-	1	Cyclopoida	Neopontius angularis	1♀

Per .1 m^2

4	P. echinipes
17	H. superflexus
16	B. typica
4	Pseudobradya
4	Tisbe
4	Dactylopodia
1	P. dubia

OCS-4	GLACIER	31 August 76
71°18.1'N	152°32.2'W	PPB-55 55 m

1.00 mm fraction

SMG 1330$_a$ - 10

3♀	2	Cerviniidae	Pseudocervinia magna	2♀
-	4	Cletodidae	Paranannopus echinipes	3♀,1C_3
-	1	Cletodidae	Argestes mollis	1♀
-	1	Laophontidae	Echinolaophonte brevispinosa	1♂
-	2	Harpacticidae	Harpacticus superflexus	2♀
1♀	2	Diosaccidae	Typhlamphiascus lamellifer	1G♀,1o(14 eggs)
-	1	Ectinosomatidae	Bradya typica	1♀
-	2	Tisbidae	Tisbe	

Per .1 m^2

11	P. magna
11	P. echinipes
4	A. mollis
4	E. brevispinosa
8	H. superflexus
9	T. lamellifer
4	B. typica
8	Tisbe

OCS-4 GLACIER 31 August 76
71°18.1'N 152°32.2'W PPB-55 55m

-

1.00 mm fraction	SMG 1335$_a$ - 09			
-	3	Cerviniidae	Pseudocervinia magna	3♀,1C_4
-	1	Cerviniidae	Cervinia langi	1♂
4♀	5	Cletodidae	Paranannopus echinipes	5♀
1♀	-	Cletodidae	Eurycletodes serratus	
-	1	Ectinosomatidae	Bradya typica	1♀

Per .1 m^2

12	P. magna
4	C. langi
24	P. echinipes
1	E. serratus
4	B. typica

OCS-4	GLACIER	31 August 76	
71°18.1'N	152°32.2'W	PPB-55	55 m

1.00 mm fraction

SMG 1336_a - 09

1♀	3	Cerviniidae	Pseudocervinia magna	
-	1	Cerviniidae	Cervinia langi	
1♀	5	Cletodidae	Paranannopus echinipes	5♀
-	1	Harpacticidae	Harpacticus superflexus	1♀

Per .1 m^2

13	P. magna
4	C. langi
21	P. echinipes
4	H. superflexus

OCS-4	GLACIER	31 August 76
71°18.1'N	152°32.2'W	PPB-55 55 m

1.00 mm fraction	SMG 1340$_a$ - 10			
1♀	3	Cerviniidae	Pseudocervinia magna	3♀
-	1	Cerviniidae	Cervinia langi	1♂
-	13	Cletodidae	Paranannopus echinipes	13♀
-	1	Cletodidae	Argestes mollis	1♀
1♀	2	Harpacticidae	Harpacticus superflexus	2♀
	1	Cyclopoida A		

Per .1 m^2

13	P. magna
4	C. langi
52	P. echinipes
4	A. mollis
9	H. superflexus

OCS-4 71°18.1'N		GLACIER 152°32.2'W	31 August 76 PPB-55 55 m

1.00 mm fraction	SMG 1341$_a$ - 08			
-	3	Cerviniidae	Pseudocervinia magna	2♀,1C$_4$
1♀	7	Cletodidae	Paranannopus echini	7♀
-	1	Cletodidae	Argestes mollis	1♀
-	4	Harpacticidae	Harpacticus superflexus	4♀
-	1	Diasaccidae	Paramphiscopsis giesbrechti	1♀
-	3	Ectinosomatidae	Bradya typica	3♀
-	1	Ectinosomatidae	Halectinosoma sarsi	1♀
-	2	Tisbidae	Tisbe	2♀
	1	Cyclopoida A		1♀
	1	Cyclopoida	Neopontius argularis	

Per .1 m^2

12	P. magna
29	P. echinipes
4	A. mollis
16	H. superflexus
1	P. giesbrechti
3	B. typica
1	H. sarsi
2	Tisbe

OCS-4 GLACIER 1 Sept. 76
71°08.2'N 152°57.5'W PPB-25 26 m

1.00 mm fraction SMG 1360_s - 10

1♀	94	Cerviniidae	Pseudocervinia magna	76♀,2G♀,11C_4,3♂
-	8	Cerviniidae	Cervinia langi	8♂
-	2	Harpacticidae	Harpacticus superf.	2♀
-	1	Diosaccidae	Paramphiascopsis giesbrechti	1♀
-	16	Ectinosomatidae	Bradya typica	14♀,2C_4
-	7	Ectinosomatidae	Halectinosoma sarsi	5♀,1C_4,1♂

19 Cyclopoida A
1 Cyclopoida B
2 nauplii

OCS-4	GLACIER	1 Sept. 76
71°08.2'N	15°57.5'W	PPB-25 26 m

SMG 1361$_s$ - 11

38	Cerviniidae	Pseudocervinia magna	24♀,8C$_4$,3C$_3$,3G♀ (4 eggs)
8	Cerviniidae	Cervinia langi	8♀ (one individual P$_1$
3	Harpacticidae	Harpacticus superflexus	3♀
3	Ectinosomatidae	Bradya typica	1♀ 1G♀,1C$_4$
3	Ectinosomatidae	Halectinosoma sarsi	3♀

