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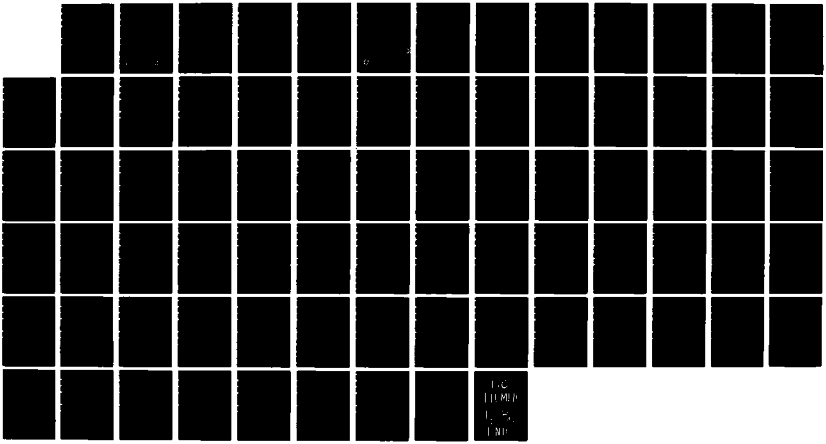

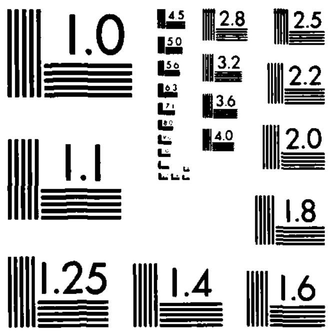

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OLD DOMINION UNIVERSITY RESEARCH FOUNDATION

APPLIED MARINE RESEARCH LABORATORY
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

MACROBENTHIC COMMUNITIES OF THE NORFOLK DISPOSAL SITE - II.

By

Rodney D. Bertelsen
and
Daniel M. Dauer, Principal Investigator
Department of Biological Sciences
Old Dominion University

Final Report
For the period ended August 31, 1984

Prepared for the
Department of the Army
Norfolk District, Corps of Engineers
Fort Norfolk, 803 Front St.
Norfolk, Virginia 23510

Under
Contract DACW65-81-C-0051
Work Order No. 22

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The macrobenthic infaunal community of the NDS is characterized as diverse and typical of undisturbed areas along the inner continental shelf of the mid-Atlantic Bight. No significant populations of commercially important macrobenthic species were identified. Continual updating of baseline data is recommended for future trend assessment and monitoring.

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Abstract

The distribution, abundance, species composition, and temporal variation of subtidal macrobenthic invertebrates of the Norfolk Disposal Site were studied. The macrobenthic infauna and epibenthic fauna were sampled five times per year from 1979 to 1981, four times per year in 1982 and 1983, and three times in 1984. The purpose of the study was: (1) to present recent information concerning the structure of macrobenthic communities of the Norfolk Disposal Site, (2) to compare this study with previous studies of the inner continental shelf of the mid-Atlantic, Southeastern U.S. and of the lower Chesapeake Bay, and (3) to examine trends, variability, and periodicity in the data in order to assess future monitoring strategies.

The macrobenthic infaunal community of the Norfolk Disposal Site can be characterized as diverse and typical of undisturbed areas along the inner continental shelf of the mid-Atlantic Bight. The Norfolk Disposal Site does not contain any significant populations of commercially important macro-invertebrates.

Analysis of seasonal and year to year trends in various community and species parameters indicates the need for continual updating of the baseline data set in order to avoid erroneous conclusions from future monitoring studies. Decreasing the frequency of sampling within each year could obscure impacts upon temporally restricted phenomena, such as, periods of peak juvenile recruitment.

Introduction

The distribution and abundance of the macrobenthic invertebrates of the inner continental shelf off the mouth of the Chesapeake Bay were studied. Density dominants, community abundance, species diversity, and animal-sediment relationships were examined from data gathered at five stations outside the mouth of Chesapeake Bay. These stations were part of an environmental study of the area (designated as the Norfolk Disposal Site) proposed for open ocean disposal of dredged materials from lower Chesapeake Bay (Alden et al. 1980, 1981a, 1981b). Samples were collected five time per year from 1979 to 1981, four times per year in 1982 and 1983, and three times in 1984. Emphasis was placed on temporal patterns of density dominant species and various community parameters. Multivariate statistical models were developed and tested. Results of those models were given in Dauer (1984) and will not be repeated here.

The purpose of this study was: (1) to present recent information concerning the structure of macrobenthic communities of the Norfolk Disposal Site, (2) to compare this study with previous similar studies of the inner continental shelf of the mid-Atlantic, Southeastern U.S., and lower Chesapeake Bay (Boesch 1972, 1979; Dauer et al. 1984; Day et al. 1971; Ewing and Dauer 1982; Frankenberg and Leiper 1977; Maurer et al. 1976; Nilsen et al. 1980), and (3) to examine trends, variability, and periodicity in the data in order to assess future monitoring strategies.

Materials and Methods

Field Collection

The macrofauna of the Norfolk Disposal Site were sampled at five stations located on two intersecting transects (Fig. 1). The Center Site (C) was located approximately 15 nautical miles east of Cape Henry (36° 59' N 75° 39' W). The other stations were five nautical miles due north, south, east, and west of the Center Site. Sampling occured five times per year from 1979 to 1981, four times per year from 1981 to 1983, and three times in 1984.

A box core sampler (10x25x30 cm) was used for the first cruise (February 1979). It sampled a 0.025 m^2 surface area. Since its use proved dangerous and time consuming, all subsequent cruises used a Shipek grab which samples a 0.04 m^2 surface area.

Fifteen box core samples (February 1979) and fifteen Shipek grabs (May 1979) were taken at the Center Site to determine the number of samples required for an a priori determined level of precision. Five samples of grabs were taken at the other sites during these cruises. All grabs were washed through a 0.5 mm mesh-sized screen, relaxed with dilute isopropyl alcohol, then preserved and stained with a formalin-rose bengal solution.

The May cruise data from the Center Site were analyzed to determine the number of Shipek grabs required for a statistically reliable estimate of the macrofaunal community. Calculations were based on the following formula:

$$N = \frac{(ts)^2}{Dx}$$

where:

s = standard deviation of the preliminary sample

t = the tabulated t value at the 0.05 level with the degrees of freedom of the preliminary set of samples

x = mean density of the preliminary sample

D = required level of precision expressed as a decimal (Southward, 1966)

Previous work with benthic organisms has shown that an error of 30 to 35 percent of the mean will give a statistically reliable estimate (Dauer et al., 1979). Assuming a 30 percent level of precision, 3.7 Shipek grabs per site would be required. Based on this calculation and available manpower, five Shipek grabs were taken per site for all subsequent cruises.

At each site an eight dram sample of sediment was retained for sediment analysis. If the sediment changed markedly between grabs at a site, an additional sediment sample was taken and the change was noted in the log. The sediment was dry sieved and the mean particle size and sorting coefficient were determined using the formulae of Folk (1974).

The epibenthic community was described from 10 minute trawl samples taken at the North, South, and Center Sites during each cruise (see Fig. 1). A 10-ft (3.05 m) beam trawl was used through May 1980. A 10-ft (3.05 m) otter trawl was used thereafter. During the 1980 and 1981 cruises, a rocking chair dredge was used to determine if deeper dwelling commercially important species such as the surf clam (<u>Spisula solidissima</u>) were missed in the trawls.

Analysis

All taxa collected from grab samples were used to compute indices of community structure. The following indices were calculated:

Shannon's Index of diversity:

$$H' = -\sum p_i \log_2 p_i$$

where p_i is the proportion of individuals of the ith species.

Margalef's Index of species richness:

$$SR = \frac{(S - 1)}{\ln N}$$

where S is the total number of species and N is the total number of individuals.

Pielou's Index of evenness:

$$J' = \frac{H'}{H_{max}}$$

where H' is the Shannon Index of diversity calculated above and H_{max} is the theoretical maximum diversity possible. It is calculated as $H_{max} = \log_2 S$.

Further analysis was conducted on selected dominant species. These were determined using the method of Biological Index

Ranking (McCloskey, 1970). The top ten density dominant species were determined at each site for all of the 26 cruises. The species with the highest density at a given site and cruise received a 10 point score, the second received a 9, etc. The fifteen species with the highest scores were used for analysis of spatial and temporal patterns. Taxonomically problematic taxa (e.g. Oligocheata spp. and Cirratulidae spp.) were excluded from further analysis.

The selected species were used in a normal classification analysis of the sites using the Bray-Curtis similarity coefficient and group average sorting on logrithmically transformed data (Boesch, 1977). The mean density of each species for each cruise was used in the calculations.

Results

Sediment Analysis

The results of the sediment analysis are given in Table 1. Overall, there appears to be two potential groups of sites based on sediment characteristics. The North and West Site contained moderately well sorted sand with a mean particle size in the fine sand range. The other three sites contained moderately sorted sands with a mean particle size in the medium sand range. Normal classification of the sites did not reveal any distinctive groupings (Alden et al., 1980, 1981a).

Community Analysis - Dominant Species

A total of 213 species were identified. Polychaetes comprised 51.2% (109 species) fo the fauna, amphipods 15.0% (32 species), bivalves 10.3% (22 species), and gastropods 8.9% (19 species). See the Appendix for a complete listing of all species collected.

The East, Center, and South Sites contained the highest densities, highest species richness, and lowest eveness values (Table 2).

The top fifteen dominant species are presented in totals and by sites in Table 3. Polychaetes made up 10 species of the list, amphipods 2, bivalves 2, and echinoderms 1. The East, Center, and South Sites contained large numbers of *Polygordius* sp., *Spiophanes bombyx*, and *Spio setosa*. The North and West Sites shared large numbers of *Ampelisca verrilli*. The West Site also contained large numbers of Amastigos caperatus and Apoprionospio pygmaea.

The temporal patterns of total community density, diversity, species richness, and eveness are given in Figures 2-6. The peaks in density during the first, third, and sixth years were due to large increases in the populations ofSpio setosa (1st year) and Polygordius sp. (3rd and 6th year) at the Center, South, and East Sites. The smaller peak in the middle of the fourth year was due to Polygordius sp. These population increases resulted in low values of diversity and eveness indices. Total community density was highest in August, 1984.

The temporal patterns of density for the fifteen dominant species are given in Figures 6-20. The patterns of density over time fall into five basic patterns: (1)irruptive (herein defined as an aperiodic steep increase of a given species by two or more orders of magnitude followed by a steep decline), (2) periodic (a regular rise and fall in density), (3) declining, (4) increasing, and (5) irregular (no obvious pattern).

Species with obvious irruptive patterns were Polygordius sp. (Fig. 6), Apoprionospio pygmaea (Fig. 12), Mediomastus ambiseta (Fig. 19), and Echinarchnius parma (Fig. 20). Amastigos caperatus (Fig. 16), Magelona sp. (Fig. 15), and Spio setosa (Fig. 13) were present in high densities at the beginning of the study and then rapidly decreased. While this suggests they are irruptive species, we have no information concerning their population dynamics before their populations decreased.

Several species showed some form of a seasonal (periodic) pattern. The amphipods Ampelisca verrilli and Protohaustorius deichmannae showed peak densities in the summer. This corresponds with juvenile recruitment (see Fig. 9 , 17). Spisula solidissima (Fig. 18) densities have peaked each year; however, the timing of the peaks has ranged from winter to summer. Spiophanes bombyx (Fig. 7) also showed signs of periodicity with peaks generally in the summer.

Nephtys picta (Fig. 8) ,Tellina agilis (Fig. 11), and Magelona sp. (Fig. 15) have generally declined over the last six years.

An overall similarity dendogram (Fig. 21) which clusters the average densities (of all cruises) of the fifteen dominant species with sites showed that the Center and South Sites contained the most similar fauna while the West Site was the least similar.

The trawl results are given in Table 4. Crangon septemspinosa accounted for 54% of the individuals collected. Echinarachnius parma accounted for 17%. The remaining 29% were divided among 83 additional taxa. No significant populations of commercially important species were collected in any trawl. No commercial species were collected in the rocking chair dredges taken in 1980 and 1981.

Discussion

Comparison of 1984 cruises with previous years

The results of the first three and five years of this study are reported in Dauer et al. (1984) and Dauer (1984), respectively. During this sixth year, coarser sediments than previously collected were present at the South Site. Over the six years of study, sediment changes while on station have occured at the Center Site more often than at other Sites. The mean grain diameter at all sites ranged from coarse to very fine sands. This heterogeniety of sediments is probably due to the presence of relic beds of sediment from the Susquehanna River which flowed through the area during the ice ages. Storm events can expose or cover portions of these relic sediments (Dr. Ludwig, Dept. Oceanogr., ODU, pers.com.).

Magelona sp. continued its decline in density and has dropped from the top ten density dominants (Table 3). In trawls, *Crangon septemspinosa* was collected in such high numbers that overall, its percentage of individuals collected rose from 44% (see Dauer, 1984 ; Table 4) to 54%. Enough individuals of *Ampelisca verrilli* were collected at the North Site for it to rank 8th. *Crepidula plana* was dropped from the top ten most common taxa at the North Site. *Polygordius* sp. set a density record for this study with 26,605 individuals per m^2 in grab samples at the Center Site during the August 1984 cruise.

As in previous years, no commercial species were found in significant numbers. While the surf clam, *Spisula solidissima* was found in sufficient numbers to rank 13th in the density dominant list (Table 3), no individuals larger than 1 cm (less than half an inch) were collected. Apparently the population of *S. solidissima* at the Norfolk Disposal Site never reaches maturity due to natural conditions.

Comparisons with other studies

Day et al. (1971) conducted a survey along a transect off Cape Lookout, North Carolina. Of the dominant species listed for the inner shelf sites only *Polygordius* sp. and *Magelona papillicornis* (ours is either that species or *Magelona rosea*) were common to both studies. Cape Hatteras, north of Cape Lookout, is considered a major zoogeographic boundary (Gosner, 1971). This perhaps accounts for the low degree of similarity; however, this zoogeographic pattern is often based on decapod, or mollusc distributions (Gosner cites a decapod distribution), and zoogeographic patterns of polychaetes and amphipods are not as distinct (see Boesch, 1979).

