BENTHIC FORAMINIFERA AS INDICATORS OF POLLUTION BY HEAVY METALS IN THE EASTERN MEDITERRANEAN SEA

by

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ABBREVIATIONS

Mg	Magnesium
Mg O	Magnesium oxide
Ca	Calcium
Ca O	Calsium oxide
Cd	Cadimium
Cr	Cromium
Zn	Zinc
As	Arsenic
V	Vanidium
Pb	Lead
Ti	Titanium
S	Spring
W	Winter
Ab	Absolute
R	Relative
HD	Hard ground
E	Estimated
Cls	Calt-Silt
VFS	Very fine sand
FS	Fine Sand
MS	Medium size sand
CS	Coarse sand
VCS	Very coarse sand
G	Granule
P	Pebbles
Tol. sp. liv.	Total species living
Tol. liv.	Total living
S	Small size test
M	Medium size test
L	Large size test
H'	Heterogenety
Def	Deformed

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AIMS OF THE STUDY

This research has been designed to contribute to pollution studies by monitoring its effect on aquatic life forms at depths of 3 to 210 m in the Levantine Basin of the East Mediterranean region. As such, the aims of the study are four-fold as presented below:

1. To present a taxonomic account of the foraminiferal population of the study area, and to distinguish and describe shells with normal and abnormal morphology.
2. To establish the relationship between the foraminifera and environmental conditions within the area (temperature, salinity, pH, dissolved oxygen, depth, substrate, and seasonal changes).
3. To examine the effect of heavy metal pollution on the foraminiferal population: their distribution, diversity, abundance as well as test chemistry and morphology. And determine which parameters from the previously mentioned can be used as indicator for heavy metal pollution.
4. To produce a classification of the types of morphological deformations exhibited by benthic foraminifera compared with the normal test shapes. Attempt to distinguish between morphological deformation caused by mechanical factors and those caused by chemical pollution.
5. To determine which species may be sensitive to heavy metal pollution based on documented types and levels of pollutants in the study area. Examine the importance of individual species as heavy metal pollution indicators to monitor the contamination of the marine ecosystem by heavy metals.

ABSTRACT

Benthic foraminifera have been investigated and used for the first time to assess the impact of pollution especially by heavy metals, in a part of eastern Mediterranean Sea From the study a total of 168 benthic foraminiferal species belonging to 75 genera and 35 families has been identified. The dead specimens where used for taxonomic purposes and as a base line against which the deformed forms can be compared. The majority are essentially shallow water species with few deep water forms. The Rotaliina represents the highest percentage of the assemblage followed by the Miliolina, whereas the Lagenina and the agglutinated forms constitute the lowest percentage in the study area.

There was a clear seasonality in benthic foraminiferal populations reflected in the reduction of foraminiferal abundance, species diversity and number of species in winter compared to spring assemblages.

By observing the changes in foraminiferal populations from contaminated sites and comparing these with populations from noncontaminated sites, inferences regarding the impact of pollution on the environment can be drawn. Changes in foraminifera populations expressed in their abundance, diversity, and richness, particularly when compared with populations from relatively noncontaminated sites suggest changes due to pollution, rather than effects of oceanographic parameters such as temperature, salinity, pH, dissolved oxygen. These parameter are generally seen to be relatively constant within the study area. Only parameters such as depth, type of substrate and heavy metals concentration in the sediments have a clear effect on the distribution of certain species. For example, *Ammonia tepida.* distribution is effected by depth and heavy metals concentration. On the other hand *Asterigerinata mamilla* doesn't show any preference to water depth and *Amphistegina lobifera* shows a preference to the type of substrate and the change in heavy metals concentration rather than to depth. Species considered sensitive to heavy metal pollution such as: *Ammonia tepida*, *Amphistegina lobifera* and *Peneroplis pertusus)* are dominant in the contaminated sites and represent the highest percentage of morphological deformations.

Analysis of available data, showed that two types of morphological deformations could be distinguished and have been categorised or grouped into mechanical and chemical deformations. Chemical deformation is here interpreted as due to ionic exchange resulting in high Mg/Ca ratios.

Mechanical deformation includes: the presence of more than one aperture, the presence of residual chambers. On the other hand, the presence of scars and specimens exhibiting fragment extensions are interpreted as predominantly due to physical abrasion and are completely unrelated to the effect of pollution. The chemically induced deformations, on the other hand, include: abnormal chamber enlargement, distorted chambers and overall test outline, lopsided pseudo-high trochospiral test and lopsided low trochospiral test whorl etc. These have been interpreted as due mainly to pollution caused by increasing heavy metal such as Cadmium, Lead, Zinc, Arsenic, Cobalt, Chromium, Lithium, and Vanadium above threshold values.

Chapter 1

INTRODUCTION

1.1 Preface

Traditionally, studies which have been conducted with the aim of unravelling the effect of pollution on the ecosystem have usually been carried out using larger marine organisms, e.g. Shrimps (Alliote and Frenet, 1990), Trout (Gramentz, 1988) and on gastropods (Nicolaidou and Nott, 1990). Such methods have proved cumbersome due to, among other things, size of the specimens involved and the quantity of organisms available for study. Usually the size of the specimens are too large and difficult to handle while only few samples are generally available to provide adequate and effective monitoring of the environmental conditions.

During the past decade, a great volume of literature have emerged in which attention shifted from such traditional methods as using macroorganisms to the use of invertebrate microorganisms such as foraminifera. Consequently, the use of benthic foraminifera has become a powerful tool for monitoring the environment, mainly due to the favourable attributes exhibited by this group of organisms. These attributes include:

(a) Their wide range of occurrence in marine environments.

(b) Their integral association within the sediments, which receive and store much of the pollutants. As a result, these benthic organisms are more readily affected by pollutants to a greater degree than planktonic and/or nektonic organisms which float in the water column.

(c) Their hard-shelled exoskeleton nature which allows them to be readily well preserved in marine sediments.

(d) Their basically small sizes which permits their being recovered in large quantities, compared to larger hard shelled fauna such as molluscs.

Their extensive morphological variability, abundance and rapid evolution make the foraminifera useful as biostratigraphic indicators. On account of the sensitivity of some species to their environment, the foraminifera are also useful in the reconstruction of the palaeoenvironment from small samples e.g. from well-cuttings or cores. Their abundance can prove quite useful in the field since a small sample can be examined with a 30x power microscope and sufficient specimen can be obtained to provide a preliminary assignment to a stratigraphic zone or a particular palaeoenvironment. The various methods for easy recovery of foraminiferal tests from the sediment are well known and documented in related biostratigraphic literature.

Based on the aforementioned attributes, the use of foraminifera for pollution studies, especially the shallow benthic forms, would appear to hold the most potential both in terms of material availability as well as cost effectiveness. Although thousands of species and genera (mostly fossils) are now catalogued, the complete life history of only a few living species are fully understood. It is only in recent years that micropalaeontologists have begun to realise the potential of precise information about the living organism (including their present day ecology and factors controlling their distribution) for environmental studies such as in being applied in this study. Consequently, it envisaged that studies such as this would invariably lead to proper management and control of environment pollution.

1.2 Introduction to Foraminifera

Foraminifera first appeared in the literature in the 5th century B.C. when Herodotus noted *Nummulites* in rocks of which the Egyptian Pyramids were constructed. However, it was not until nearly 2000 years later that foraminifera were recognised as remains of organisms by Agricola, in 1558 A.D.

The smaller or micro-foraminifera were described by Beccarius in 1731. For most of the next century, those described were variously regarded as worms, cephalopods, gastropods, or corals. Some species were described originally as belonging to Nautilus, Orthoceras or Serpula (Loeblich and Tappan, 1964).

The term "foraminifera" was originally proposed by D'Orbigny (1826) to subdivide the Cephalopoda into two orders, namely: (i) those with siphons belonging to the Order *Siphoniferes* and (ii) those lacking siphons belonging to the Order *Foraminifères*. This subsequently led to the first detailed systematic study of foraminifera in which D'Orbigny recognised a total of 5 families, 25 genera, and 544 species. D'Orbigny also examined several fossiliferous strata and noted the change in the microfauna through geological time. Although the stratigraphic and geological use of foraminifera has been recognised since the time of D'Orbigny, their economic importance was first recognised by Józef Grzybowski (1898).

1.3 The nature of Foraminifera

Foraminifera are a class of unicellular animals which are distinguished from all other single-celled organisms by their granuloreticulate pseudopodia.

The protoplasm, which is the soft part of the organism is differentiated into an outer layer of relatively clear ectoplasm and an inner, darker coloured endoplasm. The protoplasm is variously coloured and may be green, orange or red. In general, the reasons for this coloration has been attributed to one or more of the following: presence of symbiotic algae, the colour of the food, and pigment (Murray, 1963, Hedley, 1964, Haynes, 1965, 1981).

The pseudopodia are fine and hair-like and these anastomose to from a spreading, reticulate network. The most important function of the pseudopodia are for capturing and digesting prey and expelling the debris (Buchanan and Hedley, 1960; Christiansen, 1964). Other functions are for test construction, cysts formation and serving as temporary or semi-permanent substratum attachment processes.

According to Levine (1962) foraminifera constitute 25% of organisms within the animal kingdom and comprise more than half the known protozoan groups. Foraminifera are unique among the single-celled organisms with great variety of expressions in the architecture and ornamentation of their exoskeleton or test.

Foraminiferal tests generally occur in various forms. Some have a glassy (hyaline) appearance when viewed with reflected light or appear grey to clear in transmitted light. The hyaline wall is, basically, formed from calcite crystals. Others posses a hard agglutinated wall in which organic and mineral matter from the sea floor is bound together by an organic, calcareous or ferric oxide cement. Porcellaneous calcareous tests appear milky-white in reflect light and an amber colour in transmitted light. They are made up of minute needles of high magnesium calcite randomly arranged for the most part, but the outer surface are built with horizontally or vertically arranged needles.

The test of foraminifera is a secretion of the ectoplasm which acts as a barrier against unfavourable physical and/or chemical conditions of its surroundings, such as osmotic pressure (Murray, 1968). The test construction may be relatively simple or it may be complex and their sizes may range in diameter from 0.02 to 110 mm in adults (Loeblich and Tappan, 1964).

1.4 Mode of life

The majority of foraminifera live on the sea bed (benthic) while a small number of genera and species, often represented by a large number of individuals, swim freely in the water column (plankton). A relatively small number of benthic genera live permanently attached to various objects on the sea floor with their test temporarily or permanently cemented (e.g. *Cibicides*)

1.5 Review of Foraminiferal Study - Related Topics

In this section, the usefulness of foraminifera in various studies is briefly reviewed. The versatility of this group of organism is due, essentially, to the favourable attributes which they exhibit (see section 1.1). Hence this group of organism have been extensively used in studies involving both ancient and modern environments.

1.5.1 Application of Foraminifera in Ancient or Paleo-studies

The extensive morphological variability, abundance and rapid evolution of the foraminifera make them extremely useful in the geological field of biostratigraphy including paleoenvironmental reconstruction and paleoecology.

In the petroleum industry, for example, accurate biostratigraphical analysis is of fundamental importance for several reasons. Primarily, it provides information for effective age-dating and zonation of strata as well as recognition of marine depositional regimes which may either be in the near shore, foreshore or offshore environments. In addition, it provides a means of correlating strata over distances in time and space with a view to achieving a reasonable resolution of the regional extent of deposits with which hydrocarbons are associated.

Furthermore, paleoecological analysis provides a means of detailing the historical evolution of global climatic and oceanic conditions and the attendant effects on changes in the fauna and floral patterns. To this end, foraminifera have become an invaluable tool in paleostudies.

1.5.2 Application of Foraminifera in Studies of the Modern Environments

In the modern environmental studies, foraminifera have been successfully applied in aspects of ecology, environment stress analysis as well as in pollution studies.

1.5.2.1 Ecological studies

In recent times with the increase of human technology and industrial development, there have been increasing and lasting changes to the ecology of both land and marine environments. In the aquatic regimes, for example, these changes invariably have a significant impact on marine life as well as on the over-all food chain particularly at the level of primary producers. Various groups of foraminiferal species are known to live under specific environmental conditions defined by temperature, salinity, depth, food (available quantity and type), substrate, dissolved oxygen, and light.

This implies that the presence of a particular species in an area is indicative of the physico-chemical conditions of the area. Several approaches adopted for ecological studies abound in literature. Such approaches ranges from single species study to analysis of assemblages for definition of regional communities, global provinces as well as defining areas of endemism. Generally, studies based on single species are usually not reliable because of the problems of thanatocoenosis (post-mortem destruction and re-deposition). This is important to bear in mind when carrying out paleostudies, since the majority of fossil inferences are drawn based on ecological data on foraminifera.

1.5.2.2 Environmental Stress Analysis

Among the various foraminiferal groups, benthic foraminifera provide much of the information as regards degrees of stress within the marine environment. The hydrographic condition including: Oxygen, food availability, salinity, temperature and pH of associated water masses, as well as the nature of the substrate, are all factors that influence benthic foraminiferal distribution, diversity, morphology and test chemistry (Murray, 1973).

Murray (*op. cit.*) recognised that foraminifera are distributed in global belts which define faunal provinces. These distribution patterns also recognised by various authors (e.g. Vincent and Berger, 1981) have been used to relate the abundance of foraminifera to physical and chemical variables.

A. Effects due to Oxygen content of sediment:

Low dissolved oxygen content can be detrimental to benthic foraminifera, as it can to all other organisms. Miller, 1953; Said, 1953, suggested that the lack of dissolved oxygen is a factor which reduces metabolic rates and as a result produces dwarfed specimens

Low oxygen content causes one or several of the following: less ornamented tests (Bernhard, 1986), and even abnormal or aberrant tests (Gray *et al.*, 1989).

According to (Murray, 1973), one of the factors controlling the depth at which the foraminifera can live and thrive in the sediments is the thickness of the oxidised surface layer. Boltovskoy (1966) suggested that sandy sediments are penetrated more deeply by foraminifera than muddy ones, and that this is related to better aeration of the former.

Low oxygen concentration invariably leads to scarcity of benthic foraminifera (Yanko *et al.,* 1991, Ross and Kennet, 1984, Mullineaux and Lohmann, 1981). On the contrary Said (1950) indicated that an increase in oxygen content does not necessarily result in an increase in the number of benthic foraminifera since other factors may also contribute to reduced numbers even when oxygen content is high.

B. Effect due to Temperature and Light penetration:

The depth of light penetration and temperature are often mentioned as important factors affecting benthic foraminiferal distribution (Phleger, 1960; Resig, 1958; Yanko, 1990, 1991). This is, essentially, because both parameters are intricately linked to levels of productivity. Generally, the near shore and mid shelf regimes constitute areas of highest productivity (Walton, 1964). In the water column above these shore and shelf regimes, there is usually intense photosynthetic activity by primary producers within the photic zone. Upon their death, these primary producers settle on the sea bottom and provide nutrients hence availability of food for benthic organisms.

For certain species (particularly those that are symbiotic), insufficient light is unfavourable and causes size decreases. Kuile and Erez (1984), recorded the growth rate of symbiotic-associated *Amphistegina lobifera* and *Amphisorus hemprichii* increases when the light intensity increases. Walter and Faber (1991), reported that the distribution of *Peneroplis (Pyrogoella) arientinus* and *Peneroplis planatus* is controlled by light because the inter specific competition for food as well as space may control the population abundance and distribution throughout the year. The macroalgal bloom in spring, corresponding to the seasonality of sexual reproduction in *P. planatus* provides new substrate and food sources, which allow *P. planatus* to temporarily overcome this competition and increase its population.

Temperature is additionally known to have a profound effect on the reproduction of foraminifera. It has been established that reproduction takes place only within a narrow temperature range (Bradshaw, 1961). Temperature can play an important role in morphological variation of the foraminiferal test. A change in temperature can effect the sinistral/dextral ratio in some species. It also appears that intra-specific morphological variability increases with temperature (Bltovskoy *et al.*, 1991).

C. Effects due to Salinity Fluctuations:

Each benthic foraminifera species has specific limits of tolerance to salinity (as well as other factors). It has an enormous effect on benthic foraminiferal growth, survival, distribution and reproduction, especially in areas of reduced salinity (Yanko, 1991). Salinity levels between 15‰ and 40 ‰ and temperature conditions between 17°C and 32°C are optimal for foraminiferal reproduction (Bradshaw, 1957; 1961; Walton and Sloan, 1990). Salinity within the normal growth limits has no special effect on the morphology of the test. If it is reduced, the foraminifera species become smaller, thin walled, and their ornamentation can decrease or even disappear altogether (Pratje, 1931; Le Calvez and Le Calvez, 1951; Morishima, 1955; Furssenko, 1959). Furssenko reported that *Rotalia (Ammonia) beccarii* becomes larger in high salinity environments. Almogi-Labin *et al.*,(1992) suggested that the reason for the abnormal form of *Ammoina beccarii tepida* is the seasonal high temperature and salinity conditions.

D. Effect due to substrate type:

Some species change their morphology in response to a specific type of substrate, and this is obvious in sedentary species. Agglutinated foraminifera have different shapes on different substrate, e.g. *Reophax scorpiurus* and *Reophax bilocularis* , (Schroder, 1986; Kaminski *et al.*, 1988). Hada (1957) noticed that agglutinated foraminifera living in coarse-grained sediments have coarse surface textures, while those living on fine-grained deposits have fine surface textures. Hendrix (1958) concluded that thick-walled foraminifera prefer coarse grained sediments, while thin-walled species preferred fine-grained sediments. Medioli and Scott (1978) and Kitazato (1984) emphasised that the different modes of life are strongly reflected in the outline and shape of the test. Medioli and Scott (*op.cit.*) illustrate how *Discanomalina semipunctata* changes its gross morphology depending on the substrate. Its test has perfect bilateral symmetry on sandy substrates, it develops a plano-convex structure on rocky substrate, and when they are attached to blades of grass, they loose all form of symmetry because the test becomes warped under pressure of its own weight.

Both test shape and the size of pores can be correlated to micro-habitat preference. Epifaunal species have biconvex or planoconvex shapes with large surface pores absent or present on only one side of the test (an adaptation for attachment at the sediment water interface during times of bottom turbulence or for stability when moving on or near the surface), whereas infaunal species have pores evenly distributed over most of the test. This may also be an adaptation to low oxygen conditions within the sediment (Corliss and Emerson, 1990).

E. Effect due Nutrient Availability:

Food availability has a clear effect on distribution of benthic foraminifera. The reduction of nutrient may yield smaller and aberrant specimens or, in the case of larger foraminifera larger tests. The over-abundance of food is also unfavourable because it restricts pseudopodia activity and causes delay in growth. The development of symbiotic algae, as a response to low food supply, also appears to play a role in morphological changes, both externally and internally (Boltovskoy *et al.*, 1991).

It is possible that the effect of pollution on the natural environment could indirectly affect food supply rather than the foraminifera directly (Lee and Marcellino, 1967; Lee et al., 1966). Furthermore, in areas of up-welling, there can be radical changes in the food supply to the sea floor, and this invariably affects the population of foraminifera (Caralp, 1989)

1.6 Foraminifera as Pollution Indicators

Pollution is the introduction of substances or energy by man, directly or indirectly, into the marine environment which result in such deleterious effects as harm to living resources; hazard to human health; hindrance to marine activities including, fishing;

and impairment to the quality of sea water for general use. Thus the pollutant can be a naturally occurring substance if its concentration is above the natural background level for the area and for the organism. Such pollutants are, generally, referred to as contaminants.

The ocean had been used for waste because of its capacity to accommodate our waste without undergoing an unacceptable amount of change. This view has been based on the assumption that any potentially toxic waste would be diluted to innocuous levels and carried by currents far away from the coastline. Although this has been true in the past, the assimilative capacity of the coastal ocean appears to have been exceeded. This is probably as a result of the accumulative effect of human past activities as well as the current ever-increasing rates of pollutant input.

In recent times with the increase in human activities in terms of technological and industrial development, there has been an increasing influx of effluents and pollutants of various kinds into the marine environment. These have invariably had a significant impact on marine life as well as on the overall marine food chain particularly at the level of the primary producers.

Foraminifera are sensitive to pollution-induced environmental deterioration. This sensitivity is variable and related to the type and nature of the pollution. Some effluents may cause biotic condition resulting in total destruction of some of the biota whereas, other effluents can induce hypertrophic conditions and abnormally high productivity. Polluted environments and their effects upon foraminifera have been studied by many investigators from different parts of the world (Watkins, 1961, Alve and Nagy, 1986; Bates and Spencer, 1979).

A study of shallow marine environments showed that industrial pollution, especially by heavy metals (the entrance to Qishon Harbour, Israel; Southampton coast, southern England; Sorfjord, Western Norway) has deleterious effects on foraminifera (Alve 1991; 1995; Sharifi *et al.*,1991; Yanko and Kronfeld, 1992; Yanko *et al.*, 1994). This is denoted in living foraminifera by a reduced population diversity and density, stunted growth of the tests, developing test morphological abnormalities, and changes in test chemistry.

It has been established that foraminifera respond to heavy metal pollution in a number of ways, e.g. lower standing crop, high abundance of deformed test, lower diversity, changes in species dominance and test dissolution (Stubbles *et al.*, 1995). Monitoring of the trace metals in the sediment and the biota has been carried out over the years (e.g. Roth and Hornung, 1977; Hornung, 1988; Hornung *et al.*, 1984; 1989).

Abnormalities within the foraminifera test have been reported by many researchers. Several types of deformities have been reported, but few authors have attempted to describe any of them in detail. Different explanations were given by various authors as to the causes of these abnormalitie. Some believe that a rapid change in the physio-chemical environment through such parameters as salinity, nutrient supply, and temperature, may have caused an abnormal development within the test during the life span of the foraminifera (Arnal, 1955; Bartlett, 1973; a review by Boltovskoy and Wright, 1976; and Alve, 1995). Others believed that abnormalities were produced as a result of pollution (Sieglie, 1968, 1971, 1975; Setty and Nigam, 1984; Sharifi, 1986; Alve, 1991, 1995). Most of these explanations were based on field observations, while only few were based on laboratory culture experiments (Sharifi, 1991; Bresler and Yanko, 1995)

Watkins (1961) investigated foraminifera and the effect of pollution from the Orange County sewer between Huntingdon and Newport beaches in California. Although he stained his material with Rose Bengal to differentiate living from dead forms, most of his discussion related to the total assemblage (living + dead). He reported that agglutinated forms were more dominant than calcareous types around sewage fall-out regions. The agglutinated species such as *Eggerella advena* and *Trochammina pacifica* were found at depths shallower than their normal 30-80m around the effluent sources. Among the hyaline foraminifera, individuals of *Elphidium spinatum* and *Nonionella basispinata* developed certain test deformities in samples collected in the vicinity of the polluted zones. In general, the percentage of abnormal specimens increased in the area close to the fall-out. Watkins (*op. cit.*) concluded that agglutinated (arenaceous) species have affinity for water surrounding the sewage outlet.

Further studies have been conducted by Bandy and his students (Bandy *et al.*, 1964a, 1964b, 1965a, 1965b) along the southern California coast. Bandy *et al.* (1964a) in their studies of the Laguna Beach fall-out, noted that the total population of calcareous foraminifera was five times more there than elsewhere on the mainland shelf and also the total living population was about twice as much at the affected zone than elsewhere. Agglutinated foraminifera were important accessory forms away from the outlet both in terms of the living and dead forms. This latter discovery contradicted Watkins (*op. cit.*) assertion that agglutinated species were more abundant near fall-out zones.

Among the calcareous forms individuals of *Buliminella elegantissima* at the fall-out and *Bolivina vaughani* together comprised an abundance aureole of dominant living populations within 500m of the fall-out. Other less abundant species in the vicinity of the discharge point included individuals of *Nonionella scapha basispinata*, *Nonionella miocenica stella* and *Epistominella bradyana.* The species *Buccella frigida* disappeared from the vicinity of the effluent source and when tests were found they were of dead individuals. This suggests that this species has no tolerance for pollution, whereas *Buliminella elegantissima* and *Bolivina vaughani* react favourably to pollution and are able to withstand high sewage pollution levels. *Nonionella scapha basispinata*, *Nonionella miocenica stella* and *Epistominella bradyana* seem to be able to tolerate a certain amount of pollution.

Bandy *et al.*, (1964b) in their study of the Los Angeles County fall-out showed a clear correlation between the occurrence of living foraminifera and the primary sewage field. Total numbers of foraminifera were very low at the sewage discharge point and living foraminifera were completely absent within this zone. These authors called this field a "dead zone" but away from this area both the total living population and the total number of specimens increased. They grouped the foraminiferal assemblage into three categories, the hyaline (perforate-porcelaneous including planktonic species), the imperforate porcelaneous and the porcelain arenaceous group. The perforate-porcelaneous category was more than 8 times as abundant than others in the living population throughout the region, an indication that the group is more tolerant to pollution than the other two groups. Among the hyaline group, *Buliminella elegantissima* had the highest tolerance as compared to the other species, as the total species number and total living number increased towards the point just before the "dead zone". The next two species of this group *Bulimina marginata denudata* and *Discorbis columbiensis* also increased towards the fall-out point.

In Santa Monica Bay, the Hyperion sewage fall-out of Los Angles is one of the largest in South California and Zalensy (1959) noted that *Trochammina pacifica* is most abundant around the discharge point. Bandy *et al.*(1965a) investigated the effects of the effluent on foraminiferal distribution. They reported that hyaline foraminifera were more abundant than arenaceous forms in areas close to the fall-out. The dominant species were *Bulimina marginata denudata*, *Bulimunella elegantissima*, *Eggerella advena* and *Trochmmina pacifica.* The first two species are calcareous forms and are abundant in the general sewer region than elsewhere.

Ellison *et al.*(1986) investigated foraminifera and their response to heavy metal pollution (such as Zinc, Chromium and Vanadium) from the Patapsco River and Baltimore Harbour region of Maryland, USA. Their study was based on analyses of core samples. These authors examined the levels of trace-elements in Recent sediments (surface layer) and then at certain intervals to a depth of 20cm. They noted that some agglutinated foraminifera such as *Ammobaculites crassus* which were found to increase at depth, were opportunistic species that tended to avoid environmental pollution. At times when the concentrations of heavy-metals were low, calcareous foraminifera such as *Ammonia beccarii*, *Elphidium clavatum*, and *Protelphidium subarcticum* were totally eliminated from the affected zone but prior to the introduction of the pollution they were the dominant forms. Ellison *et al.*, (*op. cit.*) concluded that *Ammobaculites crassus* could tolerate heavy-metal pollution up to certain limits, whereas the calcareous species were very sensitive and could not tolerate heavy-metal pollution.

Schafer and Sen Gupta (1969) studied three rivers: the St John, Penobscot and Kennebec, located on the east coast of Canada. In their study although they did not specify the nature of the pollutant, they stated that a few species of foraminifera among the agglutinated forms showed a response to toxic effluent. *Miliammina fusca* and *Trochamina inflata* appeared to have a high degree of tolerance towards pollution. In the area within the St. John River close to an industrial discharge point no living foraminifera was recovered although all the conditions normally considered adequate for survival of these species existed. Hence they concluded that the toxic nature of the environment was the cause of absence. However, away from this zone, the population of these two species increased. Similar observations were made for the fauna from the Kennebec River which is influenced by toxicity from the adjacent St, John River. They observed that some arenaceous species may be used as pollution indicators. *M. fusca* and *T. inflata* are pollution-tolerant species, where an adverse response was observed in the cases of *Ammomarginulina fluvialis*, *Eggerella advena*, *Trochammina lobata* and *T. saquamata* which were found only as dead tests in the studied areas.

Schafer (1970) studied the distribution of benthic foraminifera in the Restigouche Estuary on the east coast of Canada. Several sewage outlets are located along both the eastern and western bank of the estuary, the Belledune Company and the Dalhousie Power Plant have the two largest fall-outs within this estuary. Temperature, pH, salinity, phosphate, and dissolved oxygen values of bottom water and sediments were measured. None of these factors seem to have been crucial with regard to the distribution of benthic foraminifera as the values were typical of an estuarine environment. However, the pH of water and pore water of the sediments were acidic (6 and 4.4 respectively) at the discharge point of the Belledune Fertiliser Company. The fauna was categorised into two groups, namely, those which inhabit the inner part of the estuary close to the discharge point and those which inhabit the offshore part of the estuary. *Elphidium incertum* was the most abundant at the edge of the "sterile zone" (the biotic zone, or the dead zone, (i.e. the zone just below the effluent discharge point where no living foraminifera have been observed) in the vicinity of the discharge point. Schafer (1970) further noted that the abundance of *E. incertum* decreased both in the inner and the outer part of the estuary with distance from the effluent source. Hence Schafer (*op. cit.*) concluded that this species was pollution tolerant. Those species which were poorly represented near the fall-out, included *Ammomarginulina fluvialis*, *Elphidium frigidum*, *Hemisphaerammina* sp., *Pseudopolymorphina novangliae*, *Reophax fusiformis*, *R. arctica*, *R scotti*, *R . nodulosa*, *Saccammina atlantica* and *Trochammina inflata* in the "outer estuary and *Eggerella advena* in the "inner estuary". Most of these species are of the agglutinated type.

The distribution of foraminifera in Chaleur Bay was investigated by Schafer (1973). Four sites along the pollution sources were sampled: Belledune Point, a power plant and shallow bays on the east and west sites of the Dalhousie Peninsula which receives effluent from a chemical plant, thermal plant, pulp mill as well as a sewage and chloro-alkali plant. *Elphidium incterum* which constituted the dominant group with living forms near the effluent sources at all the sites, appeared to be able to invade and continue to live on near shore sediment substrates which had pH values in excess of 6.4. When the pH was acidic, as at the site near to the fertiliser plant at Belledune, this species along with *Eggerella advena* migrated to the deeper part of the estuary. The low pH values are the result of the presence of rich organic matter close to the industrial zone. Schafer (*op. cit.*) noted that the living foraminifera number increases consistently with distance from the east shore pollution source. A similar pattern was found in the distribution of the living foraminifera number at the Pb-Zn smelter discharge point, however, the number of living species varied throughout the year. Schafer (*op. cit.*), subsequently, concluded that *Elphidium incretum* group are pollution tolerant.

Seiglie (1971), studied the distribution of foraminifera within the Mayaguez and Jobos Bays of Puerto Rico, which are shallow water bodies, about 12m and 9m in depth respectively. Salinity ranges between 33ppm – 39ppm in both bays whereas temperature ranges between 25°C-29°C. No modification in the foraminifera was attributed to these two factors as they were constant throughout the course of the study. In Mayaguez Bay which receives residential effluent and sewage, three species seemed significant with respect to pollution, these were: *Fursenkoina pontoni*, *F. spinicostata* and *Florilus grateloupii*. These constituted more than 6% of all the living specimens within the entire bay. Whereas *F. spinicostata* disappeared on account of pollution, *Florilus grateloupii* constituted about 30% of all living forms, however at the discharge point some specimens were abnormal.

Jobos Bay receives effluent from sewage and industrial sources e.g. a sugar mill and a fish canning plant. The dominant species at this bay were significantly different from those of Mayaguez Bay. Variants of *Ammonia tepida* were the most abundant species followed by *Quinqueloculina rhodiensis*. At the area close to the effluent source specimens of *A. tepida* were abnormal. Other species unable to tolerate pollution were *F. spinicostata* and *Q. rhodiensis* as they disappeared from the polluted sites. Seiglie (*op. cit.*) reported that some populations of *A. tepida* were deformed as a result of chemical and thermal pollution.

Setty (1976) studied the foraminifera and their distribution patterns in the Cola Bay-Goa. Setty (*op. cit.*) reported that the majority of the *Ammonia* sp. specimens near the effluent point were megalospheric with somewhat high spiral whorls which were often bent, crooked, or curved. He concluded that species of *Ammonia* were very sensitive to polluted environments and could be used as pollution indicators, since they decrease in abundance, form, size and in number of chambers with distance from the effluent points. This variation was indicative of the direct effect of waste discharge through the establishment of a hypertrophic condition which boosted the growth and development of certain deformities within the foraminifera.

Setty (1982) studied the distribution of foraminifera from Thana Creek, Bombay. This region is highly polluted as a result of effluent discharges by several local factories located on either side of the creek. Three zones were delineated based on foraminifera distribution patterns and pollution. The innermost zone surrounding the fall-out point was an abiotic zone, where discharge caused total destruction of the biota. Some of the foraminifera test were encrusted or infilled, whilst others were represented only by casts of infilling materials. The succeeding transitional zone, where toxicity was somewhat reduced, contained foraminiferal tests, many of which showed less corrosion. The third or distal zone, where pollution was significantly diluted was characterised by increased foraminiferal populations and species diversity.

Setty and Nigam (1984) investigated the distribution of foraminifera in two ecosystems in the onshore area of Karwar in the Karnataka region and Trivandum in the Kerala region along the coast of India. These two ecosystems were reported to be highly polluted as a result of effluent discharge by organic carbon content of the substrate ranging from 0.5 to 3.63%. A drastic reduction in foraminiferal population and diversity was reported at and near the discharge sources.

Sharifi (1986) studied heavy metal pollution and its effect on Recent foraminifera along the beaches of Bombay. At polluted sites (where sediments had high values of some heavy metals) the foraminifera population and diversity dramatically decreased. In areas suffering from industrial pollution, certain species showed test deformities.

Alve (1991) studied the distribution of foraminifera and the effect of heavy metals on them from Sorfjord, western Norway. This fjord is reported to be one of the most heavy metal polluted areas of the world on account of the high levels of metal within its sediments. Numerous industries such as smelting plants discharge their waste products into this fjord. Both the diversity and the abundance of foraminiferal species were reported to be extremely low. Several kinds of test deformities were reported in the study.

