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The Distribution and Abundance of *Chloeia pinnata* Moore, 1911 (Polychaeta: Amphinomidae) on the Southern California Borderland[1]

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ABSTRACT: The amphinomid polychaete *Chloeia pinnata* Moore (1911) is a widely distributed member of the benthos of the southern California borderland where it is a prominent faunal element of every major habitat including the deep basins. In this wide range of environments it lives with a large number of other taxa which differ markedly from one location to another. The population densities of *Chloeia* were highest in two very dissimilar types of environments—the offshore insular shelf of the Channel Islands and Cortes and Tanner Banks, and the nearshore mainland shelf. The two offshore areas are primarily non-depositional environments where relatively strong currents result in the development of coarse sediments rich in biogenic calcium carbonate components. These areas are influenced by persistent upwelling. By contrast, the parts of the mainland shelf where population densities of *Chloeia* were high, are in equilibrium environments highly influenced by the release of wastewaters.

THE FIREWORM *Chloeia pinnata* MOORE, 1911 is an important member of the benthos of the southern California continental borderland. It is a faunal element in every major habitat type in the borderland including two of the deep basins, Santa Catalina Basin and Santa Cruz Basin. It is particularly prominent on the insular shelves of the Channel Islands and Cortes and Tanner Banks (AHF:USC, 1965; Hartman, 1955, 1956, 1963, 1966; Hartman and Barnard, 1958, 1960; Emerson, 1971; Fauchald and Jones, 1979a, 1979b, 1983).

The purpose of this paper is to document the distribution, abundance, spatial and temporal variation, and faunal associates of *Chloeia pinnata* in the southern California borderland.

The present paper is based on data gathered during three major studies of the benthos of southern California. The Allan Hancock Foundation Survey of the southern California mainland shelf (the State Project) was conducted between 1956 and 1961 (AHF:USC, 1965). This comprehensive survey was supported by the California State Water Pollution Control Board (now termed the State Water Quality Control Board) and the late Captain G. Allan Hancock. The other two studies of the benthos of southern California were funded by the Bureau of Land Management: the Baseline Study (1975–1976) and the Benchmark Study (1976–1977). These two studies together constitute the largest investigation ever made in this marine region (Fauchald and Jones, 1979a, 1979b, 1983).

METHODS

During the State Project, deep-water samples were collected by a modified Hayward Standard orange-peel bucket (=OPB) with an areal coverage of about 0.25 m^2 (actual rated areal coverage = 2–3/5 square feet). The animals collected were limited by the size of the mesh, 1 mm, through which the sediment was screened aboard ship before preservation and sorting (Durham, 1955; Barnard and Jones, 1960; AHF:USC, 1965; Jones, 1969).

In both the Baseline and Benchmark studies samples were collected by a modified 1/16 m^2

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USNEL-Reineck spade (or box) corer (Hessler and Jumars, 1974). A subsample of each core was collected for sedimentary analysis. Benthic samples were screened through 1.0 mm and 0.5 mm stainless steel screens using the overflow-barrel method. The benthic macrofaunal invertebrates were narcotized for twenty minutes in 6% magnesium chloride in sea water prior to killing and fixation; specimens were killed and fixed in 10% buffered sea water formalin; after 36 hours samples were transferred to 70% ethanol for preservation (Fauchald and Jones, 1983).

A rapid identification procedure was used to analyze 712 benthic samples (Fauchald and Jones, 1983). Some taxa were identified to the specific level, whereas others were identified only to the generic or familial level under the limitations of this method. All taxa were identified to species for 165 of 712 samples collected during the Baseline Study and for all of the 318 samples collected during the Benchmark Study (Fauchald and Jones, 1979b).

The spatial distribution of *Chloeia pinnata* at the Benchmark sampling locations was determined using an Index of Dispersion (Fisher, 1970; Jumars, 1975).