Maurer et al. (1976) studied the benthic community off the Delmarva Peninsula. In their Table 8 they list taxa considered "typical" for the Delmarva area. Of eleven polychaetes listed, three species (*Polygordius* sp., *Magelona* spp., and *Spiophanes bombyx*) were density dominants in this area. Two of their polychaetes were cirratulids (*Caulleriella* sp. and *Tharyx* sp.). These are problematic taxa and were not included in our density dominant analysis. Cirratulids were, however, commonly collected from the Norfolk Disposal Site. Two of their five "typical" pelcypods (Spisula solidissima and Cerastoderma pinnulatum) were found here. Two of their five gastropods (Nassarius trivittatus and Polinices duplicatus) were regularly collected in our trawls. Both of our density dominant amphipods (Protohaustorius deichmannae and Ampelisca verrilli) were considered "typical" of the Delmarva area. Of the five additional taxa on their list, two (Unciola irrorata and Trichophoxus epistomus) were collected here. Both decapods listed (Cancer irroratus and Cancer borealis) were collected in our trawls. Two of three listed echinoderms (Asterias forbesi and Echinarachnius parma) were density dominants in our trawls. None of the three species of isopodsor three species of cumaceans they listed, were collected in our study.

Boesch (1979) conducted a two-year survey of the inner shelf communities from off the coast of New Jersey and the Delmarva Peninsula. He found that total community densities ranged between 2,000 and 10,000 individuals per m^2. This compares favorably with our overall density of 3,491 individuals per m^2. His Shannon's diversity value was about 3.5 (estimated from a figure) compared to our 3.49 overall figure. His eveness values were estimated at 0.62. Our figure compares favorably at 0.68.

Boesch's list of the top 10 dominant species were all found in our study with the exception of his top ranked tanaid (Tanaissus lilljeborgi). Five of his top ranked species were top ranked in this study. The differences between the studies are probably due to the influence of the nearby Chesapeake Bay and overall sediment differences (his sites contained generally coarser sand).

Nilsen et al. (1980) analyzed distributions of organisms and sediments of the lower Chesapeake Bay. They ranked organisms for different salinities and sediment types. Their top 10 rankings for poly-euhaline sand stations (those closest to our West Site), contained four species in common. Two of those species, *Amastigos caperatus* (given as Capitellidae sp.A) and *Mediomastus ambiseta* were predominant in the West Site or West and North Site.

Ewing and Dauer (1982) also sampled sandy sites within the mouth of Chesapeake Bay. They list 14 density dominant and characteristic taxa. Five of those were density dominants in our study. Three of those five common species (*Mediomastus ambiseta*, *Amastigos caperatus*, and *Ampelisca verrilli*) were found in relatively higher densities in our West or West and North Sites.

Dauer et. al. (1984) sampled along a transect along the lower Chesapeake Bay. Their top 10 density dominants for clean sand sites contained four species in common with this study. These four species were identical to those found by Nilsen et al. (1980).

Monitoring Implications and Conclusions

The need for continual monitoring is emphasized by sudden population explosions that can occur naturally (e.g. *Polygordius* sp. in August 1984 and *Spio setosa* in February 1979). These can cause marked shifts in robust community parameters such as Shannon's diversity (H') and Pielou's eveness (J') (see Figures 2 and 3). Identifying these irruptive species is essential to avoid erroneous conclusions. Also, irruptive species in one area may not behave similarly in other areas. For example, *Spiophanes bombyx* varied by more than four orders of magnitude in similar sediment types in Georgia (Frankenberg and Leiper, 1977). *Spiophanes bombyx* has exhibited periodic fluctuations of about one order of magnitude during our study. Also, yearly shifts in the community structure result in greater similarity of sites within a year than to sites between years (see Dauer, 1984; Fig.6). These yearly community shifts have not exhibited any regular pattern, thus quick or "instant" predictions at the Norfolk Disposal Site are not possible.

Potential predictive value may be found using those species which exhibit regular seasonal patterns. Deviation from a regular pattern may indicate an impact. Two of the species catagorized as periodic for the Norfolk Disosal Site (see Results) are surface dwelling amphipods (*Ampelisca verrilli* and *Protohaustorius deichmannae*). They are probably important food items for bottom feeding fishes. Alteration in their natural density patterns could have a measurable impact on fish populations.

It is also possible that natural variation in the benthic community occurs on a time scale of several years. In examining the total community density graph (Fig. 2), high densities (over 10,000 per m^2 have occured in the first and sixth years. At this time, it is too early to tell if this fluctuation is regular. Generally densities in our study hovered between

2 to 4 thousand individuals per m^2. However, if regular sampling had not taken place, this natural variation could be mistaken for an impact.

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APPENDIX - SPECIES LIST FOR THE NORFOLK DISPOSAL SITE

CNIDARIA : ANTHOZOA
- Anthozoa spp.

PLATYHELMINTHES : TURBELLARIA
- Turbellaria spp.

NEMERTEA
- Nemertea spp.

ANNELIDA : POLYCHAETA
- *Aedicira* sp.
- *Aglaophamus circinata* (Verrill)
- *Aglaophamus verrilli* (McIntosh)
- *Amastigos caperatus* Ewing and Dauer
- *Ampharete acutifrons* Grube
- *Ampharete americana* Day
- *Ampharete arctica* Malmgren
- *Ampharete parvadentata* Day
- Ampharetidae spp.
- Amphinomidae sp.
- *Ancistrosyllis hartmanae* Pettibone
- *Antinoella sarsi* (Malmgren)
- *Apoprionospio pygmaea* (Hartman)
- Arabellidae sp.
- *Aricidea catherinae* Laubier
- *Aricidea cerrutti* Laubier
- *Aricidea fragilis* Webster
- *Aricidea wassi* Pettibone
- *Armandia maculata* (Webster)
- *Asabellides oculata* (Webster)
- *Asychis carolinae* Day
- *Asychis elongata* (Verrill)
- *Autolytus* spp.
- *Boccardia* sp.
- *Brania pusilla* (Dujardin)
- *Brania welfleetensis* Pettibone
- *Capitella capitata* (Fabricius)
- *Capitella* spp.
- Capitellidae spp.
- Cirratulidae spp.
- *Cirrophorus furcatus* (Hartman)
- *Clymenella* spp.
- *Clymenella torquata* (Leidy)
- *Diapatra cuprea* (Bosc)
- Dorvilleidae spp.
- *Drilonereis longa* Webster
- *Drilonereis magna* Webster and Benedict
- *Drilonereis* spp.
- *Eteone heteropoda* Hartman
- *Eteone lactea* Claparede
- *Eteone longa* (Fabricius)
- *Eumida sanguinea* (Oersted)
- *Exogene hebes* (Webster and Benedict)
- *Flabelligera affinis* Sars

Glycera americana Leidy
Glycera capitata Oersted
Glycera dibranchiata Ehlers
Glycera robustus Ehlers
Glycera spp.
Goniadella gracilis (Verrill)
Gyptis brevipalpa (Hartmann-Schroder)
Harmothoe extenuata (Grube)
Hemipodus roseus Quatrefages
Leitoscoloplos fragilis (Verrill)
Leitoscoloplos robustus (Verrill)
Lepidonotus sublevis Verrill
Lumbrineridae spp.
Lumbrinerides acuta (Verrill)
Lumbrineris fragilis (Muller)
Lumbrineris tenuis Verrill
Macroclymene zonalis (Verrill)
Magelona sp.
Maldanidae spp.
Marphysa belli (Audouin and Milne-Edwards)
Mediomastus ambiseta (Hartman)
Microphthalmus sczelkowii Mecsnikow
Micropthalmus similis Bobretsky
Microphthalmus fragilis Bobretzky
Minuspio cirrifera (Wiren)
Nephtyidae spp.
Nephtys bucera Ehlers
Nephtys incisa Malmgren
Nephtys picta Ehlers
Nereidae spp.
Nereis acuminata Ehlers
Ninoe nigripes Verrill
Notocirrus spiniferus (Moore)
Notomastus hemipodus Hartman
Notomastus latericeus Sars
Onuphidae spp.
Onuphis eremita Audouin and Milne-Edwards
Ophelia denticulata Verrill
Ophelia sp.
Owenia fusiformis delli Chiaje
Paleanotus heteroseta Hartman
Paradoneis lyra (Southern)
Paranaitis polynoides (Moore)
Paranaitis speciosa (Webster)
Paraonidae spp.
Paraonis fulgens (Levinsen)
Paraonis pygoenigmatica Jones
Parapionosyllis longicirrata (Webster and Benedict)
Paraprionospio pinnata (Ehlers)
Pectinaria gouldii (Verrill)
Periploma spp.
Pherusa ehlersi Day
Phloe minuta (Fabricius)
Phyllodoce arenae Webster
Phyllodoce castanea (Marenzeller)

Phyllodoce mucosa Oersted
Phyllodocidae spp.
Pionosyllis sp.
Pisione remota (Southern)
Pista cristata (Muller)
Pista palmata (Verrill)
Pista quadralobata (Augener)
Podarke obscura Verrill
Polycirrus eximius (Leidy)
Polydora caulleryi Mesnil
Polydora commensalis Andrews
Polydora ligni Webster
Polydora socialis (Shmarda)
Polydora spp.
Polydora websteri Hartman
Polygordius spp.
Potamilla spp.
Proceraea sp.
Protodorvillea kefersteini (McIntosh)
Pseudeurythoe ambigua (Fuavel)
Sabellaria vulgaris Verrill
Scalibregma inflatum Rathke
Schistomeringos caeca (Webster and Benedict)
Schistomeringos rudolphi (delle Chiaje)
Scolelepis bousfieldi Pettibone
Scolelepis sp.
Scolelepis squamata (Mueller)
Scoloplos rubra (Webster)
Scoloplos spp.
Shaerosyllis sp.
Sigalion arenicola Verrill
Sigambra bassi (Hartman)
Sigambra spp.
Sigambra tentaculata (Treadwell)
Sphaerodoropsis sp.
Sphaerosyllis hystrix Claparede
Spio setosa Verrill
Spiochaetopterus oculatus Webster
Spionidae spp.
Spiophanes bombyx (Claparede)
Sthenelais boa (Johnston)
Sthenelais limicola (Ehlers)
Sthenelais spp.
Streblospio benedicti Webster
Streptosyllis pettiboneae Perkins
Syllidae spp.
Syllides convoluta Webster and Benedict
Syllides fulva (Marion and Bobretsky)
Syllides japonica Imajima
Syllides papillosa Hartman-Schroder
Terebellidae spp.
Travisia parva Day
Websterinereis tridentata (Webster)

ANNELIDA : OLIGOCHAETA

Oligochaeta spp.

ANNELIDA : HIRUDINEA

Hirudinea sp.

SIPUNCULA

Phascolion strombi (Montagu)

MOLLUSCA : GASTROPODA

Acanthodoris pilosa (Abildgaard)
Acteocina canaliculata (Say)
Anachis lafresnayi (Fischer and Bernardi)
Busycon carica (Montfort)
Corambella depressa Balch
Crepidula fornicata (Linne)
Crepidula plana Say
Cylichnella bidentata (Orbigny)
Epitonium humphreysi (Kiener)
Eupleura caudata (Say)
Gastropoda spp.
Haminoea solitaria (Say)
Hyalina sp.
Mangelia cerina Kurtz and Stimpson
Marginella roscida Redfield
Mitrella lunata (Say)
Nassarius trivittatus (Say)
Natica pusilla Say
Nudibranchia spp.
Odostomia sp. a
Odostomia sp. b
Onchidoris aspera (Alder and Hancock)
Pleurobranchaea tarda Verrill
Polinices duplicatus (Say)
Rictaxis punctostriatus (Adams)
Turbonilla interrupta (Totten)
Turbonilla spp.
Turridae spp.

MOLLUSCA : BIVALVIA

Abra spp.
Anadara transversa (Say)
Bivalvia spp.
Cerastoderma pinnulatum (Conrad)
Crassinella lunulata (Conrad)
Crassostrea virginica (Gmelin)
Crenella decussata (Montagu)
Ensis directus Conrad
Gemma gemma (Totten)
Lyonsia hyalina Conrad
Macoma tenta Say
Mercenaria mercenaria (Linne)
Mulinia lateralis (Say)
Mysella planulata (Stimpson)
Mytilus edulis Linne
Nucula proxima Say
Pandora bushiana Dall
Pandora gouldiana Dall
Pandora spp.
Pandora trilineata Say
Parvilucina multilineata (Tuomey and Holmes)

Siliqua costata Say
Solemya velum Say
Spisula solidissima (Dillwyn)
Tellina agilis Stimpson
Yoldia limatula (Say)
Yoldia sp.

MOLLUSCA : POLYPLACOPHORA
Chaetopleura apiculata (Say)

MOLLUSCA : SCAPHOPODA
Scaphopoda sp.

ARTHROPODA : ISOPODA
Ancinus depressus (Say)
Chiridotea spp.
Chiridotea stenops (Menzies and Frankenberg)
Cirolana polita (Stimpson)
Cyathura spp.
Edotea triloba (Say)
Ptilanthura tenuis (Harger)

ARTHROPODA : AMPHIPODA
Acanthohaustorius millsi Bousfield
Ampelisca vadorum Mills
Ampelisca verrilli Mills
Batea catherinensis Muller
Bathyporeia parkeri Bousfield
Bathyporeia quoddyensis Shoemaker
Bathyporeia sp.
Byblis serrata Smith
Caprellidae spp.
Corophium spp.
Elasmopis levis Smith
Erichthonius brasiliensis (Dane)
Gammarus daiberi Bousfield
Gammaropsis sp. cf. *sutherlandi* Nelson
Haustorius canadensis Bousfield
Hyperiidae spp.
Lembos smithi Holmes
Lembos websteri Bate
Liljeborgia sp.
Listriella barnardi Wigley
Listriella clymenellae Mills
Listriella sp.
Microprotopus raneyi Wigley
Monoculodes edwardi Holmes
Parametopella cypris (Holmes)
Parametopella stelleri Gurjanova
Paraphoxus spinosus Holmes
Protohaustorius spp.
Pseudunciola obliquua (Shoemaker)
Rildardanus spp.
Stenothoe minuta Holmes
Synchelidium americanum Bousfield
Synopiidae. sp.
Trichophoxus epistomus (Shoemaker)
Trichophoxus floridanus (Shoemaker)
Unciola dissimilis Shoemaker

Unciola irrorata Say
Unciola serrata Shoemaker
Unciola spp.

ARTHROPODA : CUMACEA

Cyclaspis pustulata Zimmer
Cyclaspis varians Calman
Diastylis sp.
Eudorella spp.
Eudorella truncul ata (Bate)
Oxyurostylis smithi Calman
Pseudoleptocuma minor (Calman)

ARTHROPODA : MYSIDACEA

Mysidopsis bigelowi Tattersall
Neomysis americana (Smith)

ARTHROPODA : TANAIDACEA

Leptognatha caeca (Harger)

ARTHROPODA : DECAPODA

Albunea paretii Guerin
Cancer irroratus Say
Crangon septemspinosa Say
Dissodactylus mellitae Rathbun
Euceramus praelongus Stimpson
Libinia emarginata Leach
Majidae spp.
Ovalipes ocellatus (Herbst)
Pagurus spp.
Pinnotheres ostreum Say
Thor floridanus Kingsley

ARTHROPODA : STOMATOPODA

Nannosquilla grayi (Chase)

PHORONIDA

Phoronis psammophila Cori

ECHINODERMATA : ASTEROIDEA

Asterias forbesii (Desor)
Asteroidea spp.