Alve (1995) reviewed the different types of pollutants that affect the foraminiferal assemblages. It was noted that organic matter, oil, heavy metals and chemicals were the major pollutants affecting the foraminiferal population in various aspects including: their abundance, species number, species diversity, and the modification of their original assemblage composition. Alve (*op. cit.*) further reviewed the different types of foraminiferal test deformations caused by different kinds of pollutants.

Foraminifera are sensitive to pollution-induced environmental deterioration and this sensitivity is variable and related to the type and nature of the pollutant (Setty and Nigam, 1984). When foraminifera are alive their protoplasm may absorb small amounts of chemical effluents, some may be excreted. Incorporation of pollutant (heavy metal) within the foraminiferal protoplasm and test is a complicated procedure and may take place in several possible ways such as via feeding, symbiotic algae, or during the process of test building. For physio-chemical or physiological reasons the former two appear to be the most important routs in which metal uptake takes place. Foraminifera utilise mainly phytoplankton and metazoans including micro-crustaceans. These organisms, which are part of the first level of the food chain cannot escape from environmental deterioration in a given ecosystem. In the past few years work has been carried out on the absorption, accumulation and effect of metal on phytoplankton (see for example, Sanders and Vermersh, 1982; for review of this subject).

Several heavy metal such as Cu, Cr, Co, Zn and Ni are essential for normal functioning of biological processes, however, at significantly increased concentration level these essential metal tend to become toxic. Marine organisms commonly accumulate trace metal by concentration factors of 1-10 (Bryan, 1984), hence in polluted waters tissue concentration may attain toxic level.

Clarke and Wheeler (1922) published the result of their micro-chemical analysis of the test of seven species of calcareous foraminifera. They found the test accumulated SiO_3 in quantities ranging from 0.22 to 15.3%, AlO_3 in amount from 0.002 to 3.988%, $MgCO_3$ in amount from 1.679 to 11.08% and $Ca_3P_2O_8$ was recorded as a trace in two species and questionably present in five species. They stated that the environment plays an important role in the amount of magnesium concentration by the shell, there being higher amount in wormer water than in colder water. Wood, 1949 examined the structure of many fossil and Recent foraminifera from different genera under polarised light and X-ray. He suggested that the cases of brown colouration in Recent porcelaneous foraminifera tests were probably due to the presence of traces of lead. This was later disputed by Said (1951) who reported that lead in minor quantities occurs in both porcelaneous and hyaline foraminifera. Said (1951) investigated calcareous foraminifera for 17 elements. The samples were from the Red Sea and Bikini Lagoon in the Pacific ocean and were analysed spectrochemically. He reported that foraminifera accumulate silica, strontium and sodium more intensively than do other calcareous invertebrate shells with the exception of certain colars and echinoderms. He reported that specimens of *Amphistegina radiata* had a different shell composition in two separated localities both in regards to the chemical elements presents and the quantities of these elements. Specimens from the Red Sea possessed higher elements concentrations of a wider range of trace elements than did those from the Pacific region. Moreover, he also noted that the Red Sea specimens incorporated tin, while those from the Pacific ocean did not. This was attributed to the higher salinity of the Red Sea. He concluded that the selection of elements used for the shell building and the amount of these elements are controlled solely by genetic factors but probably are due to environmental conditions. He also found that concentration of Mg within foraminiferal test varies considerably within a narrow temperature range. This study support Clarke and Wheeler's (1922) assertion that more magnesium carbonate is incorporated within foraminiferal test in warmer environment. A similar conclusion was reached by Chave (1954), who suggested that solubility of Mg increases with temperature. Boltovskoy (1956) worked on foraminifera from the Argentinean continental shelf. He reported that in the northern area where the concentration of Pb was very high within the surrounding environment, foraminifera populations decline and many specimens show different test deformities such as small size, lack of ornamentation, delay in the development of the test. He reported that tests from the dwarf fauna contained higher Pb concentrations than do the normal ones. Höbel (1984) studied the concentration of a number of major and trace metal within calcareous foraminiferals test of *Elphidium excavatum*, *Elphidium williamsoni*, *Elphidium depressulum* and *Ammonia beccarii*. She reported that the Ba values within foraminiferal tests were reported to fluctuate between 20 and 200 ppm at different localities. At highly polluted sites its value was high, while at clean sites it was as low as 20 ppm. In the case of K, a variation was observed, its values varied from site to site, with higher level being found in samples where sediments contained high K concentration. She reported that Pb, Cd and Zn could be accumulated not only within the test, but also within the protoplasm. Toyofuku *et al* (2000) reported from experiments done on *Quinqueloculina yabei* that Mg/Ca in a monospecific benthic foraminiferal sample may be used as reliable temperature proxy, if the lifetime of the species is taken into account. Sharifi (1991) reported from culture experiment that heavy metals are absorbed in the foraminiferal test and this causes morphological deformations.

The foraminiferal population in the study area exhibit variations in species abundance, species diversity, number of species, size of foraminiferal test, test deformities and test chemistry as a result of heavy metal contamination in different sites of the study area and in different seasons (spring and winter). This dissertation documents these variations, and explores the relationship between these aspects and heavy metal pollution in the eastern Mediterranean.

1.7 Constraints to the Current Research.

The current research was carried out as follow-up to the EEC-funded AVICENNE Project, the goal of which was to study heavy metal pollution in Haifa and Iskundrun Bays. The scientists and technicians associated with the AVICENNE Project (with Prof. V. Janko as the Scientific Coordinator) took responsibility for the design of the project and oversaw the collection of samples. We (the UCL team consisting of Dr. Kaminski and myself) entered into the project at a later stage. Fortunately for us, all the oceanographical, sedimentological, and geochemical data collected during the project were made available to us in good faith. We were also given splits of preserved sediment samples that had already been collected for biological purposes when we joined the study. We quickly realised that the sample set made available to us in combination with the associated environmental data would make for a very interesting and unique study. However, because of factors beyond our control the study was subject to a number of obvious constraints:

1. We had no control over the selection of sampling sites, or timing of the sampling. Samples were collected in two seasons only (Winter and Spring). Ideally, we would have preferred to have a more complete time series of samples collected during different times in the year, in order to establish the natural yearly fluctuations in species composition and abundance.

2. Because of financial constraints (since UCL was not one of the original partners, we did not receive any funding from the AVICENNE Project), there was no possibility to carry out any further sampling.

3. We did not receive any samples from Iskundrun Bay, as originally planned. Therefore, we had to concentrate all our efforts on the samples from Haifa and Atlit Bays.

4. To our knowledge, there are no "pre-industrial" samples from Haifa Bay that we could use as a baseline, to assess the "before and after" scenario. Previous studies of Mediterranean Foraminifera by Jones & Parker (1860) were from the Island of Malta. Sidebottom (1904-1909) stidied foraminifera from the Island of Delos in Greece. We know of no previous study of the benthic foraminifera from Haifa Bay.

5. All samples were preserved with formalin, therefore it was not possible to carry out observations on the structure of the cytoplasm, or on the living foraminiferal sarcode.

6. Although the concentrations of heavy metals were determined at most stations, there was no evaluation of the actual toxicity or "bioavailability" of these metals. The foraminiferal studies presented in this thesis constitutes the only assessment of heavy metal toxicity on the marine biota in Haifa Bay.

7. Some of the elements, such as As, V, Li, were not recorded for all the stations in spring, and not recorded at all from the winter sample set.

8. Grain size analyses of sediment samples were not carried out on the winter sample set. Therefore, a comparison of the distribution of sediment parameters cannot carried out between the spring (1993) and winter (1995) periods.

9. At a late stage in the project we were informed that dredging operations in Haifa Bay had removed materials that are highly contaminated by trace metals from the coastal area. Barges were used to transport the sediments for disposal further offshore. This may have caused the contamination at some stations in Atlit Bay and the highly

contaminated sites seaward e.g., Stations 50 and 40. This dredging may have been responsible for the presence of relatively unpolluted sites near the Qishon River outlet (Stations 2, 3 and 4).

10. We could not carry out any measurements of the concentration of trace metals contained within the foraminiferal calcite. This was due to (1) not having enough deformed specimens for analyses, and §2 above.

Chapter 2
Study Area

2.1 INTRODUCTION

The studied area is the eastern Mediterranean continental shelf from Akko to Atlit. One of the study regions is Haifa Bay and the other is Atlit Bay. Haifa Bay is adjacent to one of the major industrial areas and a considerable number of industries discharge their effluents into the bay either directly or through the Qishon and Na'aman Rivers. It is also one of the many commercial fishing coastal areas within the Mediterranean basin. Following a preliminary survey carried out by Roth and Hornung (1977) on the state of pollution by heavy metals in surface sediments of the bay and the effects on benthic organism populations.

In the study area, temporal information is now available about the concentration of various pollutants including trace metals, heavy metals, and organic matter. However, only a few studies have been carried out which deal with the heavy metal content in sediments of the Haifa Bay (e.g. Yanko *et al.,* 1994, 1998). There are no industrial activities on the coast adjacent to Atlit Bay, which is located south of Haifa Bay. This site was chosen as a control area becuase it has natural conditions similar to those in Haifa Bay, the same species of foraminifera are expected to be found, and it is comparatively free of industrial pollution.

The samples used in the present study of Haifa Bay are from different sample sites from those sampled by Hornung *et al.*, (1989) and Yanko *et al.*, (1994), hence direct comparison of data to the early studies is not possible. All samples were provided by the European Community "Avicenne" Project (AVI CT92-0007).

2.2. LOCATION

The Haifa Bay region is situated between Latitudes 33°00' N and 32°´50' N and Longitudes 35°´04' E. Atlit Bay region is situated between Latitudes 32°50' and 32°40' N and Longitudes 34°57 98'E. Figure 2.1 is a map showing the location of the study area and sampling sites.

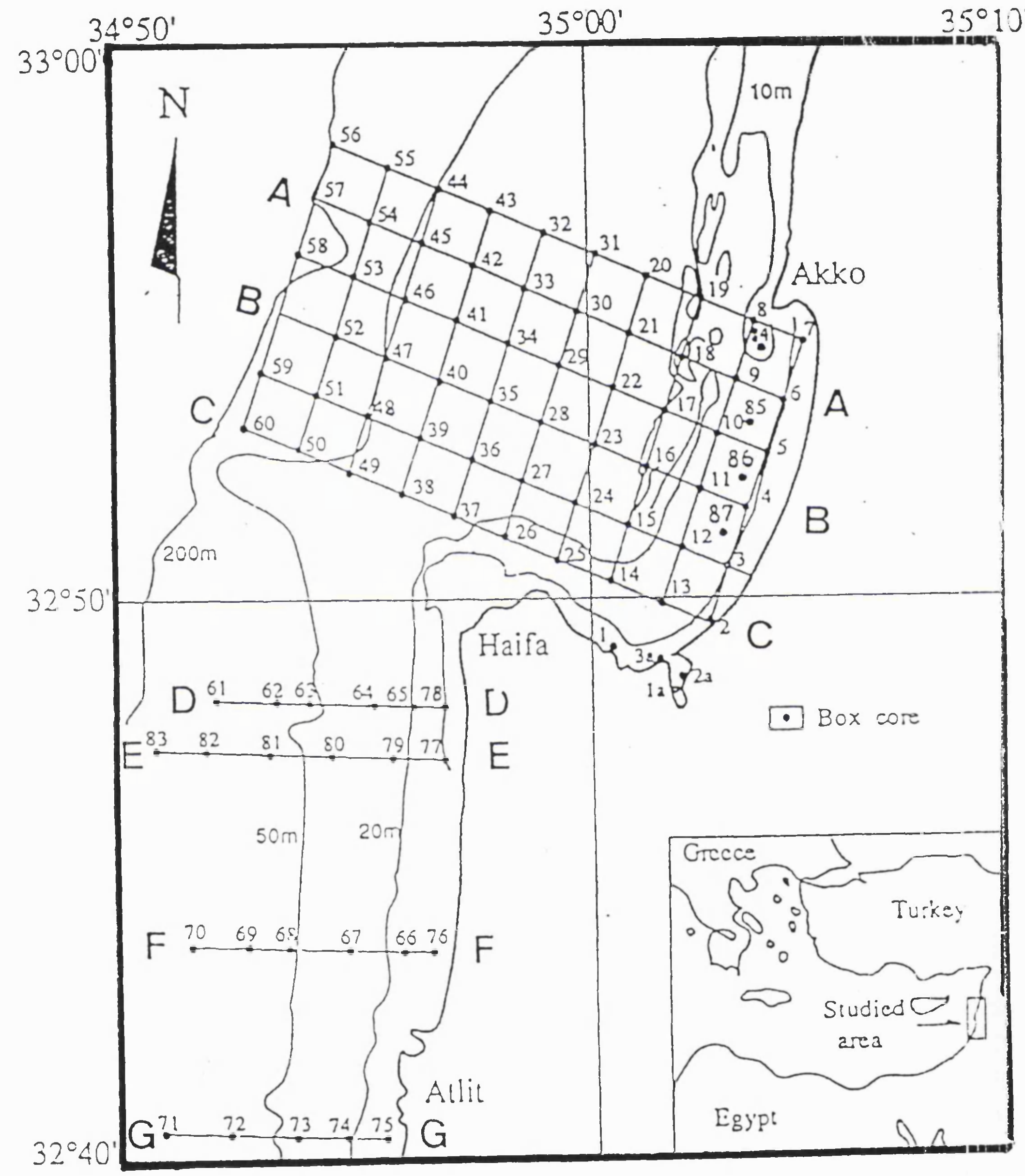


Figure 2.1. Location map (Haifa Bay and Atlit Bay). Black circles mark stations sampled during mid May, 1993. Letters mark profiles along which the sampling was repeated in winter, January, 1995.

2.3. METHODS

2.3.1 Measurement of Hydrographic Parameters

Several hydrological parameters were measured during the course of the European Community project. group (Avicenne program, AVI CT92-0007).

(i) Eighty seven stations were sampled on a one mile grid in spring and 52 stations in winter. Sediment samples where collected using box corer (BX 700 AI Compact Box Corer from depth 3 - 210 m using the research vessel "Shikmona")

(i) Depth measurement was with a Raytheon Bathometer model De 719B

(ii) Surface and bottom water temperature measurement was with a cable-thermistor thermometer.

(iv) Salinity measurements were carried out with a Neil Brown Instruments systems (STD) with a General Oceanic rosette and Niskin botteles.

(v) pH measurement was with a pH meter Beckman 20.

(vi) Dissolved oxygen measurement was done with a CTD These measurements were carried out by the ship's onboard party.

2.3.2 Measurement of Sedimentological Parameters

Sedimentological parameters including grain size, heavy metals, organic matter and calcium carbonate ($CaCO_3$) content of the sediment were measured by group of scientists.

2.3.3 Grain size measurements

The sediments were measured by J. Kronfeld and Motnenko, in the laboratories of the Institute for Nature Cinservation Research and Department of Geophysics and Planetary Sciences. The sediments were divided the sediments into nine size fractions, clay (< 0.0039 mm), silt (0.0039 - 0.0625 mm), very fine sand (0.25 - 0.5 mm), coarse sand (0.5 - 1 mm), very coarse sand (1 - 2 mm), granule (2 - 4 mm), and pebble (> 4 mm). The methods used were described in detail by Folk (1974).

The determination of water content accompained analyses of grain size for each sample. Roughly 15g of wet sediment was put into a pyrex glass and covered by lid, and weighed. Then it was placed in an oven (105C°) for 3 hours and again weighed. This procedure was repeated one hour later and then every 30 minutes until the wieght become constant. The wetness was determined by the formula $W = P_1 - P2 / P_2 *100$, Where W is water content, P_1 is wet weight (g), P_2 is dry wieght (g). Using the water content, the dry wieght of a sample for analyses were computed by $M_d = M_w / 1 + W$, where M_d is the weight of dry sample, M_w is the wieght of wet sample and W is the coefficient of water content.

2.3.4 Heavy metals

Heavy metal analysis was performed by J. Penciner. Five biologically important heavy metals (Cd, Cr, Cu, Pb, Zn) were analysed in 77 samples by Atomic Absorption Spectrometry (AAS) and another five (As, Co, Ni, Ti, V) by Induced Coupled Plasma ICP.

2.3.5 Organic matter

Organic mater was measured using the loss on ignition method (LI) as described in Vollenweider (1969). The analysis was performed by Dr. A. Parparov, of the Kinneret Limnological Laboratory.

2.3.6 Calcium carbonate ($CaCO_3$)

The total carbonate content (expressed as $CaCO_3$ percentage) of the sediment was measured by titration (86). The analysis was performed by Dr. R. Parparov, of the Kinneret Limnological Laboratory.

2.4 OCEANOGRAPHIC PARAMETERS OF THE STUDY AREA

The data of some stations in winter were not available because they were not sampled so for the sake of comparison and for the statistical analysis some of the data were predicted for winter from spring oceanographic data.

2.4.1. Oceanographic currents

According to Rozentroub and Brenner (1989) the oceanographic currents generally follow the bathymetry, becoming progressively stronger in the northward direction, and there is some internal current have a back ward to the bay. There are two rivers that are likely, at least during the rainy winter minths to influence the internal currents pattern of the bay. Figure 2.2 is a map showing the internal current pattern in the bay.

2.4.2 Temperature

The lowest temperature in spring, 1993 was 15.12°C at Station 56 at 210m depth. The highest temperature was 21.31°C at Station 85 at 6.5m depth. In winter 1995 the

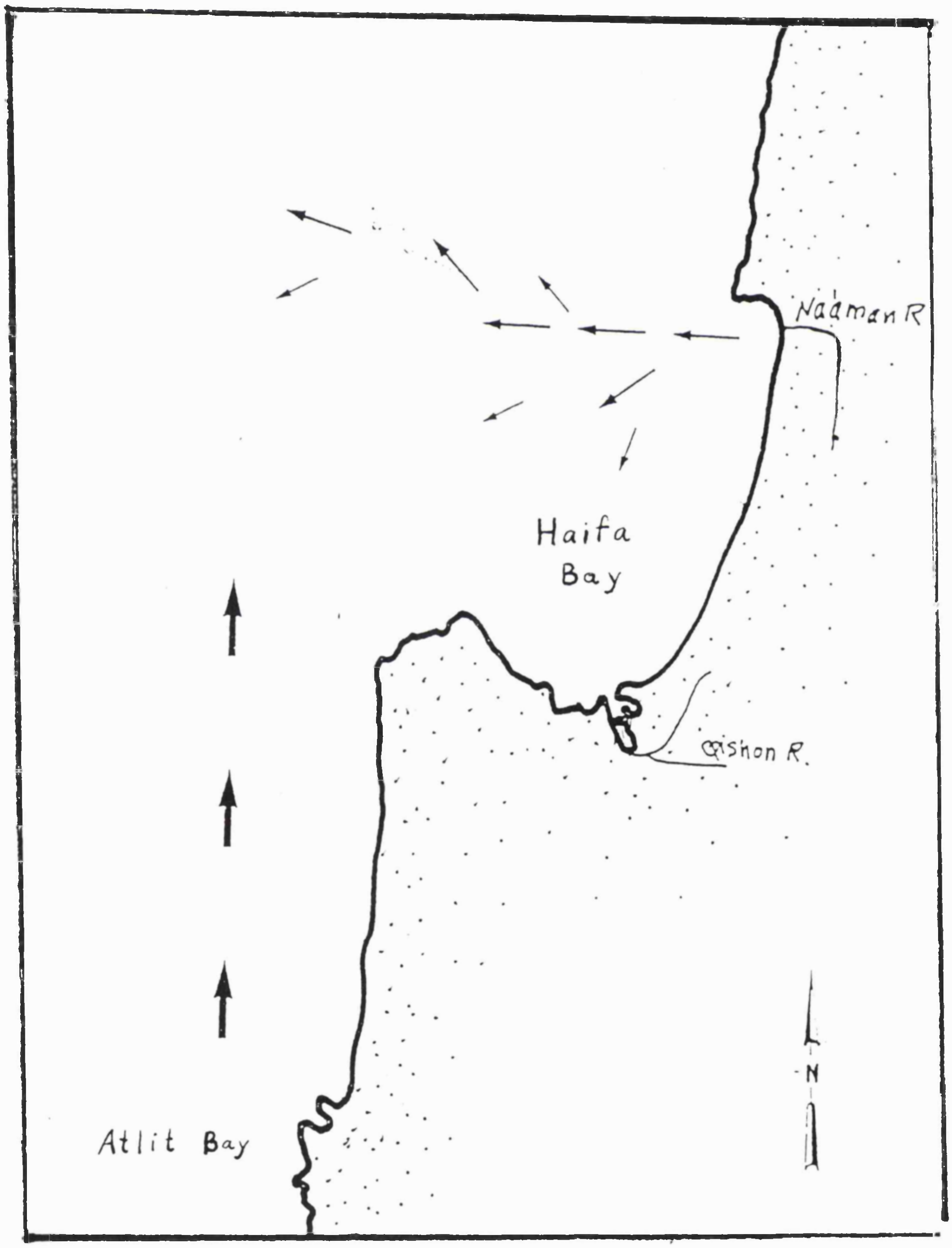


Figure 2.2 The internal current pattern in Haifa Bay and Atlit Bay (sediment dispersion pattern).

minimum temperature was 17.2°C at Station 4 at 5.9 m depth. The maximum temperature was 18.5°C at Station 82 at 72m depth. Based on these values. It is, therefore, clear that variations in temperature are not significant. Apenddix 1 presents the oceanographic parameters measured in spring and winter in the studed area. Figure 2.3 is a map showing the spatial distribution of temperature in the study area in spring and winter.

2.4.3 Salinity

In spring 1993 the salinity in Haifa Bay ranged between 38.38‰ and 39.16‰. However, at some stations lower salinity values were recorded, e.g. the salinity value was 16.62‰ - 17.42‰ at Stations 13, 14 at 12m and 15.5m depth respectively, and 21%, 97‰ - 27.7‰ at Stations 20, 4, 46 at 32m, 7m, and 45m depth and 36.4‰ 36.54‰ at Stations 44 and 57, at 48m, 200m depth respectively.

In winter 1995 the salinity ranged between 38.91‰ at Station 2 at 6.5 m depth to 39.17‰ at Station 45 at 46.5 m depth. According to Murray (1991), these values reflect typical Mediterranean salinity (38.6‰ at temperatures of 13.7°C).

In both seasons the salinity is fairly uniform approximately 38‰ to 39‰ except for a few anomalous stations measured during spring. Figure 2.4 is a map showing the spatial distribution of salinity in the study area in spring and winter.

2.4.4 pH values

In spring of 1993, the pH values recorded in the study area were typical of values for normal marine water (8-8.3). This value was uniform at all the stations. In winter, pH values recorded were (7-7.7) at Stations 49 & 76 at depths of 45 and 76 m respectively. Figure 2.5 is a map showing the spatial distribution of pH value in the study area.

2.4.5 Dissolved oxygen

In spring, the concentration of dissolved oxygen was rather uniform throughout the area. The highest concentration of 15.3 mg/L was noted at Station 85 at a depth of 6.5m. On the other hand, the lowest concentration of 7.6 mg/L was at Station 6 at a depth of 7m. During the winter months, the highest concentration of 9.9 mg/L was recorded at Station 16 at a depth of 17 m, whereas the lowest concentration of 5.2 mg/L was observed at Station 45 at a depth of 46.5 m. Figure 2.6 is map showing the spatial distribution of dissolved oxygen in the study area.

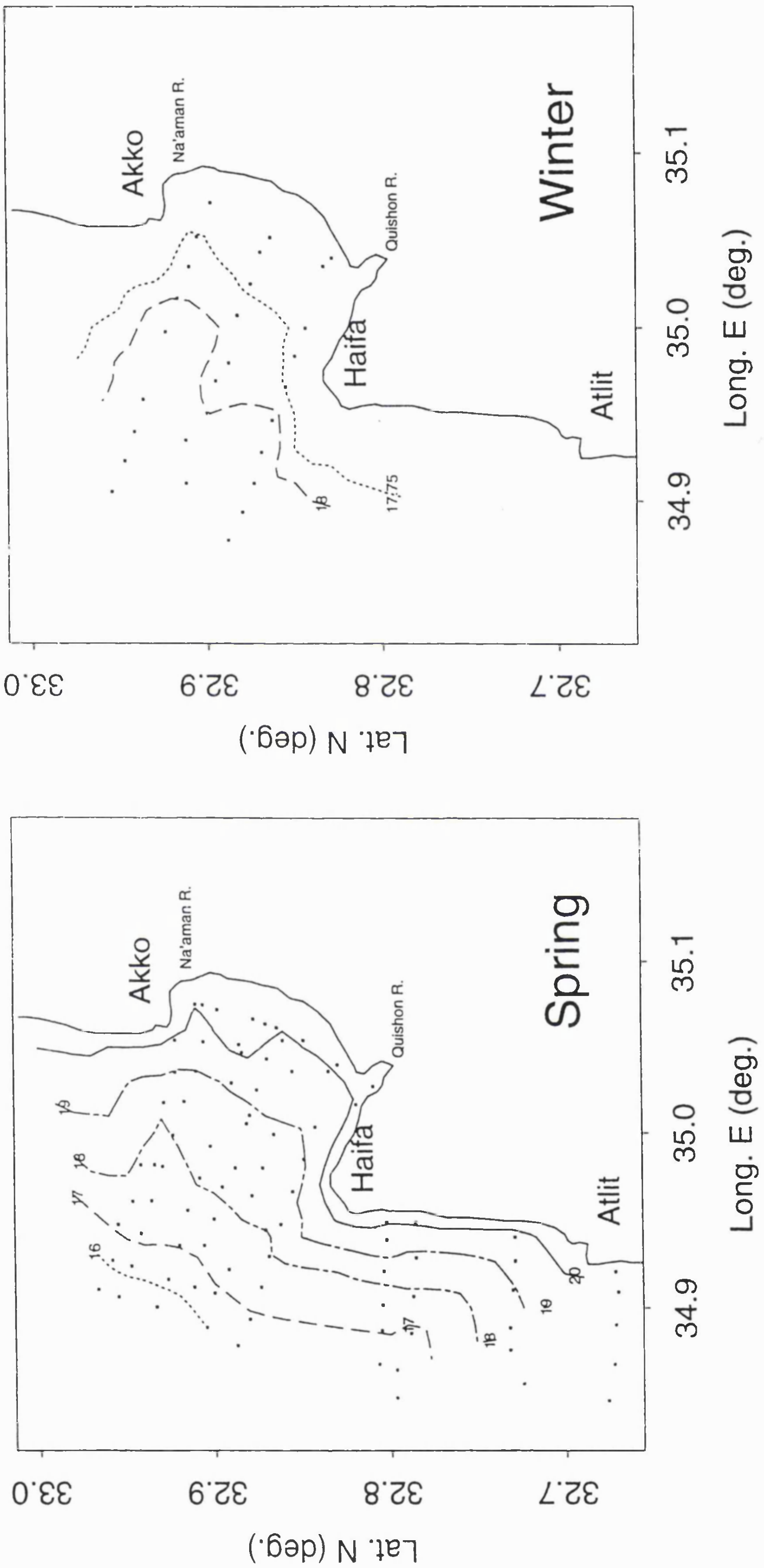


Figure 2.3. Map showing the spatial distribution of temperature in spring (May) and winter (January).

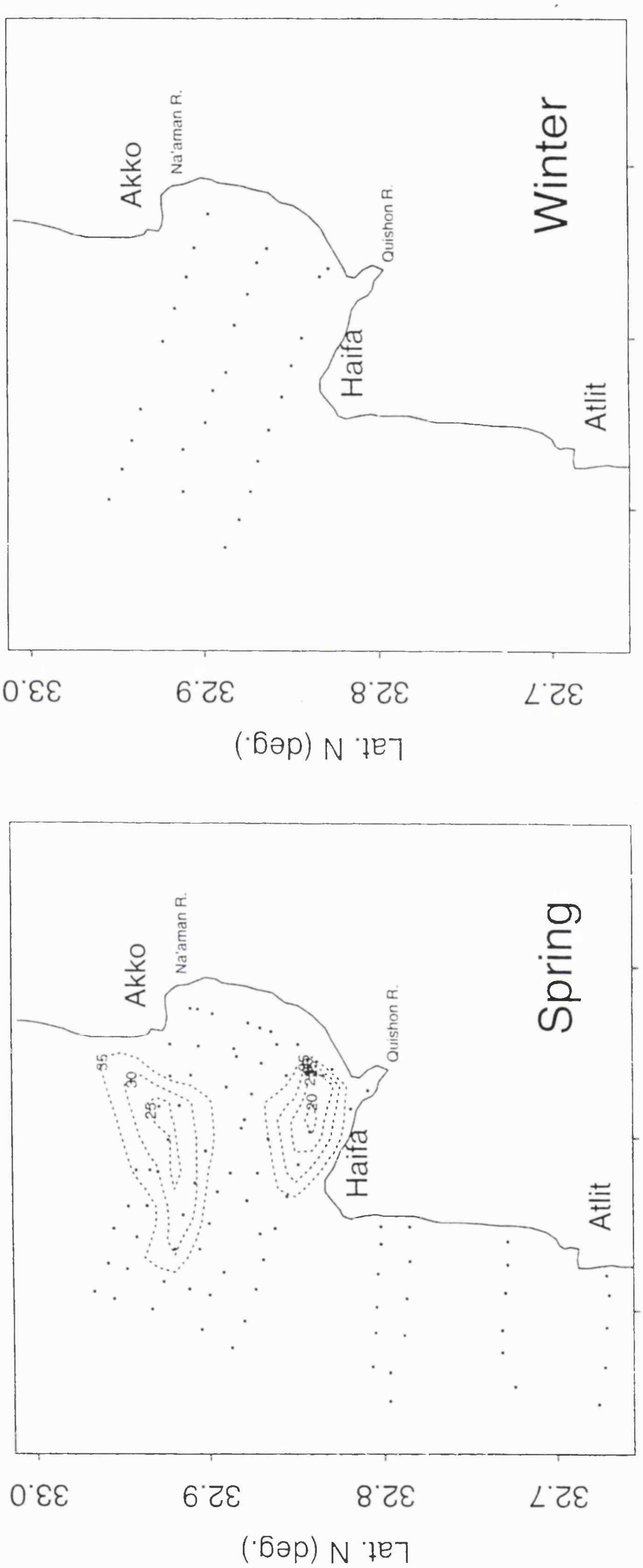


Figure 2.4. Map showing the spatial distribution of salinity in spring (May) and winter (January).

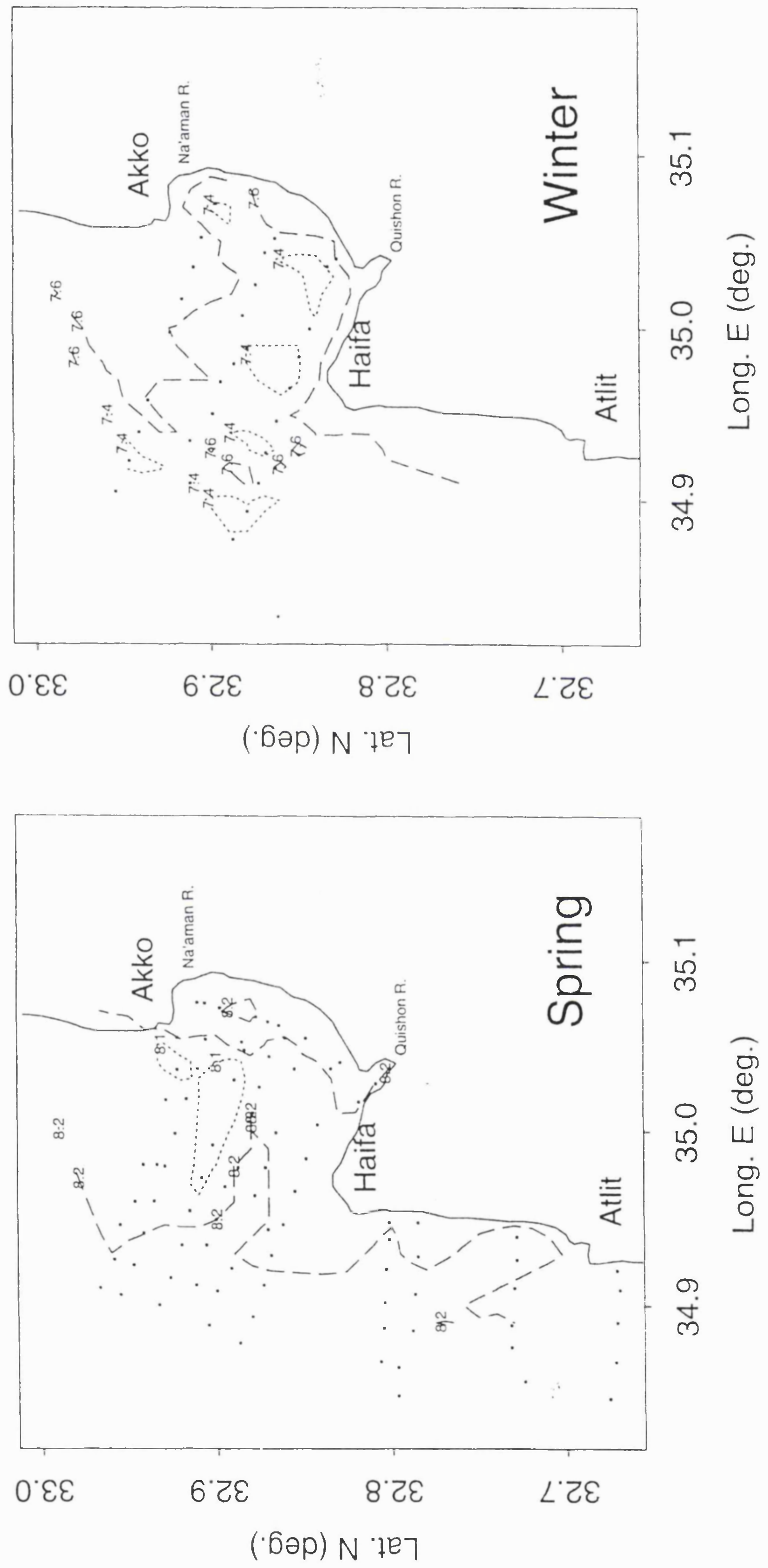


Figure 2.5. Map showing the spatial distribution of pH in spring (May) and winter (January).