Classification analysis by the methods of Smith (1976) was used to identify species associated with *Chloeia pinnata*. For this inverse classification, in which species were grouped according to their distribution among stations, the Bray-Curtis Measure (Bray and Curtis, 1957) was used as the measure of ecological distance. Dendrograms illustrating the faunal associates of *Chloeia* are included in this paper.

Sedimentary analyses were made by geologists at the University of Southern California (State Project), California State University, Northridge (Baseline Study), and the University of California, Los Angeles (Benchmark Study).

RESULTS

Geographic Distribution

Chloeia pinnata is widely distributed throughout the southern California borderland (Figure 1). It is a faunal element of every major habitat type in the borderland including two of the deep basins, Santa Catalina Basin and Santa Cruz Basin. On the mainland shelf it occurs from Point Conception to the US-Mexican border. It is a very important element of the biota of the insular shelf of the Channel Islands and Cortes and Tanner Banks at the southern end of the Santa Rosa-Cortes Ridge. It also occurs on the ridge north of Santa Catalina Island and the ridge north of Santa Barbara Island.

Chloeia was collected at 148 (20.7%) of the 712 stations sampled during the Baseline Study. Population densities range from 16 to 1,200 individuals per m^2 (mean = 198.9/m^2). Densities were highest in two very dissimilar environments: the Santa Rosa-Cortes Ridge (the southern insular shelves of San Miguel Island and Santa Rosa Island at the northern end of the ridge, and Cortes and Tanner Banks at the southern end of the ridge), and the mainland shelf (Santa Monica Bay and San Pedro Bay).

The insular shelves of the Channel Islands and the Cortes and Tanner Banks are primarily nondepositional environments. Relatively strong currents result in winnowing of finer detrital sediments and the development of ripple marks on unconsolidated sediments. Sediments are frequently coarse and relatively high in calcium carbonate content, and the sediment patterns of the region tend to be complex. These areas may be influenced by persistent upwelling centers of the Point Conception area in the north (R. C. Dugdale, personal communication) and upwelling resulting from entrainment of deeper, subsurface water by the California Current across the Santa Rosa-Cortes Ridge (Emery, 1960).

During the Baseline Study *Chloeia* was collected at 13 (28%) of the 47 stations comprising the San Miguel Island HDSA; population densities ranged from 16 to 272 individuals per m^2 (mean = 81.2/m^2). It was present at 31 (30%) of the 102 stations forming the Santa Rosa Island HDSA; in this sampling grid, population densities ranged from 16 to 560 individuals per m^2 (mean = 131.1/m^2). During the Benchmark Study much higher population densities of *Chloeia* were recorded on the Santa Rosa Island Shelf (Station 808). The four summer replicates represented densities