ECHINODERMATA : ECHINOIDEA

Arbacia punctulata (Lamarck)
Echinarachnius parma (Larmack)
Mellita quinquiesperforata (Leske)

ECHINODERMATA : HOLOTHUROIDEA

Caudina arenata (Gould)
Leptosynapta inhaerens (Ayres)

ECHINODERMATA : OPHIUROIDEA

Ophiuroidea spp.

CHAETOGNATHA

Chaetognatha spp.

HEMICHORDATA

Saccoglossus spp.

CHORDATA : CEPHALOCHORDATA

Branchiostoma virginiae Hubbs

Table 1. Summary of sedimentary parameters. Shown for each parameter are the means, and ranges calculated for all cruises from 1979 through 1984. A - mean phi, B - sorting coefficient, C - percent sand.

A. Mean phi

Site	North	South	East	West	Center
Mean	2.99	1.84	1.98	2.99	1.67
Range	(2.47)-(3.38)	(0.09)-(3.08)	(-0.80)-(3.11)	(-0.08)-(3.42)	(-0.30)-(3.11)

B. Sorting coefficent

Site	North	South	East	West	Center
Mean	0.63	0.75	0.94	0.62	0.89
Range	(0.41)-(0.78)	(-0.43)-(1.95)	(0.62)-(1.75)	(0.48)-(1.37)	(0.63)-(1.36)

C. Percent sand

Site	North	South	East	West	Center
Mean	98.1	99.4	99.1	97.6	99.1
Range	(97.1)-(99.2)	(96.4)-(100)	(97.0)-(99.9)	(95.6)-(99.9)	(97.6)-(99.9)

Table 2. Summary of total community parameters by site at the Norfolk Disposal Site. See Fig. 1 for site locations. Total community density in individuals per m^2. H' - Shannon's informational diversity index, SR - Margalef's richness index, J' - Pielou's eveness index. Shown are means (one standard error).

Parameter	All Sites	North	South	Center	East	West
Total density	3,491 (504)	1,660 (269)	3,941 (675)	5,017 (1266)	5,153 (1160)	1,684 (299)
H'	3.49 (0.08)	3.62 (0.13)	3.40 (0.19)	3.45 (0.17)	3.40 (0.13)	3.52 (0.10)
SR	5.97 (0.14)	5.23 (0.18)	6.42 (0.19)	6.80 (0.33)	6.15 (0.24)	5.25 (0.21)
J'	0.68 (0.02)	0.74 (0.03)	0.64 (0.04)	0.64 (0.03)	0.64 (0.02)	0.72 (0.02)

Table 3. Density dominants of the Norfolk Disposal Site based upon density ranking analysis of data from all sites and cruises from 1979 through 1984. All Sites is given as mean number of individuals per m^2 (Standard error). The spatial distribution among the sites is also shown as means See Fig. 1 for site locations. Shown are individuals per m^2. Taxon code: A - amphipod B - bivalve, E - echinoderm, P - polychaete.

Species	Total Rank Score	All Sites	North	South	Center	East	West
Polygordius sp. (P)	638.0	867 (158)	108	1,829	1,764	536	96
Spiophanes bombyx (P)	428.4	168 (13)	113	218	113	271	127
Ampelisca verrilli (A)	403.1	145 (19)	432	54	32	20	188
Nephtys picta (P)	369.9	60 (3)	66	109	61	38	46
Aricidea wassi (P)	369.0	75 (4)	90	89	72	119	4
Tellina agilis (B)	291.2	74 (6)	47	101	58	113	52
Apoprionospio pygmaea(P)	253.0	99 (12)	82	63	33	117	202
Aricidea catherinae (P)	187.8	58 (7)	55	60	38	137	1
Spio setosa (P)	169.5	387 (100)	4	112	238	1,581	1
Amastigos caperatus (P)	131.7	70 (10)	12	102	12	12	212
Protohaustorius deichmanae (A)	114.2	30 (5)	31	35	79	1	0.2
Magelona sp. (P)	110.3	30 (4)	87	22	15	4	33
Spisula solidissima (B)	73.0	30 (3)	16	41	60	18	14
Mediomastus ambiseta (P)	85.5	36 (4)	4	28	36	20	93
Echinarchnius parma (E)	57.9	33 (7)	44	52	38	8	25

Table 4. Summary of results of trawl samples collected from 1979 through 1984 by collection site. Shown for each site are the total number of individuals of the ten most common taxa, their percent compostion of the entire number of individuals, and the number of trawls (frequency) that contained each taxon. A - North Site, B - South Site, C - Center Site.

A. North Site	Number collected	Percent of total	Frequency
Crangon septemspinosa	4,733	52.1	22
Echinarchnius parma	2,149	23.7	18
Neomysis americana	674	7.4	5
Pagurus spp.	421	4.6	17
Nassarius trivittatus	402	4.4	21
Lolliguncula brevis	241	2.7	8
Asterias forbesii	88	1.0	12
Ampelisca verrilli	85	0.9	6
Cancer irroratus	47	0.05	10
Crepidula fornicata	31	0.03	7
Total Individuals - 9,083	Total Species - 46		

B. South Site	Number collected	Percent of total	Frequency
Crangon septemspinosa	4,122	50.3	21
Echinarachnius parma	1,702	20.7	20
Pagurus spp.	640	7.8	19
Nassarius trivittatus	570	6.9	17
Neomysis americana	266	3.2	5
Crepidula plana	173	2.1	5
Cancer irroratus	108	1.3	13
Crepidula fornicata	107	1.3	5
Lolliguncula brevis	88	1.1	4
Pleurobranchia tarda	80	1.0	8
Total Individuals - 8,201	Total Species - 54		

C. Center Site	Number collected	Percent of total	Frequency
Crangon septemspinosa	5,081	60.1	20
Neomysis americana	804	9.5	6
Pagurus spp.	670	7.9	16
Echinarachnius parma	40	4.8	15
Nassarius trivittatus	327	3.9	17
Cancer irroratus	178	2.1	17
Asterias forbesi	172	2.0	13
Crepidula fornicata	117	1.4	8
Crepidula plana	66	0.8	6
Lolliguncula brevis	36	0.4	7
Total Individuals - 8,454	Total Species - 60		

Figure 1. Study area. The Center Site (C) is located at 36° 59' N, 75° 39' W. The other 4 sites are located five nautical miles due north (N), south (S), east (E), and west (W) of the Center Site.

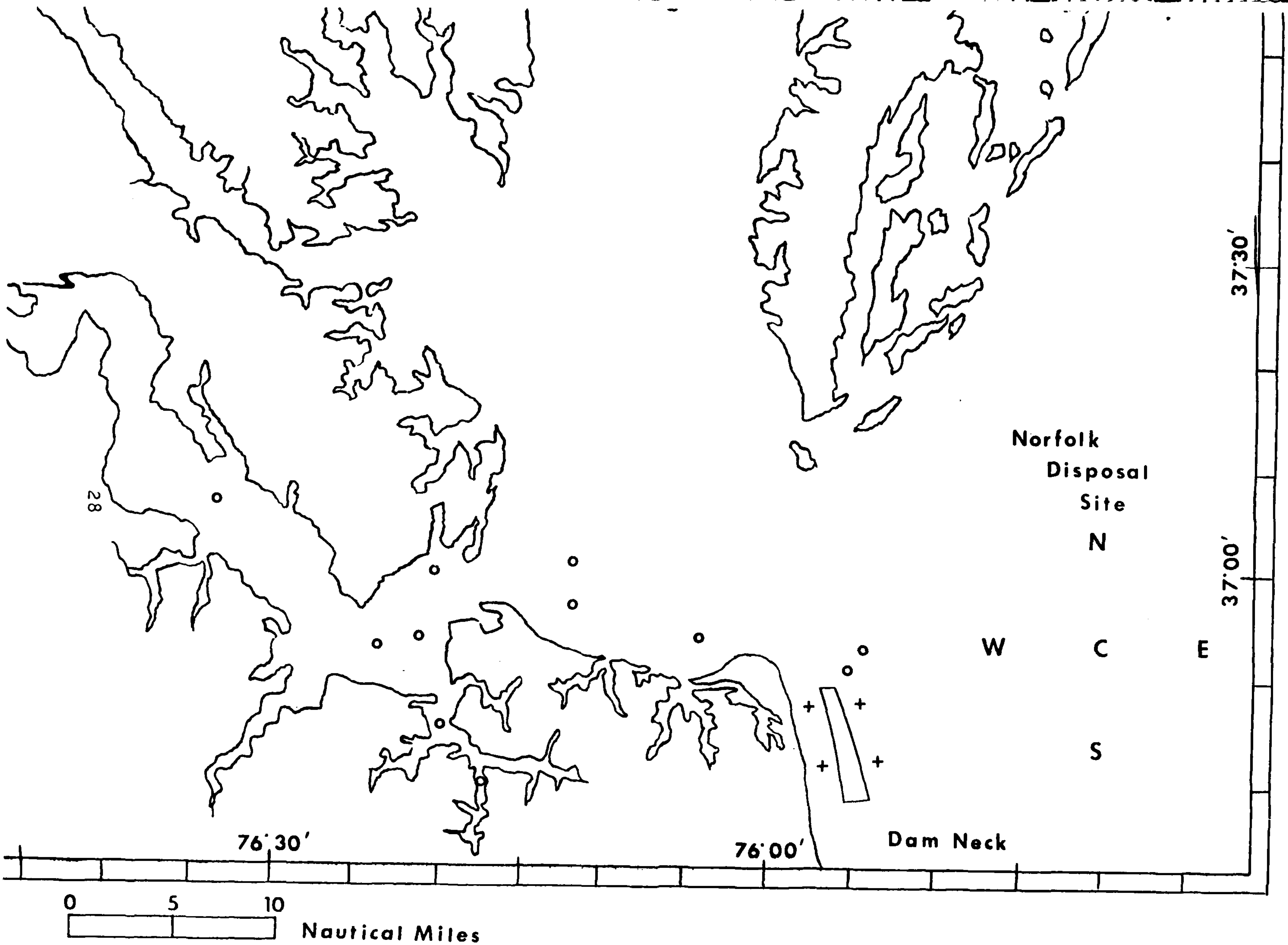

37°30'
37°00'
Norfolk
Disposal
Site
N
W
C
E
S
Dam Neck
76°30'
76°00'
0
5
10
Nautical Miles