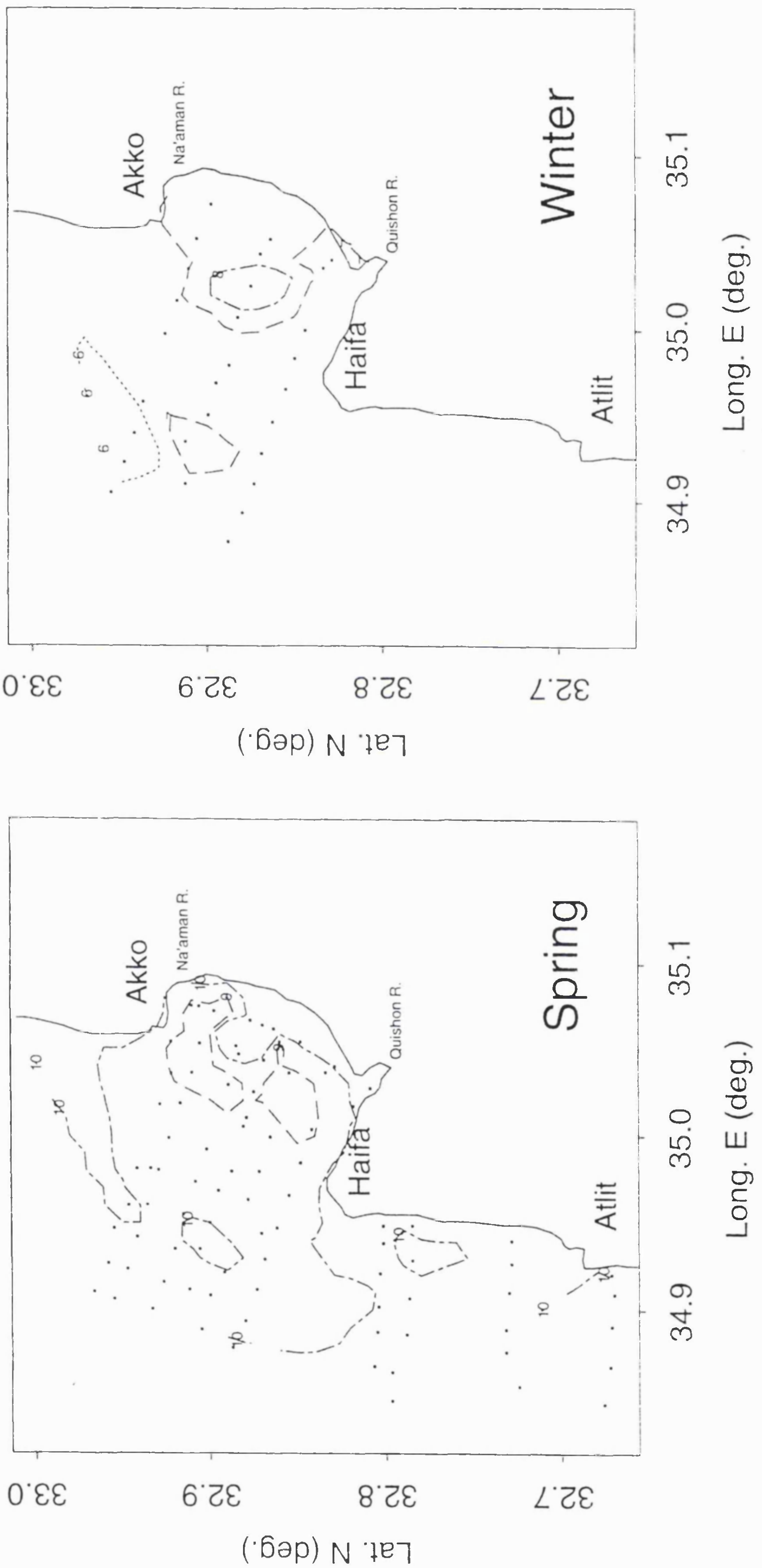


Figure 2.6. The spatial distribution of dissolved Oxygen in spring (May) and winter (January).

2.5. ENVIRONMENTAL FLUXES

2.5.1 Sources of fresh water

Fresh water input is from the few rivers from the hinterland to the coast. The Qishon River and Na'aman River are the main sources of fresh water to Haifa Bay. The main contributary sources of effluent are from industries, sewage treatment plants, as well as sea water. The Qishon River has a mean monthly flow of 0.5 x 10^6 m per month in winter and 0.1 x 10^6 m per month in summer and Na'aman River has an even lower flow rate (Hornung *et al.*, 1989).

2.5.2 Sources of pollution

The pollution inputs are of relatively recent origin, having increased since 1948 (Yanko, 1994). Haifa Bay offers a variety of recreational opportunities and serves as a commercial fishing port with heavy ship traffic. It is surrounded by industries that release a variety of industrial and domestic waste into the bay via the Qishon river (Abdou *et al.*, 1991). These sources include crude oil refineries, a petrochemical and fertiliser plant, and according to Hornung *et al.*, 1989, in the southern part of the bay there is a large chemical works complex (Frutarom chemicals) and a chloro-alkali plant along its banks, and various other chemical factories that discharge their effluents into the bay, either directly or through the Qishon River and Na'aman River. The Qishon-Gadura river system is the second largest after the Jordan River system. It is exposed to an increasing amount of waste products as it flows seaward. The wastes are from agricultural run-offs, domestic sewage, and industrial effluents. The Nahal Gadura River is lined by numerous industrial enterprises which include: metal works, chemical factories, battery and electrode plants. These use the Nahal Gadura River as a drainage channel, from where the wastes flow into the Qishon River and then into Haifa Bay (Kronfeld and Navrot, 1974).

Studies in Haifa Bay during the 1980's indicated that the Qishon River is the major source of pollution to the bay (Kress *et al.*, 1991) which receives Cu, Cd, Pb, and Zn. In the lower reaches of the Qishon River, just before the harbour is a major oil refinery that seriously contaminates the river with an organic sludge which appears to introduce Cu into the bay. The other source is from sediments transported by the Nahal Gadura River, which bring Cd, Cr, Pb, and Zn into the Qishon River. The source of metal pollution in the Nahal Gadura River is mainly from industrial drainage pipes and streamlets bringing wastes from the numerous factories and workshops which lie along the stream. Another pollutant source appears to be the use of the river and its banks as domestic waste disposal sites.

2.5.3. Types of pollutants

The Qishon River is polluted by organic compounds including sulphide and a large variety of heavy metals (Hornung *et al.*, 1981, 1991; Krom *et al.*, 1990; Kronfeld and Navrot, 1974, 1975; Navrot *et al.*, 1973). In the northern part of the Haifa Bay, the Na'aman River discharges primarily agricultural and domestic waste products.

A preliminary survey of heavy metal pollution in surface sediments and the effects on benthic organisms of the Haifa Bay was carried out by Roth and Hornung (1977). Later Hornung *et al.*, (1984) showed that the sediment and benthic biota of the entire bay were contaminated by anthropogenic mercury but that the pollution level was low. Hornung *et al.*, (1989) further reported that the bay was not significantly contaminated by anthropogenic copper, zinc, lead, and cadmium, based on sediment and benthic organisms.

Heavy metals are also present in muddy sediments of the Nile River and the Eolian dusts from the Sahara desert. The eolian dusts have been noted to be enriched in Pb (465 ppm), Zn (683 ppm), Ca (157 ppm), Ni (91 ppm) and V (145 ppm) (Chester and Stone, 1973). According to Emelyanov *et al.*, (1979), the muddy deposits of the Nile River contain an average of Ti (1.23%), Cr (135 ppm), Cu (52 ppm), Zn (108 ppm) and Ni (67 ppm). The Eocene and Cenomanian carbonates of the Carmel and Galilee hills that may contribute carbonate detritus are generally low in their trace metal content (Ilani *et al.*, 1991). The pure quartz sand from the Kurkar ridges would be expected to contribute no trace metals.

2.5.4 Origin of the sediments

The dominant sediment source is the Nile River, probably through the erosion of the Kurkar Ridge, which is basically a calcareous quartz sandstone formation (Nir, 1982). However, since sediments of the Nile River are known to be very poor in carbonates (Nir, 1973), the small amount of calcium carbonate that occurs in the sediments is considered to be precipitated in-situ. The sediments are transported northward by the prevailing long shore current (Nir, 1973). Goldsmith and Golik (1978) have reported that Haifa Bay is the terminus for all the sediment that have passed through the Carmel mountain shore and discharged by the Nile. The Haifa bay region receives sediments from the surrounding land as well as material derived from the Nile River, along with secondary wind-blown deposits coming from northern Sinai (Emery and Neev, 1980, Nir, 1973). The Nile sediments are carried northwards along the Israeli coast by the Mediterranean current.

Nir (1980) divided the bay into three sedimentological zones extending seawards and disposed parallel to the coast as follows: (i) a shallow water zone consisting of fine-grained quartz sands extending from the shore to bathymetric depths of 10-12m; (ii) an intermediate region of rocky, submerged reefs and ridges extending from 12m to about 25m water depth; (iii) an outer region of fine grained sand and silt. Beyond these areas in the seaward direction, muddy bottom conditions prevail.

Hornung *et al.* (1984) reported that the Haifa Bay harbour is an area of net sedimentation and there is no northward transportation of sediments. This result is compatible with the observations of Goldsmith and Golik (1980), in which they suggested, from wave modeling studies, that the Haifa Bay in general and the southern portion in particular are areas of net sedimentation. Hornung *et al.*, (1989) noted that this area has very little natural input of sediment from adjacent rivers, with the larger part of the supply of the Qishon and Na'aman River being intercepted and used for agricultural and other purposes. The remaining smaller part of the supply from the rivers comprises, principally, the waste products from the chemical industry. For the northern part of the bay, there appears to be some sediment transport both to the north and to the south of Haifa Bay. Wave and current action moves this sediment morht wards as well as back toward the bay. The local current pattern mostly plays a role in redistributing the sediments farther away from the shore.

Sediments of the Haifa bay, composed primarily of quartz and shell particles, exhibit a unimodal grain size distribution pattern consisting of greater than 90% sand and gravel sized particles. The gravel and coarse sand fractions are of biogenic origin. Locally, carbonate shells constitute the dominant coarse grained material. Much of the coarse material, especially quartz sand, is derived from erosion of the Kurkar ridge and dunes. The grain size of the coarse clastic particles and mineralogy of the clays which occur in the study area, clearly reflect the provenance or source of derivation of the materials. The main type of sediment in the area of investigation are silts and clay. The clay minerals are dominantly smectite with abundant kaolinite in places. The main source of the clayey material, which are channeled through the Nile, are derived from the more humid regions of central and east Africa. The Recent sediments present in the study area are analysed at spring 1993 only and are discussed in chapter 3.

Chapter 3

FAUNAL TRENDS OF BENTHIC FORAMINIFERAL ASSEMBLAGES IN THE STUDY AREA

3.1 INTRODUCTION

The study of benthic foraminifera and their distribution in modern sediments constitute the basis for palaeoenvironmental interpretations, at least from the Miocene to the Recent.

Very little information on benthic foraminiferal species abundance and distribution is available for the eastern part of the Mediterranean sea. The previously published studies provide limited data on total assemblages only (Parker, 1958; Massiota *et al.* 1976; Cita and Zocchi, 1978). Hooper (1969) reinterpreted Parker's data. Murray (1991) reported that the Mediterranean is impoverished in terms of species, especially in deeper water. De Rijk *et al* (1999) reported that the distribution patterns of species in the western and eastern Mediterranean are controlled by more than one factor.

Previous quantitative studies on benthic foraminifera from Haifa Bay were conducted by Yanko (1994). There is no previous study apart from that previously mentioned which includes a taxonomic list of 163 species occurring in Haifa Bay.

This chapter deals with the distribution of the species identified in the study area and provides a detailed analysis of their relationship to different environmental conditions within the study area. This chapter further examines the influence of various environmental parameters on the benthic foraminiferal distribution and evaluates whether the bathymetric zonation of the area can be described by studying the distribution of selected benthic foraminifera. In addition, this chapter focuses on the control of different oceanographic parameters (temperature, salinity, pH value, dissolved Oxygen, substrate type, and water depth) on the distribution.

3.2. MATERIALS AND METHODS

3.2.1 Microfaunal analysis

The samples for microfaunal analysis were preserved in a solution of 4% formalin and sea water buffered with sodium borate (20g of $NaBO_4$ / liter). This was to prevent dissolution of calcium carbonate (Boltovkskoy and Wright, 1976) and prevent the degeneration of the cytoplasm of living foraminifera.

For each sample the wetness was determined by using the formula:

W =[P1 - P2) / P2]*100, where W=Wetness, P1=Weight of wet sample, P2=Weight of the sample after drying. For foraminiferal analysis in the wet sediment, samples equal to 5g dry sediment volume were sub-sampled. The amount of wet sediment needed was calculated by means of the Wetness (water content) at each station using the formula: P_S = ([W/100]+1)*5 Where Ps = wet sediment samples equal to 5g of dry sediment mass.

Foraminifera were studied by standard methods. Rose Bengal stain was added to the preserved sample to differentiate living from the dead foraminifera. The samples were stained for 48 hours, then washed with distilled water using a 0.063 mm sieve to remove the surplus stain, and dried gradually.

For specimens that were alive at the time of collection, the protoplasm is stained bright red, whereas the test wall of dead specimens remain either unstained or takes on a light pink colouration. However, it is necessary to check that the red colour is not caused by a cluster of bacteria or other organisms using the test wall as a refuge.

The samples were sieved through meshes of 0.063 mm - 0.5 mm and microscopically analysed in the laboratory. It is a matter of observation that when 250 or more individuals are counted, the relative proportions of the component species are reasonably constant. It is therefore superfluous to count large numbers (e.g. >500 individual) from a sample if there is no gain in accuracy. Hence when deciding on the size of the sub-sample to be counted, it is sensible to select a size which will give >250 living test, and a sample of about 300 individuals is adequate (Murray, 1991).

Specimens of >0.063 mm sizes were picked, and the initial 5g sample yielded a count of <300, successive 5g samples were counted until either a total count exceeding 300 was reached or the material was exhausted. In order to normalise the counts to provide values equivalent to that of 5g of sample, the specimens counted were averaged with the dividing factor being the number of replicate counts made, which were generally 5 or less.

Specimens with hyaline tests, many agglutinated tests, and thick porcelaneous tests may obscure the stain when dry. This problem can be overcome by wetting such specimens with a moistened brush (Murray, 1991). The test morphology was examined using the SEM and standard binocular microscope.

Both living and dead foraminifera populations have been studied. Living foraminifera were used mainly for environmental monitoring, and non-living foraminifera were studied for taxonomic purposes.

3.2.2. Statistical analysis methods

The quantitative analysis of foraminiferal assemblages included a determination of number of species, i.e. species richness. This is calculated as the α index, first defined by Fisher et al., (1943) thus:
$\alpha = (n_i / x)$, where x is a constant having a value < 1 (which can be read from figure 125 of Williams, 1964), and n_i represents the number of particular individuals and can be calculated from the formula: N (1 - x), with N being the size of the sample (number of all individuals). This index assumes that the number of individuals of each species follow a logarithmic series. It takes the rare species into account (Murray, 1991).

The relative species abundance was also calculated. This refers to the proportion of a species of the entire living assemblage: $(N_i / N*100)$, where N_i = number of individual in the assemblage, and N = total number of individual in the entire station.

The absolute species abundance was also calculated. It refers to the number of individuals in a unit area of the sea floor or the volume of a sediment or, as in this study, it is the average number of individuals in 5g dry weight $(N_{/5g})$, (all the tests which were found in 5g of sample were counted).

The Heterogeneity takes into account both the number of species and the distribution of individuals between species (equability). This is calculated by using the Shannon-Weaver index, $H(S) = -\sum P_i \ln P_i$, here S is the number of species and P_i is the proportion of the i-th species (100 P = percentage).

Optimum regression models in the form $Y = b_0 + b_1 * X$ were calculated for the prediction of foraminifera count based on the Atlit Bay data [These were used to fill in the missing data for winter from the spring data. Estimated values are distinguished in the figures], shows the optimum regression model for prediction of foraminifera counts ect., based on Atlit Bay data, see, appendix 2 (A, B).

The Robust regression (Rousseeuw, 1997, 19984), which automatically down weighs any outlying points on the best fit curve, was used where appropriate. Where b_0 is the constant, b_1 is the coefficient for x (x is the known value, Y is the predicted value).

Linear regression analysis uses a linear equation to explain the relation between two point, X (e.g. depth) and Y (e.g. size of the test) so that if the value of X is known we can determine the value of Y.

The maximum, minimum and median of each oceanographic parameter and the concentration of heavy metals in the study area was determined. By using the crustal average concentration of heavy metals of Clark (Beus, 1975) and the average concentration of given metals in Mediterranean carbonates (Drever, 1982), an enrichment factor was calculated using the formula: $E_1=C_{max} / C_{median\ Atlit}$, $E_2=C_{i\ max}/C_{clark}$ and $E3=C_{imax}/C_{carbonates}$. For the above equation E_1= local enrichment factor of a given heavy metal, E_2 global enrichment factor of a given heavy metal, E_3= regional (Mediterranean) enrichment factor of a given metal found in given study area, $C_{median\ Atlit}$ = median concentration of a given metal in Atlit, C_{Clark}= crustal average concentration (Clark value) of a given metal, and $C_{carbonate}$ average concentration of given metal in Mediterranean carbonates.

Multidimensional scaling, which can be thought of as a type of non-hierarchical cluster analysis was carried out on the data set of all samples in winter and spring. Multidimensional scaling of Kruskal (1964), which project points onto a 2-dimensional plane so that their "distance" apart in the "space" of their composition, in terms of a selected number of descriptive variables, is preserved as much as possible. Samples of similar composition will appear close together in the resultant non-linear mapping and vice-versa.

Contour maps are plotted based on either selected absolute values or the 25%, 50% and 75% percentiles of all values, with the value of 1 being the base contour, as this seems appropriate to best show the spatial distribution patterns.

Principle component analysis on the entire data-set was performed. The method of Zheng and Fu (1990) was followed to see if the population parameters are affected by depth. The depths where samples were collected were divided into ranges from 0-10m, 10-20m, 20-50m and 50-210m. The average abundance (absolute and relative), number of species, species diversity and heterogeneity were also calculated and compared.

Statistical analysis was carried out using S-plus, with the assistance of Professor Richard Howarth. This is a statistical programming language which is an enhanced version of S (originally developed at Bell Laboratories in the USA), and distributed by the Statistical division of Math Soft Inc., Seattle, Washington.

3.3 SEDIMENT PARAMETERS

In this investigation the sedimentological conditions as they existed in spring 1993 are represented. The weight and percentage of the grain fractions in the study area are given in Appendix 1, Paenciner, *et al.*, 1995.

The clay fraction ranges between 0% and 64%. Clay was absent in a majority of stations located along the shore (e.g. Stations 4 to 13). Percentages of clay and silt increase with depth towards the sea. However, there is also a high percentage of silt and clay at stations located near the shore (e.g. Station 84 at 6m depth). Within the coastal dune deposits, local "Hard Grounds" of shell beds occur. Between the ridges, fine-grained muddy sediments accumulate in the sheltered hollows, such that patches of mud can be encountered near to the shore. The near-shore wave region is where the mud resettles and accumulates. Superimposed upon the normal sediment distribution pattern may be the limited local effect of dumping of near shore derived sediment off the coast of the bay. Dredging has been carried out to deepen the Qishon Harbour and its entrance. Here 1.5 million m^3 of sediment, which contains fractions highly contaminated by trace metals, have been removed (Kronfeld and Navrot, 1974; Yanko, 1994).

The silt fraction varies between 0% (Station 6, depth 7m) and 47% at Stations 56 and 57 at 200- 210m depth. The very fine sand fraction ranges between 0.03% (Station 17 at 21m depth) and 82.4% (Station 33 at 32m depth). Figure 3.1 is a map showing the distribution of clay-silt and very fine sand. The fine sand fraction varies between 0.2% (Station 16 at 19m depth) and 88.1% (Station 77 at 6m depth). The medium sand fraction ranges between 0.16% (Station 56 at 210m depth) and 25.1% (Station 11 at 12.5 m depth); see Figure 3.2. The coarse sand fraction varies between 0.3% (Station 1 at 7m depth) and 52.2% (Station 26 at 19m depth), and the very coarse sand fraction ranges between 0% (Station 1 at 7m depth) and 44% (Station 17 at a depth of 21m); see Figure 3.3. The gravel fraction varies between 0% (Stations 3, 20, 21, 35, 66 at depths ranging between 7m and 32 m) and 39% (Station 40 at 33.5 m depth). The pebble fraction ranges between 0% (Stations, 22) and 70.3% (Station 64).

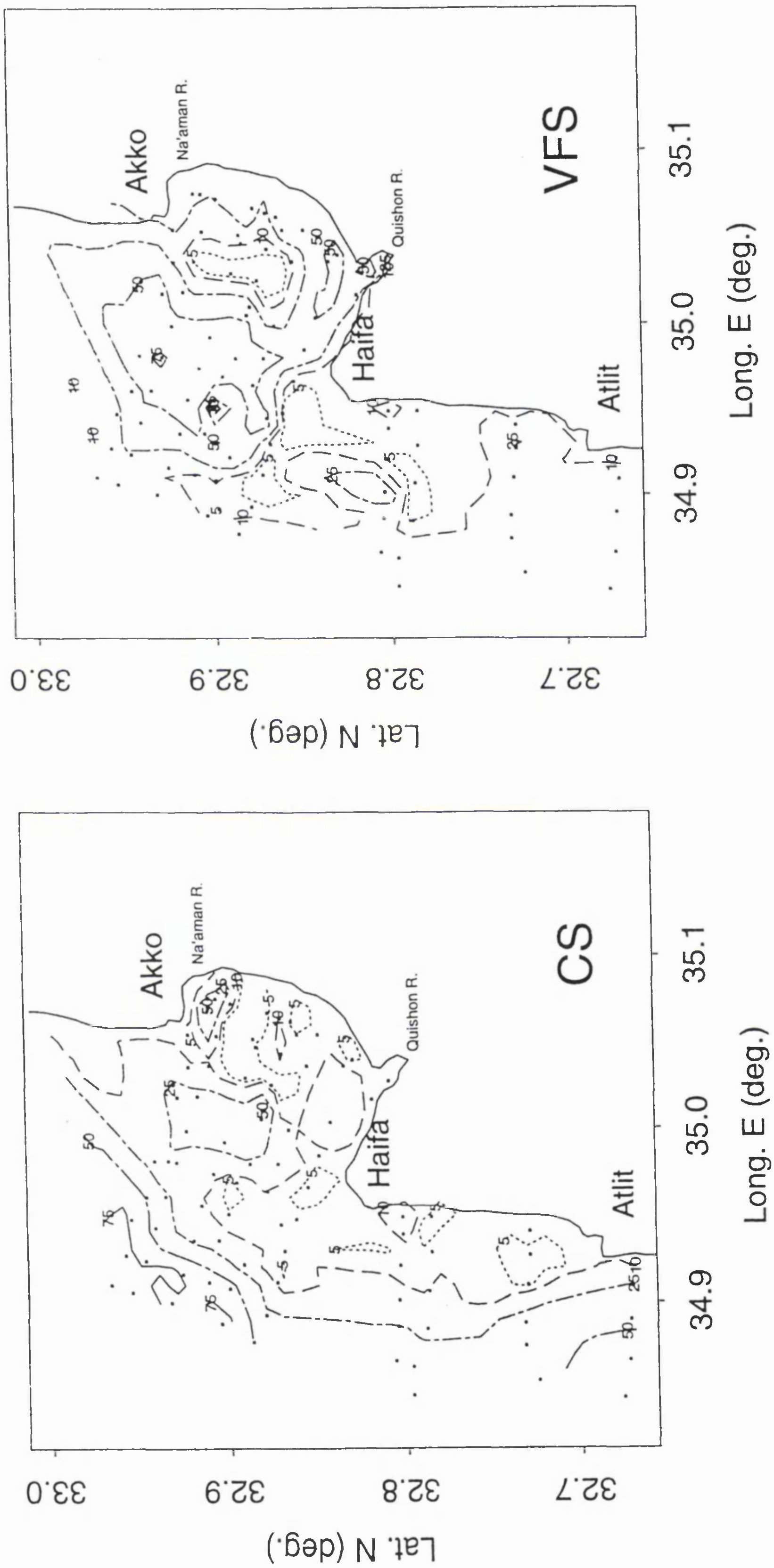


Figure 3.1. The spatial distribution of clay-silt and very fine sand in spring (May)

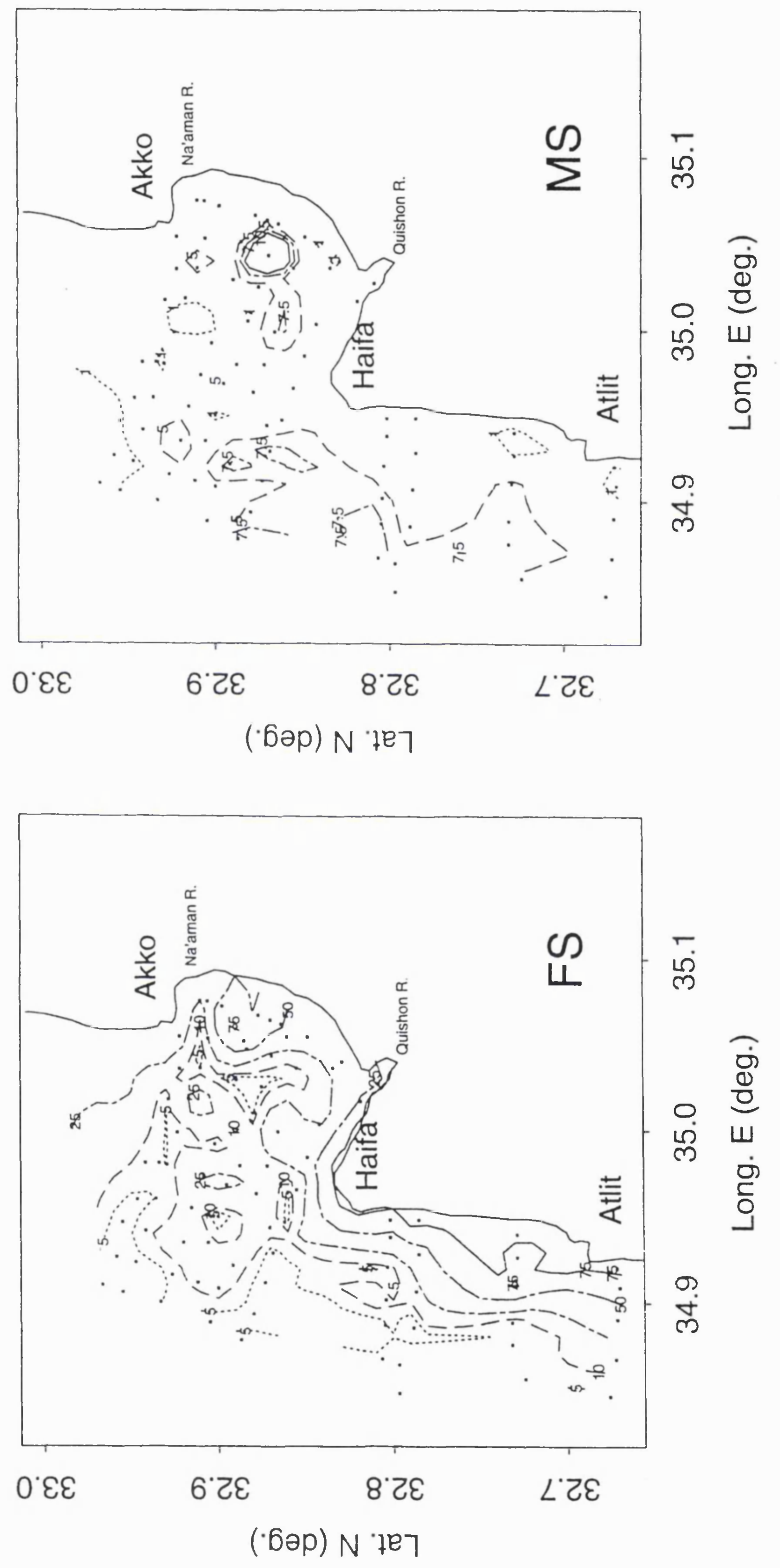
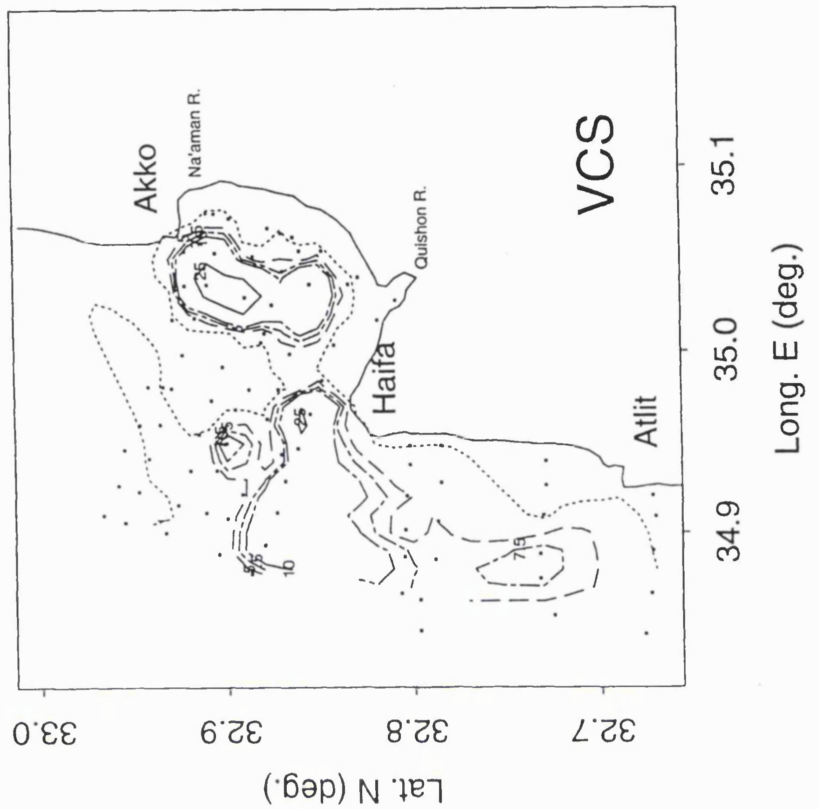


Figure 3.2. The spatial distribution of fine and medium size sand in spring (May).



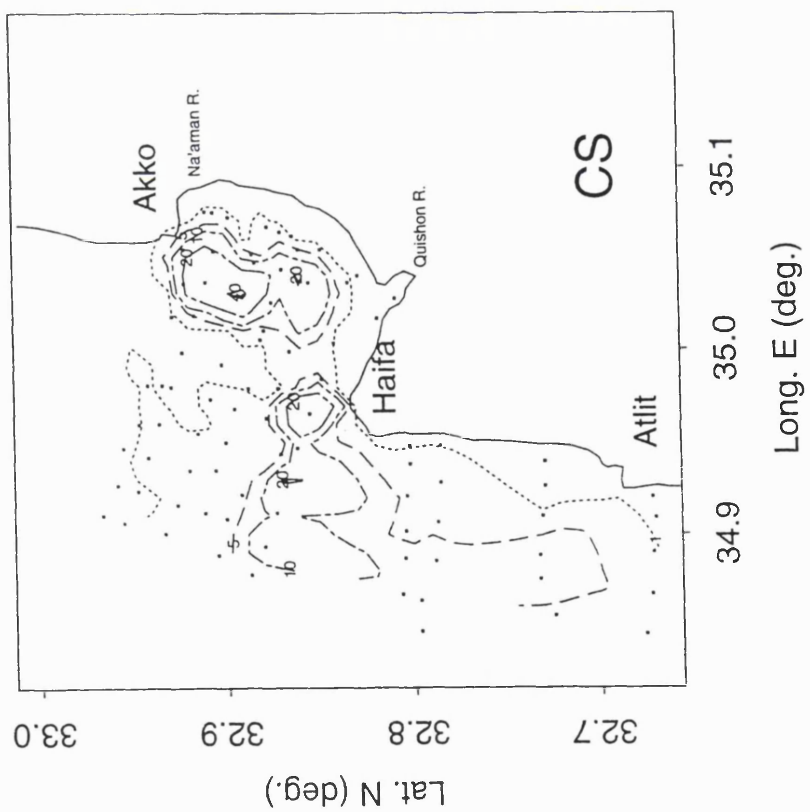


Figure 3.3. The spatial distribution of coarse sand and very coarse sand in spring (May).