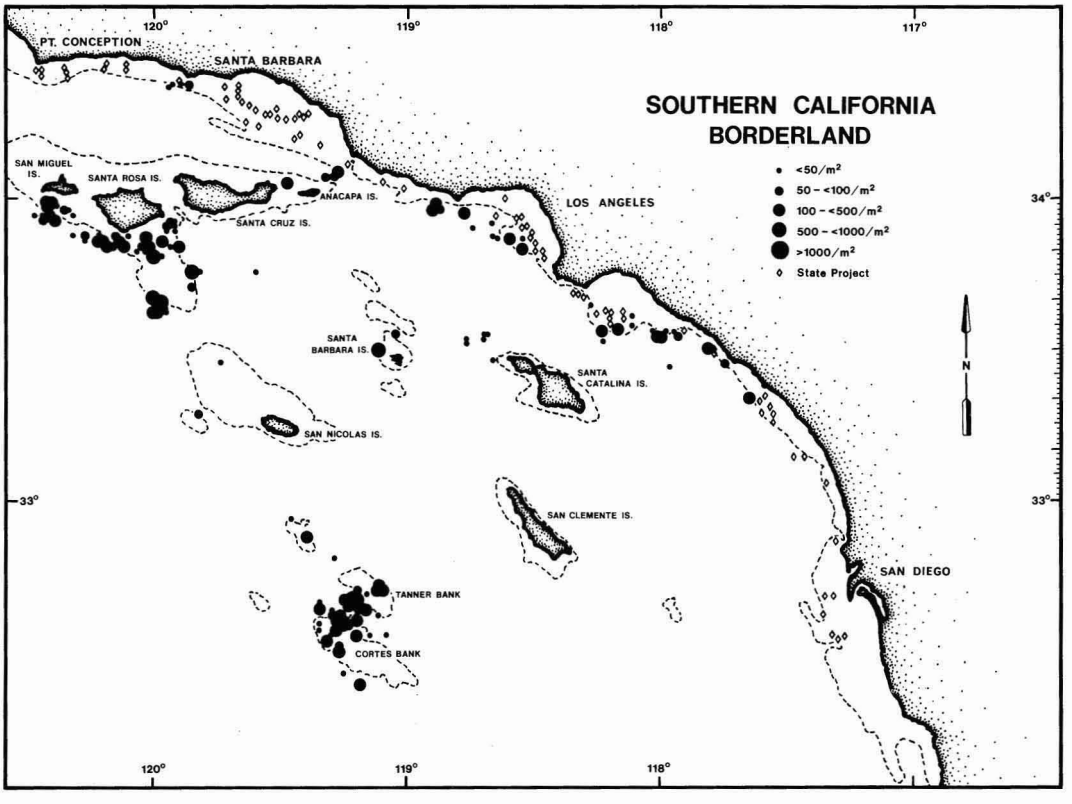

FIGURE 1. Chart of the southern California borderland showing the locations where *Chloeia pinnata* was collected during the Baseline and Benchmark Studies. Circle-size indicates population density; see legend. State Project sampling locations on the mainland shelf are indicated by ◇'s; population density at these locations is not shown.

ranging from 16/m^2 to 5984/m^2 (mean = 2404). In the Cortes-Tanner HDSA, a grid of 119 stations, *Chloeia* was present at 37 stations (31%); its population densities ranged from 16 to 1200 (mean = 180.6/m^2).

By contrast to these offshore areas, the areas on the mainland shelf, where densities of *Chloeia* were high, are equilibrium environments modified by man's activities, particularly the release of domestic and industrial wastewater into the marine environment. The combined discharge levels are in excess of one billion gallons of effluent per day (Schafer, 1980). Except for areas of rock and relic sediments, sediments in this area are finer, much lower in calcium carbonate and higher in total organic carbon than on the Santa Rosa-Cortes Ridge. Neither strong currents nor major upwelling are major factors in the area.

On the mainland shelf at 26 stations in Santa Monica Bay (including the Point Dume HDSA) and San Pedro Bay (including the Huntington Beach HDSA), population densities of *Chloeia* ranged from 16 to 320 individuals per m^2 (mean = 90.5/m^2).

Distribution by Depth

The depth distribution of *Chloeia pinnata* reflects the fact that this species primarily inhabits the topographic highs—shelves, ridges, and banks—of the borderland, but it also has been collected from two of the deep basins of the borderland. It was collected at 157 sampling locations of the 733 sampled during the Baseline (712) and Benchmark (21) studies; in this sample set its depth distribution was 20 to 1,877 m (mean = 202.0 m) (Figure 2). The