Figure 2. Total community parameter

Total community density

Ordinate = number of individuals per $m^2 \times 10^3$

Abscissa = months since start of program

Vertical bars = Year markers

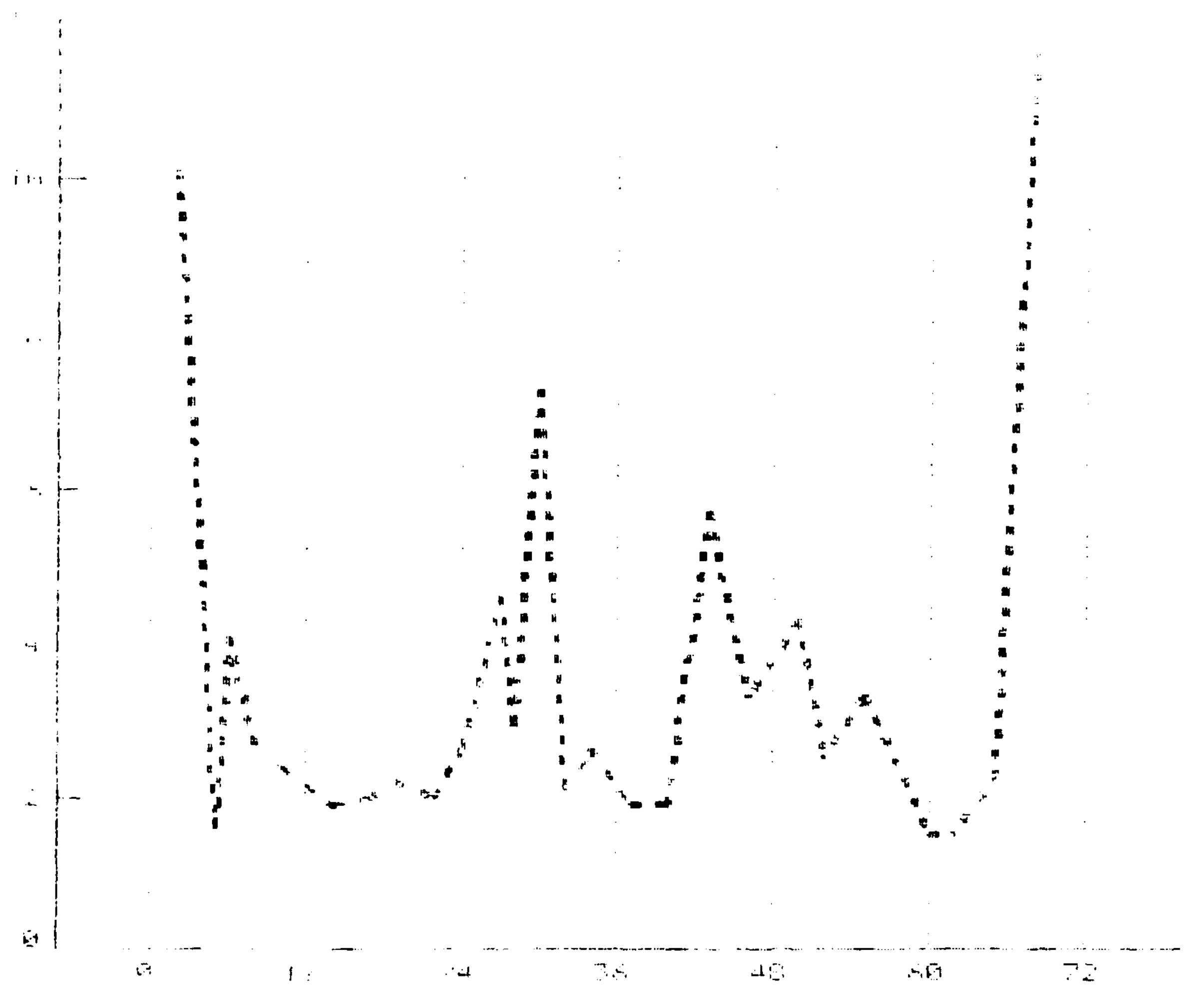

48
60
72

Figure 3. Total community parameter

Ordinate = Shannon's index of species diversity

Abscissa = months since start of program

Vertical bars = Year markers

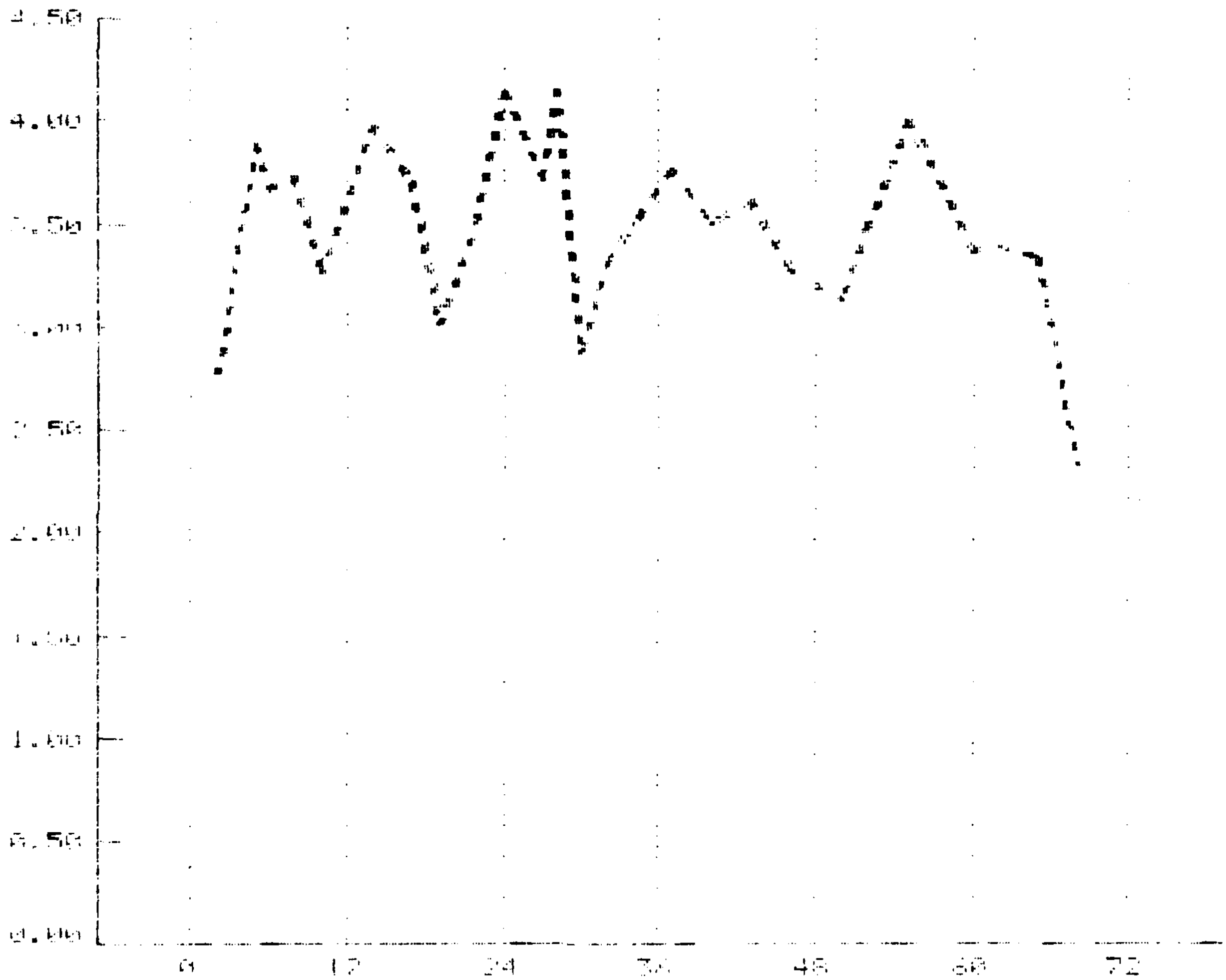

4.00
1.00
0.50
0.00
6
12
24
36
48
60
72

Figure 4. Total community parameter

Ordinate = Pielou's index of eveness

Abscissa = months since start of program

Vertical bars = Year markers

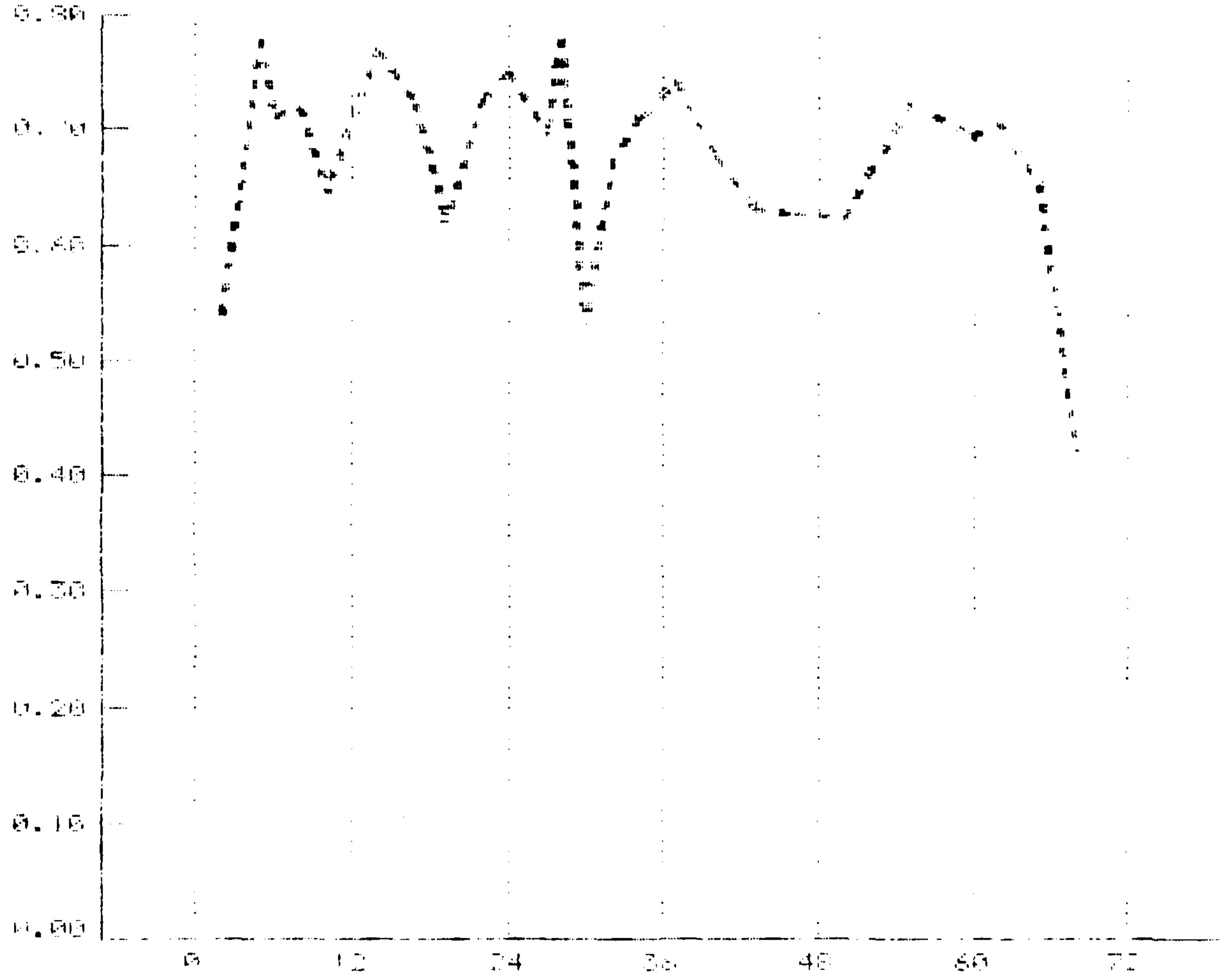
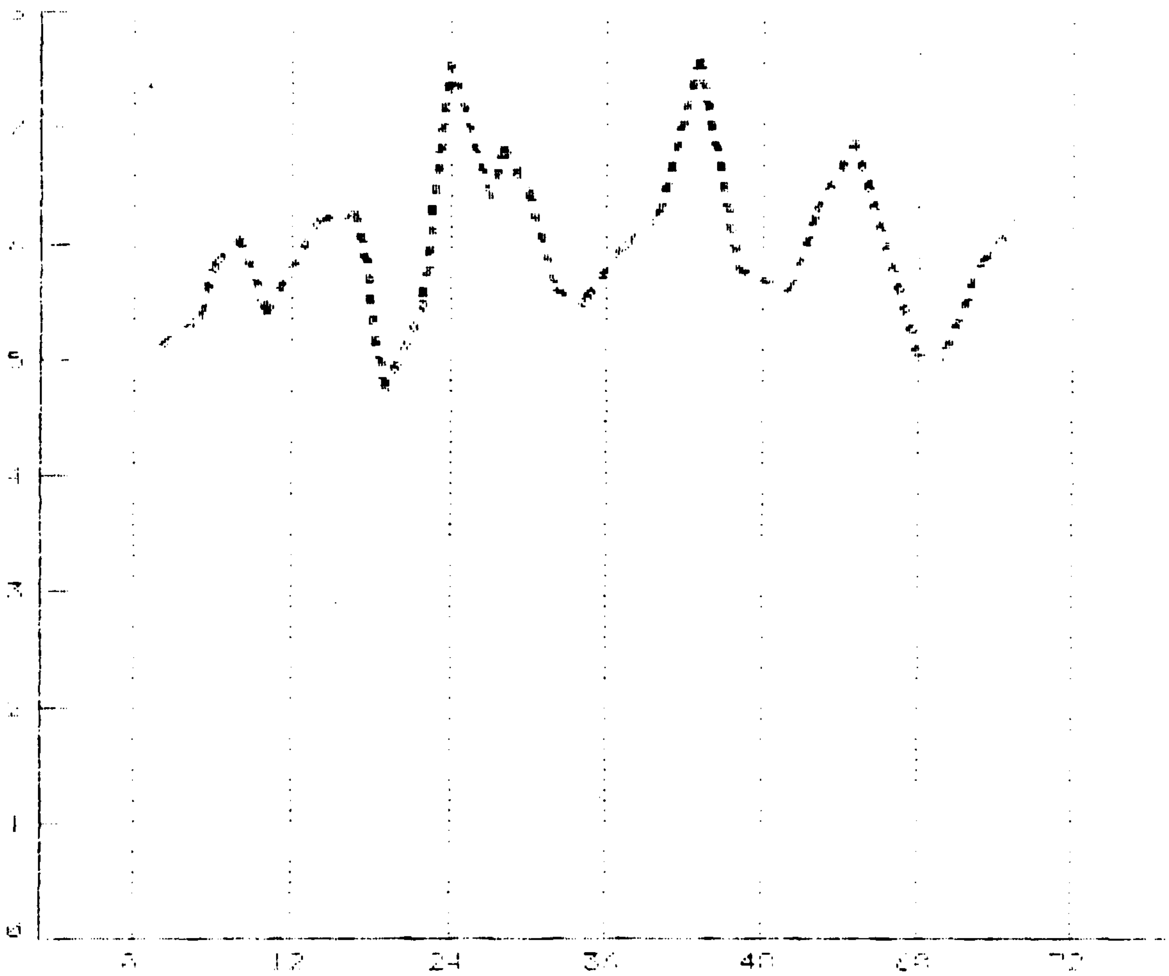