13 Cyclopoida A

OCS-4 GLACIER 1 Sept. 76
71°08.2'N 152°57.5'W PPB-25 26 m

SMG 1362_s - 09

68	Cerviniidae	Pseudocervinia magna	50♀,8C$_4$,6C$_3$,3G♀,1C$_4$
4	Cerviniidae	Cervinia langi	4♂
3	Harpacticidae	Harpacticus superflexus	3♀
1	Diosaccidae	Stenhelia nuwukensis	1♀
2	Ectinosomatidae	Bradya typica	1♀,1C$_4$
1	Ectinosomatidae	Halectinosoma sarsi	1♀

18 Cyclopoida A

OCS-4 GLACIER 1 Sept.76
71°08.2'N 152°57.5'W PPB-25 27 m

1.00 mm
fraction
1♀
-

SMG 1363_s - 08

50	Cerviniidae	Pseudocervinia magna	35♀,9C$_4$,6C$_3$
8	Cerviniidae	Cervinia langi	8♂
1	Diosaccidae	Stenhelia nuwukensis	1C$_4$
5	Ectinosomatidae	Bradya typica	5♀
3	Ectinosomatidae	Halectinosoma sarsi	2♀,1C$_4$

6♀ Cyclopoida A

OCS-4		GLACIER	1 Sept. 76
71°08.2'N		152°57.5'W	PPB-25 27 m

SMG 1364_s -08

97	Cerviniidae	Pseudocervinia magna	69♀,14C_4,8C_s,6G♀
8	Cerviniidae	Cervinia langi	7♂,1C_4♂
1	Diosaccidae	Stenhelia borqueti	1♀
6	Harpacticidae	Harpacticus superflexus	
18	Ectinosomatidae	Bradya typica	15♀,3C_4
6	Ectinosomatidae	Halectinosoma sarsi	4♀,2C_4
1	Ectinosomatidae	Halectinosoma neglectum	1♀

6 Cyclopoida A

OCS-6		Helo	11 Nov. 76
71°12.0'N		152°49.0'W	PPB-25 30 m

SMG 1500_s - 09

7	Cerviniidae	Pseudocervinia magna	3♀,3C_4,1♂
8	Cletodidae	Paranannopus echinipes	1♀, 7G♀(eggs 6,13,11,12,13, 11)
5	Harpacticidae	Harpacticus superflexus	5♀
1	Ectinosomatidae	Bradya typica	1♀
2	Ectinosomatidae	Halectinosoma sarsi	2♀
1	Tisbidae	Tisbe sp.	1♀

9♀ Cyclopoida A

OCS-6 Helo 11 Nov. 76
71°21.0'N 152°49.0'W PPB-25 30 m

SMG 1501_s - 09

7	Cerviniidae	Pseudocervinia magna	4♀,2C$_4$,1G♀
1	Cerviniidae	Cervinia magna	1♂
10	Cletodidae	Paranannopus echinipes	6♀,4G♀ (10,7,9,12)
1	Cyclopoida A		

OCS-6 Helo 11 Nov. 76
71°12.0'N 152°49.0'W PPB-25 30 m

SMG 1502_s - 07

8	Cerviniidae	Pseudocervinia magna	6♀,2C$_4$
7	Cletodidae	Paranannopus echinipes	5G♀, 2♀ (9,11,8,9,10)
1	Harpacticidae	Harpacticus superflexus	1♀
1	Thalestridae	Thalestris frigida	1♀
1	Ectinosomatidae	Bradya typica	1♀
1	Ectinosomatidae	Halectinosoma sarsi	1♀

OCS-6	Helo	11 Nov. 76
71°12.0'N	152°49.0'W	PPB-25 30 m

SMG 1503_5 - 07

2	Cerviniidae	Pseudocervinia magna	1♀,1G♀
4	Cletodidae	Paranannopus echinipes	4G♀(8,11,8)
1	Harpacticidae	Harpacticus superflexus	1♀

SMG 1504_s - 05

2	Cerviniidae	Pseudocervinia magna	2♀
2	Cletodidae	Paranannopus echinipes	2♀
1	Diosaccidae	Paramphiascopsis giesbrechti	1G♀

OCS-6 | Helo | 4 Nov. 76
71°17.6'N | 152°43.4'W | PPB-55 53 m

1.00 mm fraction	SMG 1495_a - 06			
-	2	Cerviniidae	Pseudocervinia magna	2♀
1	6	Cletodidae	Paranannopus echinipes	4♀,1G♀,$1C_3$
-	1	Laophontidae	Echinolaophonte brevispinosa	1♀
-	1	Ectinosomatidae	Bradya typica	1♀
1♀	-	Harpacticidae	Harpacticus superflexus	