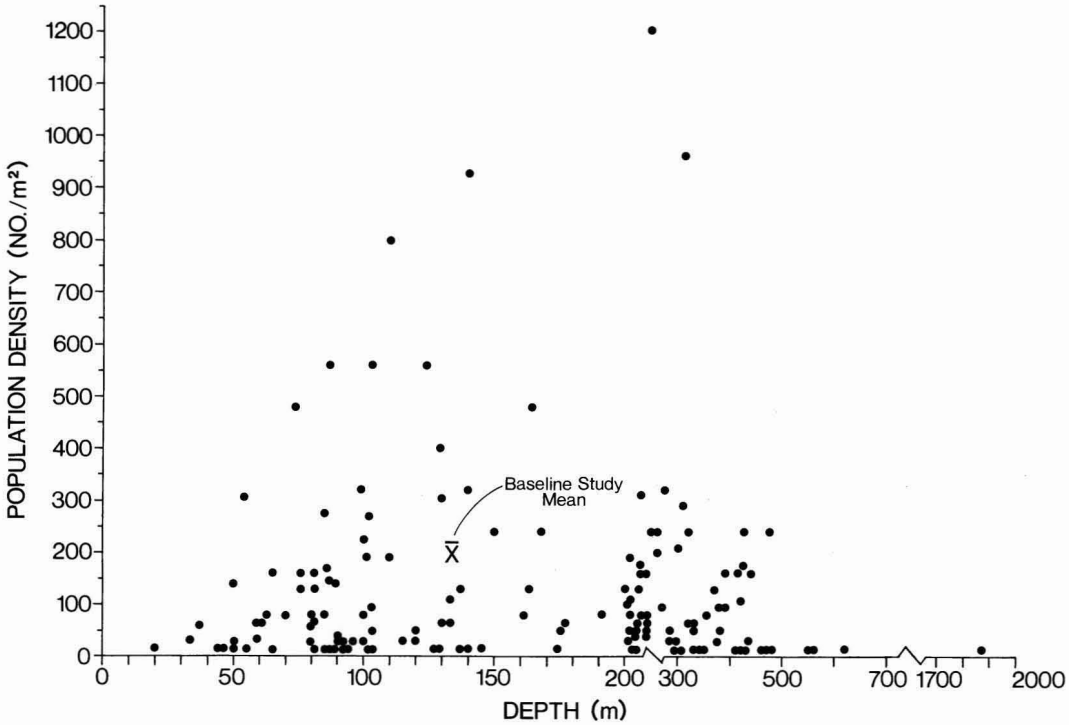

FIGURE 2. Depth distribution of *Chloeia pinnata* on the southern California borderland. The symbol $\bar{x}$ indicates the position of the mean depth and the mean density.

deepest recorded collection was from the Santa Cruz Basin (Station 234; 1,877 m). Hartman and Barnard (1958; 1960) reported its collection from the Santa Catalina Basin (Station 2130; 1,260 m).

On the insular shelves of San Miguel and Santa Rosa Islands the samples containing *Chloeia* were collected in depths from 20 to 560 m (mean = 156.8). The samples from Cortes and Tanner Banks were collected in depths from 65 to 390 m (mean = 186.2 m). There are three estimates of the depth range of *Chloeia* on the mainland shelf and its adjacent slopes: the 32 samples collected by Hartman (1955; 1966) were collected in depths from 47 to 819 m (mean = 265.1 m); the 95 samples collected during the Water Control Board study of the mainland shelf were from sampling locations ranging from 13 to 415 m (mean = 97.8 m); and the samples collected during the BLM Baseline Study were from locations ranging from 33 to 622 m (mean = 184.6 m). Combining the data from these three surveys the overall range of this species on the mainland shelf and its slopes is 13 to 819 m (mean = 164.0 m). Except for the specimens collected in the basins, *Chloeia pinnata* was not collected in water depths greater than 820 meters on the continental borderland.

Distribution in Relation to Sediments

Data are available on the sedimentary characteristics of the substrate at most of the Baseline sampling locations (118 of 148) where *Chloeia pinnata* was collected. A comparison of the sedimentary habitat of *Chloeia* on the Channel Island shelf (San Miguel and Santa Rosa Islands), Cortes and Tanner Banks and the mainland shelf is presented in Table 1. Sediments are generally coarser on the insular shelf and the banks than on the mainland shelf (average mean *phi* of 3.4 and 3.0 compared to 4.6). An important difference between the two