0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
12
24
36
48
60
72

Figure 5. Total community parameter

Ordinate = Margelef's index of species richness

Abscissa = months since start of program

Vertical bars = Year markers


4
1
24

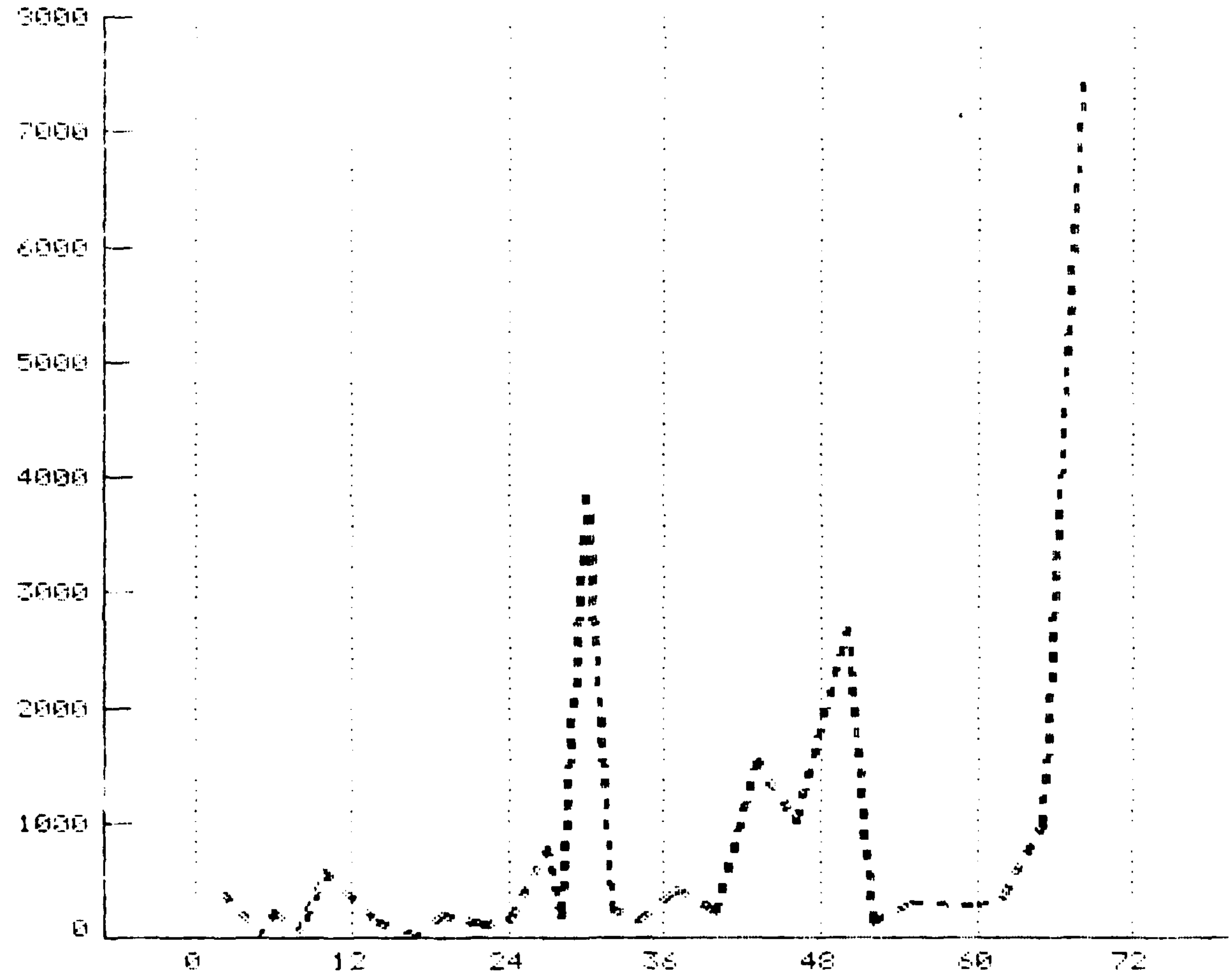
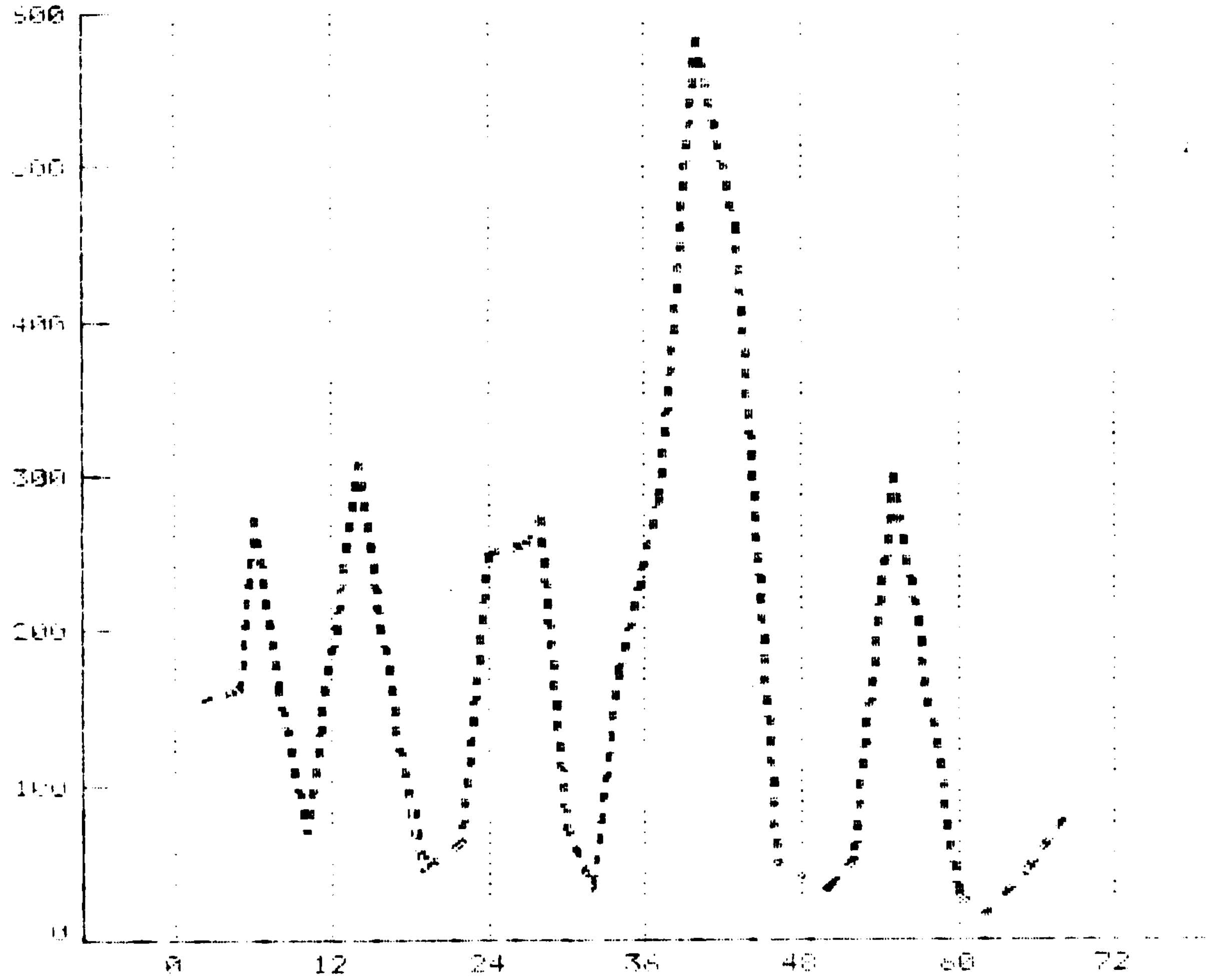

8000
7000
6000
5000
4000
3000
2000
1000
0
0
12
24
36
48
60
72

Figure 7. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Spiophanes bombyx* x 10^3

Abscissa = months since start of program

Vertical bars = Year markers



500
400
300
200
100
0
12
24
36
48
60
72

Figure 8. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Nephtys picta* $\times 10^3$

Abscissa = months since start of program

Vertical bars = Year markers

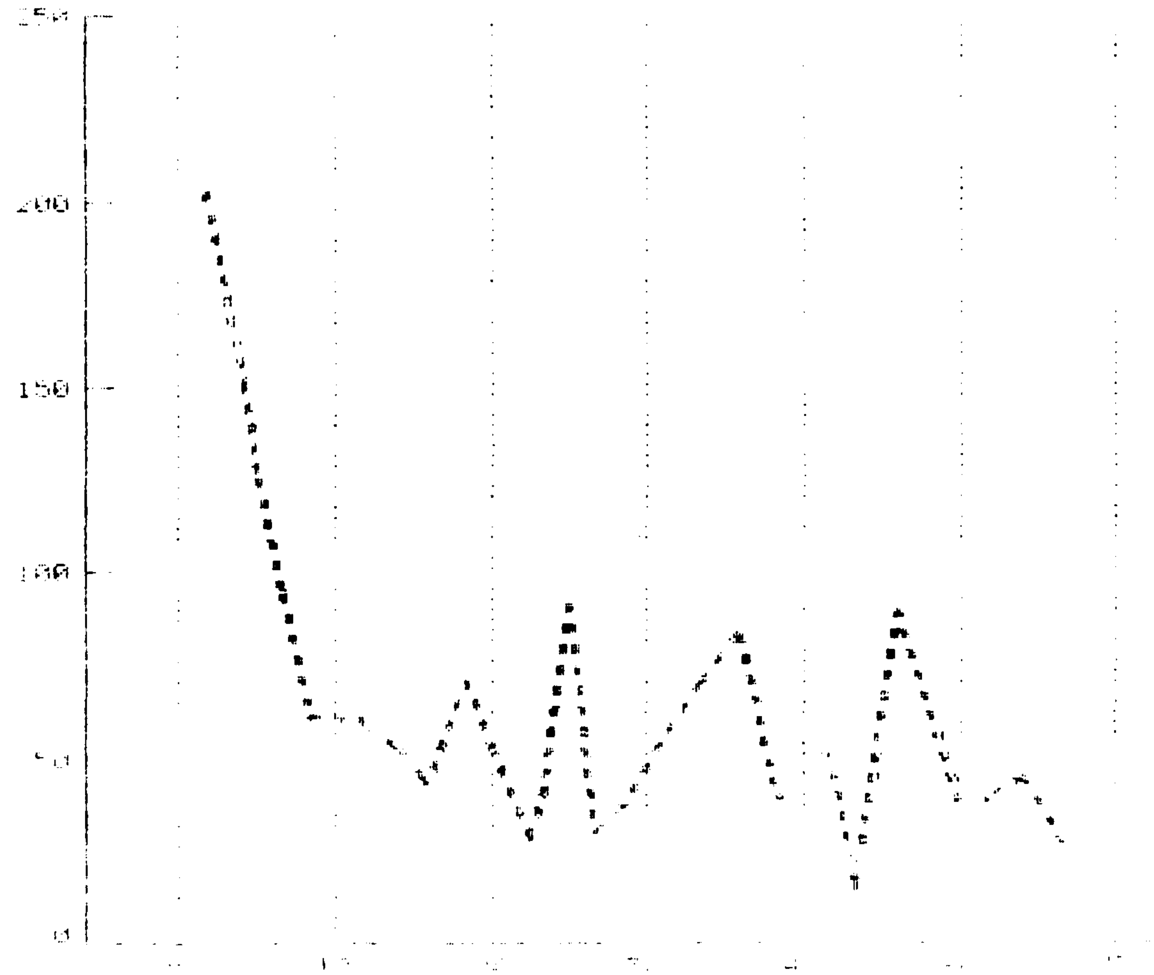


Figure 9. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Ampelisca verrilli* $\times 10^3$

Abscissa = months since start of program

Vertical bars = Year markers

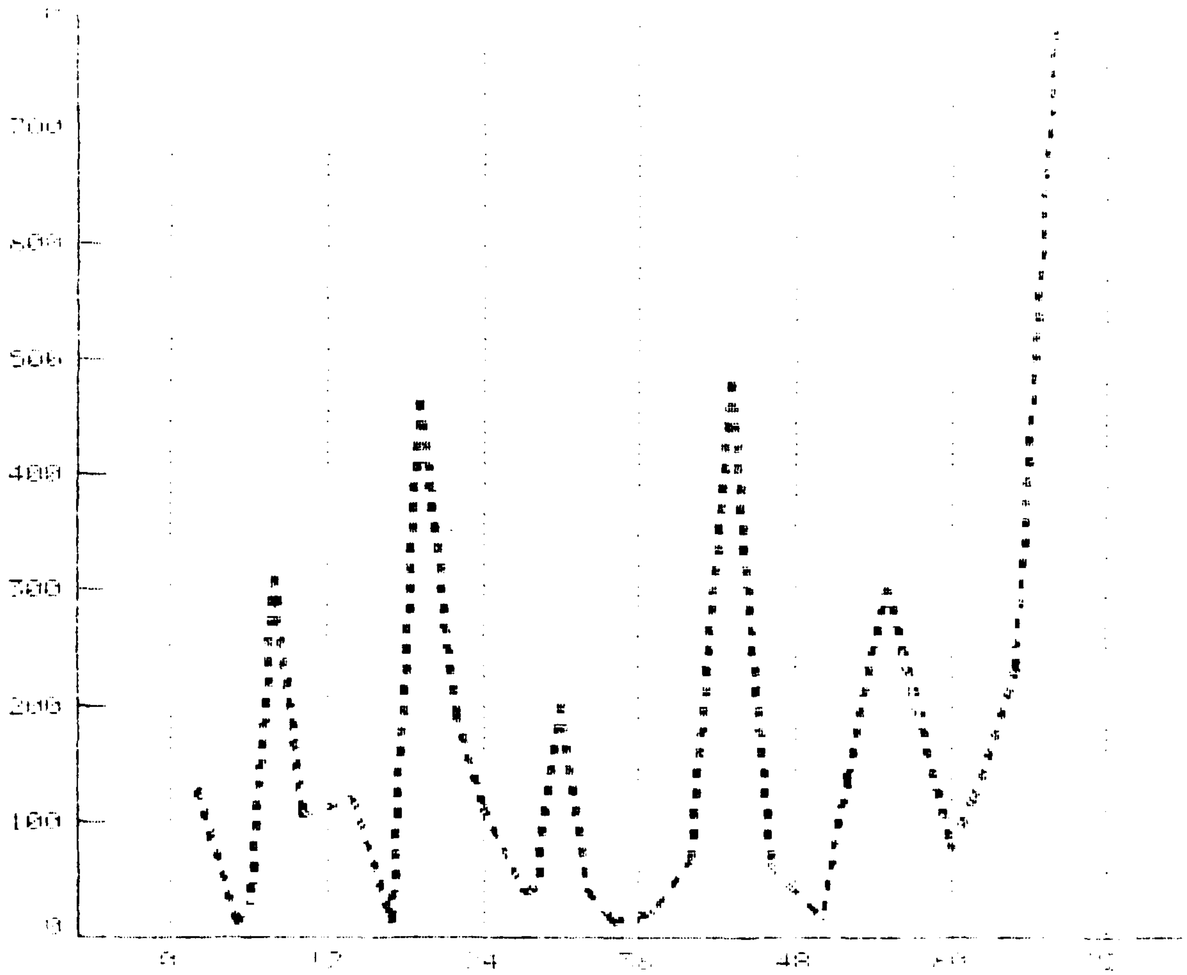
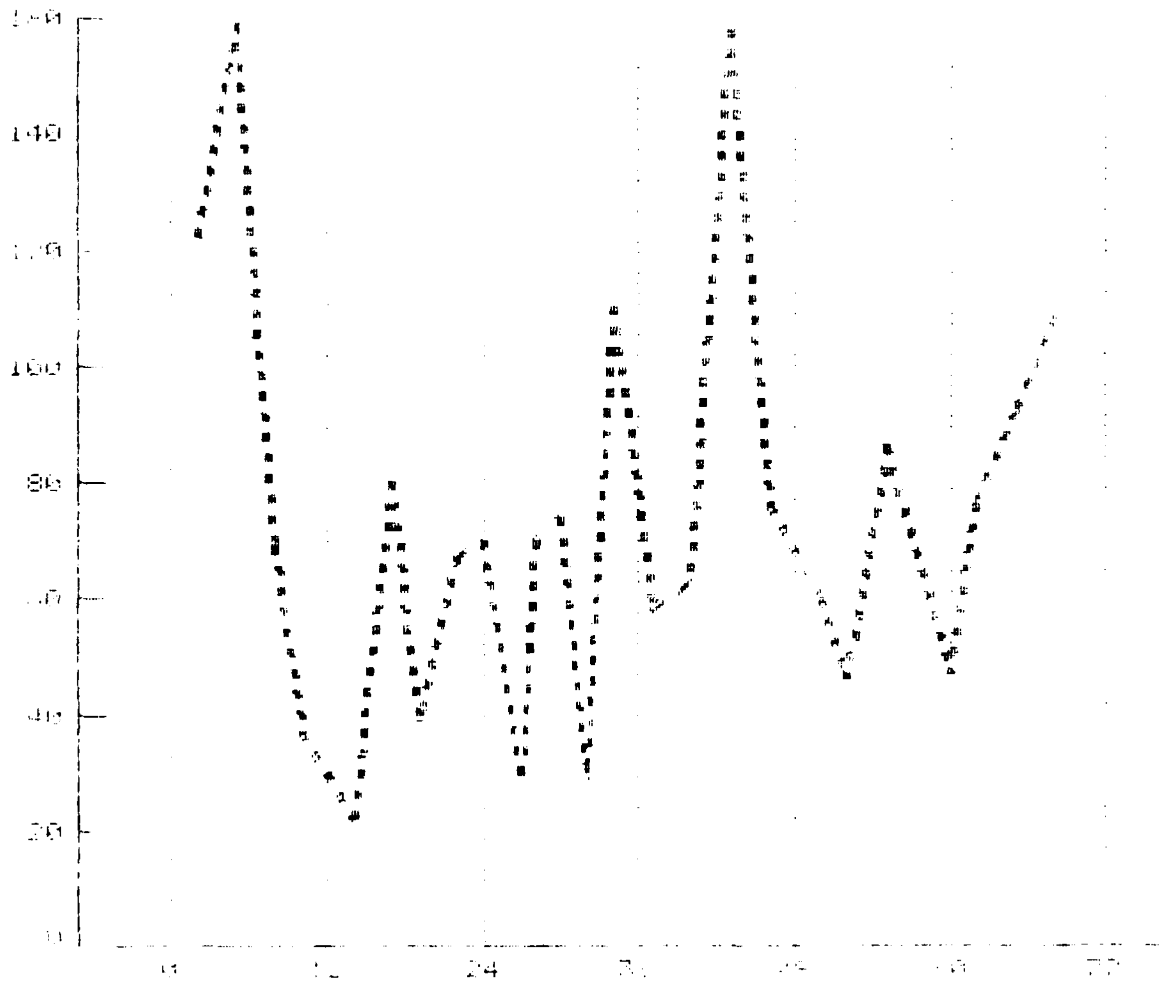