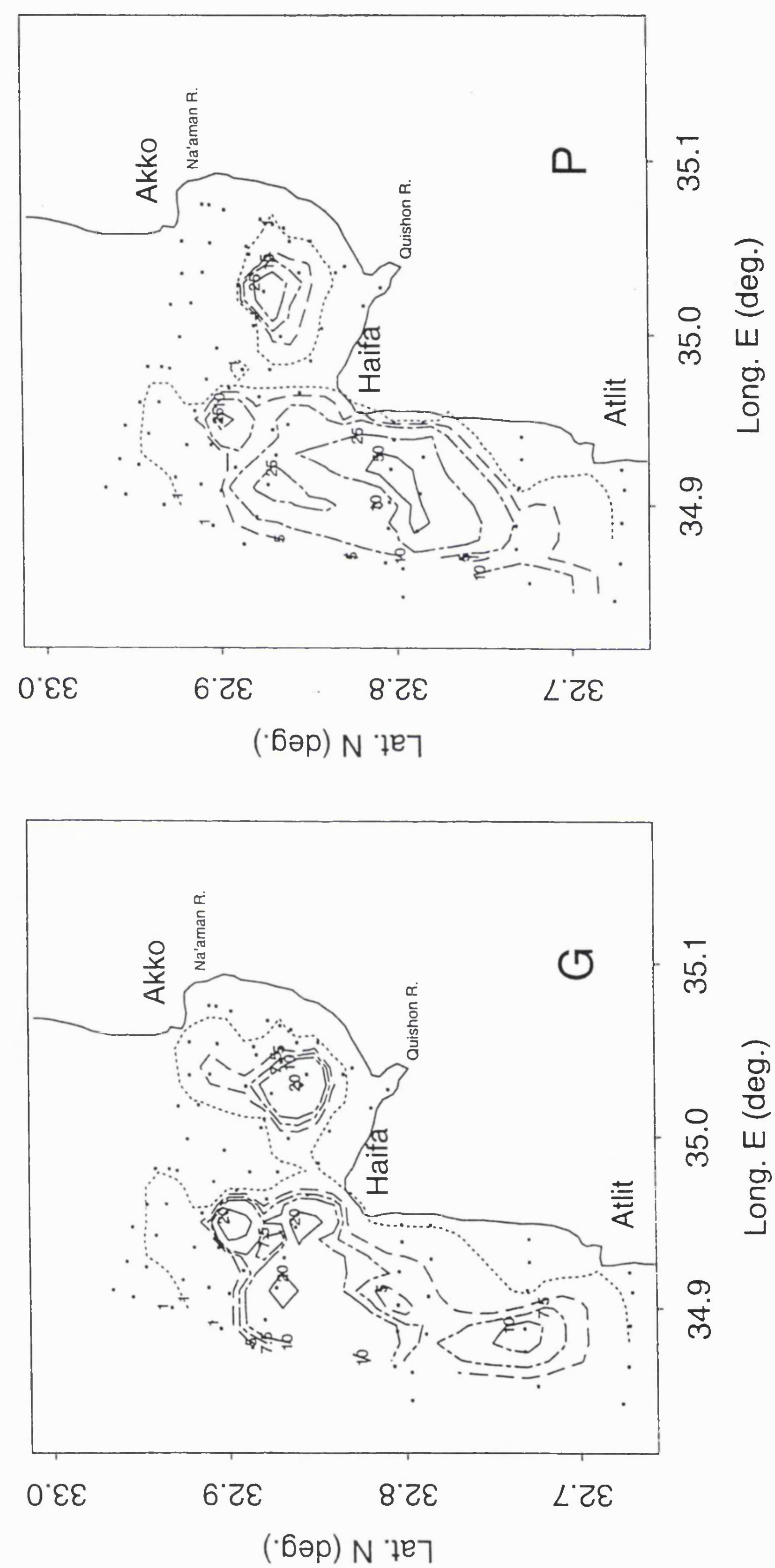


Figure 3.4. The spatial distribution of gravel and pebbles in spring (May).

The total sand percentage decreases with depth towards the sea, and the percentage of large size grains, in general, represented by the coarse fractions (coarse sand, very coarse sand, gravel and pebbles) increases at stations located in submerged areas in the vicinity of the Kurkar ridge. The sand-size material of Haifa Bay consists primarily of sand-sized quartz and calcite minerals. The granules and pebble fractions are mainly of biogenic origin. Carbonate shells predominate over other coarse grained materials.

Generally, the grain size contours run parallel to the coast. Sand-sized material can be 100% near the shore, but decreases to less than 30% at stations farther away from the shore. On the other hand, the clay fraction is 0% near the shore, but increases to an excess of 50% in stations further from the shore.

3.4. FORAMINIFERAL POPULATION TRENDS IN SPRING AND WINTER

A total of 168 foraminiferal species were identified (see appendix 3, 4), Surface sediment box core samples were collected from depth ranges of 6.5 - 210 m depth. The table below shows the seasonal changes inthe percentage of agglutinated forms, Miliolina, Rotaliina and Lagenina. The Rotalina represent the highest percentage in the area in both seasons, the Lagenina constitute the lowest percentage, but higher in winter than in spring.

Table 1. Proportions (%) of the foraminifera orders in the collected samples.

Season	Agglutinates	Miliolina	Rotalina	Lagenina
Spring Haifa Bay	7.3	39	52	0.2
Winter Haifa Bay	1.7	43.3	48.7	4.5
Spring Atlit Bay	1.1	30	68	0.7
Winter Atlit Bay	1.2	36	61	3.1

3.4.1. Species Diversity and Richness in spring and winter

Measured environmental factors such as salinity, temperature, pH and dissolved oxygen content of the sea water did not show any obvious differences during the sampling program at different sites. Their values are well within limits tolerated by the species found in the study area. Hence these parameters were not considered as crucial factors in the development changes in population structure. Considerable differences between sites occur in depth, substrate texture and the concentration of heavy metal rather than any other factors.

Figure 3.5 plots the number of living species (spring and winter) as a function of depth and oceanographic parameters in the study areas fitted Robust regression trend are also shown in spring, there a slight decrease with shallowing of the depth but no clear pattern is shown in winter, nor are there any obvious relationship between the oceanographic parameters and the number of species. The number of species, increases with increasing percentage of clay-slit in the sediment in both seasons.

The regressions show that the number of species increases with the content of very fine sand, but it is the opposite in winter. As the grain size of the sediments becomes larger in size the number of species decreases. This trend is obvious when the sediment is composed mainly of pebbles. Figures 3.6 and 3.7 are maps that show the distribution of number of species.

The species diversity increases with depth in both seasons, but it does not show any relation to the other oceanographic parameters (see Figure 3.8). In Figure 3.9 it is clear that species diversity increases with increase in the clay-silt percentage and decreases when the percentage of pebbles increase in both season. Figure 3.10 shows the species diversity distribution in the study area.

Following the Zheng and Fu (1990) method, Table 2 summarises the changes of absolute abundance, relative abundance, number of species, species diversity, heterogeneity and size of foraminiferal test.

During spring in Haifa Bay, the average species number, species diversity (Fisher index) and heterogeneity (Shannon-Winner index) was lowest in shallow water (10 m). specially near the shore line. The average species number initially increases with depth, then decreases at 210m depth. In Atlit Bay, the average species number is lowest in shallow water, especially near the shore line and then increases with depth. The average S-W index shows more or less similar trend as in Haifa Bay.

During winter in Haifa Bay, the average species number increases with depth from about 11 - 210m, with the highest value noted at 10m depth. The Fisher index and S-W index followed the same trend. In Atlit Bay, the average number of living species, species diversity and the S - W index increase with depth.

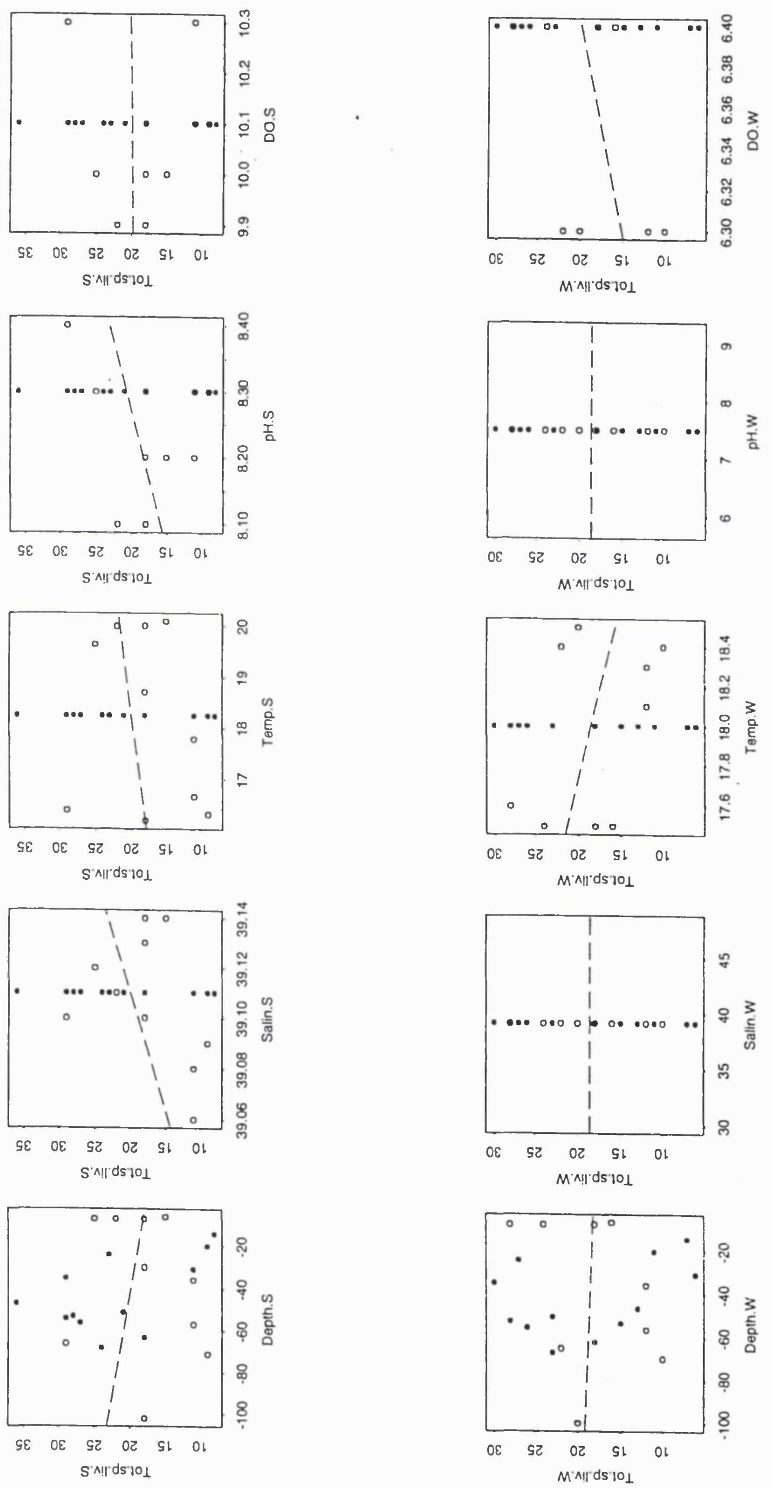


Figure 3.5. Total live species (S, W) as function of oceanographic parameter (Atlit Bay); open points, estimated.

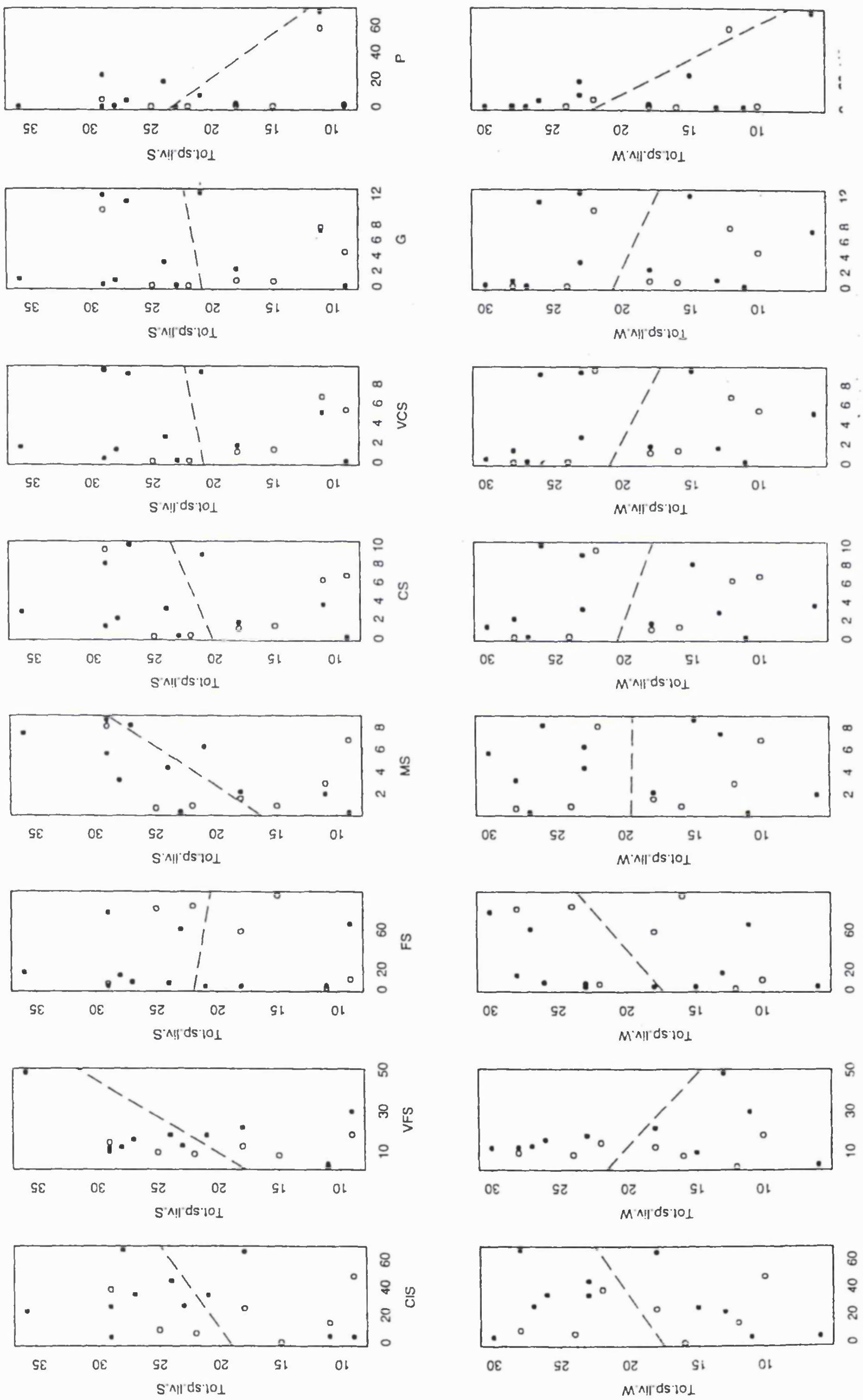


Figure 3.6. Total live species (S, W) as function of sediment grain size (ι Bay); open points, estimated.

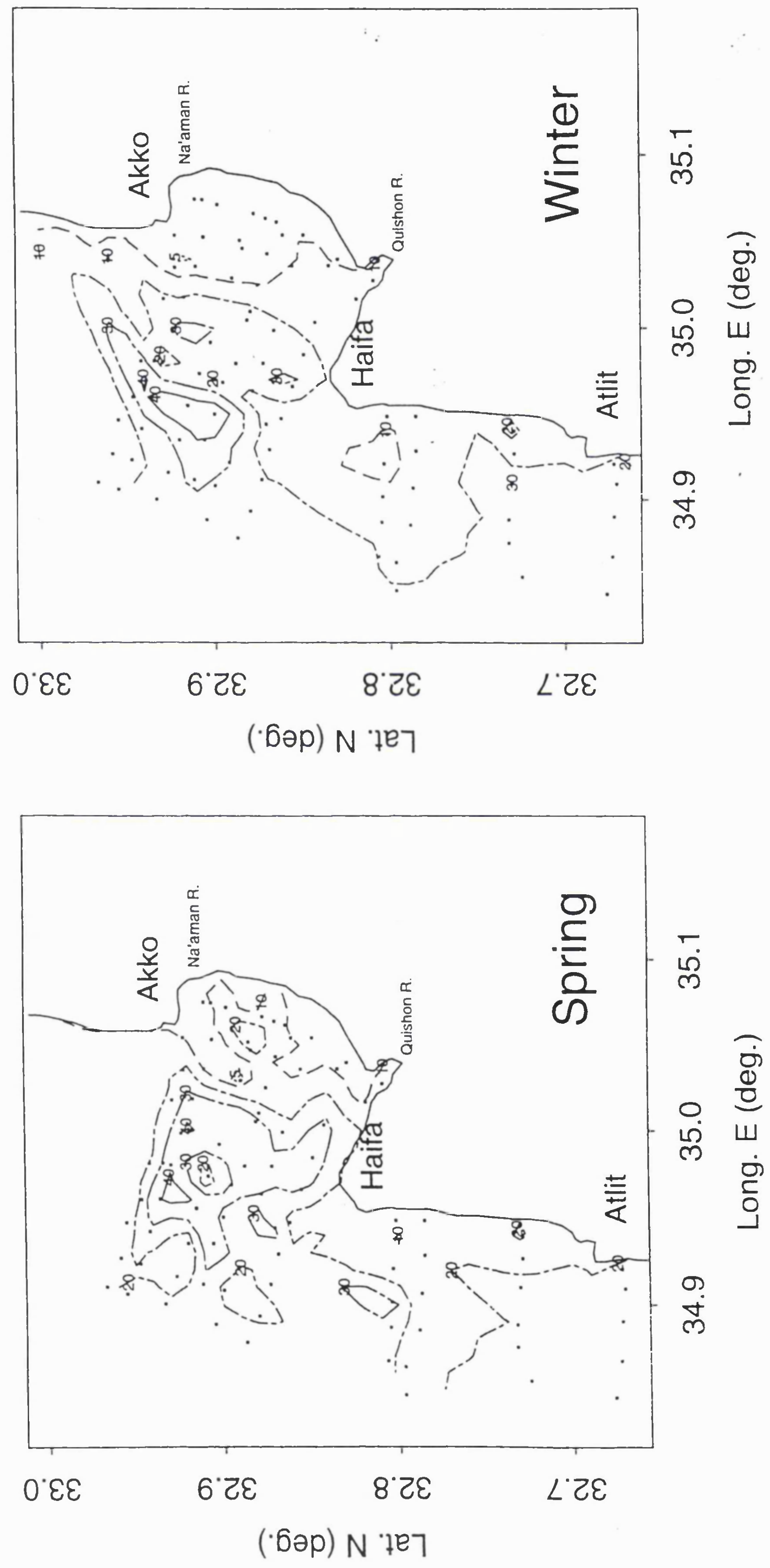


Figure 3.7. The spatial distribution of total live species (S andW) in the study area.

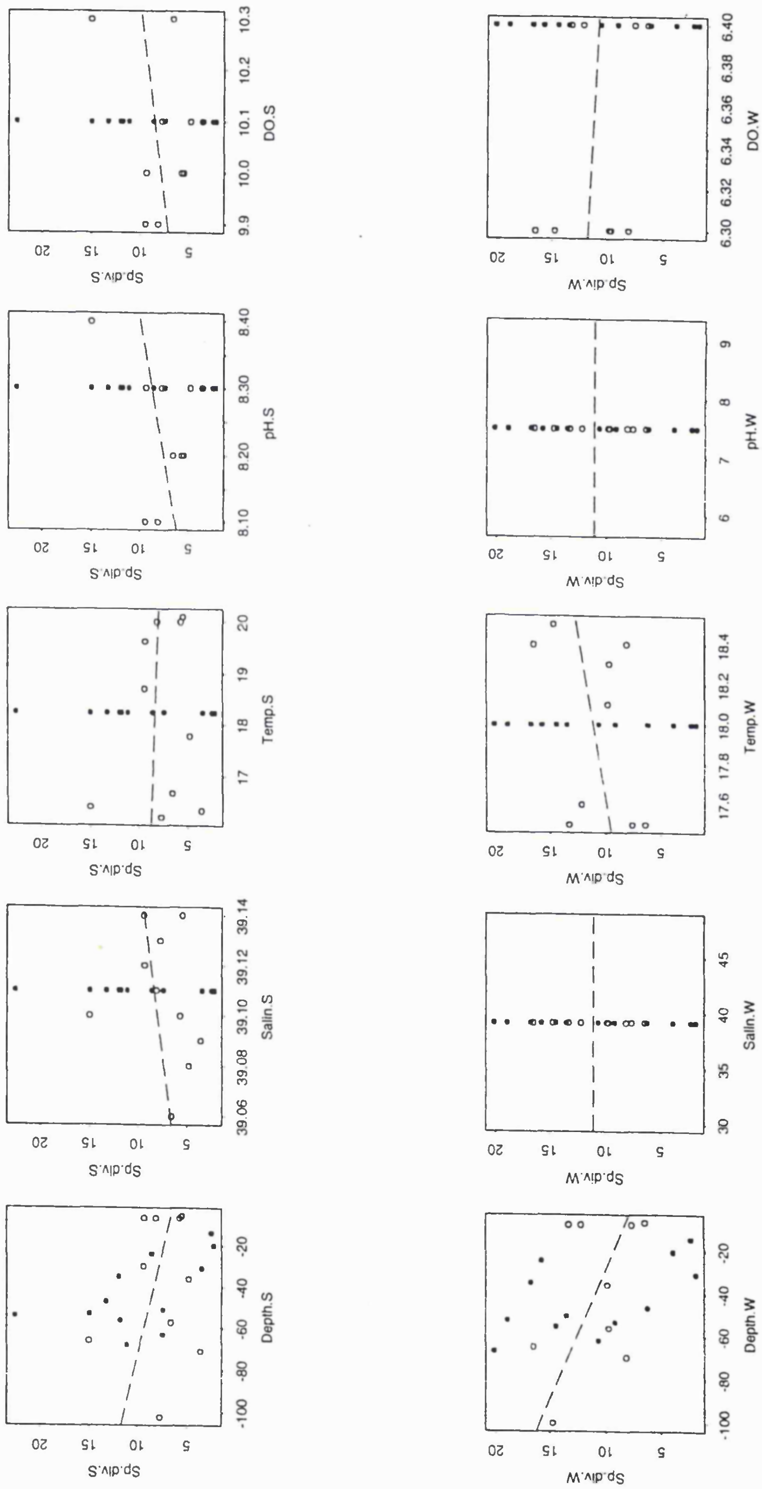


Figure 3.8. Species diversity (S, W) as function of oceanographic parameters (Atlit Bay); open points, estimated.

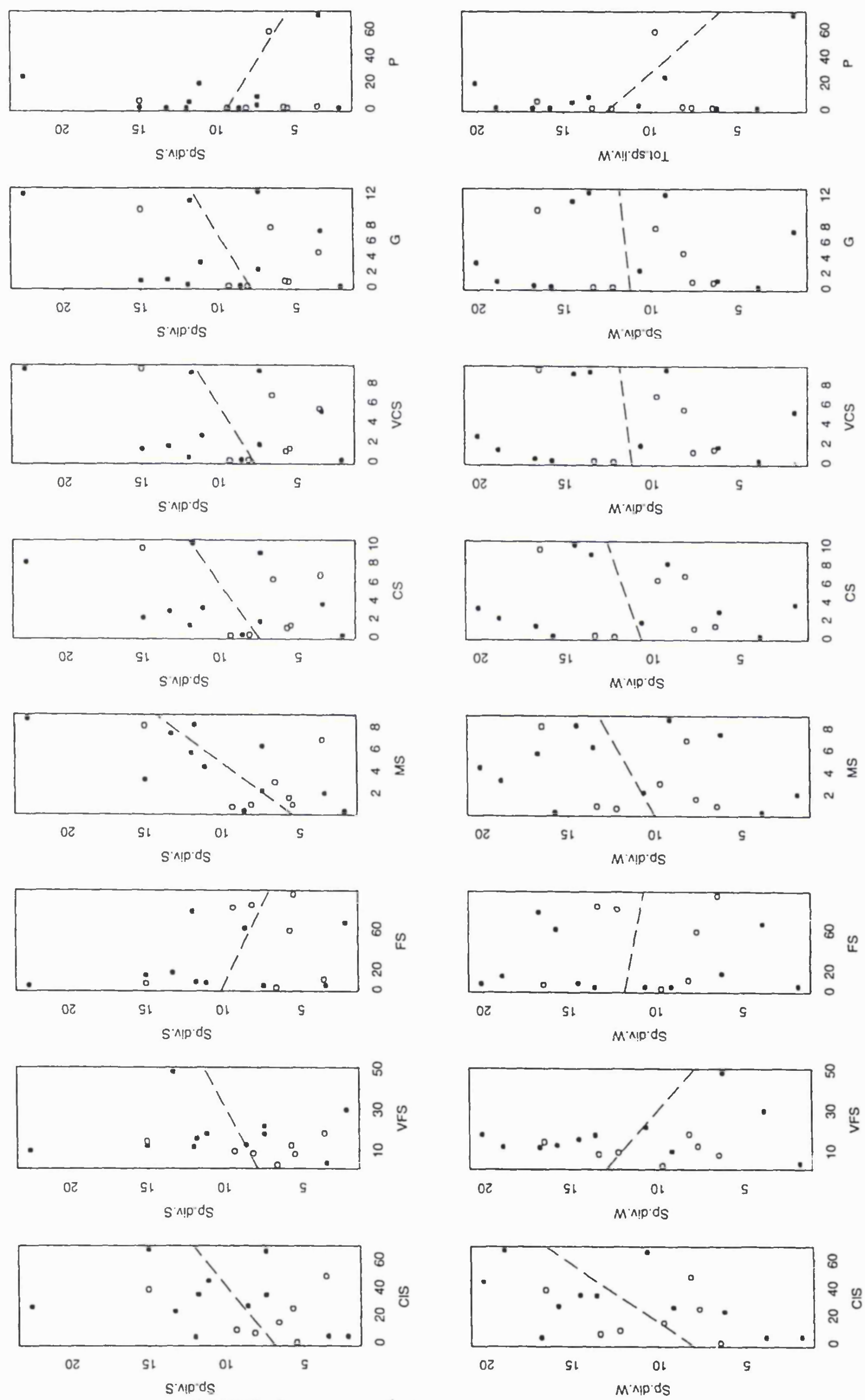


Figure 3.9. Species divesity (S, W) as function of sediment grain size (Atlit Bay); open points, estimated.

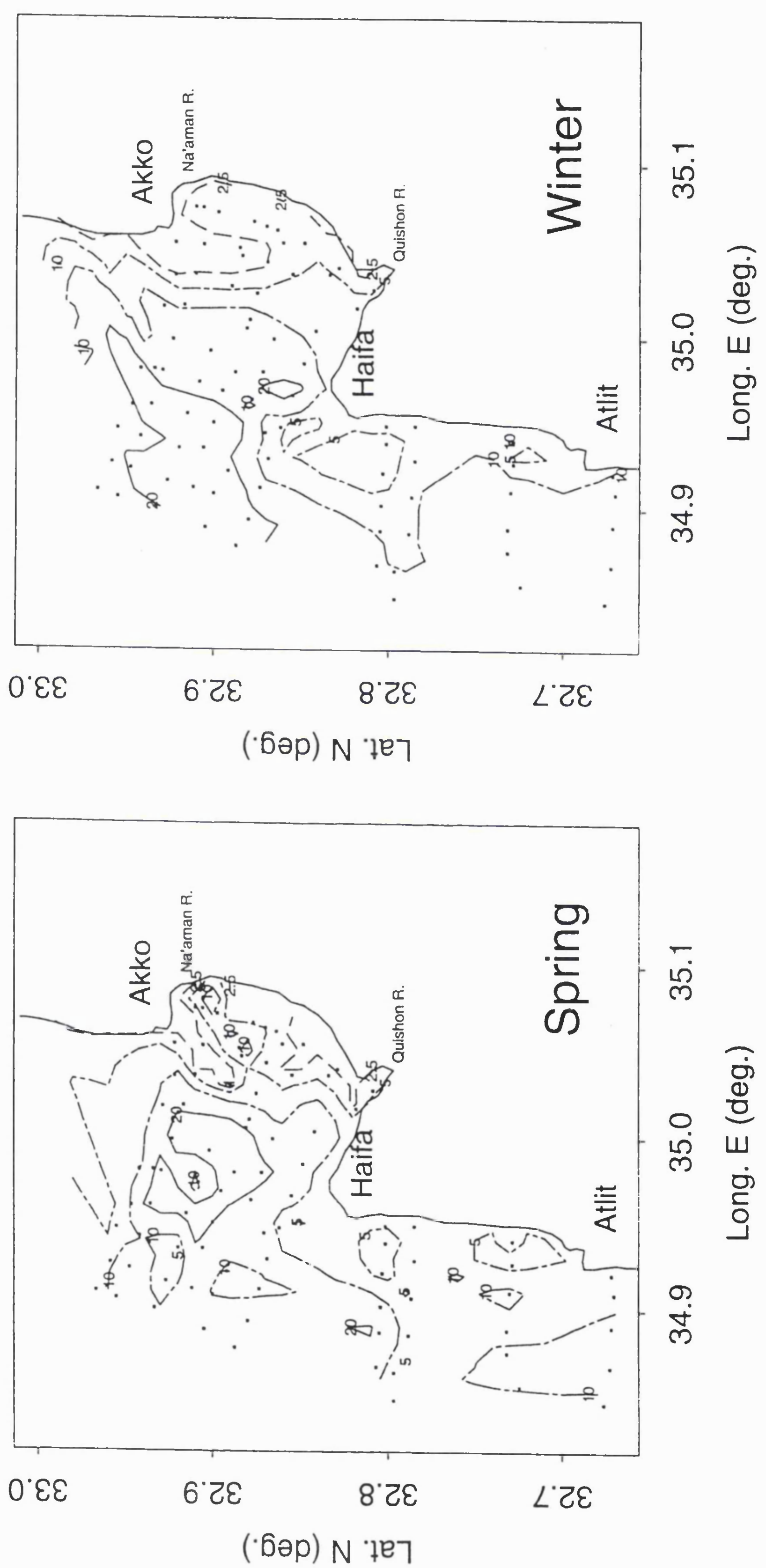


Figure 3.10. The spatial distribution of species diversity (S and W) in the study area.

In general the total number of living species and the species diversity do not show an increase with increasing depth, but they increase when the grain size of sediment is mainly clay-silt and decrease when the size of sediment increases.

Table 2. Faunal parameters in Haifa and Atlit Bays during Spring and Winter.

			Spring			
	Haifa Bay			Atlit Bay		
Depth (m)	Av. species number	Fisher indcx	S-W index	Av. species number	Fisher index	S-W index
10 m	12	7	1.9	20	7.1	2.5
11-20 m	18.9	15.2	2.2	17	5.9	2.5
21-50 m	26.2	21.8	2.7	18.4	7.6	2.7
51-210 m	20.2	10.6	2.4	20.4	10.8	2.6
			Winter			
10 m	21.5	10.3	2.6	7	2.8	1.8
11-20 m	10.3	4.1	2.1	13	7.4	1.9
21-50 m	18.7	11.7	2.5	26	17	2.7
51-210 m	19.7	13.5	2.6	25	26.7	2.9

3.4.2. Abundance of total living foraminiferal test in spring and winter

The regression plots for the absolute abundance as a function of oceanographic parameters do not show any consistent relation between the absolute abundance and oceanographic parameters (Figure 3.11). This is also shown in the Table 3, which summarises the changes of absolute and relative abundance in the study area during spring and winter. Abundance increases through depth ranges in winter. The absolute abundance is higher in Atlit Bay than in Haifa Bay, and it is higher in spring than in winter.

From Figure 3.12. the total living count of the foraminiferal tests decreases slightly with increasing depth and increases with the increase of fine sand sediment. It decreases with increasing clay and silt, coarse, granule and pebble sediments. Figure 3.13 shows the distribution of total living foraminiferal test (absolute abundance).

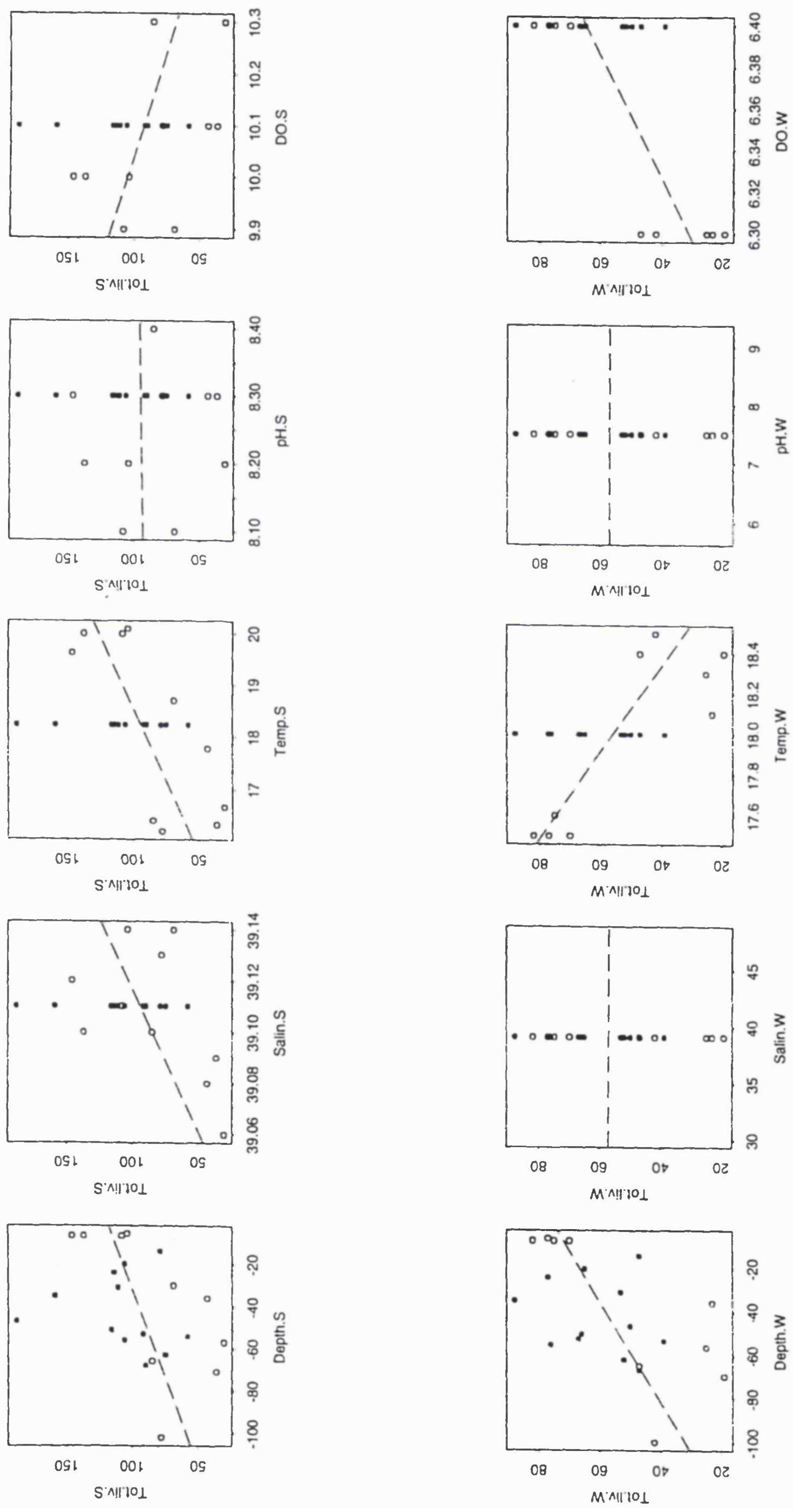


Figure 3.11. Absolute abundance of foraminifera (S and W) as a function of oceanographic parameters (Atlit Bay); open points, estimated.