Per .1 m^2

8	P. magna
25	P. echinipes
4	E. brevispinosa
4	B. typica
1	H. superflexus

1.00 mm fraction	SMG 1496_a - 09			
-	1	Cerviniidae	Pseudocervinia magna	1♀
-	1	Cletodidae	Eurycletodes arcticus	$1C_4$
1♀	4	Cletodidae	Paranannopus echinipes	4♀
-	6	Harpacticidae	Harpacticus superflexus	6♀
1o	-	Harpacticidae	Zaus sp. A	
-	1	Ectinosomatidae	Halectinosoma neglectum	1♀

Per .1 m^2

4	P. magna
4	E. arcticus
17	P. echinipes
24	H. superflexus
1	Zaus
4	H. neglectum

	OCS-6 71°17.6'N		Helo 152°43.4'W	4 Nov. 76 PPB-55 53 m
1.00 mm fraction	SMG 1497_a - 07			
- ♀	3	Cletodidae	Paranannopus echinipes	3♀
-	1	Diosaccidae	Pseudomesochar longifarcuta	1♀
-	2	Ectinosomidae	Halectinosoma neglectum	1♀,$1C_4$

Per .1 m^2

17	P. echinipes
4	P. longifurcata
8	H. neglectum

SMG 1498_a - 06

6	Cerviniidae	Pseudocervinia magna	1G♀,4♀,$1C_4$
9	Cletodidae	Paranannopus echinipes	9♀

Per .1 m^2

24	P. magna
36	P. echinipes

SMG 1499_s - 09

1	Certiniidae	Pseudocervinia magna	1♀
7	Cletodidae	Paranannopus echinipes	7♀
2	Harpacticidae	Harpacticus superflexus	2♀
2	Lasophontidae	Echinolaophonte brevispinosa	1♀,$1C_4$
1	Diosaccidae	Paramphiascopsis giesbrechti	1♀

OCS-6	Helo	3 Nov. 76
71°21.9'N	152°33.4'W	PPB-100 99m

SMG 1490_a - 08

1	Cletodidae	Paranannopus echinipes	1♀
1	Ectinosomatidae	Halectinosoma sarsi	1♀
1	Ectinosomatidae	Halectinosoma neglectum	1♀

Per .1 m^2

4	P. echinipes
4	H. sarsi
4	H. neglectum

SMG 1491_a - 08

1	Harpacticidae	Harpacticus superflexus	1♀
1	Harpacticidae	Zaus B	1♀
1	Ectinosomatidae	Halectinosoma neglectum	1♀
1	Thalestridae	Thalestris normani	1♀
2	Cyclopoid B		1♀,1♂

Per .1 m^2

4	H. superflexus
4	Zaus
4	H. neglectum
4	T. normani

SMG 1492_a - 07

1.00 mm fraction				
1♀	2	Cerviniidae	Pseudocervinia magna	2♀
-	1	Cletodidae	Paranannopus echinipes	1♀
-	2	Harpacticidae	Harpacticus superflexus	2♀
-	2	Disaccidae	Paramphiascopsis giesbrechti	1♂,$1C_3$
-	6	Ectinosomatidae	Halectinosoma neglectum	6♀
-	1	Tisbidae	Tisbe	1G♀

Per .1 m^2

9	P. magna
4	P. echinipes
8	H. superflexus
8	P. giesbrechti
24	H. neglectum
4	Tisbe

	OCS-6 71°21.9N		Helo 152°33.4'W	3 Nov. 76 PPB-100 99 m
1.00 mm fraction	SMG 1493_a - 05			
1♀	-	Cletodidae	Paranannopus echinipes	
-	3	Diosaccidae	Paramphiascopsis giesbrechti	2♀,$1C_4$
-	2	Harpacticidae	Harpacticus superflexus	2♀
-	2	Ectinosomatidae	Halectinosoma neglectum	2♀

Per .1 m^2

1	P. echinipes
12	P. giesbrechti
8	H. superflexus
8	H. neglectum

OCS-1		Truck	22 Oct. 75
72°41'N		156°30'W	Elson Lagoon 2 m
6	Harpacticidae	Harpacticus uniremis	6♀
3	Ectinosomidae	Halectinosoma neglectum	3♀
13	Tisbidae	Tisbe sp.	13♀

OCS-4	GLACIER	31 Aug. 76
71°18.1'N	152°32.2'W	PPB-55

SMG 1331 - 08

1	Harpacticidae	Harpacticus superflexus	1♀
2	Cletodidae	Paranannopus echinipes	1♀
2	Cerviniidae	Pseudocervinia magna	1♀

SMG 1333 - 10

1	Harpacticidae	Harpacticus superflexus	1♀
4	Cletodidae	Paranannopus echinipes	4♀
2	Cerviniidae	Pseudocervinia magna	1♀,1C
1	Ectinosomidae	Halectinosoma neglectum (sp. A)	1♀
2	Diosaccida	Parampiascella fulvofasciata	2♀