700
600
500
400
300
200
100
0
48

Figure 10. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Aricidea wassi* $\times 10^3$

Abscissa = months since start of program

Vertical bars = Year markers



140
100
80
20
24

Figure 11. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Tellina agilis* x 10^3

Abscissa = months since start of program

Vertical bars = Year markers

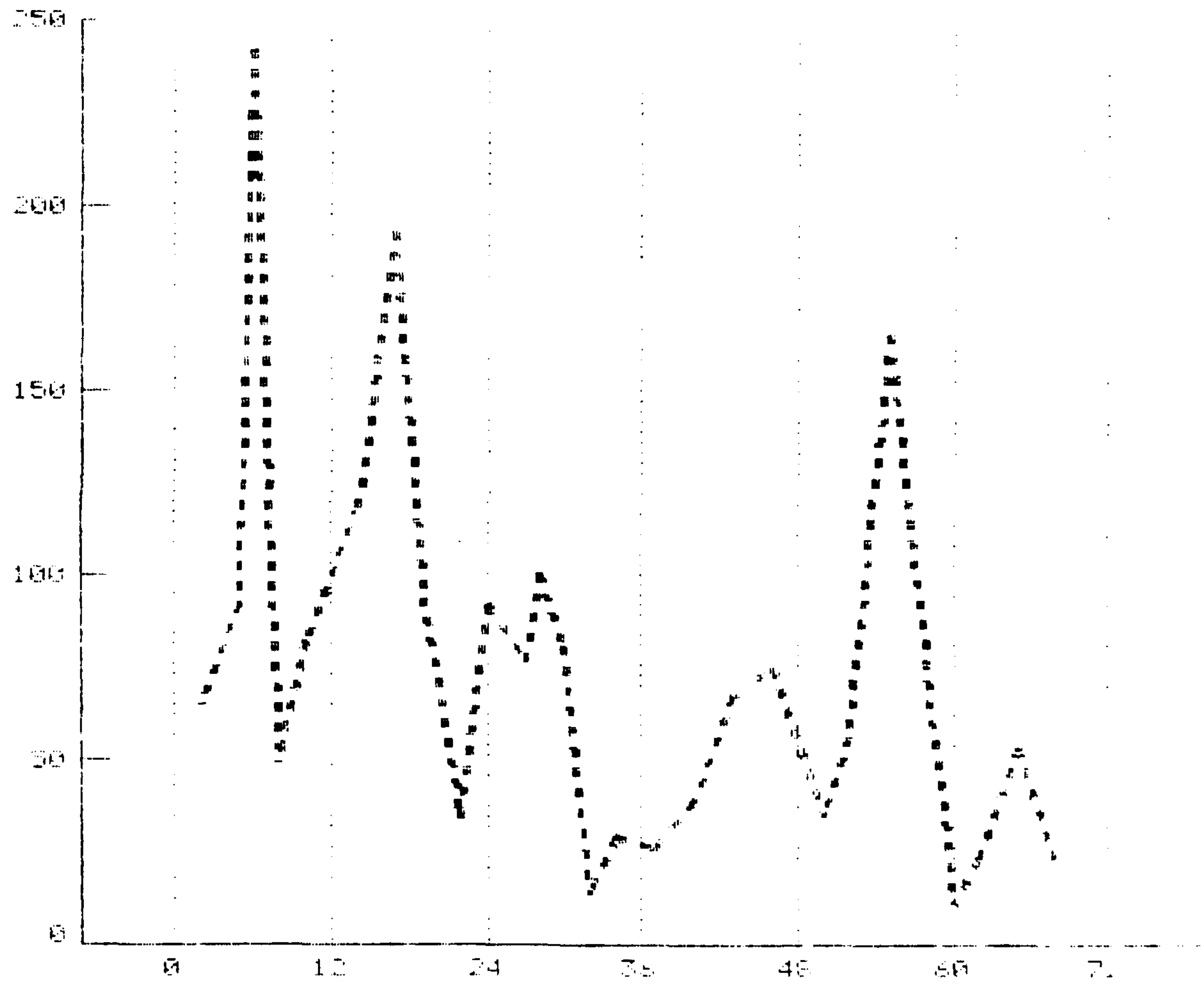

250
200
150
100
50
0
0
12
24
36
48
60
72

Figure 12. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Apoprionospio pygmaea* x 10^3

Abscissa = months since start of program

Vertical bars = Year markers

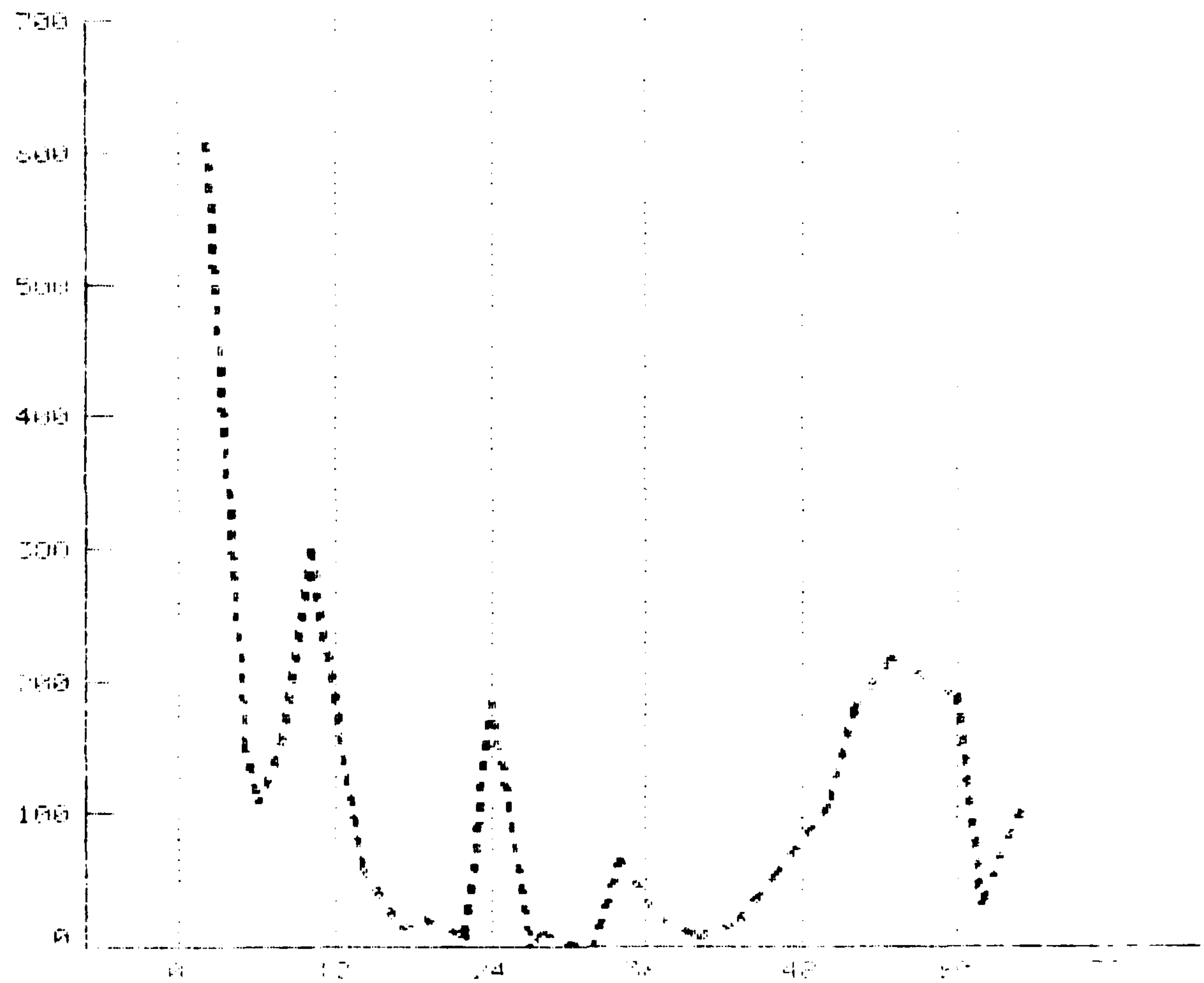

700
600
500
400
300
200
100
0

Figure 13. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Spio setosa* x 10^3 (log scale)

Abscissa = months since start of program

Vertical bars = Year markers

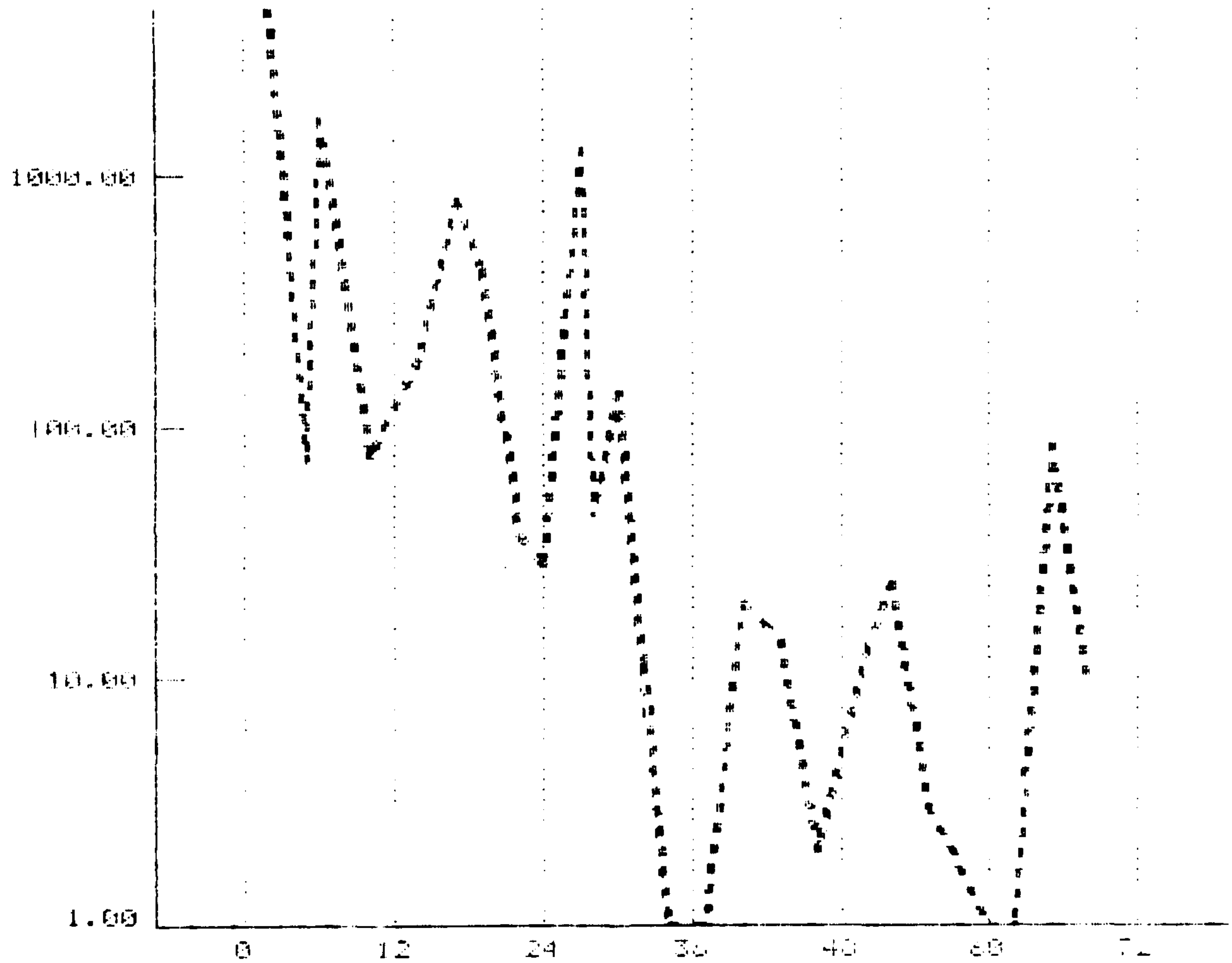

1000.00
100.00
10.00
1.00
0
12
24
36
48
60
72

Figure 14. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Aricidea catherinae* x 10^3