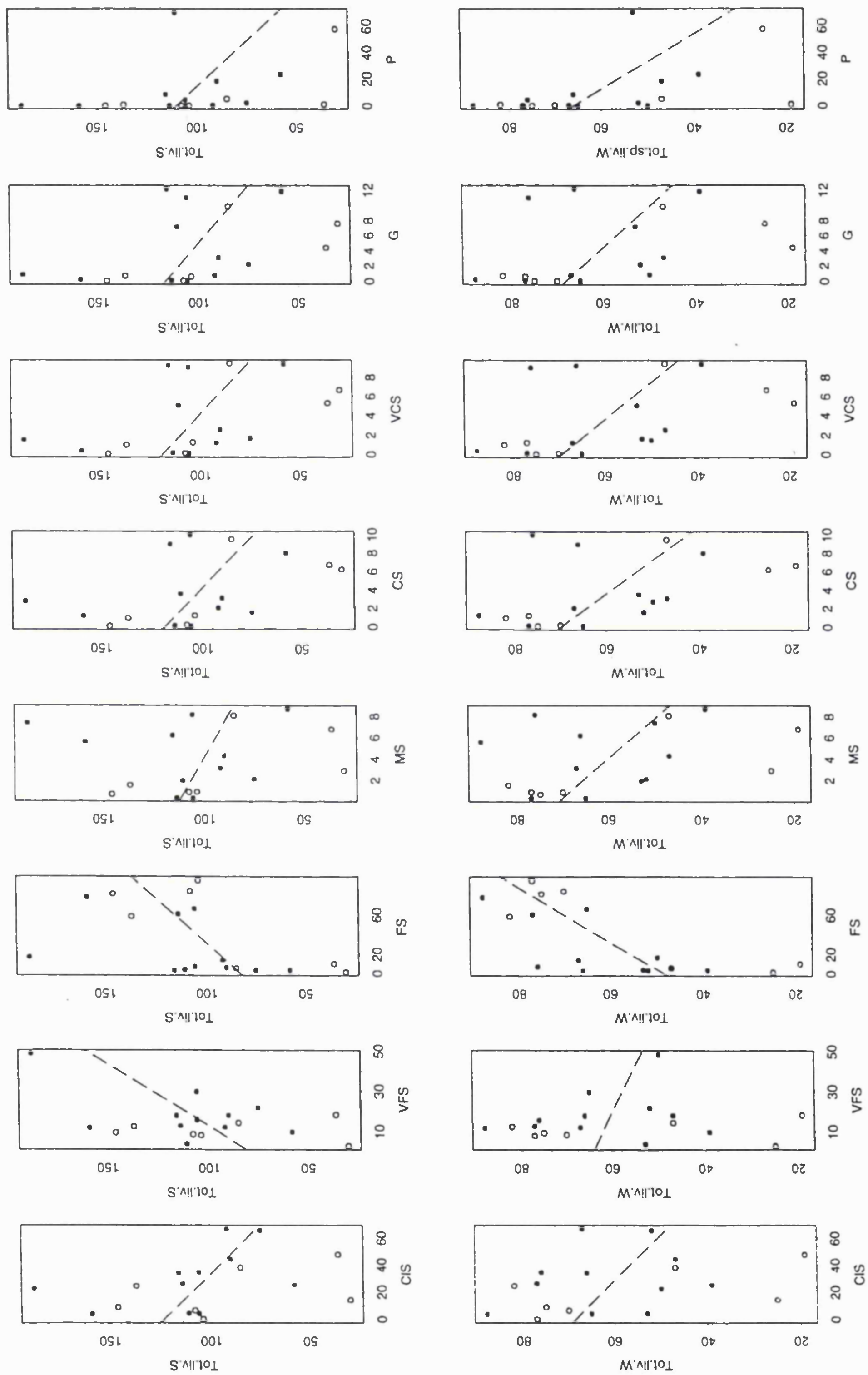


Figure 3.12. Absolute abundance (S, W) as a function of sediment grain size (Atlit Bay); open points, estimated.

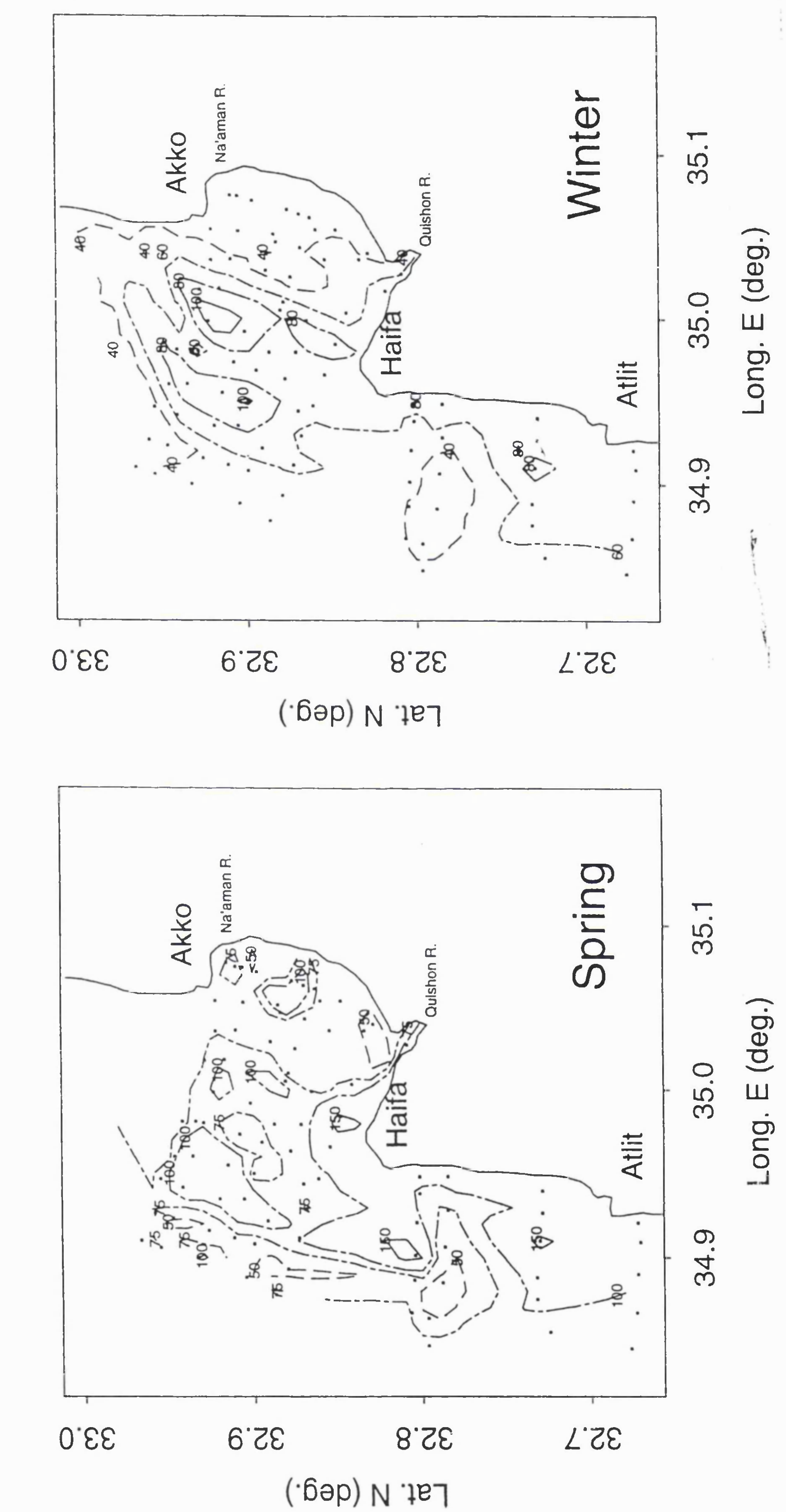


Figure 3.13. The spatial distribution of absolute abundance (S and W) in the study area.

Table 3. Relative and absolute abundance of foraminifera.

Depth (m)	Haifa Bay Av.Absolute abandance	Spring R.abundance	Atlit Bay Av.Absolute abandance	R.abundance
10 m	77.27	2.3	123.75	4.8
11-20 m	212.17	3.7	124.3	4.8
21-50 m	218.9	3.5	99.2	3.8
51-210 m	69.6	1.4	76.6	2.99
		Winter		
10 m	30.6	1.7	76	6.4
11-20 m	49.3	2.7	54	4.54
21-50 m	71.46	4.05	60.25	5
51-210 m	51.3	2.91	48	4.04

3.4.3 Size distribution of foraminiferal tests in spring and winter.

The foraminifera of the Atlit and Haifa bays were divided into four groups based on their sizes. Those with sizes > 500μm were regarded as extra large tests; 500 - 250μm fraction were counted as large tests; 250 - 125μm fraction as medium test, and 125 - 63μm, as small tests.

Depth does not affect the distribution of test size as shown in Table 4. and Figure (3.14). The dominant size for both seasons fall within the medium size (250 - 125 μm) range, with percentages of 52% - 43% in both regions.

From Figure 3.15 it is evident that the changing size of the living test is function of substrate. In Figure 3.16 shows that the extra large and the large size living test (> 500 μm and < 500 > 250 μm) have a higher percentage at the sites that are characterised by high percentages of large grain size substrate. In general, the percentage of coarse fractions (coarse sand, very coarse sand, gravel and pebbles) increase at stations located in submerged areas in the vicinity of the Kurkar ridge. These sites are characterised by high dissolved oxygen and high percentage of chlorophyll as a result of higher illumination. Figure 3.17 and 3.18 is map shows the distribution of extra large and large test size in the study area.

The medium size living tests (250 - 125μm) display a higher percentage at the sites where the substrate is mostly small grained (clay and silt, very fine sand and fine sand)

and it increases away from the shoreline (Figure 3.19). The small test size (<125 - 63μm) represent the lower percentage. Its highest percentage is at the deep sites and near the river outlets (Figure 3.20).

Table 4. Distribution of Test Size parameters in Haifa and Atlit Bays.

		Haifa Bay		
% size of the test	> 500	<500>250	<250>125	<125 >63
10 m(S)	4.4	45.13	50.42	0
11-20 m(S)	15.9	29.1	52.77	2.17
21 - 50m(S)	19.21	31.45	46.68	2.64
50 - 210 m(S)	8.16	20.51	61.32	10
10 m(W)	13.3	29.5	44.43	12.66
11-20 m(W)	31.9	73.6	70.94	15.75
21 - 50m(W)	25.7	69.7	80.89	10.45
50 - 210 m(W)	9.49	27.69	56.88	5.92
		Atlit Bay		
10 m(S)	19.9	40.44	34.88	4.75
11-20 m(S)	13.12	33.68	53.19	0
21 - 50m(S)	20.6	33.36	42.74	3.26
50 - 210 m(S)	19.75	34.26	42.22	3.75
10 m(W)	21.6	35.6	41.61	1.02
11-20 m(W)	27.7	37.49	34.71	
21 - 50m(W)	22.36	42.12	35.5	
50 - 210 m(W)	19.18	37.01	43.15	0.646

3.4.4. Bathymetric Zonation of the dominant species

Multidimensional scaling (non-hierarchical cluster analysis) carried out on the combined data-set of all samples was not successful, (see appendix 5) The principle component analysis on the entire data-set showed that only 4.92% of the faunal variation is explained by the first factor and 4.54%, 4.19%, 3.59%, 3.28% and 3.05% by the second, third, fourth, fifth, and sixth factors respectively, (see appendix 6). Hence it was decided not to proceed with the statistical method but to concentrate on the distribution of selected dominant species which occur in more stations and show a higher abundance compared to other species. Comparison of the various neighbouring transects, however, showed no consistent distribution of these dominant species in relation to water depth.

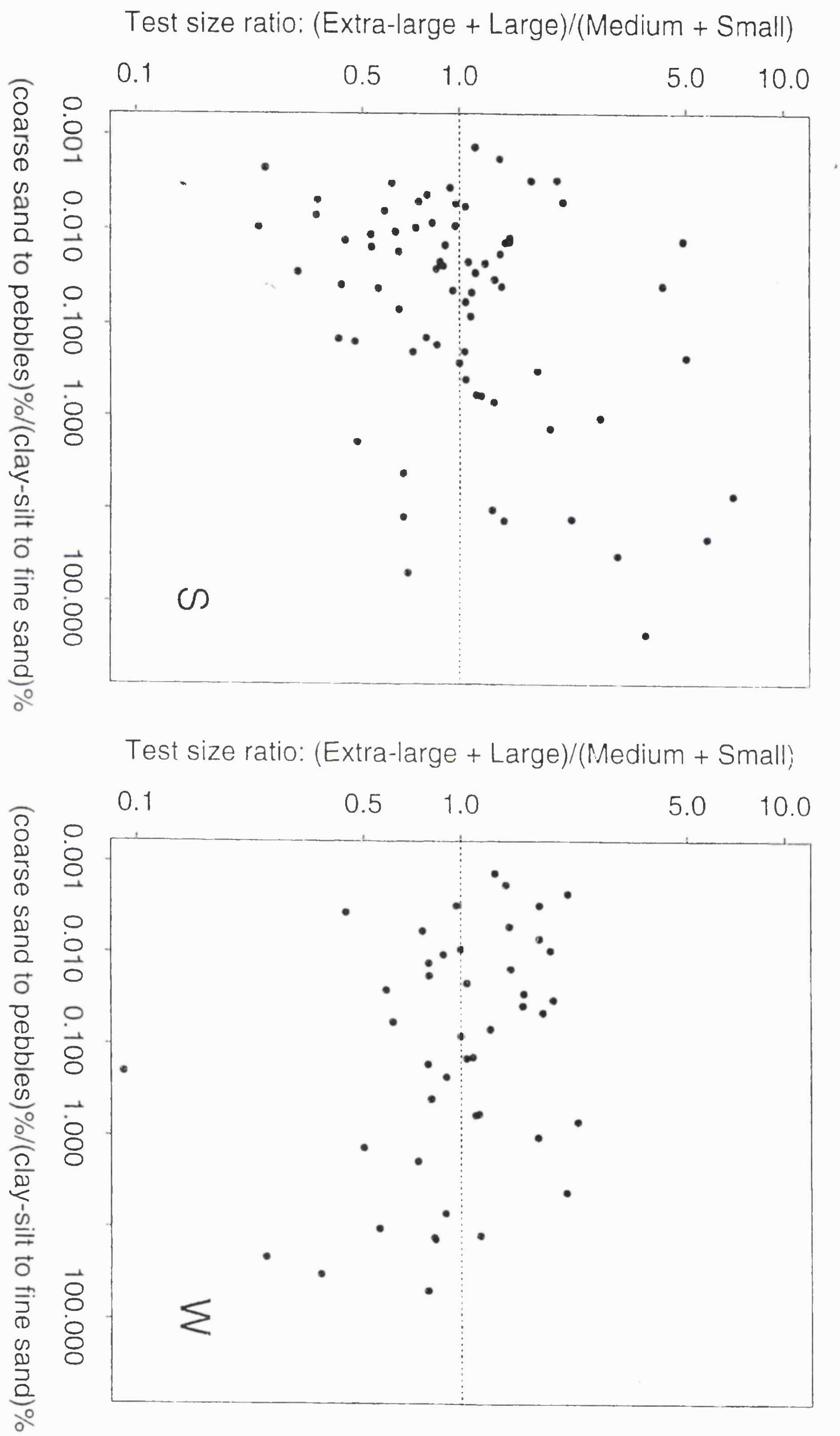


Figure 3.14. Proportion of larger living test size as a function of depth and season.

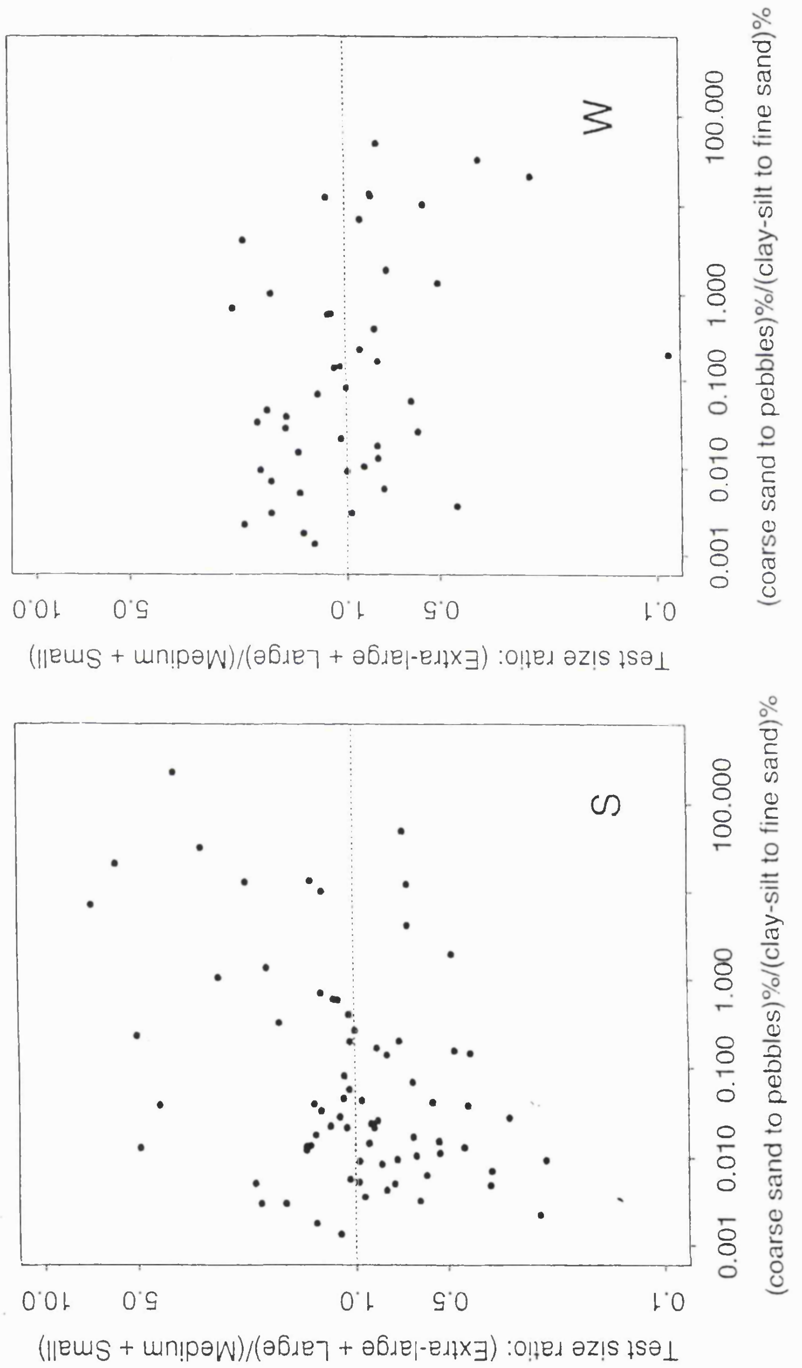


Figure 3.15. Proportion of larger living test size as a function of coarsening sediment size grade and season.

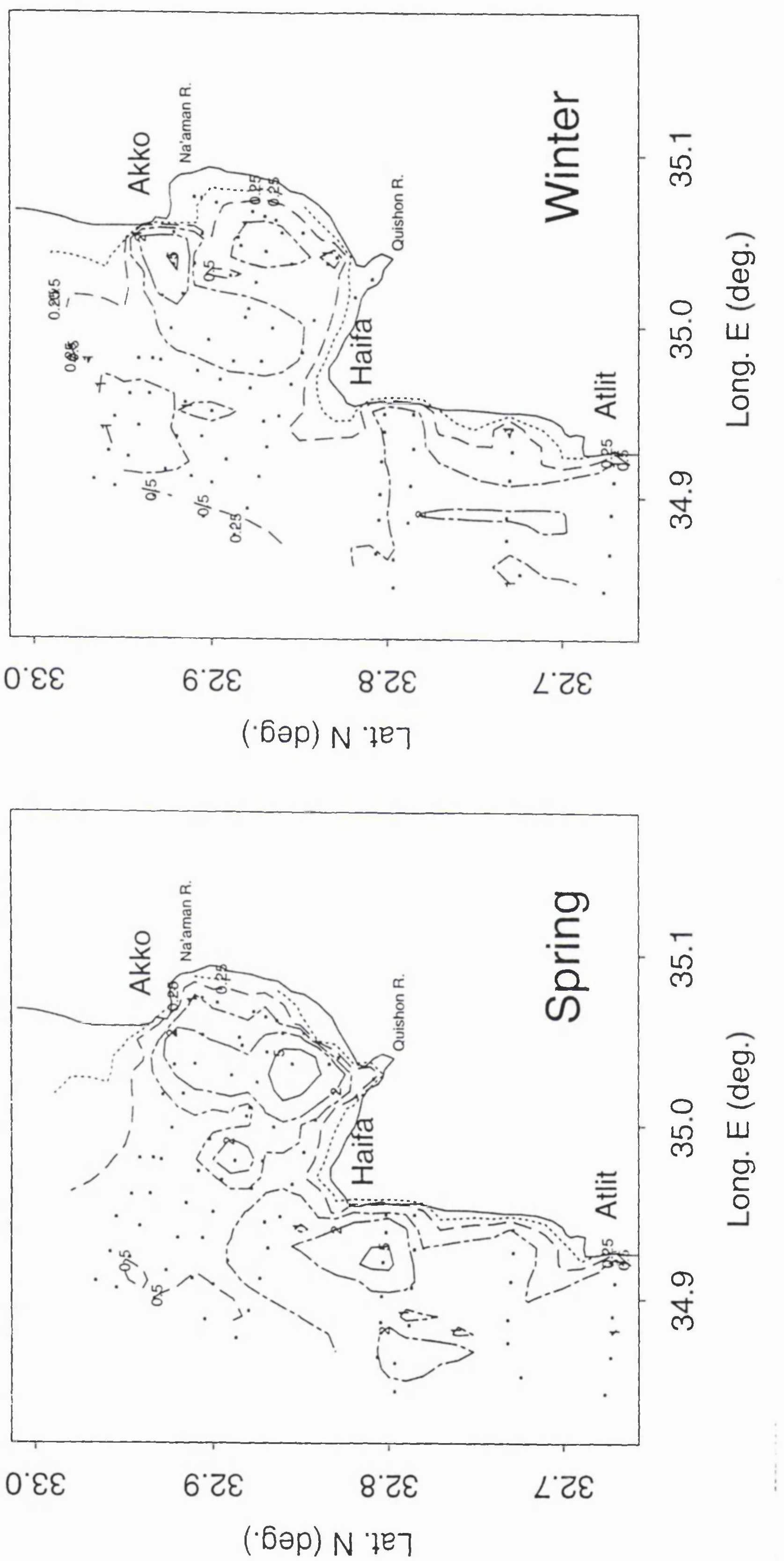


Figure 3.16. The distribution of living test size ratio (XL+) (M+S), (S and W) in the study area.

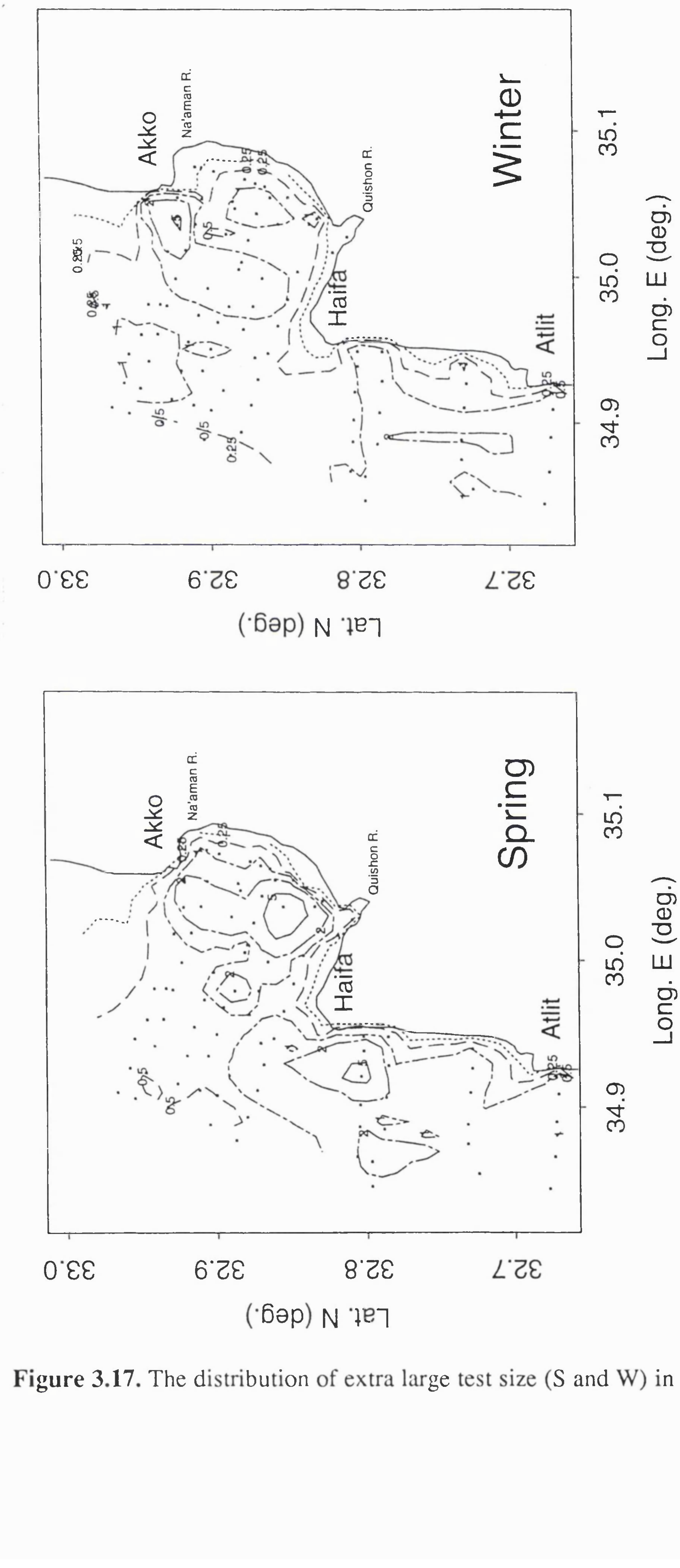


Figure 3.17. The distribution of extra large test size (S and W) in the study area.

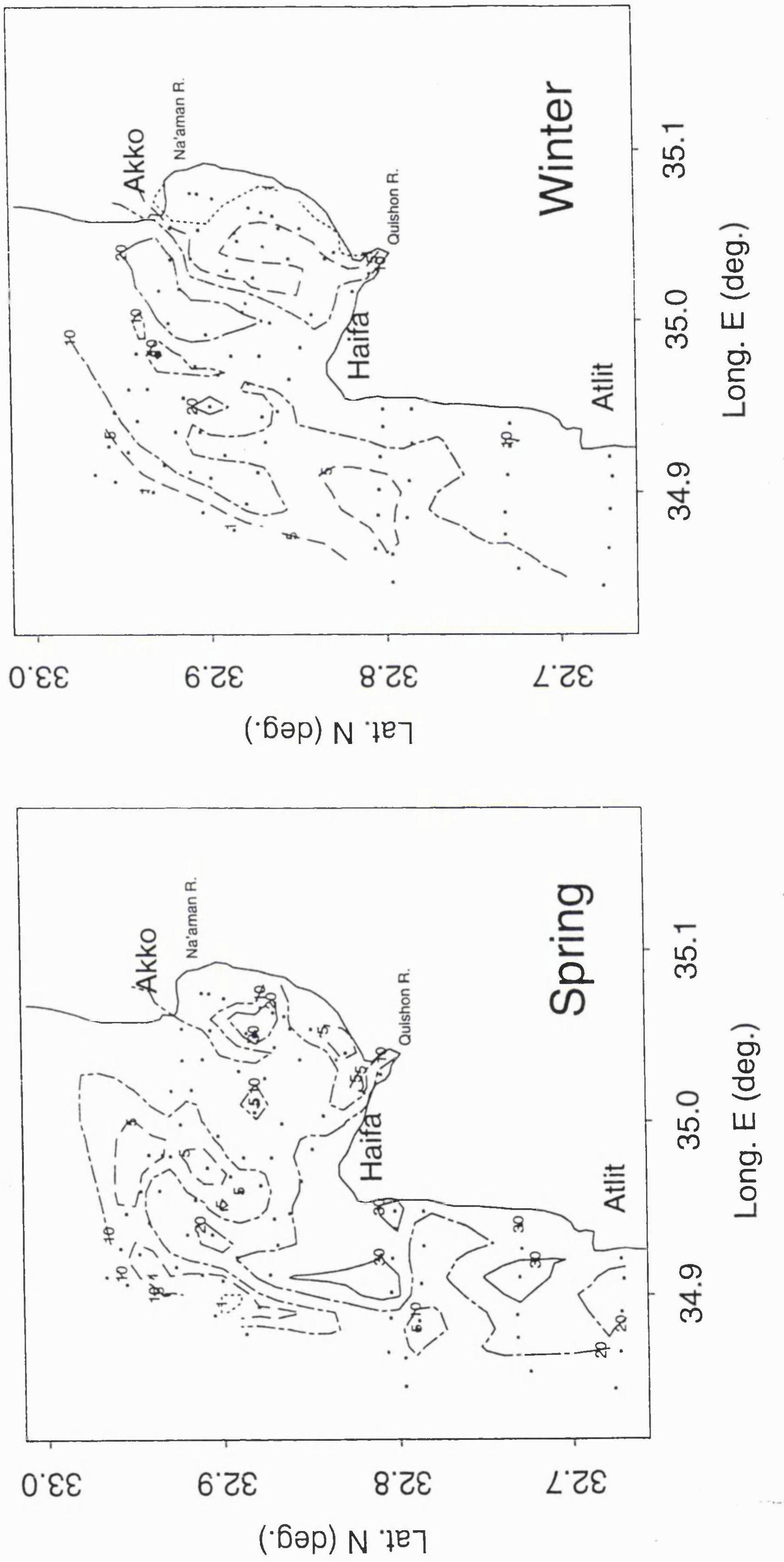


Figure 3.18. The distribution of large test size (S and W) in the study area.

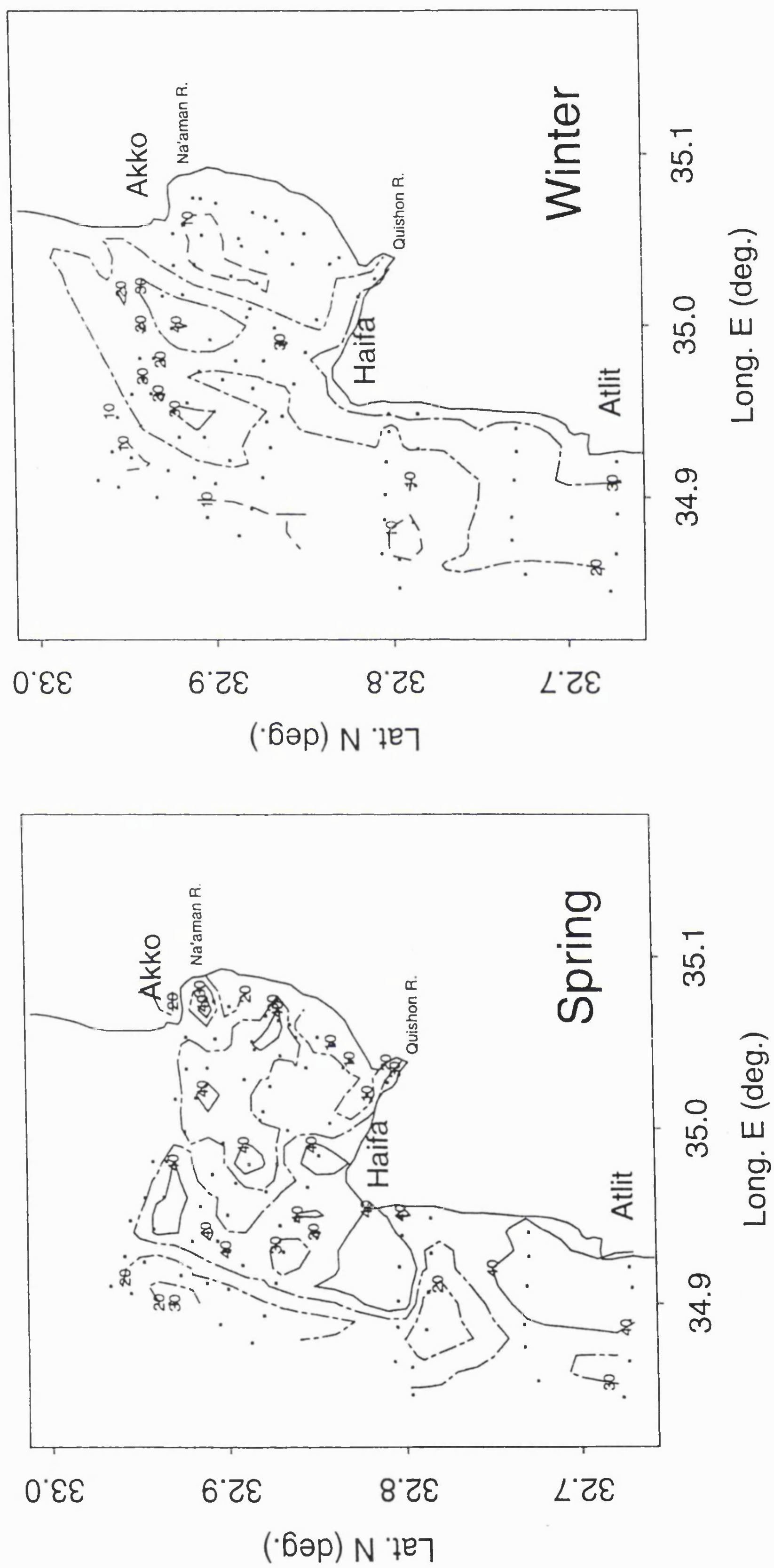


Figure 3.19. The distribution of medium test size (S and W) in the study area.