SMG 1334 - 09

9	Cletodidae	Paranannopus echinipes	9♀
2	Cerviniidae	Pseudocervinia magna	2♀

SMG 1337 - 09

2	Cletodidae	Paranannopus echinipes	2♀
1	Cerviniidae	Pseudocervinia magna	1♀

SMG 1338 - 07

15	Cletodidae	Paranannopus echinipes	14♀,1C
1	Cletodidae	Argestes mollis	1♀
2	Cerviniidae	Pseudocervinia magna	2♀
1	Ectinosomidae	Bradya typica	1♀
1	Diosaccidae	Typhlamphiascus lamellifer	1♂

SMG 1339 - 09

1	Cerviniidae	Pseudocervinia magna	1♀
1	Harpacticidae	Harpacticus superflexus	1♀

SMG 1342 - 09

7	Cletodidae	Paranannopus echinipes	7♀
1	Cerviniidae	Pseudocervinia magna	1♀

SMG 1343 - 06

2	Cletodidae	Paranannopus echinipes	1♀,1C
1	Ectinosomidae	Bradya typica	1G♀
1	Tisbidae	Tisbe sp.	1♀

OCS-4	GLACIER	31 Aug. 76
71°18.1'N	152°32.2'W	PPB-55 53 m

SMG 1345 - 08

1	Cerviniidae	Pseudocervinia magna	1♀
1	Harpacticidae	Harpacticus superflexus	1♀
2	Cletodidae	Parananopus echinipes	2♀

SMG 1346 - 09

1	Cerviniidae	Pseudocervinia magna	1♀
1	Cletodidae	Parananopus echinipes	1♀

SMG 1347 - 08

1	Harpacticidae	Harpacticus superflexus	1♀
1	Cletodidae	Argestes mollis	1♀
1		Cervinia	1♂

SMG 1348 - 09

5	Cletodidae	Parananopus echinipes	5♀
3	Cerviniidae	Pseudocervinia magna	3♀
1	Diosaccidae	Paramphiascopsis giesbrechti	1G♀
1	Ectinosomidae	Bradya typica	1♀
1	Ectinosomidae	Halectinosoma neglectum (A)	1♀
1	Lasophontidae	Echinolaophonte brevispinosa	1♀

SMG 1349 - 08

1	Cerviniidae	Pseudocervinia magna	1♀

SMG 1350 - 10

8	Cletodidae	Parananopus echinipes	8♀
3	Cerviniidae	Pseudocervinia magna	3♀
2	Harpacticidae	Harpacticus superflexus	2♀
5	Lasophontidae	Echinolaophonte brevispinosa	5♀
2	Ectinosomidae	Bradya typica	1♀,1G♀
1	Cletodidae	Rhizothrix	1♀

OCS-5	ALUMIAK	20 Aug. 76
70°56.4'N	153°12.9'W	PPB-5 5.5 m

SMG 1395

3	Harpacticidae	Harpacticus superflexus	3♀
1	Thalastridae	Thalestris frigida	1♀
15	Diosaccidae	Stenhelia nuwukensis	15♀

SMG 1396

1	Thalestridae	Thalestris frigida	1♀
8	Diosaccidae	Stenhelia nuwukensis	8♀
1	Diosaccidae	Stenhelia C	1♀

SMG 1398

31	Harpacticidae	Harpactucus superflexus	31♀
4	Thalestridae	Thalestris frigida	4♀
400	Diosaccidae	Stenhelia nuwukensis	400♀
7	Ectinosomidae	Bradya typica	5♀,2G♀
1	Diosaccidae	Stenhelia proxima	1G♀
4	Echinosomidae	Halectinosoma A	1♂,3♀
1	Echinosomidae	Halectinosoma neglectum	1♀
2	Tachidiidae	Thompsonula hyaenae	2G♀
1	Cyclopoida	Euryte longicordata	1♀
14	Diosaccidae	Stanhelia B	14♀
8	Diosaccidae	Stenhelia C	8♀
2	Diosaccidae	Stenhelia D	2♂

SMG 1399

1	Thalestridae	Thalestris frigida	1♀
6	Harpacticidae	Harpacticus superflexus	6♀
1	Diosaccidae	Stenhelia nuwukensis	
1	Diosaccidae	Stenhelia B	

SMG 1400

5	Thalestridae	Thalestris frigida
21	Harpacticidae	Harpacticus superflexus
2	Cletodidae	Eurycletodes arcticus
1	Cletodidae	Heteropsyllus rostratus similis
2	Ectinosomatidae	Halectinosoma neglectum
1	Ectinosomatidae	Bradya typica
1	Ectinosomatidae	Halectinosoma
505	Diosaccidae	Stenhelia nuwukensis
72	Diosaccidae	Stenhelia B (may be S. nuwukensis C_4)
3	Diosaccidae	Stenhelia proxima (CF)

OCS-5	ALUMIAK	20 Aug. 76
70°56.4'N	153°12.9'W	PPB-5 5.5 m

SMG 1396_s

5	Tachidiidae	Thompsonula hyaenae	3G♀
1	Cletodidae	Eurycletodes arcticus	1♀
16	Ectinosomidae	Halectinosoma neglectum	
9	Harpacticidae	Harpacticus superflexus	9♀
5	Thalestridae	Thalestrus frigida	5♀
341	Diosaccidae	Stenhelia nuwukensis	♀
6	Diosaccidae	Stenhelia B	♀
3	Diosaccidae	Stenhelia C	♀