Abscissa = months since start of program

Vertical bars = Year markers

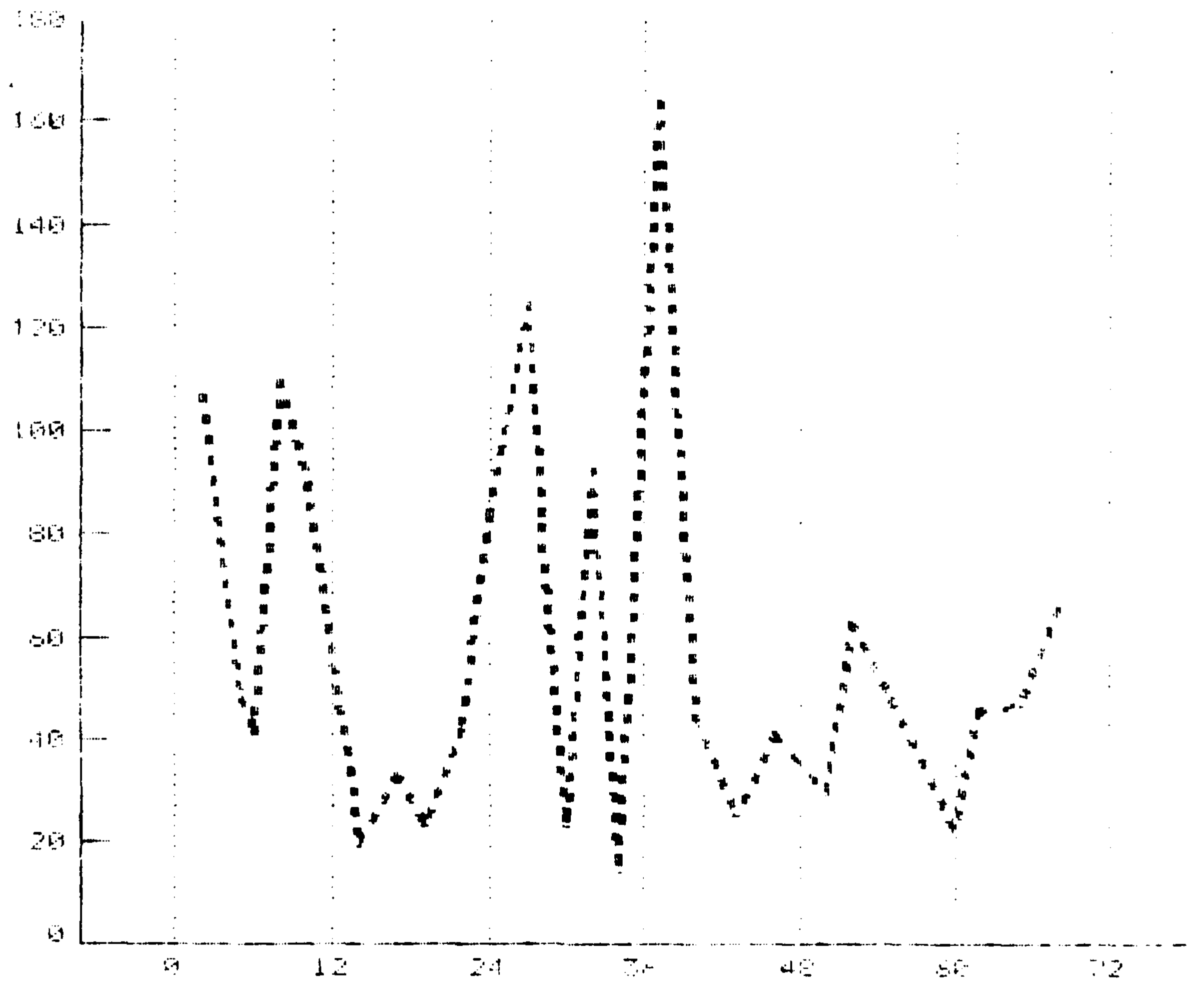
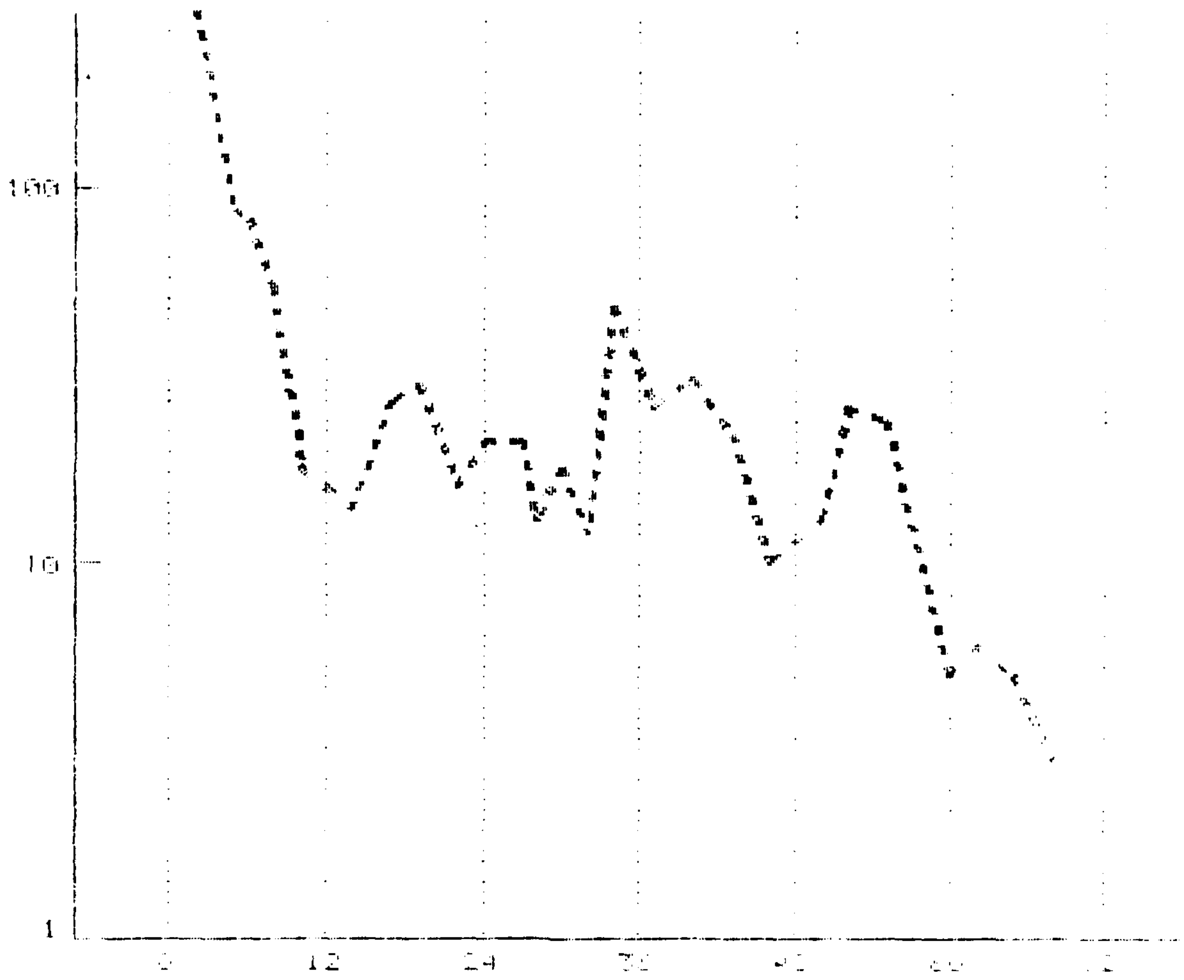

180
160
140
120
100
80
60
40
20
0
0
12
24
36
48
60
72

Figure 15. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Magelona* sp. x 10^3 (log scale)

Abscissa = months since start of program

Vertical bars = Year markers



100
10
1
12
24

Figure 16. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Amastigos caperatus* $\times 10^3$ (log scale)

Abscissa = months since start of program

Vertical bars = Year markers

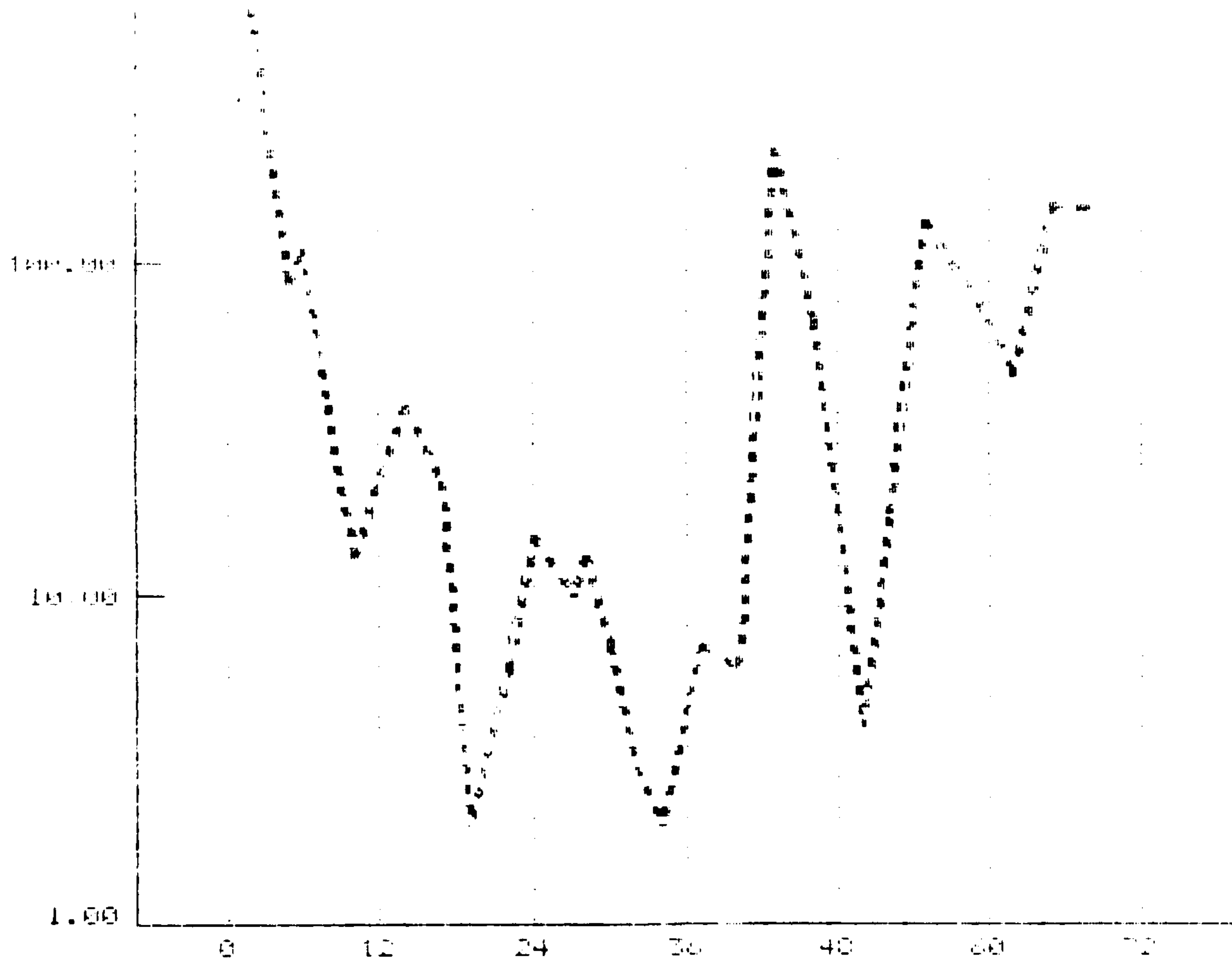
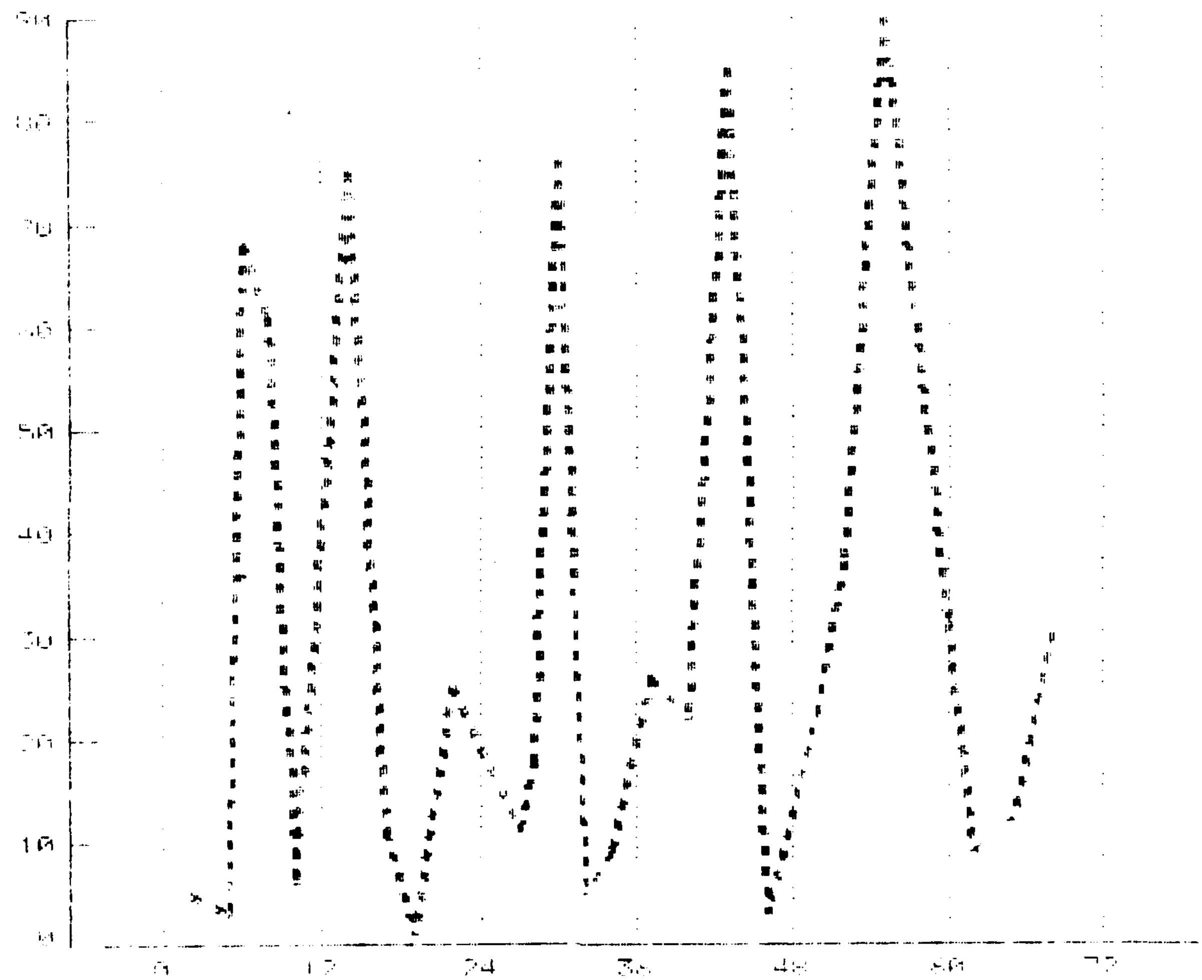

1.00
0
12
24

Figure 17. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Protohaustorius deichmannae* x 10^3