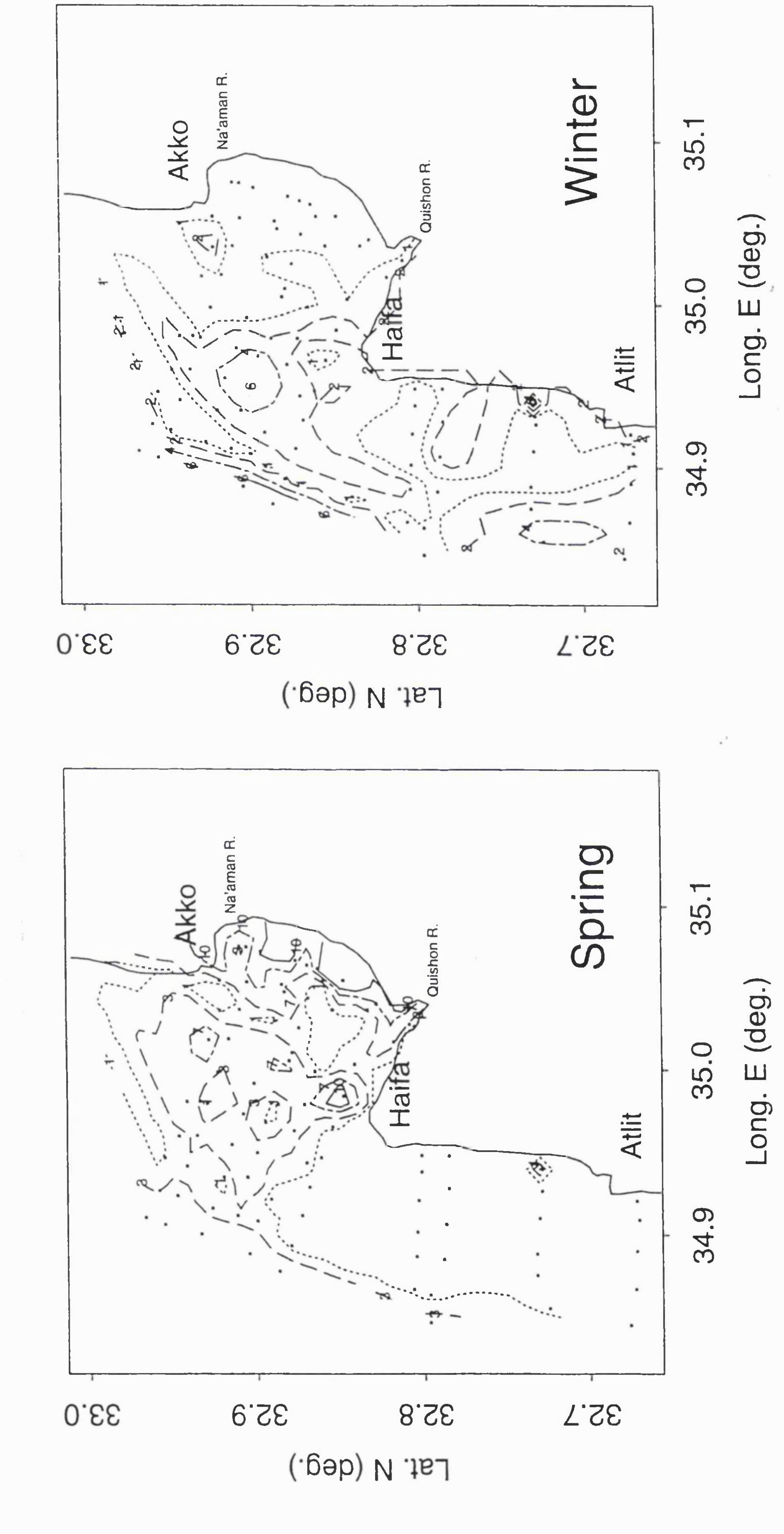


Figure 3.20. The distribution of small test size (S and W) in the study area.

Contour maps are plotted based on either selected absolute values or the 25%, 50% and 75% percentiles of all values, with the value of 1 being the base contour, as this seems appropriate to best show the spatial distribution patterns of the species during spring and winter. From this we can differentiate between relatively shallow species and the deep water species. The following species are considered to be dominant at some sites but some did not show water depth preference in any of the transects.

The distribution of recovered species in the study area are shown in the table provided in Appendix 9.

1) *Ammonia tepida*

The absolute abundance of *Ammonia tepida* decreases in a seaward direction. It disappears at deeper depths, and has higher abundance values near the shoreline. Its absolute abundance is higher in Haifa Bay than in the Atlit Bay during both seasons. Seasonally, their absolute abundance is higher in spring than during the winter.

2) *Ammonia parkinsoniana*

This is a characteristic shallow water species. Its absolute abundance decreases seawards, and it is not present at deeper stations. Its absolute abundance is higher at sites south of Haifa Bay, and in the Atlit Bay.

3) *Amphistegina lobifera*

This species is also a typical shallow water form, but it does not show any trend with depth. Interestingly, its absolute abundance is higher at hard ground locations and at sites characterised by coarse sand, gravel and pebbles. It is here considered a dominant species at most of the stations where it occurs

4) *Asterigerinata mamilla*

This is a widespread species but it does not show preference to water depth.

5) *Discorbinella bertheloti*

This species has a wide depth range from 6.5 to 200m in spring and from 7 to 68m in winter. This species occurs more often in spring than in winter (47 stations in spring and 27 in winter). It was mostly found at sites characterised by fine grained sand size substrate.

6) *Challengerella bradyi*

The distribution of this species as depicted in the map (appendix 6) reveals that it is not water depth dependent. It has a wide depth range from 12 - 59m in Haifa Bay and it occurs in very small percentages near the shore line. In Atlit Bay it has a wider depth range from 7 to 102m, and the 25% value occurs near the shore line especially to the south of the bay. The absolute abundance is lower during winter compared to spring, and also lower in Haifa Bay relative to the Atlit Bay. It occurs mostly on fine sandy substrate and at three stations where the grain size is coarse.

7) *Elphidium crispum*

This species occurs at sites with clay-silt substrate. It is a typical shallow water species occurring from 6 to 72m in Haifa Bay and from 7 to 57m in Atlit Bay. In winter the species does not occur near the shore in Haifa Bay.

8) *Eponides concameratus*

This species occurs from 18 - 67m in Haifa Bay and from 14 - 54m in Atlit Bay. The abundance of this species increases toward the south of Haifa Bay. The abundance is low at sites near the shore and at deeper water sites. The absolute abundance is lower in winter than in spring. It occurs mostly at sites characterised by coarse sand, gravel and pebble substrate.

9) *Hauerina diversa*

This species is a shallow water form. It occurs from 7 to 44m in Haifa Bay and at 7m near the shore line in Atlit Bay. Its abundance is lower in winter. It shows a preference to fine sand and clay-silt substrate.

10) *Heterostegina depressa*

The species is found at shallow sites characterised by hard ground and coarse to pebble substrate.

11) *Lobatula lobatula*

This species is widespread. It occurs from 7 - 200m depth. its absolute abundance increases towards the sea in both bays and during both seasons.

12) *Pararotalina spinigera*

This is a characteristic shallow water species. It occurs from 6 to 35m in both bays. The map shows that it has a high abundance at sites near the outlets of the Na'aman River and Qishon River (pollutant point sources). Its abundance increases toward the southern part of Haifa Bay, and near the shore line of Atlit Bay. Its absolute abundance decreases in a seaward direction. Its substrate preference is mostly very fine sand and fine sand.

13) *Reussella spinulosa*

This species has a wide depth range from 6 - 200m in Haifa Bay and from 6 - 68m in Atlit Bay. It occurs at few stations and in low abundance, but its occurrence increases towards the sea. Its abundance is higher in spring than in winter.

14) *Rosalina* (*bradyi*, *macropora* and *globularis*)

These three species occur from 6 - 200m at Haifa Bay and from 7 - 68m in Atlit Bay. The maps show that they have the same distribution trend, and their abundance increases toward the sea. Their absolute abundance decreases towards Atlit Bay and *R. globularis* disappears during winter in Atlit Bay. Their substrate preference is mostly very fine sand and clay-slit.

15) *Asterorotalia gaimardii*

This species is a characteristic shallow water form. Its substrate preference is fine sand. It occurs near the shore line and has a higher absolute abundance in Atlit Bay in both seasons compared to the Haifa Bay.

16) *Vertebralina striata*

The species is widespread in Haifa Bay from 6.5 - 200m depth. Its absolute abundance decreases towards the sea. The map shows that the species abundance near the shoreline in Atlit Bay is higher in winter than in spring.

17) *Triloculina marioni*

The species is widespread from 6 to 200 m depth. Its absolute abundance is higher toward the sea, but it does not have any obvious depth preference. However, its substrate preference is very fine sand. In winter the species abundance appears to shift toward the sea in Haifa Bay. The species also occurs in the outlet of Na'aman River and Qishon River in spring.

18) *Melonis affinis*, *Rectuvigerina* sp, *Bolivina variabilis*, *Brizalina spathulata*, *Brizalina striatula,* and *Amphicorina sp* .

These species occur in small numbers and at few stations. Their occurrence is predominantly at deep stations. Their substrate preference is very fine sand and clay-silt.

CHAPTER 4
THE EFFECT OF HEAVY METAL CONTAMINATION ON BENTHIC FORAMINIFERA

4.1 INTRODUCTION:

The benthic foraminiferal distribution in surface sediment was examined to investigate its response to heavy metal pollution in Haifa Bay and Atlit Bay (the control area). This response is reflected by changes in the foraminiferal population structure (absolute abundance, relative abundance, species diversity, number of species, the size and morphological deformations of the living foraminiferal test). The polluted sites were found to have lower absolute and relative abundance than sites which are less polluted; the species diversity and the number of species also follow the same trend.

Morphological abnormalities of the foraminiferal test within the modern sediments in the study area have been found, for example, twinning, multiaperture, additional chambers, twisted arrangement of the chambers, and abnormal apertures. Deformities similar to these have been reported by many authors (for example Sharifi, 1991; Alve, 1991, 1995; Seigle, 1971, 1975; Tufescu, 1968; Stephens, 1969; Setty, 1976; Setty and Nigam, 1984, Yanko *et al* 1994, 1998;and Stouff *et al* 1999 a, b).

Some studies have compared trace metal content (Cu and Zn) and morphology of the foraminiferal test (Sharifi, 1991); others examined heavy metal content within the foraminiferal test (Stubbles, 1999, and Stouff *et al* 1999).

In this study the electron microprobe was used to examine variations of some elements (particularly magnesium) in the calcite of the test, and to determine whether or not there is replacement of Ca in the test by another element (e.g. heavy metals from the surrounding environment), and if there is a difference in selected elements concentrations between deformed specimens and undeformed tests.

One species that was selected from among 50 species in the study area that exhibit morphological deformities is *Amphistigina lobifera.* This species was chosen because it constitutes the highest percentage of the deformed foraminiferal assemblage within the stations studied (38%), and its abundance varies greatly from site to site, in particular between unpolluted sites and a highly polluted sites.

In this part of the study I wished to determine which heavy metals appear to be biologically harmful to the benthic foraminifera. Additionally, which parameters of the population structure (absolute and relative abundance, number and diversity of the living species and the size of the test) are affected by pollution? Which species are sensitive to heavy metal pollution and how this sensitivity is reflected in the abundance of the species, morphology and geochemistry of the test?

4.2 MATERIALS AND METHODS:

4.2.1 The abundance and distribution of the living foraminiferal test (normal and deformed)

The methods of microfaunal examination are mentioned in Chapter 3.2.1. The percentage of living deformed specimens from the total number of living specimens is caculated by $P_d = (N_d / N_t) * 100$, and the percentage of living deformed specimens of a given species from the total number of living deformed test in each station was calculated using $P_{ds} = (N_{ds} / N_d) * 100$ where N_d = number of deformed living specimens / 5g sediment, N_{ds}= number of deformed living specimens of a given species / 5g sediment, and N_t = total number of living specimens (deformed and nondeformed) / 5g dry sediment.

4.2.2 The chemistry of the foraminifera

Typical specimens of *Amphistigina lobifera* and *Asterigerinata mammilla* were chosen from polluted stations and relatively unpolluted stations. Each specimen was pressed into a drop of epoxy on a Scanning Electron Microscope stub. This procedure ensured that the specimens remained at approximately the same level on the stub. Specimens were sectioned, ground and polished to form a completely flat surface exposing the stained protoplasm, and the interior of the chambers by wet-grinding on a lap plate with 1000-grit silicon-carbide abrasive powder.

Immediately prior to microanalysis, specimens and standards were coated with carbon to make them electrically conductive. The following standards have been used for Mg, the standard is UCL Olivine; and the standard for Ca is Birkbeck Wollastonite. The chemistry of the deformed specimens was analysed by E.S.M, Energy Dispersive Spectrometer, (EDX). A JEOL Superprobe 733, with Oxford Instruments-ISIS system and ATW detection (Atmosphere thin window). The accelerating voltage used was 15V and the count time was 100 seconds. In this study the electron beam is focused to a spot approximately 2-4 µm in diameter. Major element concentrations are calculated in oxide and reported as a percentage. The software used is Quantitative method: (ZAF) software.

To check the internal variability of the test, or whether there is any difference in the Mg/Ca ratio between chambers depending on the availability of optimum surfaces for probing the number of spot analyses made on each specimen was 15. Generally, larger specimens provided a greater area for probing than smaller specimens. The test wall was avoided as this is considered to be prone to metal absorption and thus may not be related to metal accumulation within the organism. The magnesium concentration of the test and of any elements present in the protoplasm were then measured.

4.3 RESULTS

4.3.1 Heavy metal pollution situation in the study area

The heavy metal pollutants measured in the study area in spring 1993 were Cd, As, Pb, Ti, Cr, Co, Cu, Ni, and V, represented in provided in appendix (1). In winter 1995 Cd, Cr, Cu, Pb, and Zn were the only metals measured. The variations in concentration of heavy metals between stations can be summarised as follows: Cadmium (Cd) content ranges between 0.1 and 4 ppm (Station 72 and 12 respectively), Figure 4.1 is a map showing that Cd concentration increases in hard ground sites and where there is a higher percentage of $CaCO_3$. The concentration of Cd is higher in spring than in winter (Figure 4.2). Cd increases with the increasing percentage of large sized sediment (coarse and very coarse sand, gravel and pebbles).

Chromium (Cr) has a concentration of 2.2 to 56.6 ppm (Station 76 and 50 respectively). The map in figure 4.3 shows an increse in Cr concentration in a seawards direction. Figure 4.4 showing that the concentration of Cr increases with increasing clay-silt.

Copper (Cu) concentration varies from 0.3 to 35.6 ppm (Station 76 and 50 respectively). The map in Figure 4.5 shows that Cu concentration also increases toward the sea, and its concentration is lower in winter than in spring. From Figure 4.6 we can see that Cu concentration increases with clay-silt.

Lead (Pb) concentration ranges from 2.3 to 96.0 ppm (Station 75 and 40 respectively). Its concentration increases in the hard ground sites and high concentration of $CaCO_3$

(Figure 4.7). It has the same trend as Cd, increasing with $CaCO_3$, and large grain-size sediments (figure 4.8).

Zinc (Zn) concentration ranges from 2.7 to 75 ppm, (Station 75 and 50 respectively). Its concentration increases toward the sea (Figure 4.9). Zn concentration increases with increasing of clay-silt (Figure 4.10).

Arsenic (As) concentration ranges from 0.9 to 17.1 ppm (Station 77 and 40 respectively). and the concentration of Cobalt (Co) ranges from 0.02 to 13.4 ppm (Station 78 and 56 respectively).Figure 4.11 shows that Arsenic concentration is associated with large grain sized sediments and $CaCO_3$, and Co concentration increases with depth and toward the sea.

Nickel (Ni) has a concentration of between 0.4 and 25.9 ppm (Stations 77/78 and 56 respectively) and the concentration of Vanadium (V) ranges from 1.1 to 49.3 ppm (Station 77 and 56 respectively). Figure 4.12 is a map showing that the percentage of the two previously mentioned metals increase towards the sea.

Titanium (Ti) concentration ranges from 0.1 to 456.0 ppm (Station 78 and 22 respectively). The concentration of Ni, V, and Ti all increase with clay-silt, and towards the sea (Figure 4.13).

The local, regional, and global enrichment factors (E_1, E_2, E_3), are given in Table 9. Comparing the concentration of heavy metals in Haifa Bay and Atlit Bay with their local background values, regional values in the Mediterrnean carbonate, and crustal averages, we can say that Haifa Bay has elevated concentrations of Cd, Pb and As.

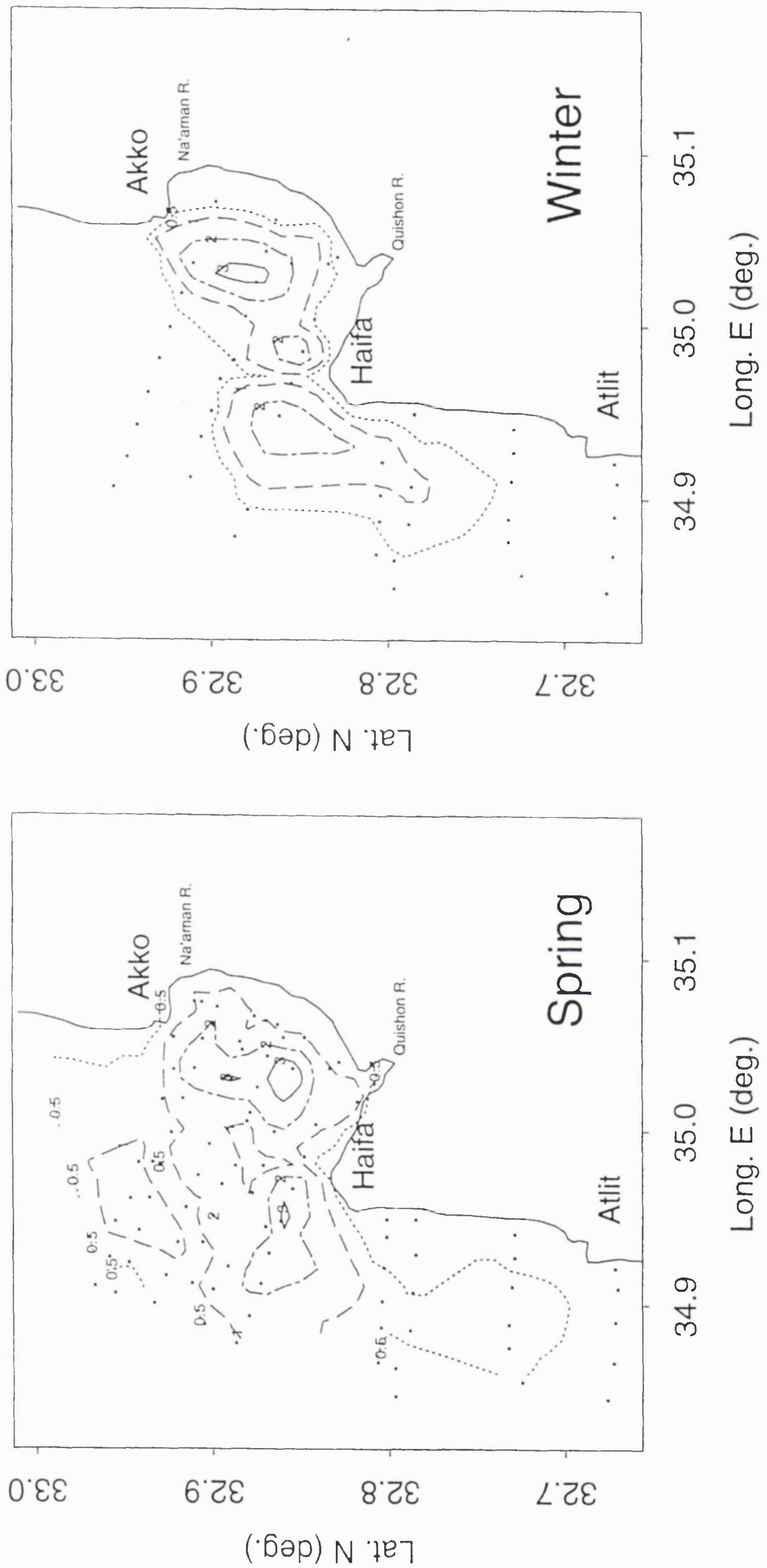


Figure 4.1. Map showing the spatial distribution of Cd concentration (ppm) in spring (May) and winter (January).

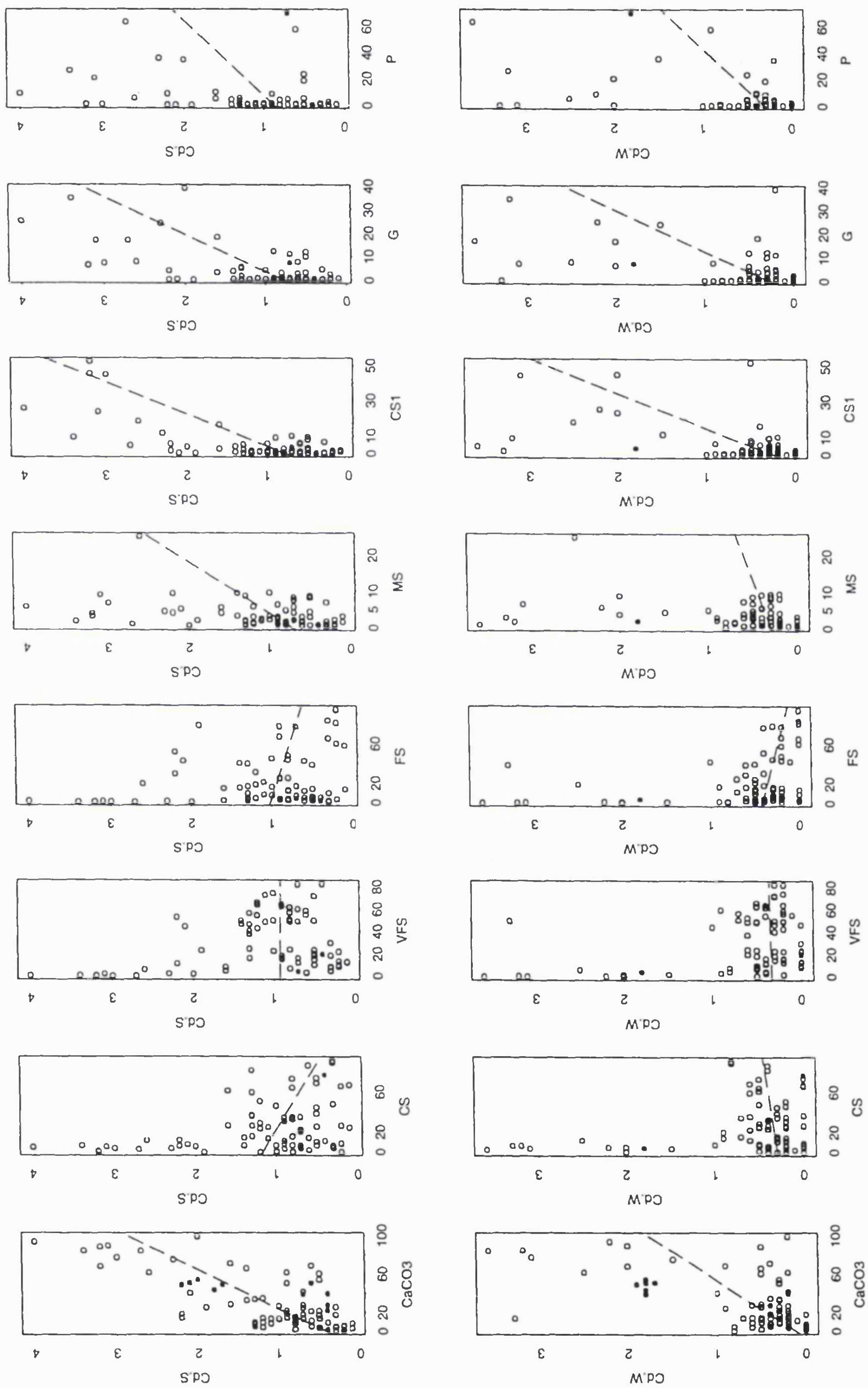


Figure 4.2. Cadmium concentration as function of sediment grain size fractions and $CaCO_3$ in spring and winter.

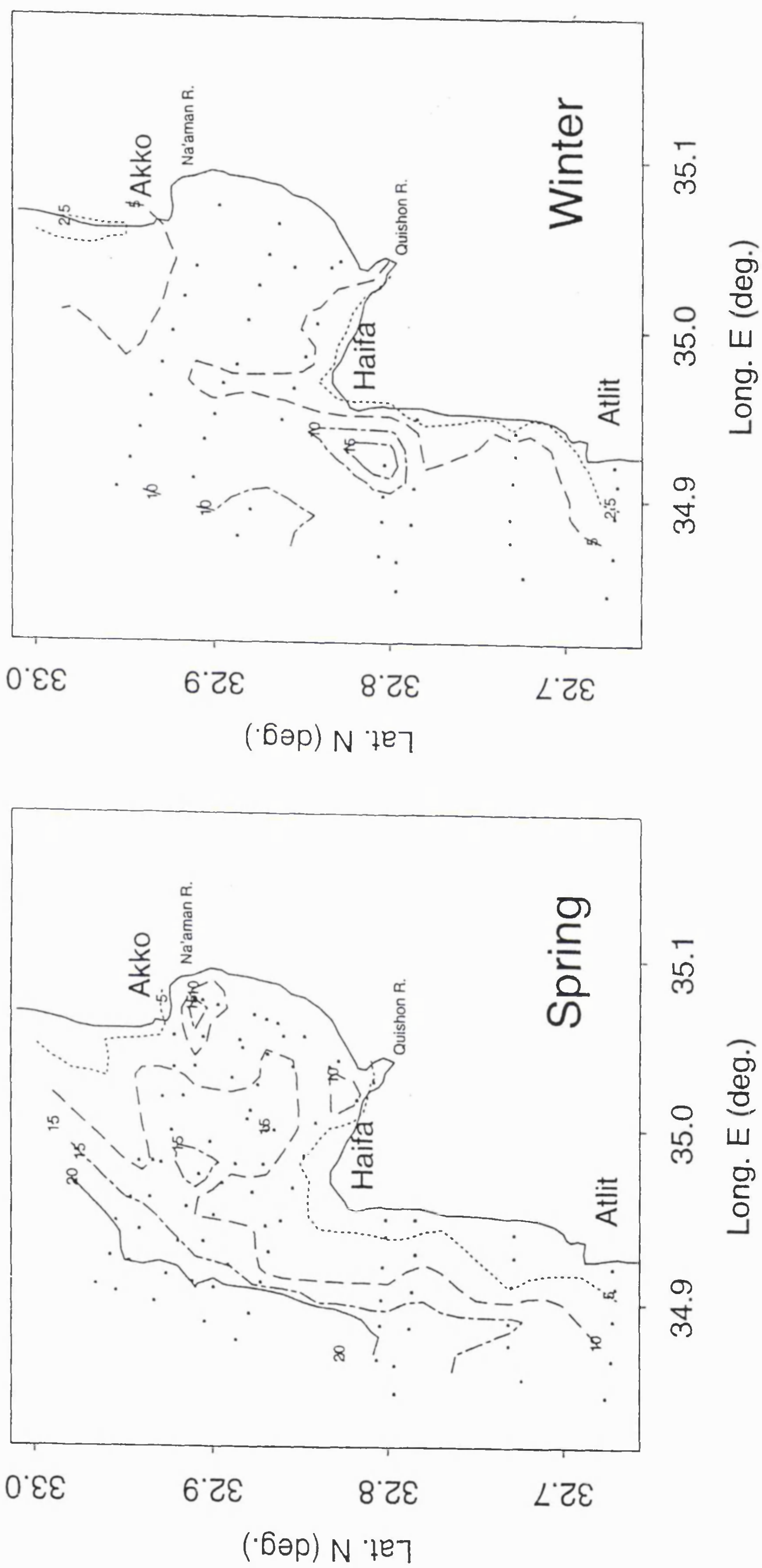


Figure 4.3. The spatial distribution of Cr concentration (ppm) in spring (May) and winter (January).

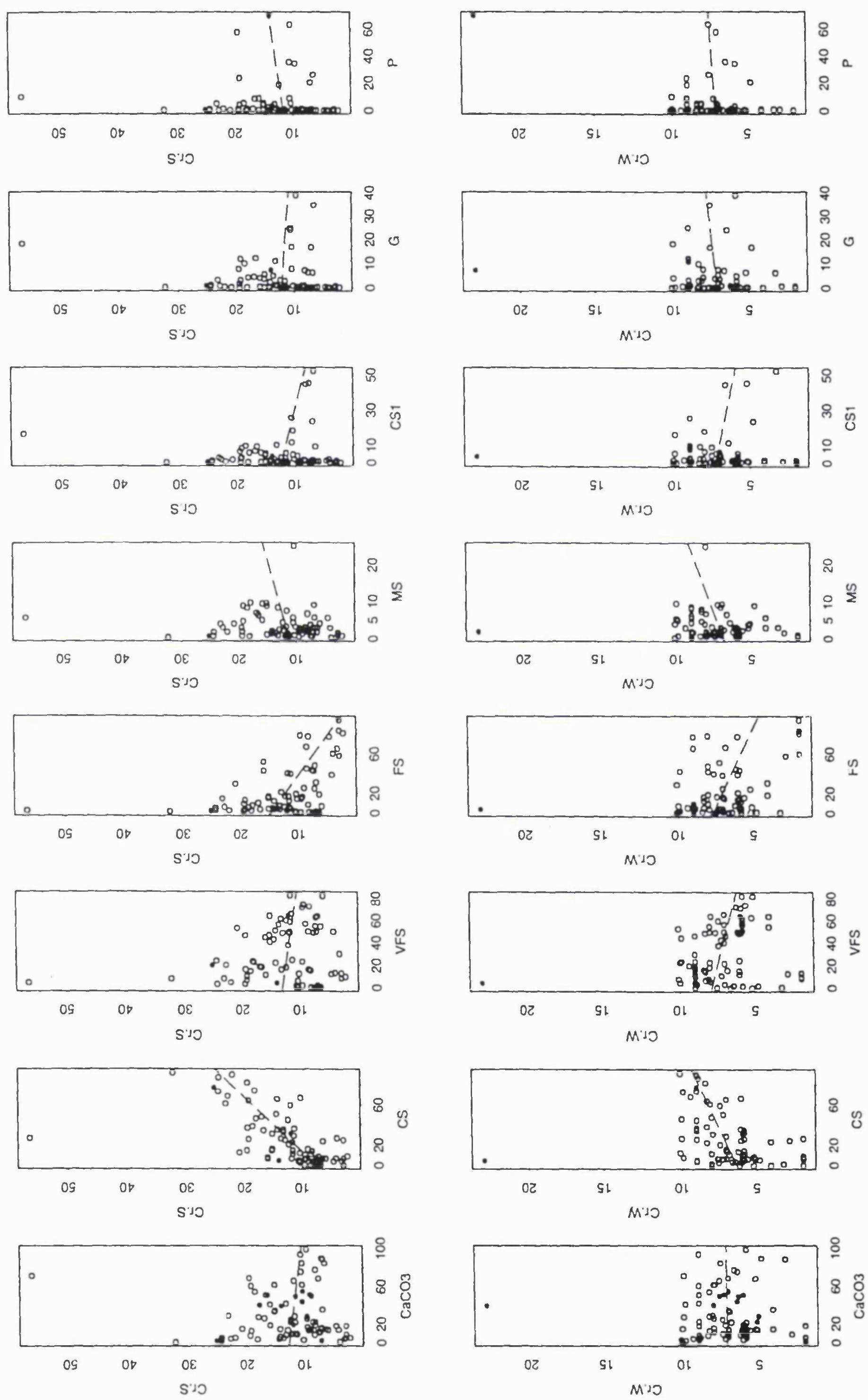


Figure 4.4. Chromium concentration as function of sediment grain size fractions and $CaCO_3$ in spring and winter.