OCS-5	ALUMIAK	20 Aug. 76
70°59.1'N	153°08.8'W	PPB-10 9.9 m

SMG 1401

1	Harpacticidae	Harpacticus superflexus	1♀

SMG 1406

6	Harpacticidae	Harpacticus superflexus	1♀
3	Diosaccidae	Stenhelia nuwukensis	3♀

OCS-5	ALUMIAK	27 Aug. 76
70°24.9'N	147°30.5'W	NIB-5 5.0 m

SMG 1440

1	Harpacticidae	Harpacticus superflexus	1♀

OCS-5	ALUMIAK	28 Aug. 76
70°26.0'N	147°26.2'W	NIB-15 16.2 m

SMG 1443

1	Harpacticidae	Harpacticus superflexus	1♀

SMG 1445

1	Harpacticidae	Harpacticus superflexus	1♀
1	Ectinosomidae	Bradya typica	1♀

SMG 1447

2	Harpacticidae	Harpacticus superflexus	2♀

OCS-5	ALUMIAK	28 Aug. 76
70°24.3'N	147°29.2'W	NIB-10 9.8 m

SMG 1454

2	Harpacticidae	Harpacticus superflexus	2♀

OCS-5	ALUMIAK	19 Aug. 76
71°24.9'N	156°23.8'W	BRB-10 9.8 m

SMG 1388

4	Harpacticidae	Harpacticus superflexus	4♀
1	Thalestridae	Thalestris frigida	1♀
1	Ectinosomidae	Halectinosoma neglectum	1G♀

CS-5	ALUMIAK	19 Aug. 76
71°23.4'N	156°27.1'W	BRB-5 5.2 m

SMG 1389

1	Thalestridae	Parathalestris jacksoni	1♀

SMG 1390

1	Thalestridae	Thalestris frigida	1♀

SMG 1393

2	Thalestridae	Thalestris frigida	1♀
4	Harpacticidae	Harpacticus superflexus	4♀
2	Ectinosomidae	Bradya typica	1♀,1 juv ♀

OCS-5	ALUMIAK	22 Aug. 76
70°34.8'N	153°08.8'W	PIB-10 10.2 m

SMG 1427

3	Thalestridae	Thalestris frigida	3♀
3	Diosaccidae	Stenhelia nuwukensis	3♀

OCS-5	ALUMIAK	31 Aug. 76
70°10.8'N	143°33.7'W	BAB-20 20.3 m

SMG 1461

7	Harpacticidae	Harpacticus superflexus	7♀

SMG 1463

2	Harpacticidae	Harpacticus superflexus	2♀

SMG 1466

170	Harpacticidae	Harpacticus superflexus	
4	Diosaccidae	Stenhalia proxima	2♀,2G♀
10	Diosaccidae	Stenhelia nuwukensis	
3	Diosaccidae	Stenhelia boaqueti	3♀
1	Tisbidae	Tisbe	1G♀
5	Thalestridae	Thalestris frigida	5♀
4	Cletodidae	Parananopus echinipes	2♀, 2 Juv.
1	Tisbidae	Zosime sp. A	1♀
2	Ectinosomidae	Bradya typica	Juv.
1	Ectinosomidae	Halectinosoma sp. C	1 Juv.
1	Ectinosomidae	Halectinosoma neglectum	1
20	Ectinosomidae	Bradya typica	2♂, 18♀

OCS-5 ALUMIAK 3 Sept. 76
70°09.5'N 143°36.2'W BAB-15 15.1

SMG 1467

82	Harpacticidae	Harpacticus superflexus	82♀
5	Thalestridae	Thalestris frigida	5♀
3	Diosaccidae	Stenhelia nuwukensis	3♀
1	Ectinosomidae	Bradya typica	1♀

SMG 1468

60	Harpacticidae	Harpacticus superflexus	59♀, 1 Juv.
1	Thalestridae	Thalestris frigida	1♀
10	Diosaccidae	Stenhelia nuwukensis	10♀
6	Ectinosomidae	Bradya typica	1G♀,1♂,4♀

SMG 1469

6	Harpacticidae	Harpacticus superflexus	5♀, 1 Juv.
3	Diosaccidae	Stenhelia nuwukensis	3♀
1	Ectinosomidae	Bradya typica	1♀

SMG 1470

28	Harpacticidae	Harpacticus superflexus	28♀
3	Diosaccidae	Stenhelia nuwukensis	3♀
2	Ectinosomidae	Bradya typica	2♀

SMG 1471

2	Harpacticidae	Harpacticus superflexus	2♀

OCS-5 ALUMIAK 3 Sept. 76
70°09.0'N 143°32.2'W BAB-10 10.1 m

SMG 1473

1	Harpacticidae	Harpacticus superflexus	1♀

SMG 1475

5	Harpacticidae	Harpacticus superflexus	5♀

OCS-7	GLACIER	30 Aug. 76
71°12'N	145°35'N	Sta. 54 2104 m

SMG 1661_s

1	Harpacticidae	Harpacticus supervlexus
1	Cletodidae	Argestes mollis

OCS-7	GLACIER	31 Aug. 77
71°05'N	146°33'N	Sta. 58 1144 m

SMG 1663_s

6	Harpacticidae	Harpacticus superflexus	6♀
1	Cletodidae	Argestes mollis	1♀
12	Thalestridae	Pseudotachidius	12♀
1	Thalestrida	New genus	1♀
2	Ectinosomidae	Bradya confluens	
5	Cerviniidae	Cervinia BB (brevipes)	
1	Cerviniidae	Cerviniopsis smirnovi	