TABLE 1

A COMPARISON OF THE HABITAT, DEPTH AND SEDIMENT CHARACTERISTICS OF *Chloeia pinnata* ON THE INSULAR SHELF, CORTES AND TANNER BANKS AND THE MAINLAND SHELF. Mean, range and number of stations are given for each variable

	INSULAR SHELF	CORTES AND TANNER BANKS	MAINLAND SHELF
Number/m^2	199.0 16–560 n = 44	180.6 16–1200 n = 37	90.5 16–320 n = 26
Depth (m)	160.0 20–472 n = 44	186.2 65–390 n = 37	184.6* 33–622 n = 36
Mean *phi*	3.4 2.0–7.0 n = 37	3.0 1.2–5.4 n = 32	4.6 2.8–6.6 n = 19
% Gravel	0.89 0.0–18.0 n = 37	6.9 0.0–97.0 n = 32	no Sta w/Gravel n = 19
% Sand	80.7 2.0–67.0 n = 37	68.2 2.0–93.0 n = 32	49.2 2.0–96.0 n = 19
% Silt	13.3 2.0–67.0 n = 37	21.4 0.0–67.0 n = 32	42.4 4.0–77.0 n = 19
% Clay	4.4 0.0–31.0 n = 37	5.3 0.0–15.0 n = 32	8.1 0.0–23.0 n = 19
% $CaCO_3$	23.7 2.5–66.4 n = 37	44.7 19.2–81.1 n = 32	3.6 0.2–22.7 n = 19

* Yr. I BLM Baseline; combined estimates (Hartman 1955, 1966; AHF: USC, 1965) = a range of 13 to 819 m (mean = 164.0, n = 275)

offshore nondepositional environments and equilibrium mainland shelf environments is that the calcium carbonate content of the sediments is much higher on the insular shelf and the banks: banks, 44.7%; insular shelf, 23.7; and the mainland shelf, 3.6. This illustrates the fact that in the nondepositional environment biogenic contributions of calcium carbonate materials are a much more important sedimentological component than in the equilibrium environment of the mainland shelf. On the mainland shelf biologically derived calcium carbonate materials are diluted by the much higher deposition of clastic origins.

Spatial and Temporal Variation

Limited information was available on the temporal variation of *Chloeia pinnata* populations. Only a single-year sequence (winter-summer) was analyzed and is interpreted cautiously. Pronounced seasonal differences were apparent (Table 2). *Chloeia* was collected at 13 of the 21 Benchmark sampling locations. In the winter sampling period it was collected at only four of the 13 sampling sites; densities were low, $\bar{x}/m^2$ ranged from 4 to 60/m^2 (mean of all winter samples = 40.0/m^2; n = 8 samples). In the summer sampling period it was

TABLE 2

AVERAGE DENSITIES ($\bar{x}/m^2$) AND INDICES OF DISPERSION (I.D.) AND SEASONAL COMPARISONS FOR *Chloeia pinnata* AT BENCHMARK STUDY SAMPLING SITES FOR THE WINTER AND SUMMER OF 1977. Significant value (3 d.f.) $\alpha = 0.5$, indicates clumped distribution (*)

LOCATION AND STATION	WINTER, 1977 $\bar{x}/m^2$	WINTER, 1977 I.D.	SUMMER, 1977 $\bar{x}/m^2$	SUMMER, 1977 I.D.
Mainland Shelf and Slope; San Pedro Bay and Slope:				
819 (33 m)	0	—	20	3.8
827 (504 m)	4	3.0	0	—
Mainland Shelf and Slope; Coal Oil Point:				
801 (68 m)	0	—	8	2.0
802 (336 m)	0	—	20	7.0
Insular Shelves:				
806 (99 m)	8	2.0	20	7.0
808 (105 m)	0	—	2404	471.6*
805 (239 m)	8	2.0	20	3.8
Northern Santa Rosa Ridge and Slope:				
809 (255 m)	0	—	20	3.8
810 (468 m)	60	13.5*	4	3.0
Tanner Bank and Slope:				
816 (75 m)	No Winter Samples		1044	783.0*
815 (100 m)	0	—	4	3.0
818 (188 m)	0	—	512	121.6*
817 (519 m)	0	—	4	3.0