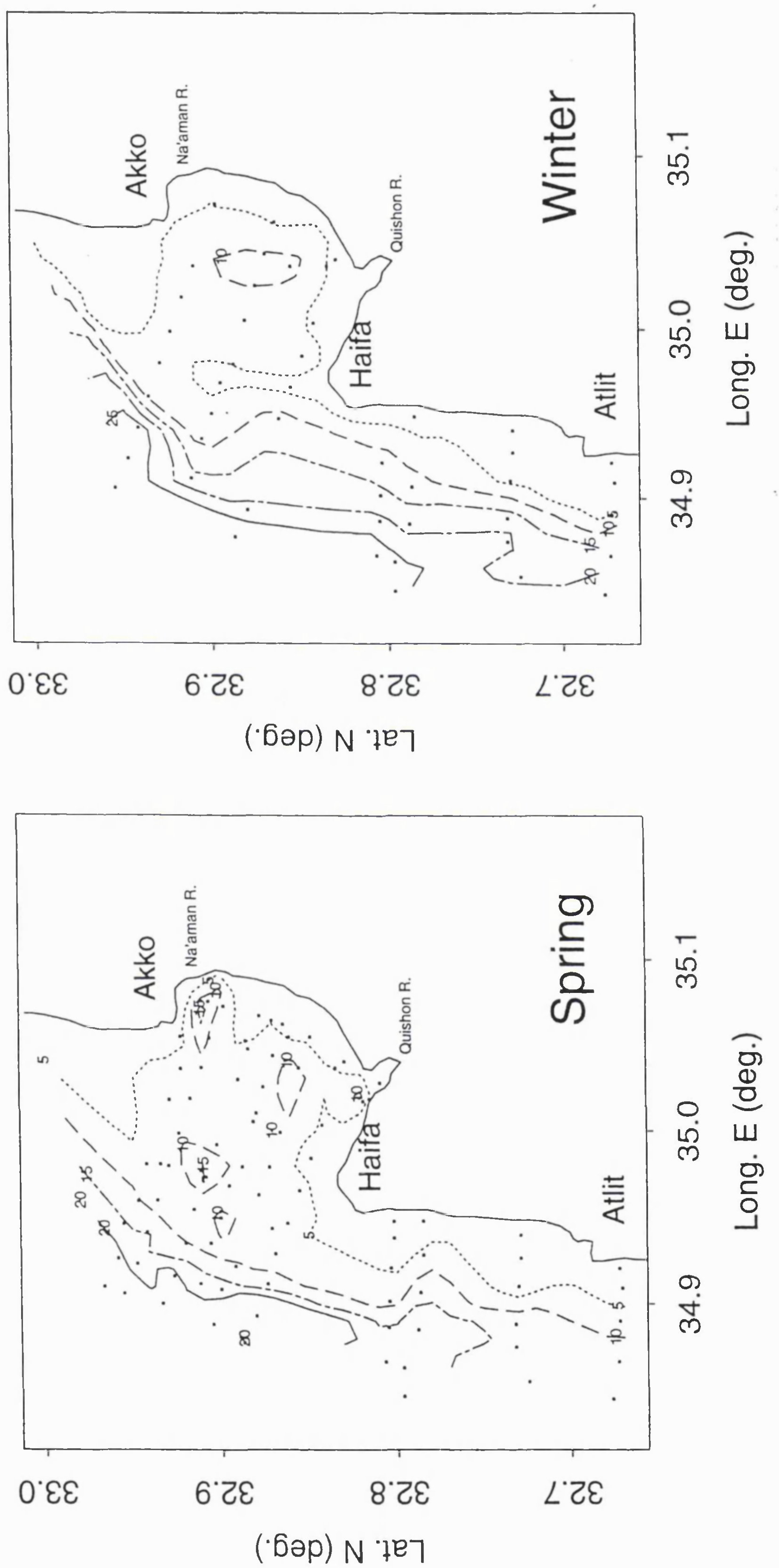


Figure 4.5. Map showing the spatial distribution of Copper concentration (ppm) in spring and winter.

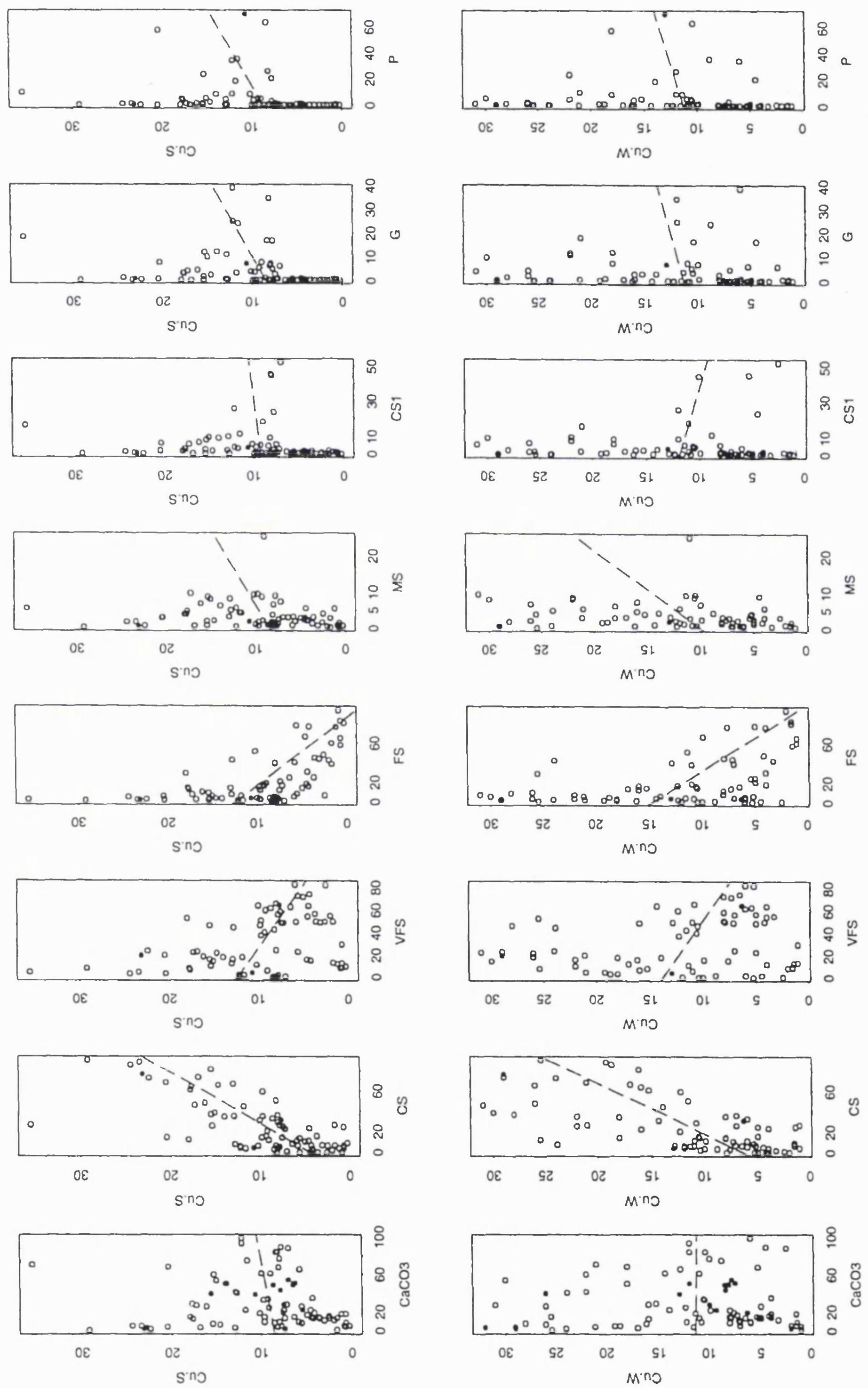


Figure 4.6. Copper concentration as function of sediment grain size fractions and $CaCO_3$ in spring and winter.

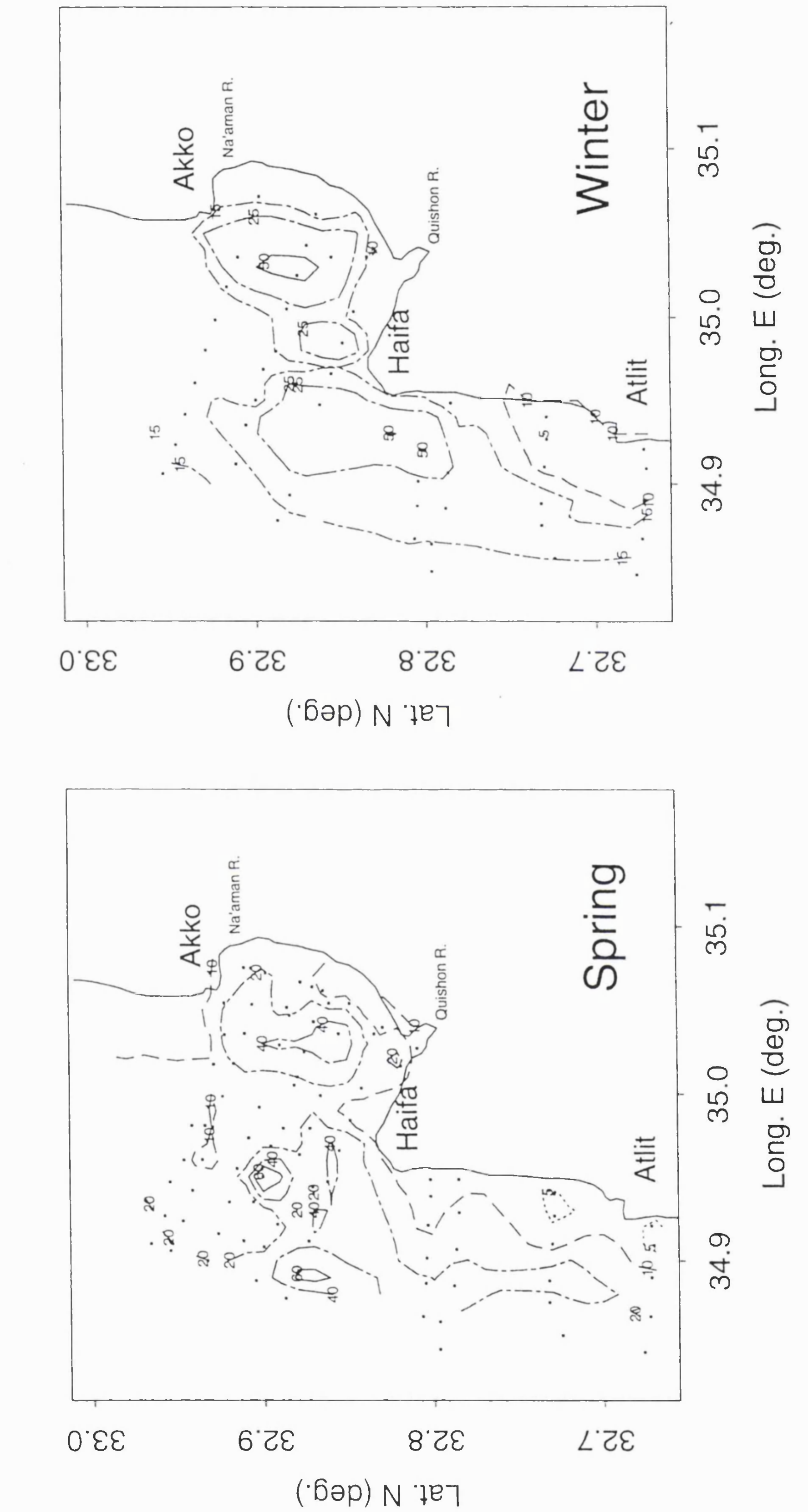


Figure 4.7. Map showing the spatial distribution of Lead concentration (ppm) in spring (May) and winter (January).

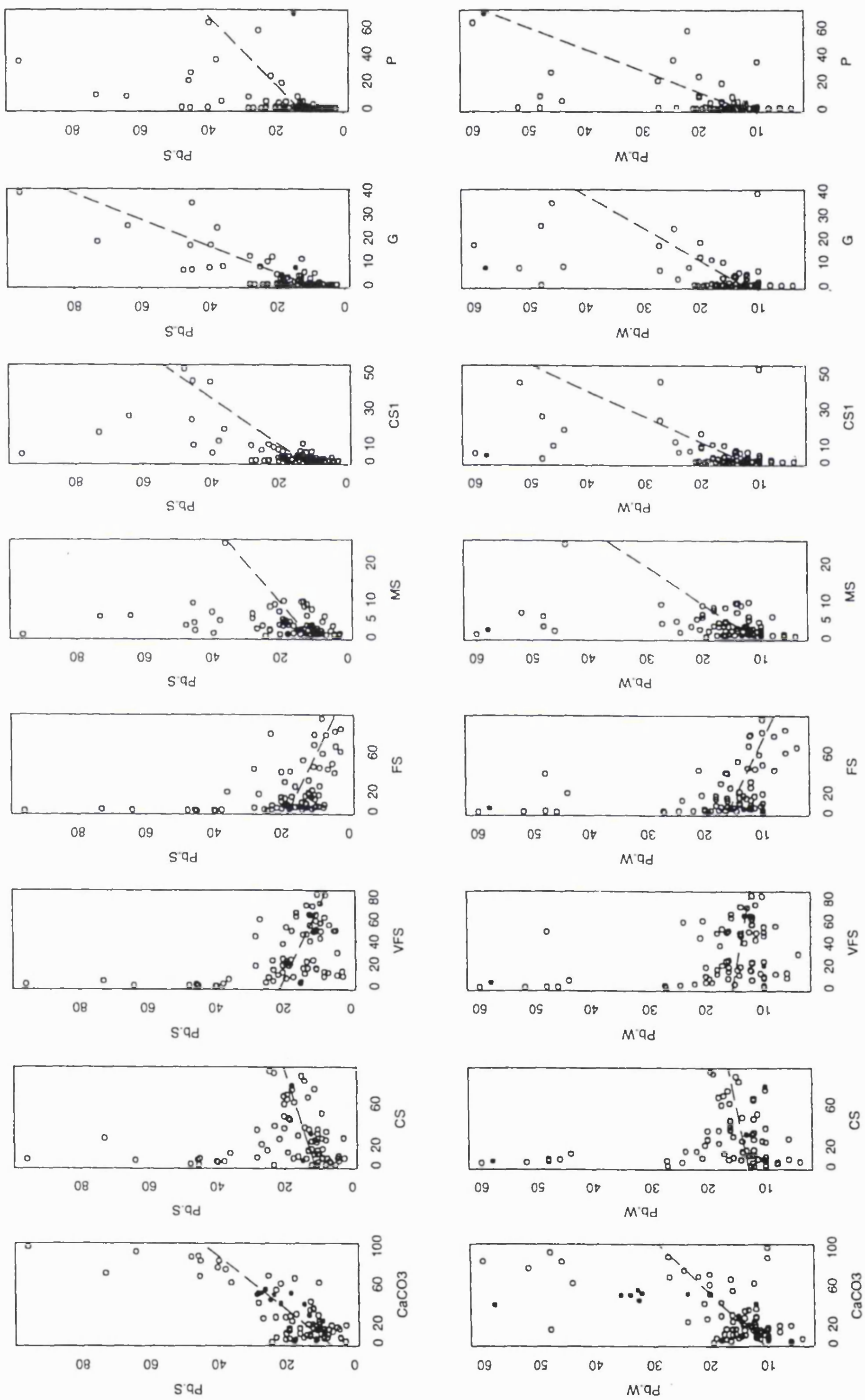


Figure 4.8. Lead concentration as function of sediment grain size fractions and $CaCO_3$ in spring and winter.

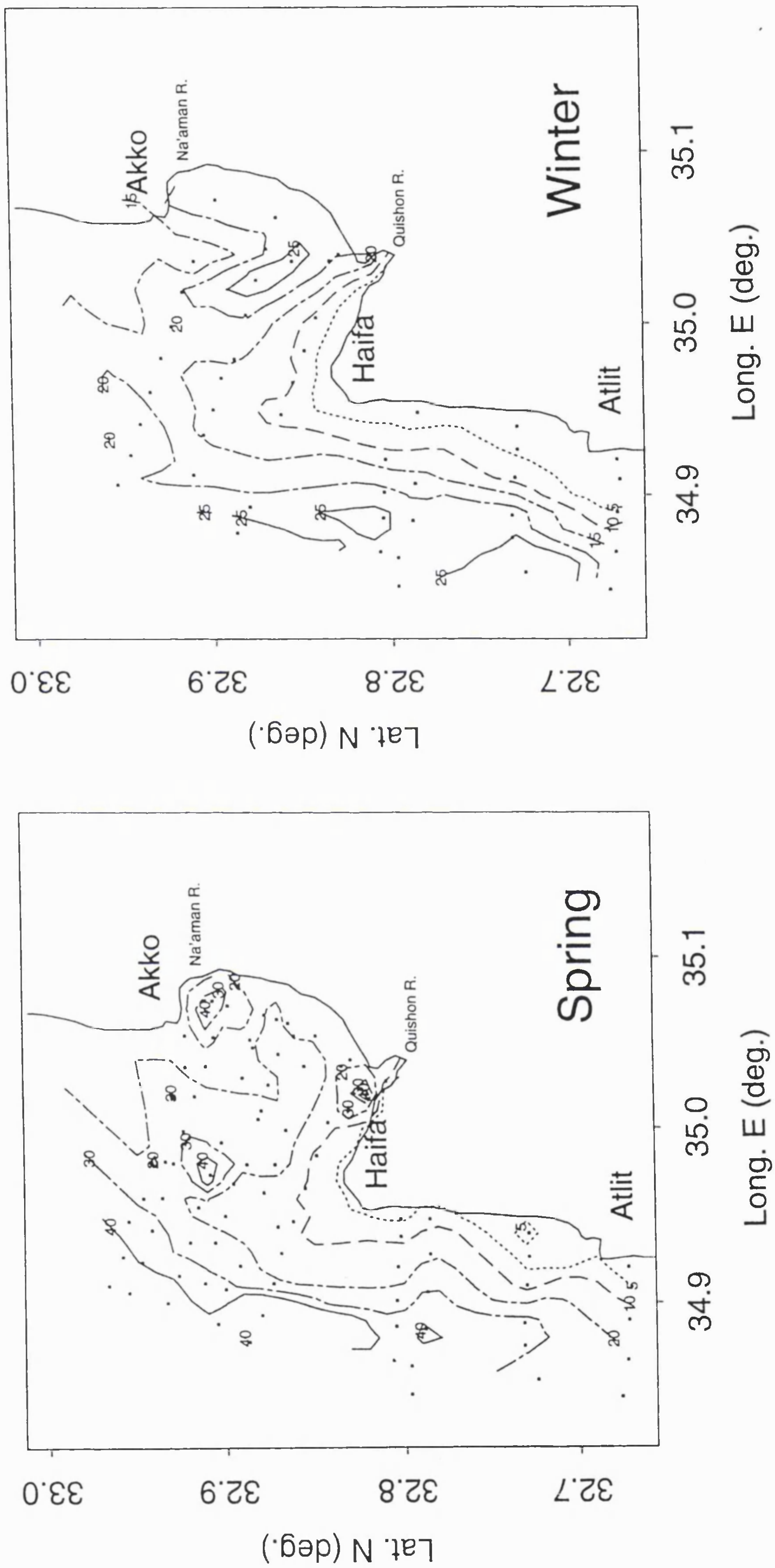


Figure 4.9. The spatial distribution of Zinc concentration (ppm) in spring (May) and winter (January).

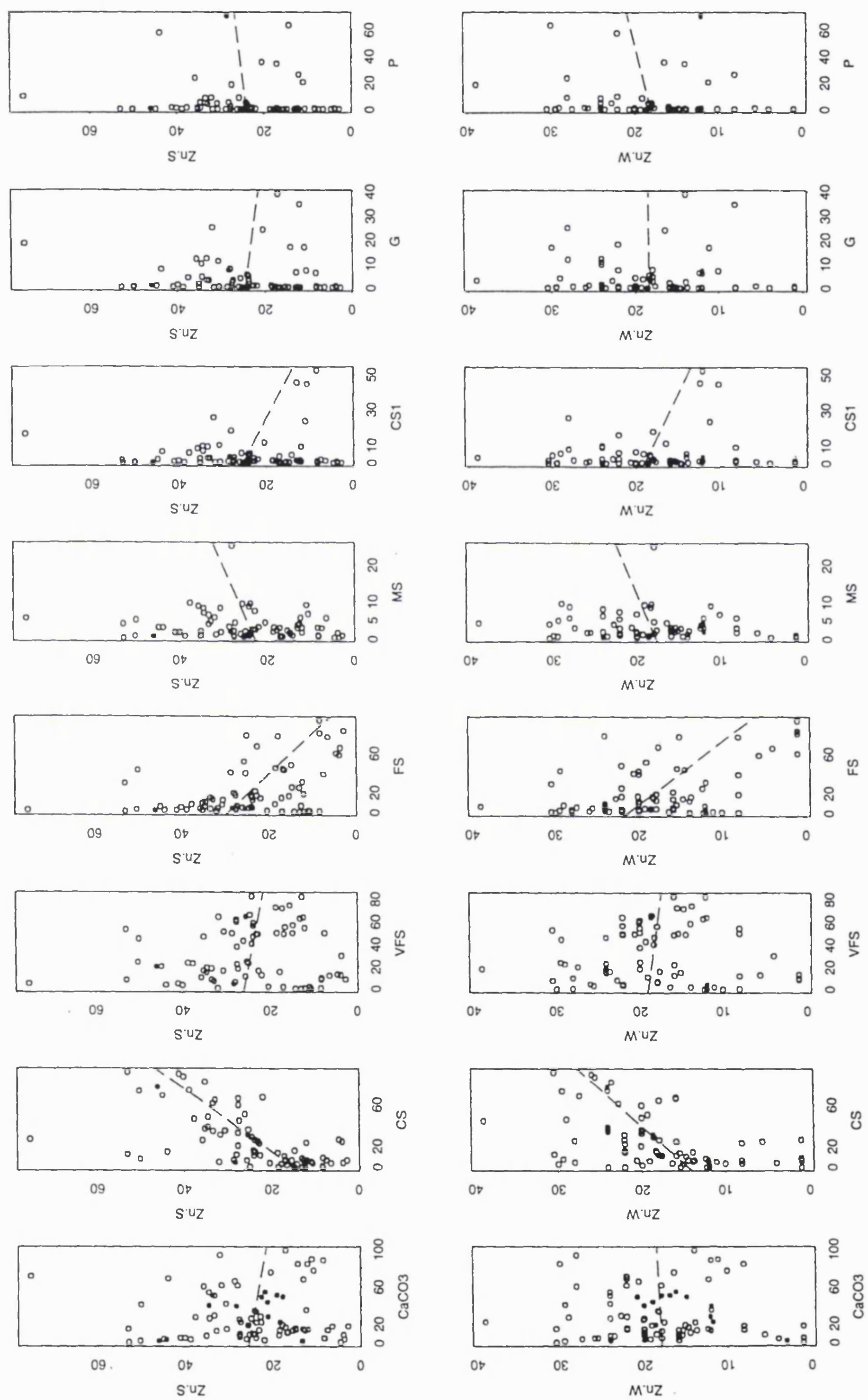


Figure 4.10. Zinc concentration as function of sediment grain size fractions and $CaCO_3$ in spring and winter.

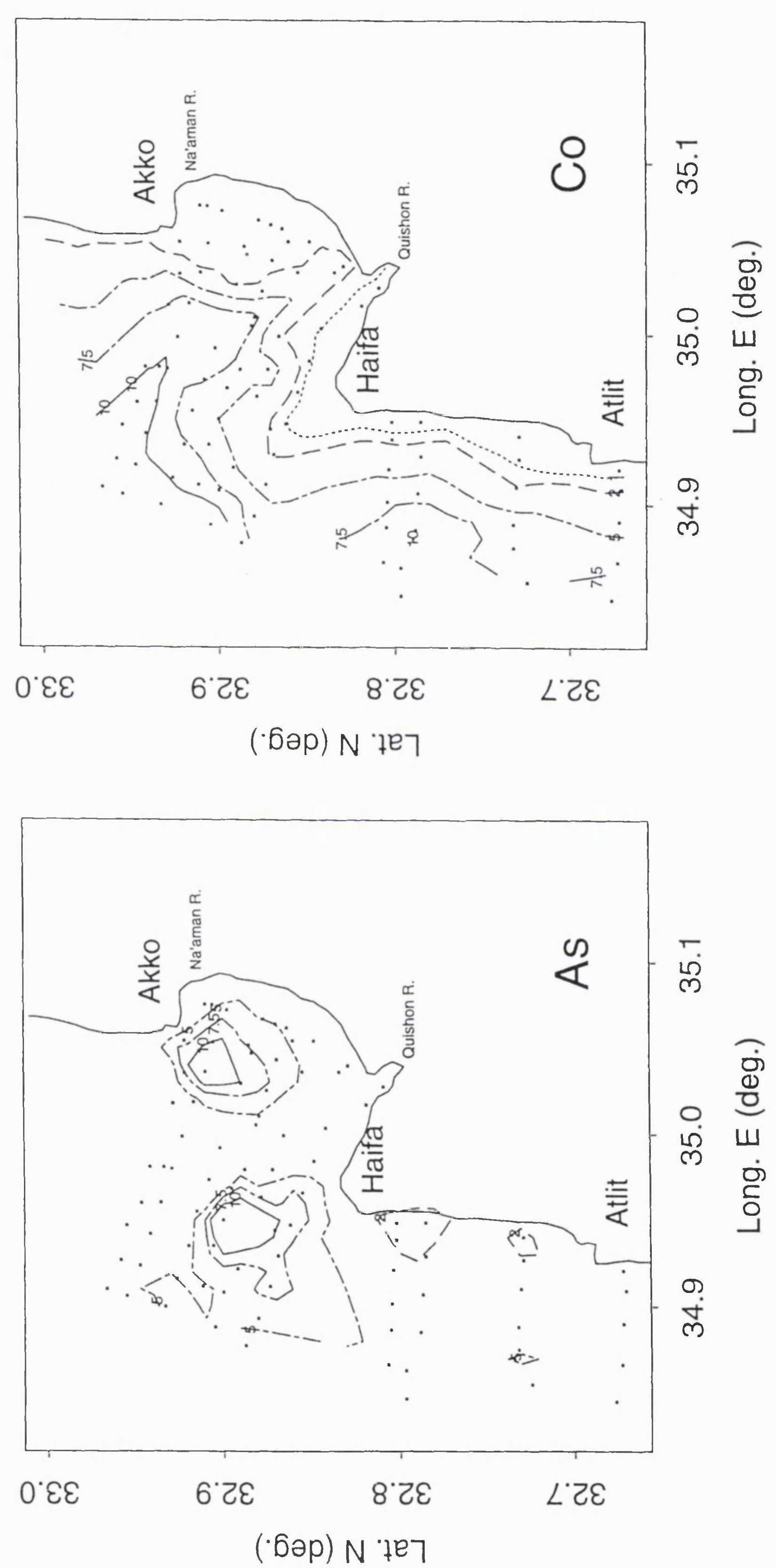


Figure 4.11. The spatial distribution of Arsenic and Cobalt concentration (ppm) in spring (May).

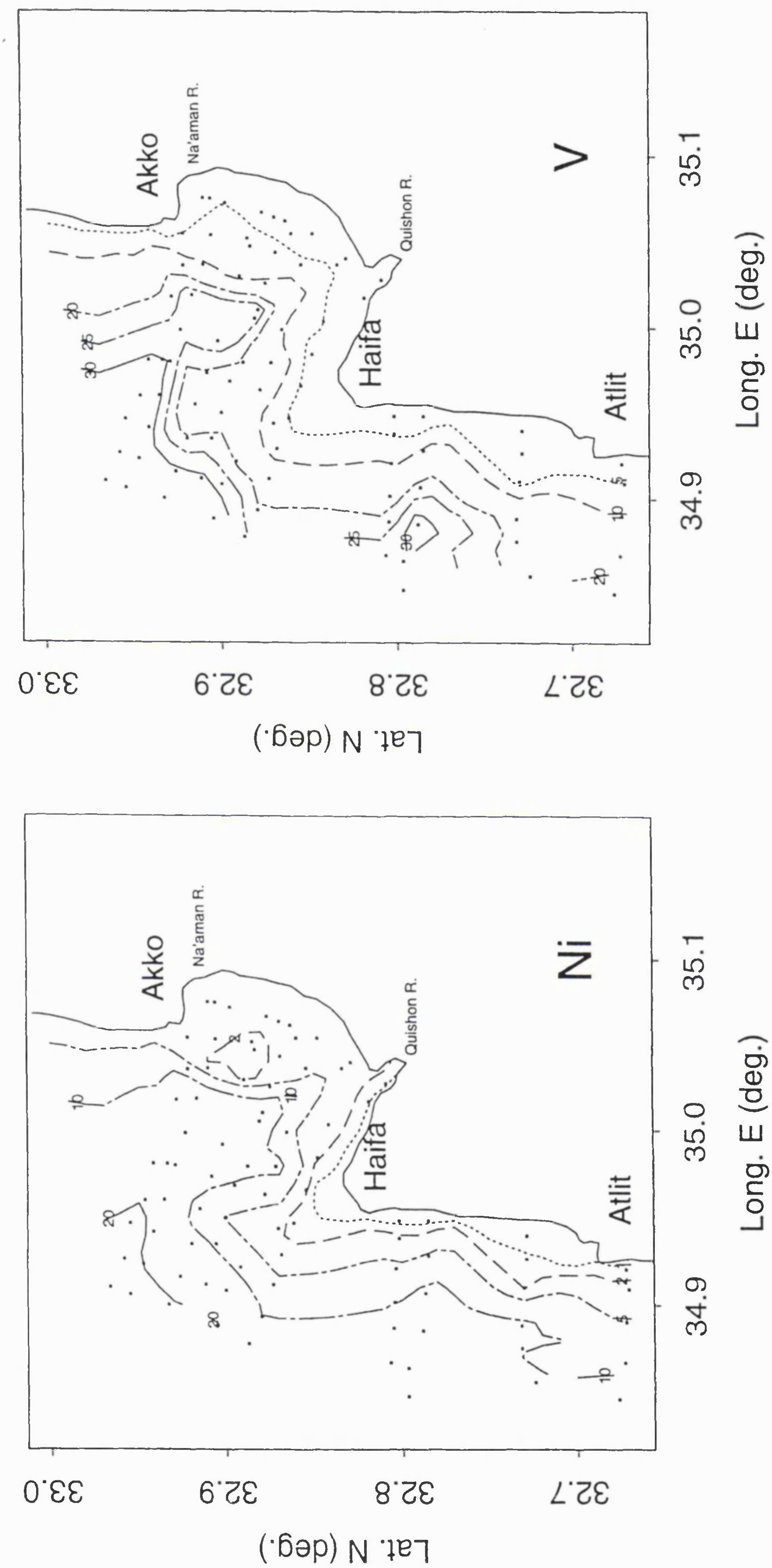


Figure 4.12. The spatial distribution of Nickel and Vanadium concentration (ppm) in spring (May).

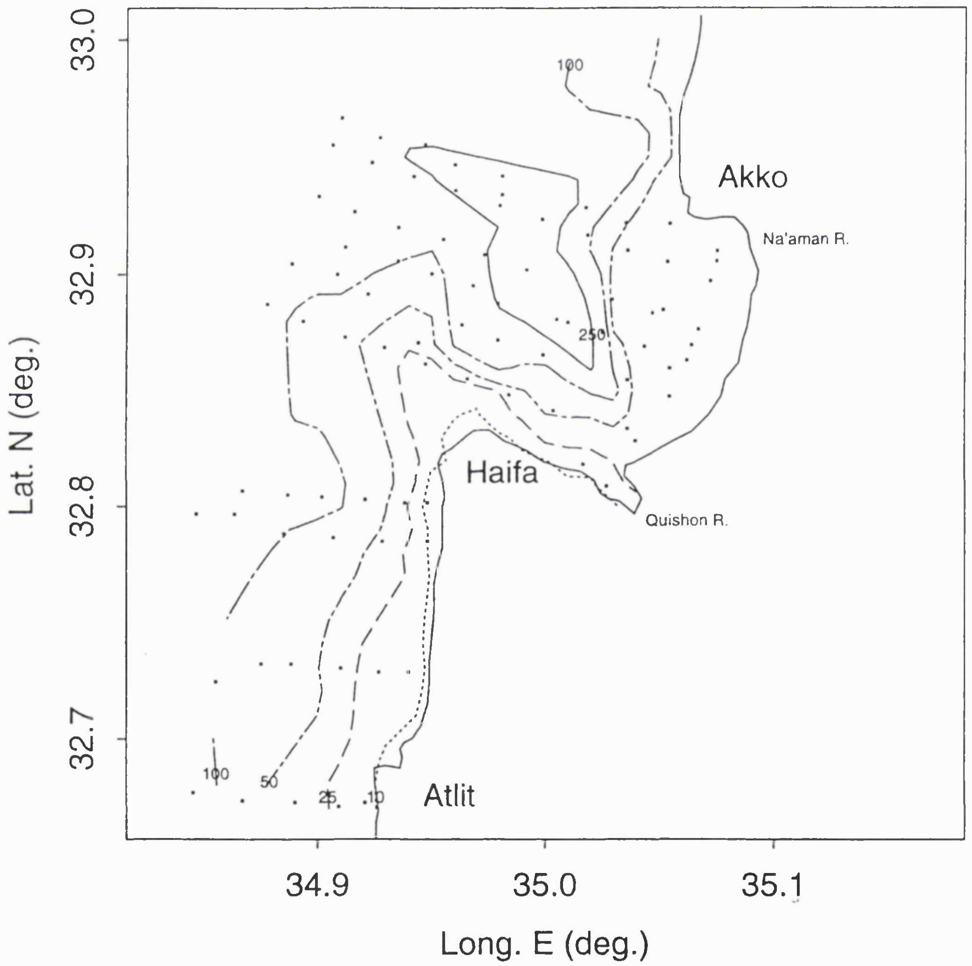


Figure 4.13. The spatial distribution of Titanium concentration (ppm) in spring (May).