OCS-7 GLACIER 11 Aug. 77
71°06.7'N 153°01.5'W PPB-25 24 m

SMG 1565

1	Harpacticidae	Harpacticus superflexus	1♀
1	Cerviniidae	Pseuodcervinia magna	

SMG 1566

1	Harpacticidae	Harpacticus superflexus	1♀
2	Cerviniidae	Pseudocervinia magna	2♀

71°14.7'N 152°53.5'W PPB-40 39 m

SMG 1549

1	Harpacticidae	Harpacticus superflexus	1♀

SMG 1550

3	Harpacticidae	Harpacticus superflexus	3♀

SMG 1552

1	Ectinosomidae	Bradya typica	1♀

SMG 1556

1	Harpacticidae	Harpacticus superflexus	1♀

SMG 1557

2	Harpacticidae	Harpacticus superflexus	2♀
1	Diosaccidae	Paramphiascopsis giesbrechti	

OCS-7	GLACIER	11 Aug. 77
71°19'N	152°50'W	PPB-55 54 m

SMG 1541

12	Harpacticidae	Harpacticus superflexus	11♀, 1 Juv.
8	Cerviniidae	Pseudocervinia magna	7♀,1C
2	Diosaccidae	Paramphiascopsis giesbrechti	1♀,1G♀
1	Diosaccidae	Pseudomesochra longifurcata T. Scott, 1902	1♀
1	Tisbidae	Tisbe	1♀

SMG 1542

5	Harpacticidae	Harpacticus superflexus	5♀
6	Cerviniidae	Pseudocervinia magna	5♀,1C♀
1	Laophontidae	Echinolaophonte brevispinosa	1♂

SMG 1543

5	Harpacticidae	Harpatcicus superflexus	5♀
2	Cerviniidae	Pseudocervinia magna	
1	Cletodidae	Argestes mollis	1♀
1	Ameiridae	Sarsameira n. sp.	1♀

Smg 1545

1	Cerviniidae	Pseudocervinia magna	1♀

SMG 1546

1	Harpacticidae	Harpacticus superflexus	1♀
4	Cerviniidae	Pseudocervinia magna	3♀,1C
1	Diosaccidae	Pseudocervinia giesbrechti	1G♀

OCS-7	GLACIER	12 Aug. 77
71°19'N	152°50'W	PPB-70 66 m

SMG 1570

11	Harpacticidae	Harpacticus superflexus	11♀
7	Cerviniidae	Pseudocervinia magna	7♀

SMG 1571

1	Cerviniidae	Pseudocervinia magna	1♀

SMG 1572

2	Harpacticidae	Harpacticus superflexus	2♀
1	Cerviniidae	Pseudocervinia magna	1♀

SMG 1573

1	Cerviniidae	Pseudocervinia magna	1♀
2	Cerviniidae	Cervinia langi	1♀

SMG 1574

2	Cerviniidae	Pseudocervinia magna	2♀

71°23.4'N	152°43'W	PPB-100 100 m

SMG 1576

1	Harpacticidae	Harpacticus superflexus	1♀

SMG 1577

1	Harpacticidae	Harpacticus superflexus	1♀
1	Diosaccidae	Typhlamphiascus lamellifer	1♀
1	Cletodidae	Paranannopus echinipes	1♀

SMG 1578

2	Harpacticidae	Harpacticus superflexus	1♀

SMG 1579

1	Harpacticidae	Harpacticus superflexus	1♀
1	Cerviniidae	Pseudocervinia magna	1C

OCS-7		GLACIER	9 Aug. 77
72°23.7'N		154°37.2'W	Sta. 10 2470 m
SMG 1530$_s$			
1	Cletodidae	Mesocletodes brevicauda?	1♀
2	Cerviniidae	Cerviniopsis smirnovi	

OCS-7		GLACIER	20 Aug. 77
72°58'N		146°29'W	Sta. 29 3576 m
SMG 1602$_s$			
1	Cerviniidae	Cervinia n. sp. AA	1♀

OCS-7		GLACIER	21 Aug. 77
72°55.8'N		146°36.0'W	Sta. 29 3843 m
SMG 1603$_s$			
1	Cerviniidae	Cervinia sp. AA	1♀

OCS-7		GLACIER	22 Aug. 77
72°42'N		143°40'W	Sta. 32 3386 m
SMG 1608$_s$			
1	Cerviniidae	Cervinia sp. AA	1C

OCS-7		GLACIER	24 Aug. 77
70°51'N		141°36.8'W	Sta. 34 1958 m
SMG 1610$_s$			
1	Cletodidae	Argestes mollis	1♀