collected at 12 of the 13 sampling sites; densities were much higher, with $\bar{x}/m^2$ ranging from $4/m^2$ to $2404/m^2$ (mean of all summer samples $605.6/m^2$; n = 27 samples). At station 808, densities up to $5983/m^2$ were sampled. During the Benchmark Study *Chloeia* was collected at seven insular shelf and ridge sites (excluding slope locations 810 and 817); the mean for all samples, winter and summer, was 945.8 (n = 17 samples). Indices of dispersion (I.D.) at three sites (808, 816, 818) for the summer sampling period were significant at the 0.5 level (d.f. = 3) indicating a clumped distribution. Mostly juveniles, these populations formed large patches on a kilometer scale. These patches no doubt represent a spring recruitment cohort. The only indication of a clumped distribution in the winter sampling period was a small patch at Station 810.

During the Benchmark Study *Chloeia* was also collected at four sites on the mainland shelf, but the maximum density was only $80/m^2$ (mean of all samples, winter and summer = 28.4; range, $16/m^2$ to $80/m^2$). Most of the individuals from the mainland shelf sites were adults and were collected in the summer. Dispersion values indicated random distributions of these populations.

Macrofaunal Associates

Determination of the organisms associated with *Chloeia pinnata* has been made for three borderland habitats where it is most frequent and abundant: the Channel Islands shelf (San Miguel Island and Santa Rosa Island), Cortes and Tanner Banks, and the mainland shelf. The faunal composition of representative sample sets from each of these areas was examined by classification analysis. The results of these analyses are shown in the form of three dendrograms: Figure 3a, the San Miguel Island HDSA and the Santa Rosa Island HDSA (97 samples); Figure 3b, the Cortes and Tanner Banks HDSA (82 samples); and Figure 3c, the Coal Oil Point HDSA, the Point Dume HDSA, the Huntington Beach HDSA, and the Laguna Beach HDSA (118 samples). In each sample set the species clustering with *Chloeia* were quite different. No single species was common to all three species clusters. Indeed only two species of the total of