Abscissa = months since start of program

Vertical bars = Year markers



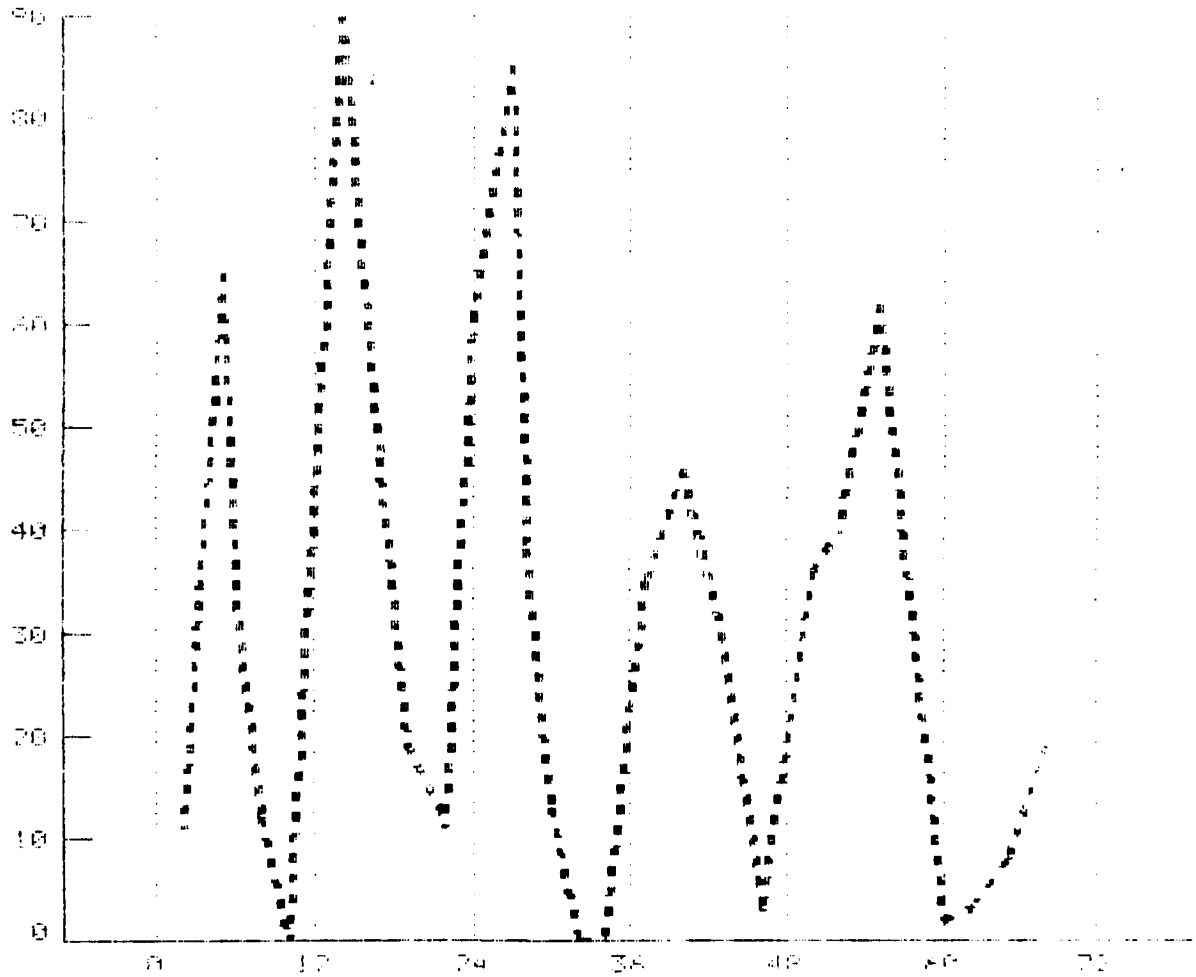
90
80
70
60
50
40
30
20
10
0
0
12
24
36
48
60
72

Figure 18. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Spisula solidissima* x 10^3

Abscissa = months since start of program

Vertical bars = Year markers



90
80
70
60
50
40
30
20
10
0

Figure 19. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Mediomastus ambiseta* x 10^3

Abscissa = months since start of program

Vertical bars = Year markers

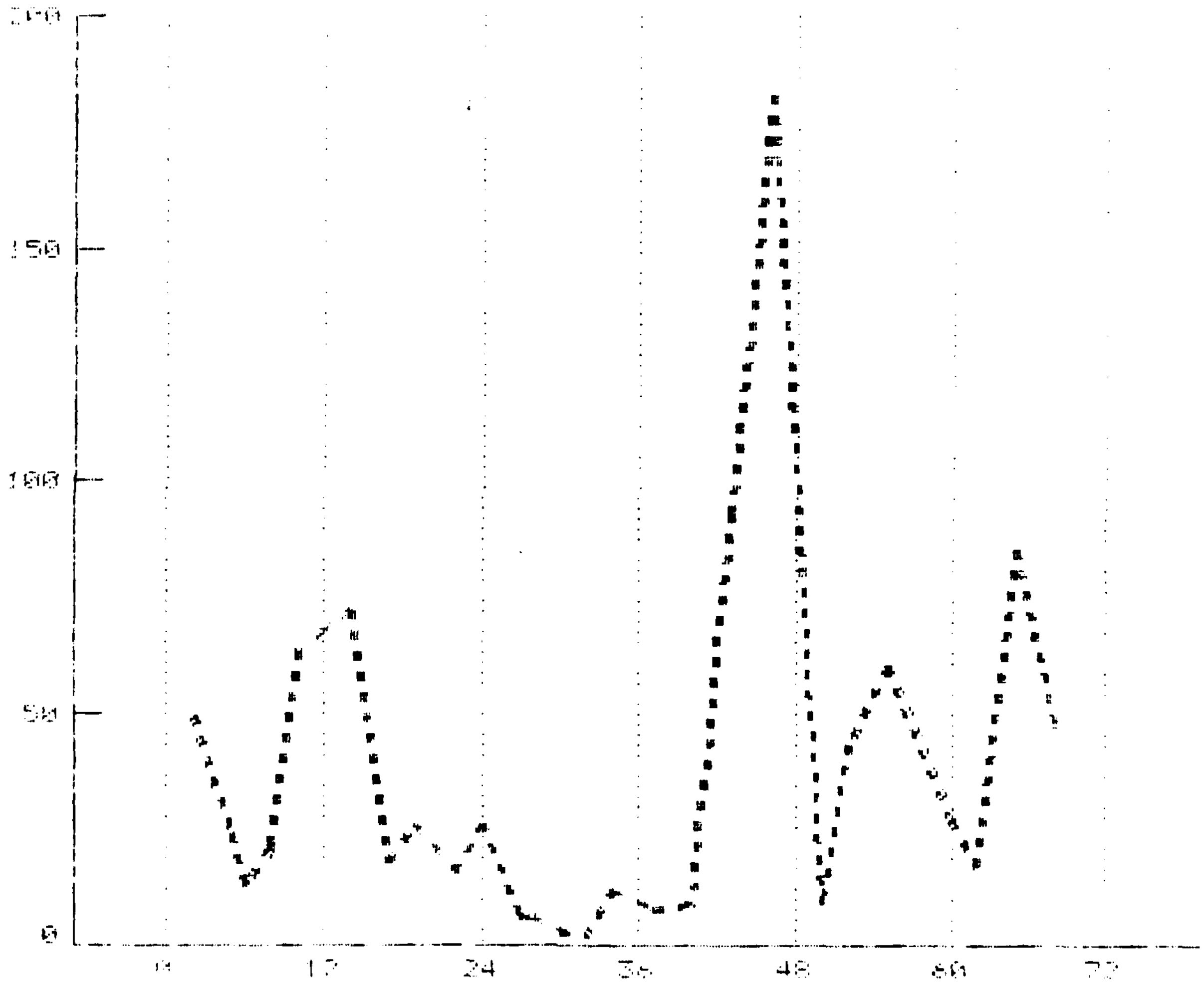

200
150
100
50
0
0
12
24
36
48
60
72

Figure 20. Temporal pattern of abundance of density dominant species.

Ordinate = number of individuals of the species *Echinarachnius parma* x 10^3

Abscissa = months since start of program

Vertical bars = Year markers

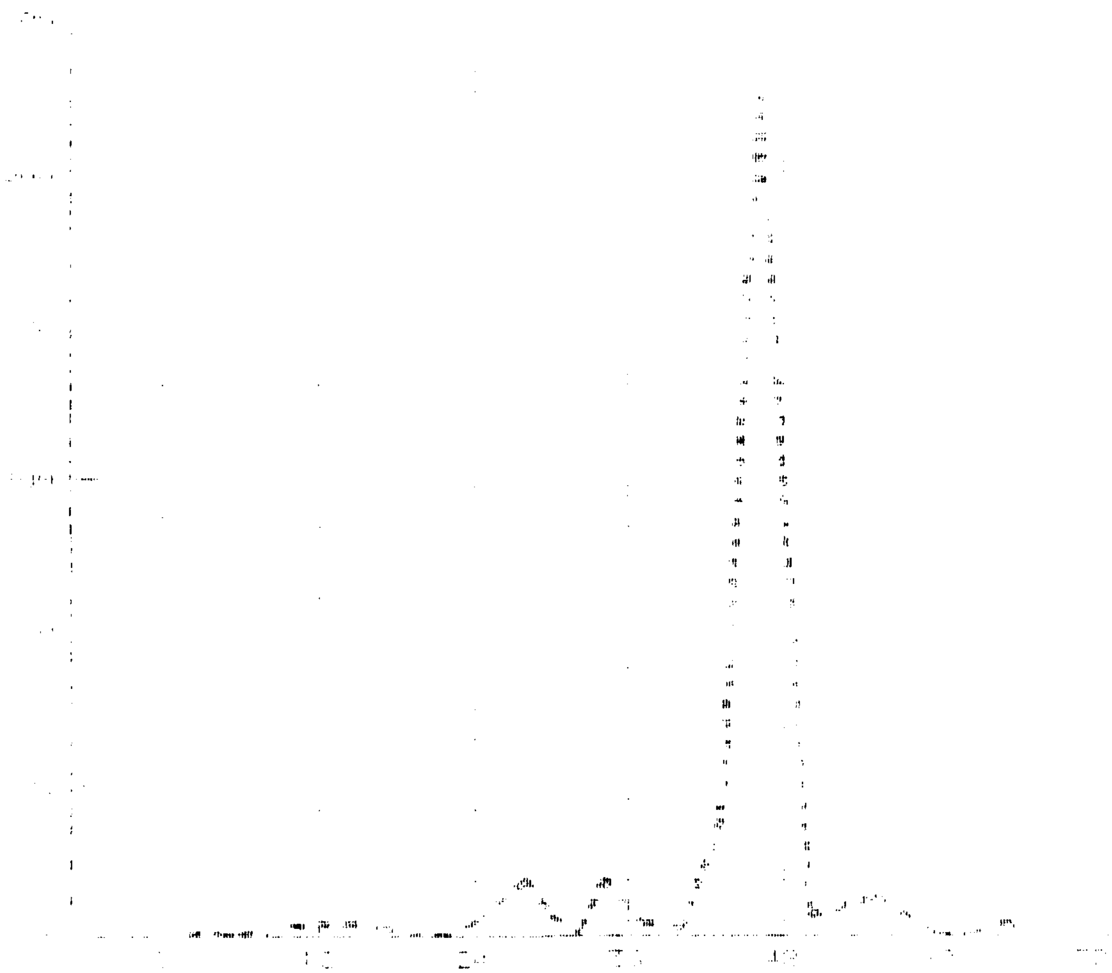
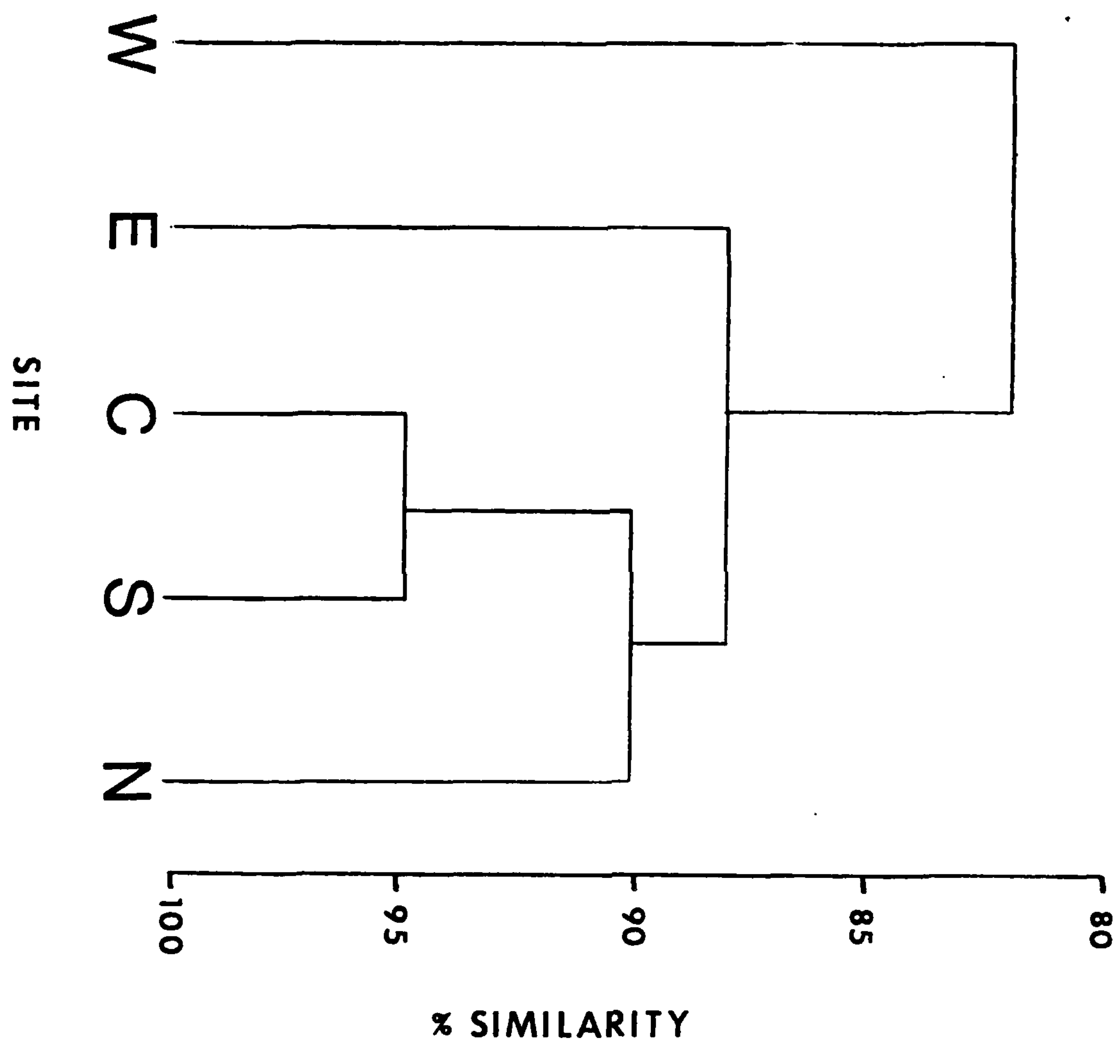


Figure 21. Similarity dendogram of the five sampling sites for the top 15 density dominants.

N - North Site   S - South Site   C - Center Site

E - East Site   W - West Site


W
E
C
S
N
SITE
100
95
90
85
80
% SIMILARITY

DTIC

FILMED

4-86

END