OCS-7 GLACIER 24 Aug. 77
70°52.8'N 141°46.5'W Sta. 34 2086 m

SMG 1613_s

4	Harpacticidae	Harpacticus superflexus	4♀
1	Cerviniidae	Cervinia longi	1C

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24 Aug. 77
70°40'N 41°35.5'W Sta. 35 1097 m

SMG 1614

2	Harpacticidae	Harpacticus superflexus	2♀

SMG 1614_s

8	Harpacticidae	Harpacticus superflexus	2♀
1	Ectinosomidae	Bradya confluens	1♀
4	Thalestridae	Pseudotachidius coronatus	3♀,1C

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25 Aug. 77
70°40.5'N 141°38'W Sta. 35 997 m

SMG 1615_s

12	Harpacticidae	Harpacticus superflexus	12♀
3	Thalestridae	Pseudotachidius coronatus	3♀,1C

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25 Aug. 77
70°40.6'N 141°41.1'W Sta 35 686 m

SMG 1616

8	Harpacticidae	Harpacticus superflexus	8♀

SMG 1616_s

14	Harpacticidae	Harpacticus superflexus	12♀
1	Thalestridae	Pseudotachidius	1C♀
1	Cerviniidae	Cervinia langi	1♀
2	Ectinosomidae	Bradya confluens	

OCS-7 GLACIER 25 Aug. 77
70°42'N 141°41.1'W Sta. 35 640 m

SMG 1617$_s$

16	Harpacticidae	Harpacticus superflexus	16♀
7	Thalestridae	Pseudotachidius	6♀,1o
1	Cerviniidae	Cervinia langi	1C
2	Ectinosomidae	Bradya confluens	2♀

70°42.5'N 141°38.5'W Sta. 35 644 m

SMG 1618$_s$

17	Harpacticidae	Harpacticus superflexus	17♀
12	Thalestridae	Pseudotachidius	12♀
2	Thalestridae	New genus	1♀,1C
1	Cerviniidae	Cervinia langi	1C

70°40.6'N 141°43'W Sta. 35 659 m

SMG 1619

8	Harpacticidae	Harpacticus superflexus	8♀

SMG 1619$_s$

7	Harpacticidae	Harpacticus superflexus	7♀
3	Thalestridae	Pseudotachidius	3♀
1	Thalestridae	New genus	1C

70°42.8'N 141°39.5'W Sta. 35 659 m

SMG 1620

2	Harpacticidae	Harpacticus superflexus	2♀

SMG 1620$_s$

15	Harpacticidae	Harpacticus superflexus	2♀
16	Thalestridae	Pseudotachidius	14♀,1G♀,1♂
1	Thalestridae	New genus	1♀
4	Cletodidae	Argestes mollis	4♀
2	Cerviniidae	Cervinia langi	1♀,1C

OCS-7 GLACIER 25 Aug. 77
70°41.0'N 141°27'W Sta. 35 1025 m

SMG 1622_s

12	Harpacticidae	Harpacticus superflexus	12♀
2	Thalestridae	Pseudotachidius	2♀
1	Thalestridae	New genus	1♂

70°30.5'N 141°35'W Sta. 36 403 m

SMG 1623

2	Harpacticidae	Harpacticus superflexus	2♀

SMG 1624

2	Harpacticidae	Harpacticus superflexus	2♀

70°29.8'N 141°35'W Sta. 36 401 m

SMG 1625

1	Harpacticidae	Harpacticus superflexus	1♀

70°29.0'N 141°35'W Sta. 36 403 m

SMG 1626

1	Harpacticidae	Harpacticus superflexus	1♀
2	Cerviniidae	Cervinia langi	2♀
1	Thalestridae	Pseudotachidius coronatus	1♀

SMG 1627

5	Harpacticidae	Harpacticus superflexus	5♀
1	Cerviniidae	Cervinia langi	1♀

OCS-6	HELO	2 Nov. 76
71°20.3'N	152°37.8'W	PPB-70 66 m

SMG 1485

1	Cerviniidae	Pseudocervinia magna	1♀

SMG 1487

1	Harpacticidae	Harpacticus superflexus	1♀

OCS-6	HELO	3 Nov. 76
71°21.9'N	152°33.4'W	PPB-100 99 m

SMG 1492

1	Cerviniidae	Pseudocervinia magna	1♀

SMG 1493

1	Cletodidae	Paranannopus echinipes	1♀

OCS-6	HELO	4 Nov. 76
71°17.6'N	152°43.4'W	PPB-55 53 m

SMG 1495

1	Harpacticidae	Harpacticus superflexus	1♀
1	Cletodidae	Paranannopus echinipes	1♀

SMG 1496

1	Cletodidae	Paranannopus echinipes	1♀
1	Harpacticidae	Zaus sp. A	1♂

SMG 1497

3	Celtodidae	Paranannopus echinipes	3♀

OCS-7	GLACIER	26 Aug. 77
69°50.5'N	141°24.5'W	Sta. 37 25 m

SMG 1631

1	Harpacticidae	Harpacticus superflexus	1♀

69°50.2'N 141°25.0'W

SMG 1632

1	Harpacticidae	Harpacticus superflexus	1♀
1	Diosaccidae	Stenhelia nuwukensis	1C

69°48.9'N 141°27.2'N

SMG 1633

6	Harpacticidae	Harpacticus superflexus	6♀
2	Diosaccidae	Paramphiascopsis giesbrechti	2♀
3	Diosaccidae	Stenhelia nuwukensis	3C
4	Cletodidae	Paranannopus echinipes	4♀
1	Cerviniidae	Pseudocervinia magna	1♀
2	Ectinosomidae	Halectinosoma neglectum A	2♀
1	Ectinosomidae	Bradya typica	1C