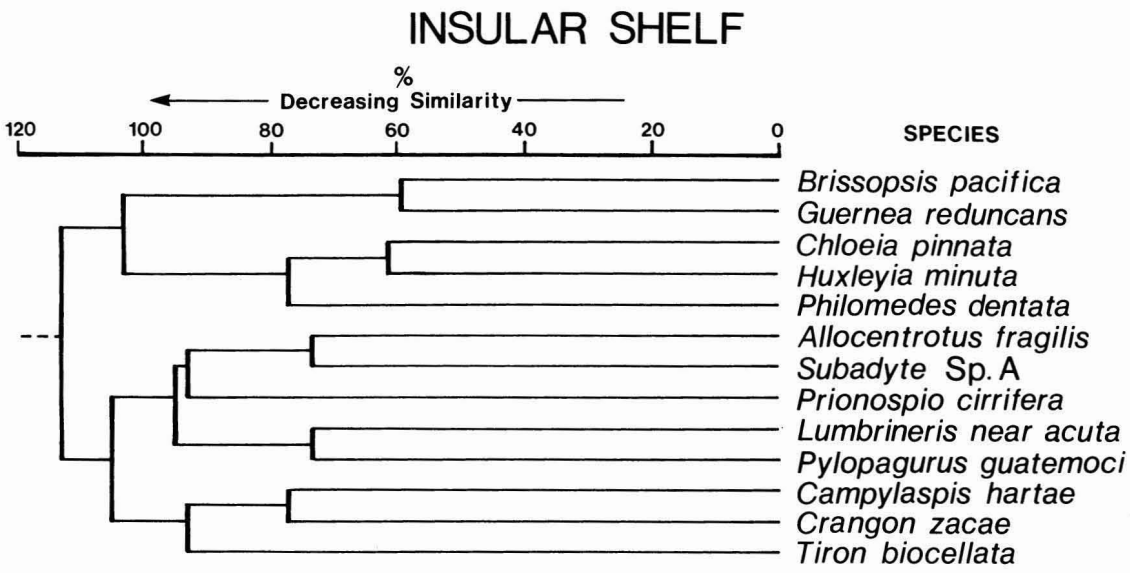

FIGURE 3a Macrofaunal associates of *Chloeia pinnata* on the insular shelf of the Channel Islands (San Miguel and Santa Rosa Islands), as determined by inverse classification analysis.

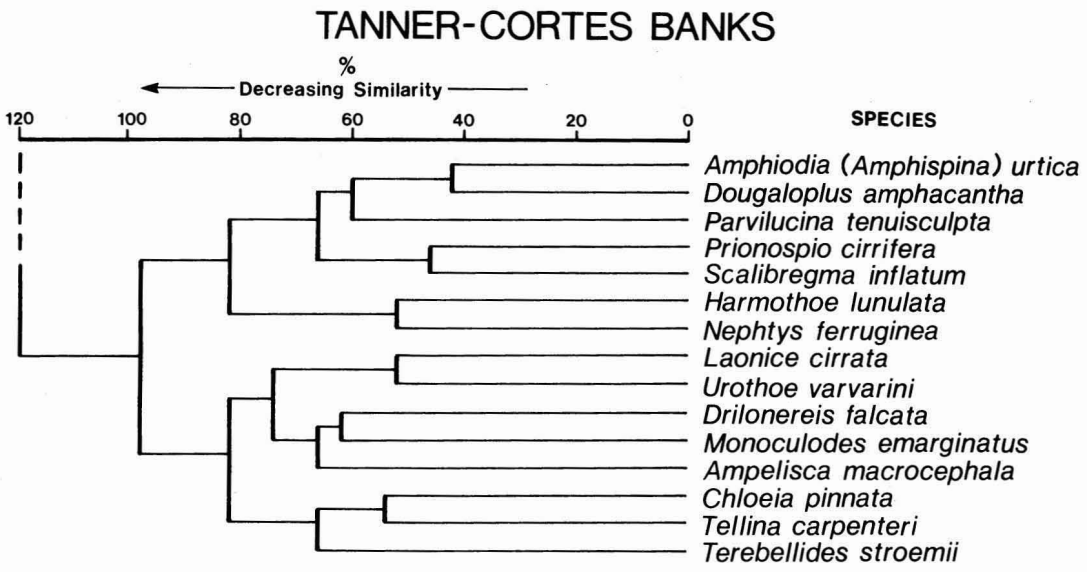

FIGURE 3b Macrofaunal associates of *Chloeia pinnata* on Cortes and Tanner Banks as determined by inverse classification analysis.

31 species making up the three clusters were common to two of the three clusters: the polychaete *Prionospio cirrifera,* occuring in both the insular shelf cluster and the banks cluster; and the urchin *Brissopsis pacifica.*

Species richness was higher on the insular shelf (mean number of specimens/sample = 61.5; range, 20–127) than on either the banks (mean = 33.0; range, 13–54) or the mainland shelf (mean = 29.3; range, 4–75).

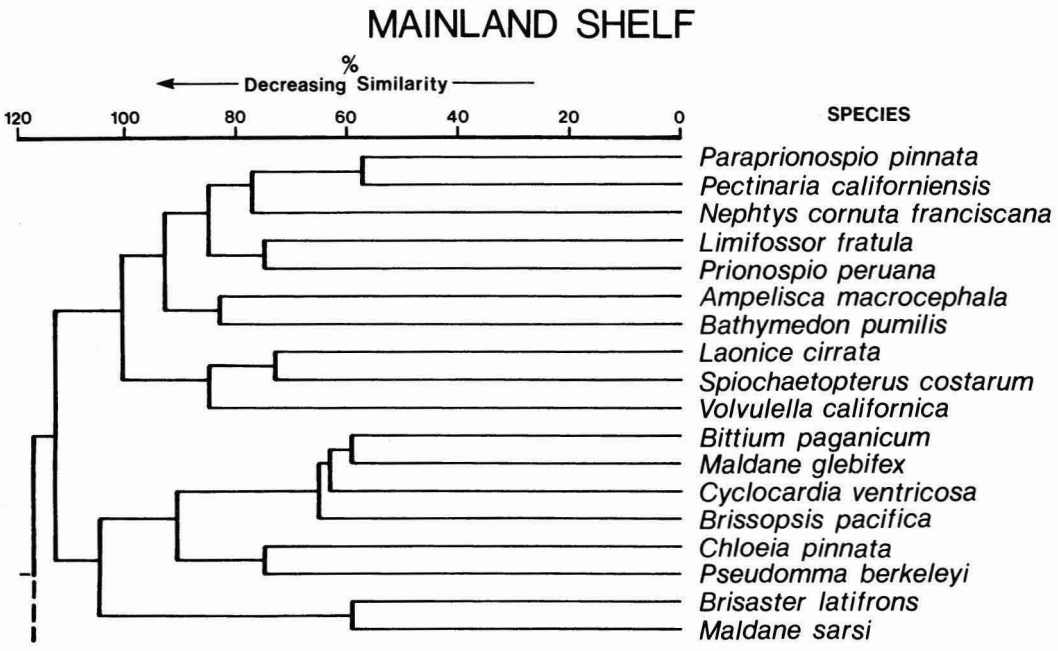

FIGURE 3c Macrofaunal associates of *Chloeia pinnata* on mainland shelf. (Coal Oil Point, Point Dume, Huntington Beach and Laguna Beach HDSA's) as determined by inverse classification analysis.

SUMMARY AND DISCUSSION

The amphinomid polychaete *Chloeia pinnata* is an important, widely distributed member of the benthos of the southern California borderland, where it is a member of every major habitat type including the deep basins. Its population densities were highest in two very dissimilar environments—the offshore areas including the insular shelf of the Channel Islands and Cortes and Tanner Banks, and the nearshore mainland shelf. The insular shelf and the banks are primarily non-depositional environments. Relatively strong currents result in the winnowing of finer detrital sediments, and the development of coarse sediments rich in biogenic calcium carbonate components. The area is influenced by persistent upwelling. By contrast, the mainland shelf is an equilibrium environment highly influenced by man's activities, particularly the release of wastewaters into the marine environment.

Chloeia exhibited pronounced temporal variations. Summer collections were much more frequent and population densities were much higher. These high population densities were in offshore areas and consisted mostly of juvenile specimens. This no doubt reflects spring recruitment. These populations formed large clumped patches on a kilometer scale.

Chloeia pinnata is a short-bodied, active polychaete that can walk or run across the bottom; it can also swim (Mettam, 1984). According to Fauchald and Jumars (1979) it is a carrion feeder. *Chloeia* lacks jaws but has an eversible proboscis. Gut content analyses of 19 worms were made by Thompson (1982). A shift in diet of *C. pinnata* between major habitats and seasons was noted. Summer samples (regardless of habitat) were higher in proportion of animal remains. Mainland shelf specimens contained more detrital aggregates but less POM and single mineral particles than those examined from the offshore areas.

The large patches of juveniles collected from the outer ridge-bank areas had variable diets, which included all major food categories but were mostly composed of animal remains and single mineral particles. Foramini-

fera contributed 11% of their gut contents and were observed in 37% of the specimens examined.

The macrofaunal associates of *C. pinnata* in three different areas—the insular shelf, the banks and the mainland shelf—were identified by cluster analysis. The composition of these faunal groups was almost totally dissimilar.

Ecologically *Chloeia pinnata* appears to be able to live in a wide range of environments populated by very different taxa.

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