70°10.7'N	141°28'W	Sta. 39 50 m

SMG 1637

1	Harpacticidae	Harpacticus superflexus	1♀
1	Cerviniidae	Pseudocervinia magna	1C
1	Cerviniidae	Cervinia langi	1♀

70°10.5'N 141°25.0'W

SMG 1638

1	Harpacticidae	Harpacticus superflexus	1♀
2	Cerviniidae	Pseudocervinia magna	2♀
1	Diosaccidae	Paramphiascopsis giesbrechti	1

70°10.4'N 141°22.0'W

SMG 1639

2	Harpacticidae	Harpacticus superflexus	2♀
4	Cerviniidae	Pseudocervinia magna	4♀

OCS-7	GLACIER	26 Aug. 77
70°10.1'N	141°19.6'W	Sta. 39 50 m

SMG 1641

5	Harpacticidae	Harpacticus superflexus	5♀
1	Tisbidae	Tisbe sp. C	1♀

OCS-7	GLACIER	27 Aug. 77
70°28'N	141°34.5'W	Sta. 40 160 m

SMG 1644

7	Harpacticidae	Halectinosoma superflexus	7♀
11	Cerviniidae	Cervinia langi	11♀
1	Ectinosomidae	Bradya confluens	1C
1	Cletodidae	Mesocletodes katharinae	1♀

70°28'N	141°34.5'W	164 m

SMG 1645

1	Harpacticidae	Harpacticus superflexus	1♀
3	Cerviniidae	Cervinia langi	3♀

70°28'N	141°34.5'W	148 m

SMG 1646

3	Harpacticidae	Harpacticus superflexus	3♀
2	Cerviniidae	Cervinia langi	2♀

70°28'N	141°34.5'W	136 m

SMG 1647

1	Harpacticidae	Harpacticus superflexus	1♀
5	Cerviniidae	Cervinia langi	5♀
1	Cerviniidae	Pontostratiotes ameliotes?	
1	Cletodidae	Argestes mollis	1♀

C. Estimate of Funds Expended

	Budget	Spent	Spent This Quarter
Salaries & Wages	$271,960	$243,794	$11,780
Payroll Assessment	48,483	41,951	2,900
Supplies & Services	53,978	52,181	5,013
Travel	20,623	16,581	1,204
Equipment	50,617	50,431	0
Overhead	133,835	119,911	7,397
TOTAL	$579,496	$524,849	$28,294

Salaries Committed	(30 June 1980)	Paid	Outstanding
Carey, A.G.	$14,616	$ 9,966	$ 4,650
Montagna, P.	1,862	1,862	0
Ruff, R.	13,758	9,030	4,728
Scott, P.	10,236	6,824	3,412
Bilyard, G.	3,276	3,276	0
Walters, K.	7,274	3,954	3,320
Hill, R.		13	
Secretarial	15,264	15,205	59
			$16,169

Students:

Cronin, D.	154
Eckhout, T.	24
Gollubier, K.	308

X. Auxiliary Material

A. References Used (Bibliography)

See reference lists at the end of each report section.

B. Papers in Preparation or in Print

1. Papers in print

a. Bilyard, G.R. and A.G. Carey, Jr. Zoogeography of western Sea Polychaeta. Sarsia. In press.

2. Papers in preparation

a. Carey, A.G., Jr., P.H. Scott, and K. Walters. The distribution and abundance of nearshore bivalve molluscs in the southwestern Beaufort Sea.

b. Carey, A.G., Jr. and R.E. Ruff. The distribution and abundance of nearshore polychaetous annelids in the southwestern Beaufort Sea.

c. Carey, A.G., Jr. and R.E. Ruff. The ecology of polychaetous annelids across the southwestern Beaufort Sea continental shelf.

d. Carey, A.G., Jr. and P.H. Scott. The ecology of bivalve molluscs across the southwestern Beaufort Sea continental shelf.

e. Dickinson, J.J. and A.G. Carey, Jr. The distribution, abundance and ecology of gammarid amphipods across the southwestern Beaufort Sea shelf.

f. Carey, A.G., Jr. Temporal variability of benthic communities and species populations across the western Beaufort Sea continental shelf.

C. Oral Presentations

Carey, A.G., Jr. Sea ice epontic community-benthic faunal community interactions. NOAA-OCSEAP Winter Studies Synthesis Meeting, Fairbanks, AK, March 1980.