4.3.2 The effect of heavy metal contamination on population structure (Abundances, number of species, species diversity)

4.3.2.1 The effect of heavy metal contamination on foraminiferal abundance

The plots are based on the Atlit Bay data which is the least contaminated, so any trends shown could be expected to operate in the more contaminated environment of Haifa Bay. This is confirmed by the patterns shown on the maps. Some of the elements, such as As, were not included in the plots because thay were recorded for only a few stations in one season.

Figure 4.14 shows that the total living foraminiferal test abundance (N_t) decreases with increasing $CaCO_3$. The abundance also decreases with increasing concentrations of all heavy metals concentration in the study area in both spring and winter. The only exception is the Cd plot for spring, where no trend is apparent. However, in some selected sites, eg. Station 1 (a polluted site) the N_t is less (26 tests / 5g sediment) than at station 76 (146 tests / 5g sediment), a relatively nonpolluted site.

4.3.2.2. The effect of heavy metal contamination on number of species and species diversity

No clear correlation is shown between the number of total living species and the concentration of the $CaCO_3$ in either season. The species number decreases when the concentration of the Cd, Cr, and Pb increases, and this effect is more obvious in winter than in spring (Figure 4.15).

It is instructive to compare Cd concentrations and species numbers at selected sites. For example, Stations 78, 41 and 59 are less contaminated with Cd (0.1 ppm, 0.5 ppm and 0.3 respectively) and have the species numbers of 18, 41, and 23 respectively. By contrast, Stations 12, 37 and 51 which have higher Cd concentrations (4 ppm, 3.4 ppm and 1.6 respectively); have species numbers of 6, 13 and 18 respectively. From this comparison we can see that Cd has a negative effect on the number of species in the study area in both seasons.

Figure 4.16 shows a similar trend for diversity as the number of species, except for the Cd, Cr, Pb plots for winter, which show a decrease in species diversity with increasing concentration of those heavy metals. The other plots show a very weak increase of species diversity when the concentration of heavy metal increases. From the examples listed in section 4.3.4 we see that the species diversity at some selected stations decreases with increasing heavy metal concentrations

4.3.2.3. The effect of heavy metal contamination on the size of the foraminiferal test.

The size ratio of the number of (extra large + large) / (small + medium) test sizes for the living foraminifera as a function of element concentration applied to the combined Atlit and Haifa Bay data set is plotted in Figure 4.17. This plot shows that in spring the number of large sized living tests increase slightly at the stations that have high $CaCO_3$ concentrations. The samples taken from the hard ground are dominated by *Amphistegina lobifera* and *Heterostegina depressa* (larger foraminifera) and are characterized by the highest $CaCO_3$ content in the sediments. The ratio decreases when the concentration of heavy metal increases. The $CaCO_3$ plot in winter is contrary to the plot for spring, but overall trends are generally similar in the two seasons.

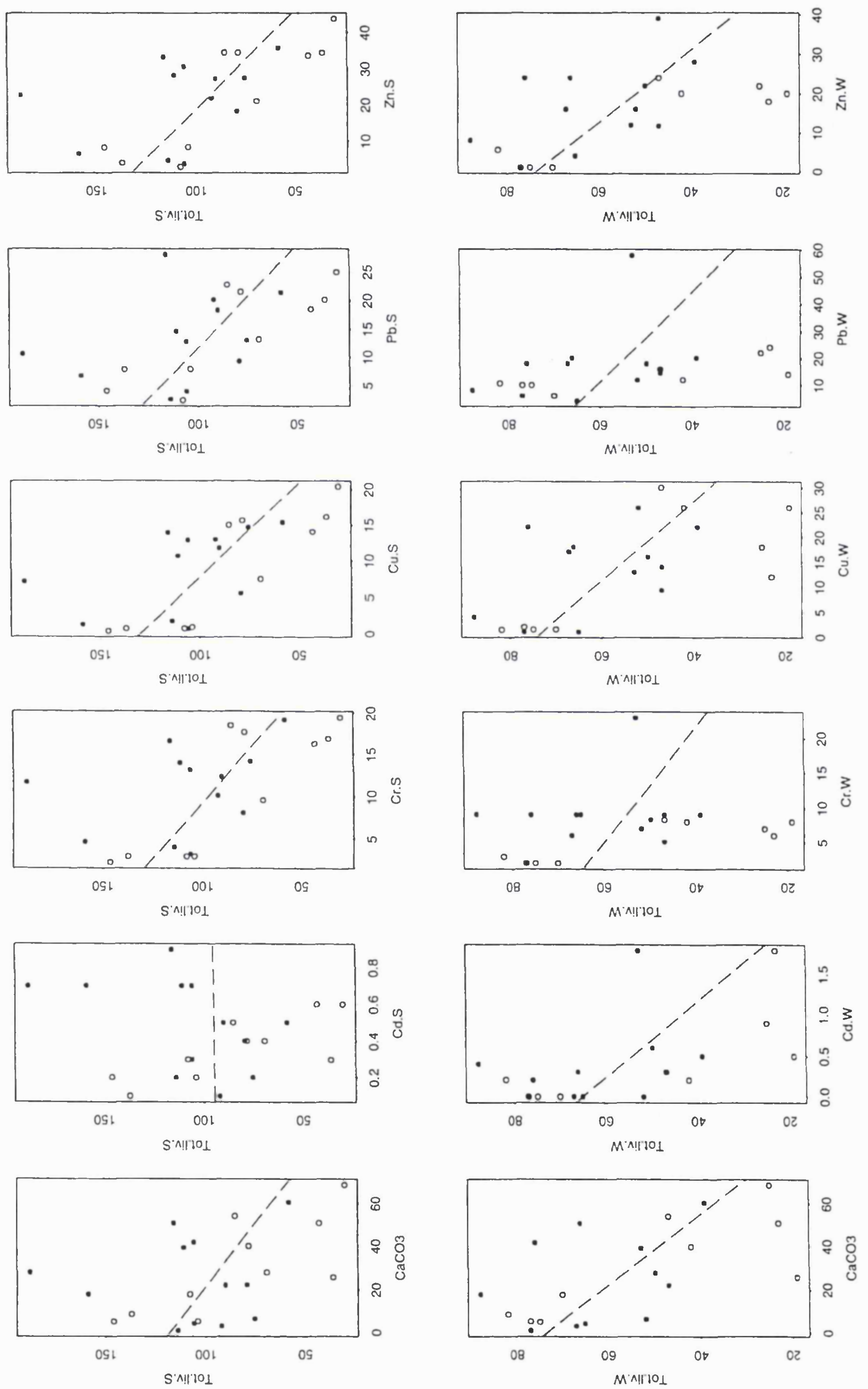


Figure 4.14. Total live count (S and W) as function of geochemistry (Atlit Bay); open points, estimated.

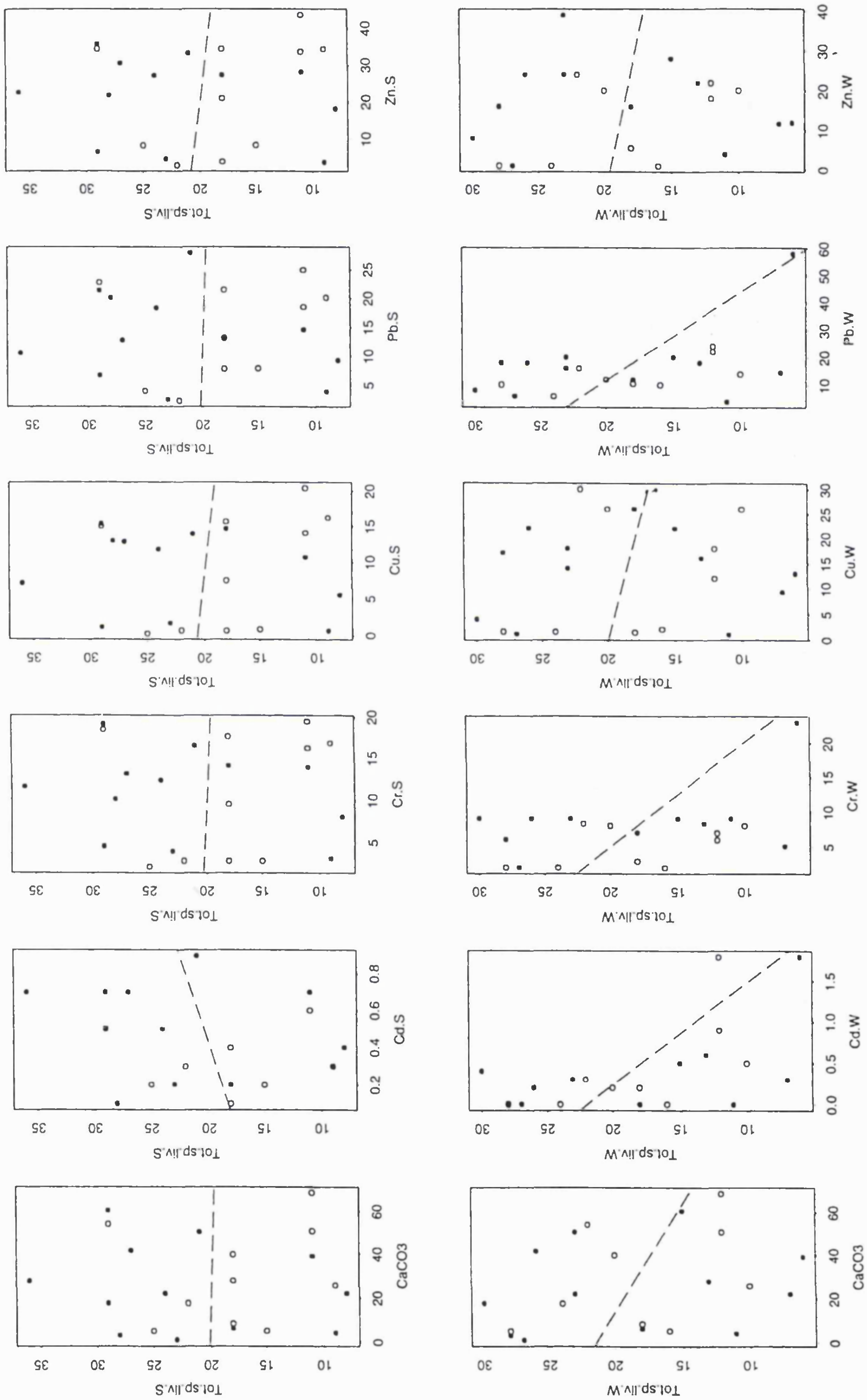


Figure 4.15. Total live species (S and W) as function of geochemistry (Atlit Bay); open points, estimated.

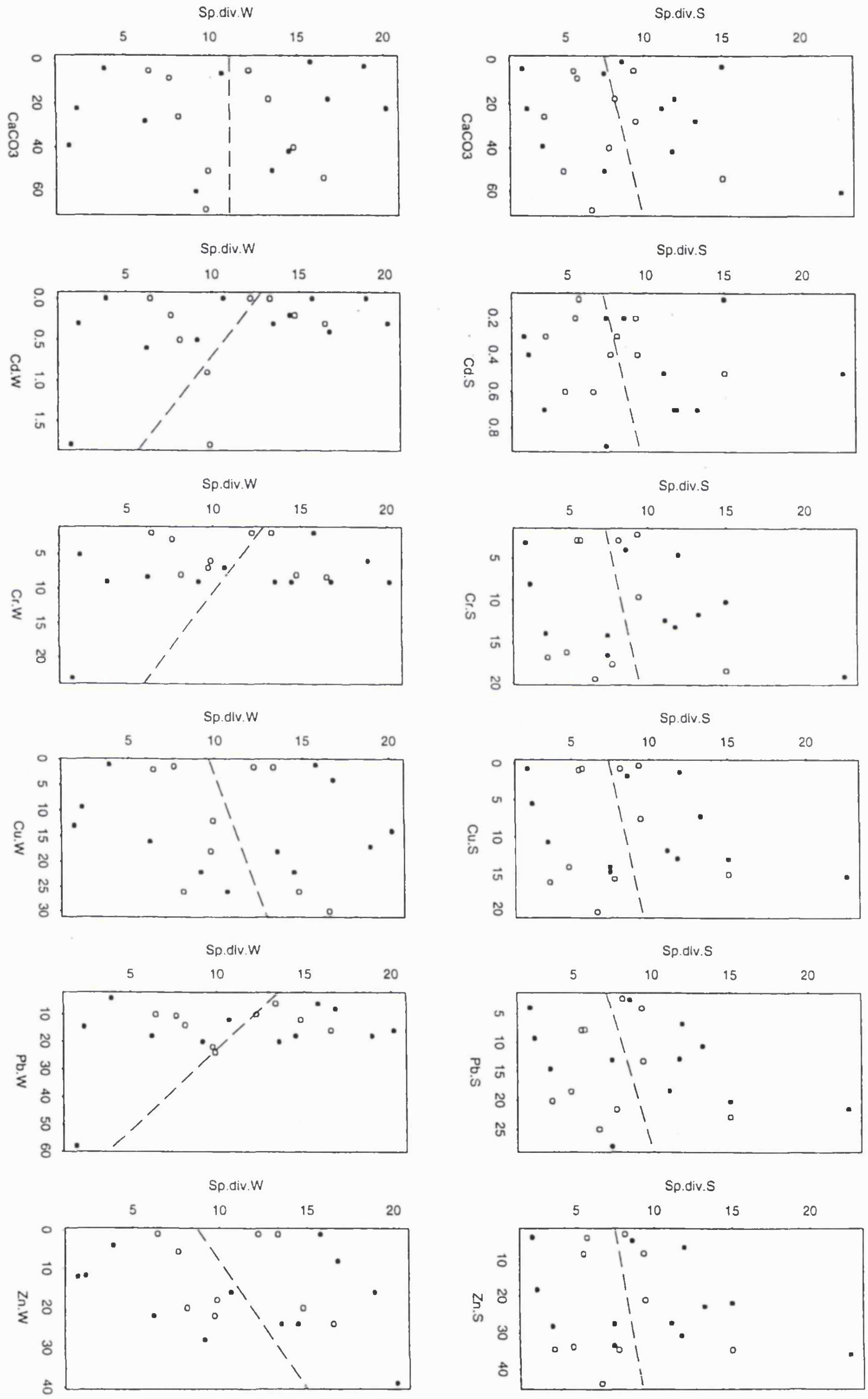


Figure 4.16. Species diversity (S and W) as function of geochemistry (Atlit Bay); open points, estimated.

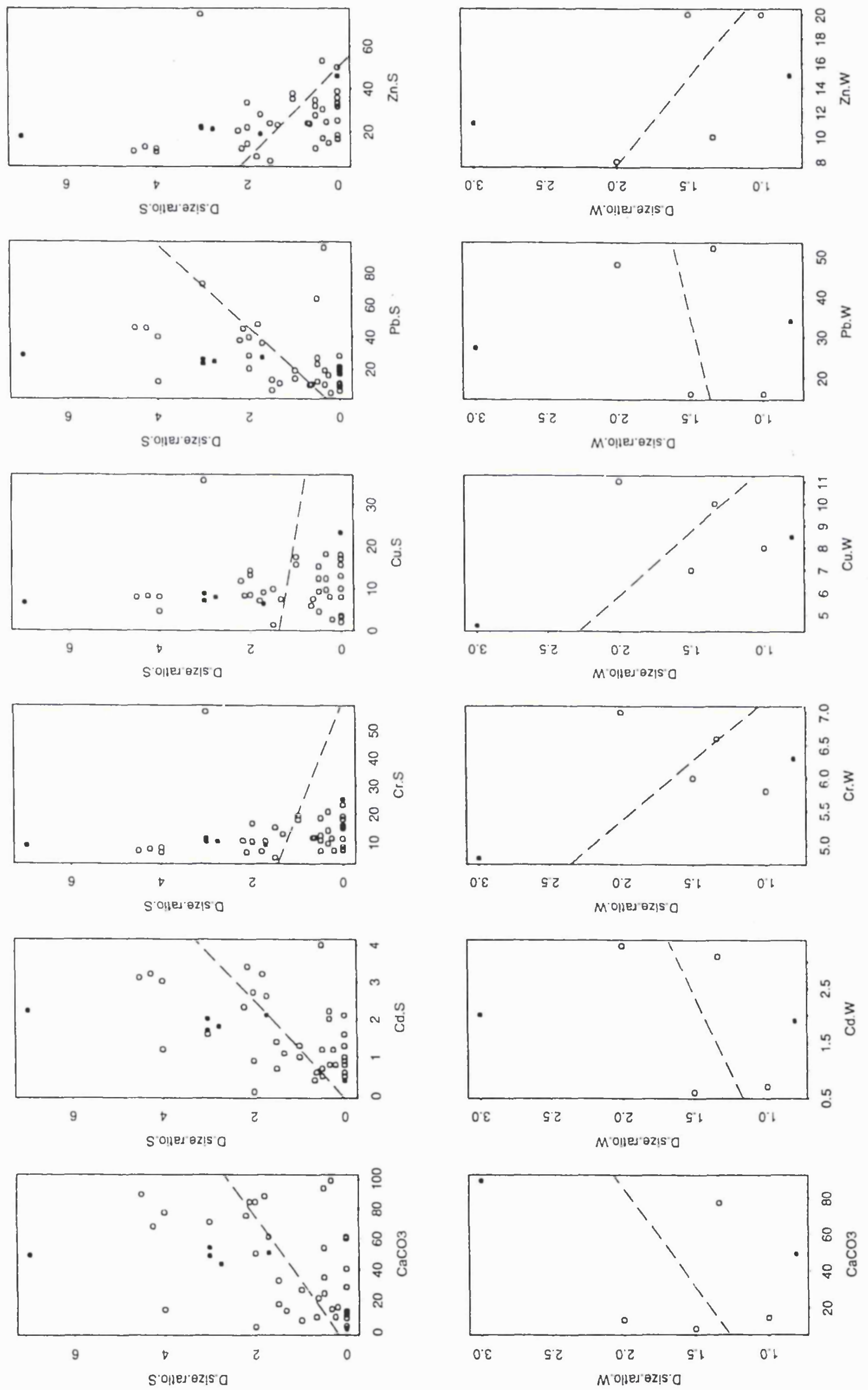


Figure 4.17. Living foraminiferal test size ratio (XL + L) / (S+M) as function of geochemistry (Atlit Bay); open points, estimated.

4.3.2.4. Examples of the effect of heavy metal pollution on the foraminiferal population at selected stations.

The following section, particular stations were chosen for comparison because they are characterized by similarity in some oceanographic parameter (e.g depth, substrate), yet they differ in the concentration of heavy metals.

1) Station 77 is considered to be a relatively unpolluted station. The absolute and relative abundances, species diversity, and number of species is higher than at Station 40 (a polluted site). the substrate is sand at Station 77, whereas at Station 40, 75% is large sized grains (pebbles, gravel).

2) Station 50 is a highly polluted station, and is chosen as an example of heavily polluted site and Station 76 is chosen as relatively unpolluted site. The absolute and relative abundances, species diversity, and number of species is higher at Station 76 than at Station 40. The size of the foraminiferal test 50% and 32% is XL+L test size at Station 76 and Station 50 respectively. The M+S size represents 43% and 67% of the foraminiferal test at Stations 76 and 50 respectively.

The difference in the population parameters between the two stations can be affected by more than one factor. One such factor is the substrate at Station 76 is 80% fine sand, whereas at Station 50, 60% is large size grains (pebbles, gravel and coarse sand) and 23% is clay and silt. No deformed tests where found at Station 76, whereas 10% of the living tests at Station 50 are deformed.

3) Another example is Station 1, a polluted site in Haifa Bay near the outlet of Qishon River and station 76, an unpolluted site in Atlit Bay. The same difference mentioned in the previous examples can be applied in this case. Ninteen percent of the foraminiferal tests are of the L size and 57.7% of the M size and 23.1% is of the S size at station 1. This changes to 21.9% of the XL size, 30.8% of the L size, 43.2% od the M size and 4% of the S size. It is obvious that the absolute abundance, relative abundance, number of species and species diversity are of lower values at Station 1 than at Station 76. The foraminiferal tests are smaller in size at Station 1 than at Station 76. Deformed living test were found at all the polluted sites, whereas there were no deformed living individuals at the unpolluted site.

4.3.3 The effect of heavy metal contamination on test morphology

4.3.3.1. Spatial distribution of deformed tests

Living deformed tests have been observed at 65% of the stations in Haifa Bay and at 50% of the stations in Atlit Bay, in the spring sample set. In winter, the percentage of deformed living tests decreased to 26.6% and 9.5% in Haifa and Atlit Bay respectively. The number of deformed tests increase with increasing Cd and Pb concentrations and with increasing percentage of $CaCO_3$ (this can be observed mostly in spring).

In winter, the percentage of living deformed tests in the near shore region is 0% except for the hard ground regions, and the area close to 200 m depth. This might be because in winter the wave action is much greater (Nir, 1985), so that the redistribution of sediments and probably heavy metals is most intense. The erosional power of the waves against portions of the submerged ridges should likewise be greater, and may be responsible for an additional internal sediment supply. Figure 4.18 shows that the number of deformed living tests / living test per site. The ratio increases with increasing Cd and Pb in spring. The number of deformed tests are fewer in winter, and these disappear from station near the shoreline at Qishon River harbour, but a weak correlation with Cd and Pb is still found. Figure 4.19 presents a map of the count of number of deformed tests at each site.

4.3.3.2. Number of living deformed species

The number of deformed living species in spring at Haifa and Atlit Bay is 47 and 22 respectively. In winter the number of living deformed species decreases to 13 and 2 species in Haifa and Atlit Bay respectively. Figure 4.20 gives a map of the spatial distribution of the ratio of deformed / living species in the study area in spring and winter. Figure 4.21 represents the number of deformed living species / number of living species. The ratio has a positive correlation with $CaCO_3$, Cd, and Pb in both seasons.

4.3.3.3. Size of living deformed foraminiferal tests

The living deformed tests in the study area are dominated by large size tests. The distribution of the XL, L, and M deformed test size are shown in Figures 4.22, 4.23, and 4.24. The ratio of XL+L (living deformed test) / S+M (living deformed test) show a positive relationship with $CaCO_3$, and the concentration of Cd and Pb in spring. On the other hand it has negative relation to Cr, Cu and Zn. Because of the disposition of the data points these trends may not be significant. The winter data are based

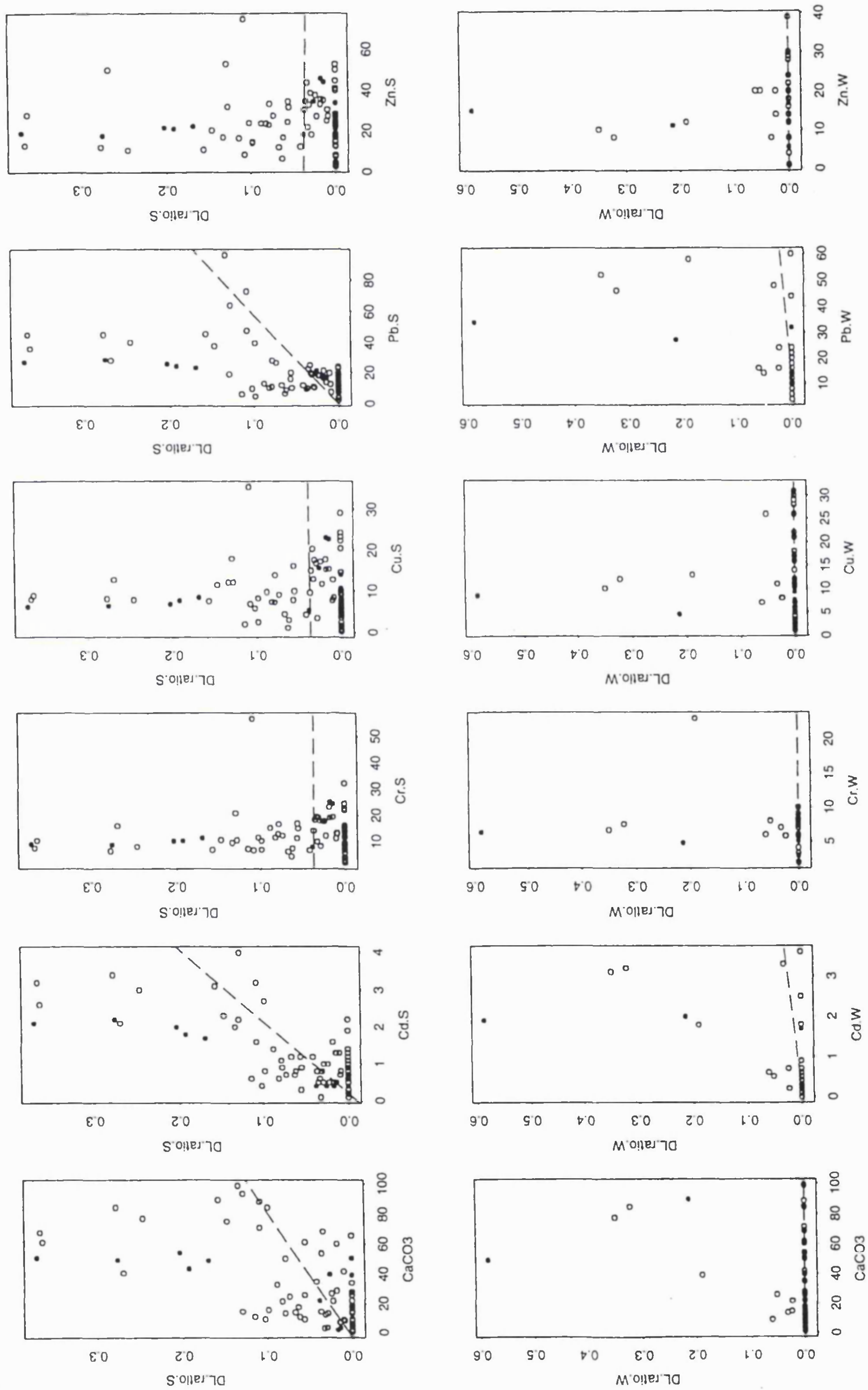


Figure 4.18. The deformed living test (S and W) as function of geochemistry; open point, estimated.

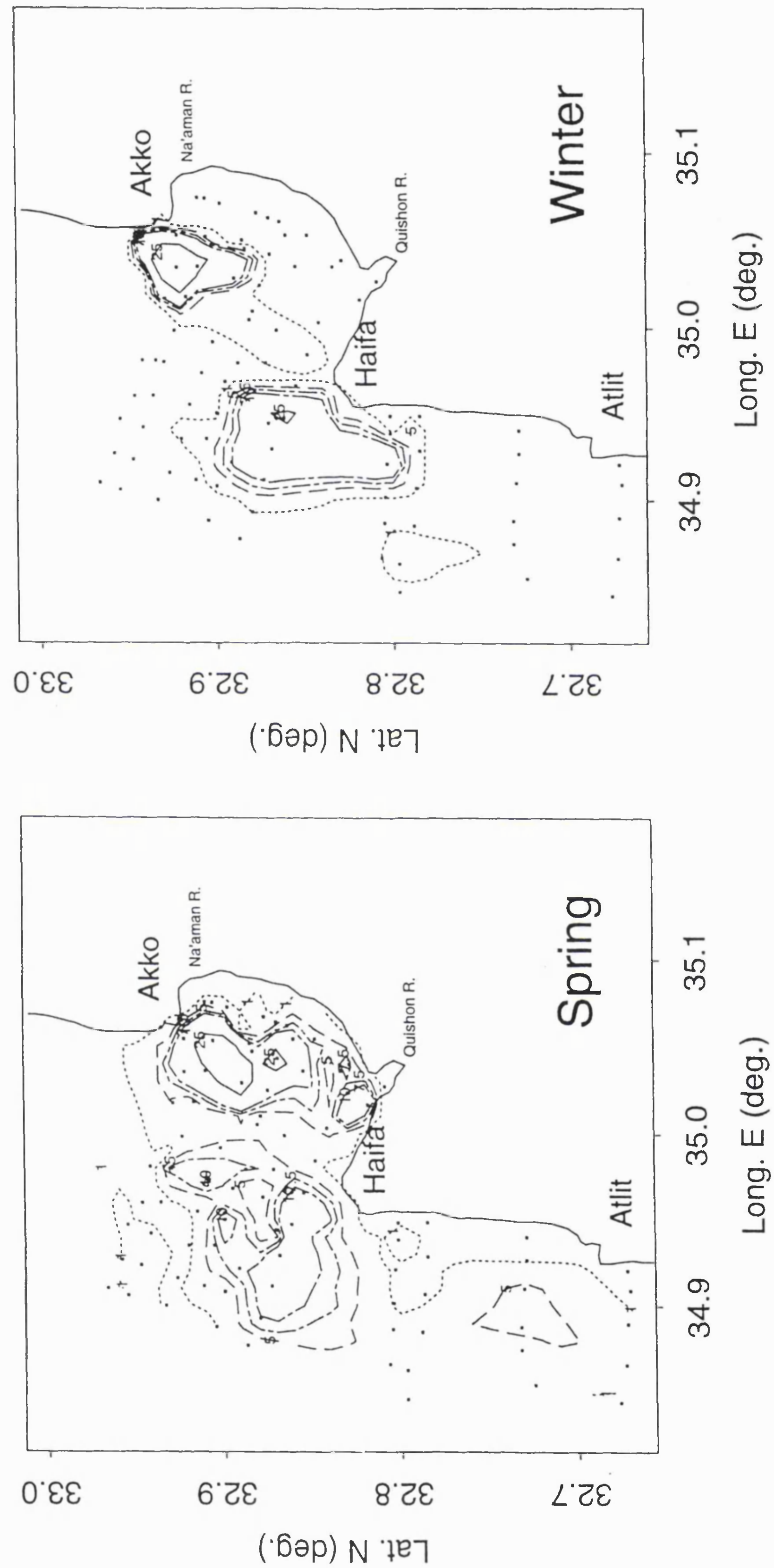


Figure 4.19. The spatial distribution of deformed living total count per station.

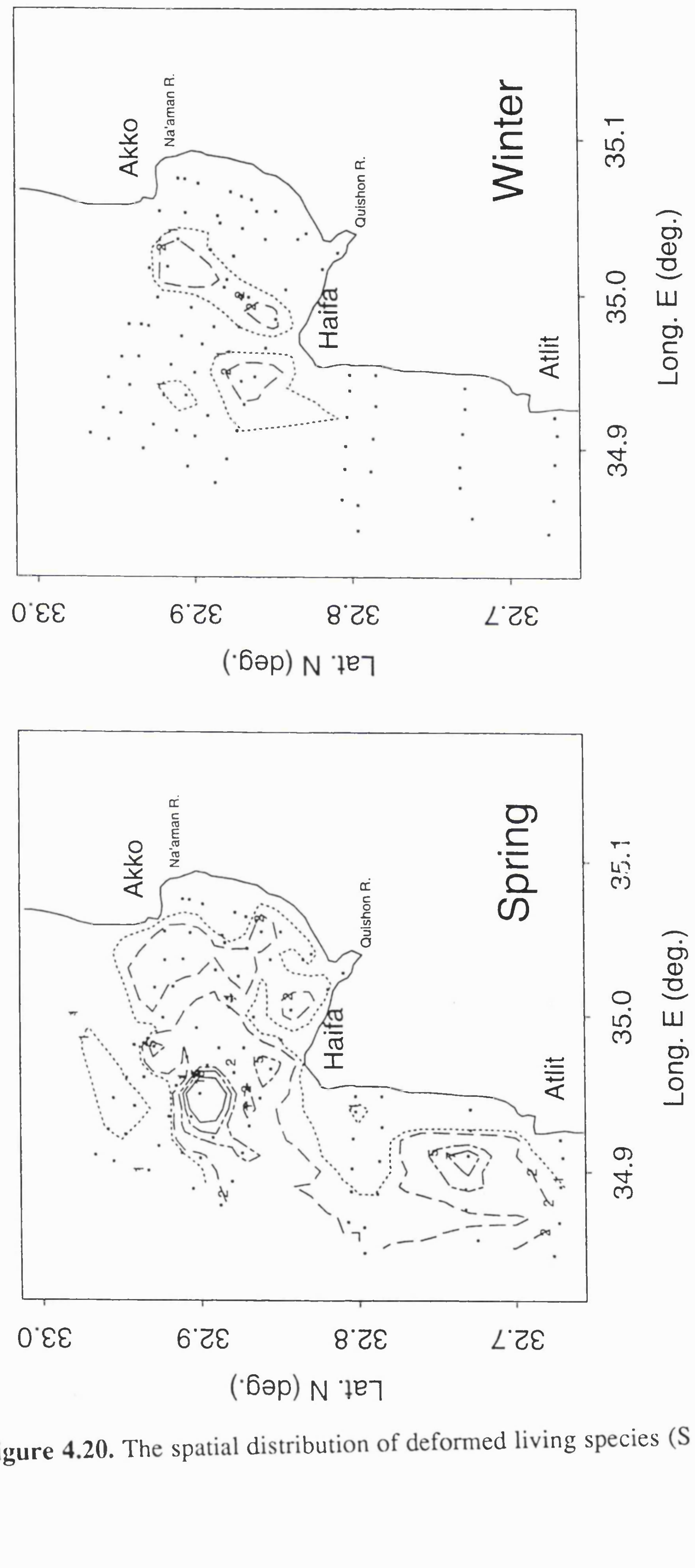


Figure 4.20. The spatial distribution of deformed living species (S and W).

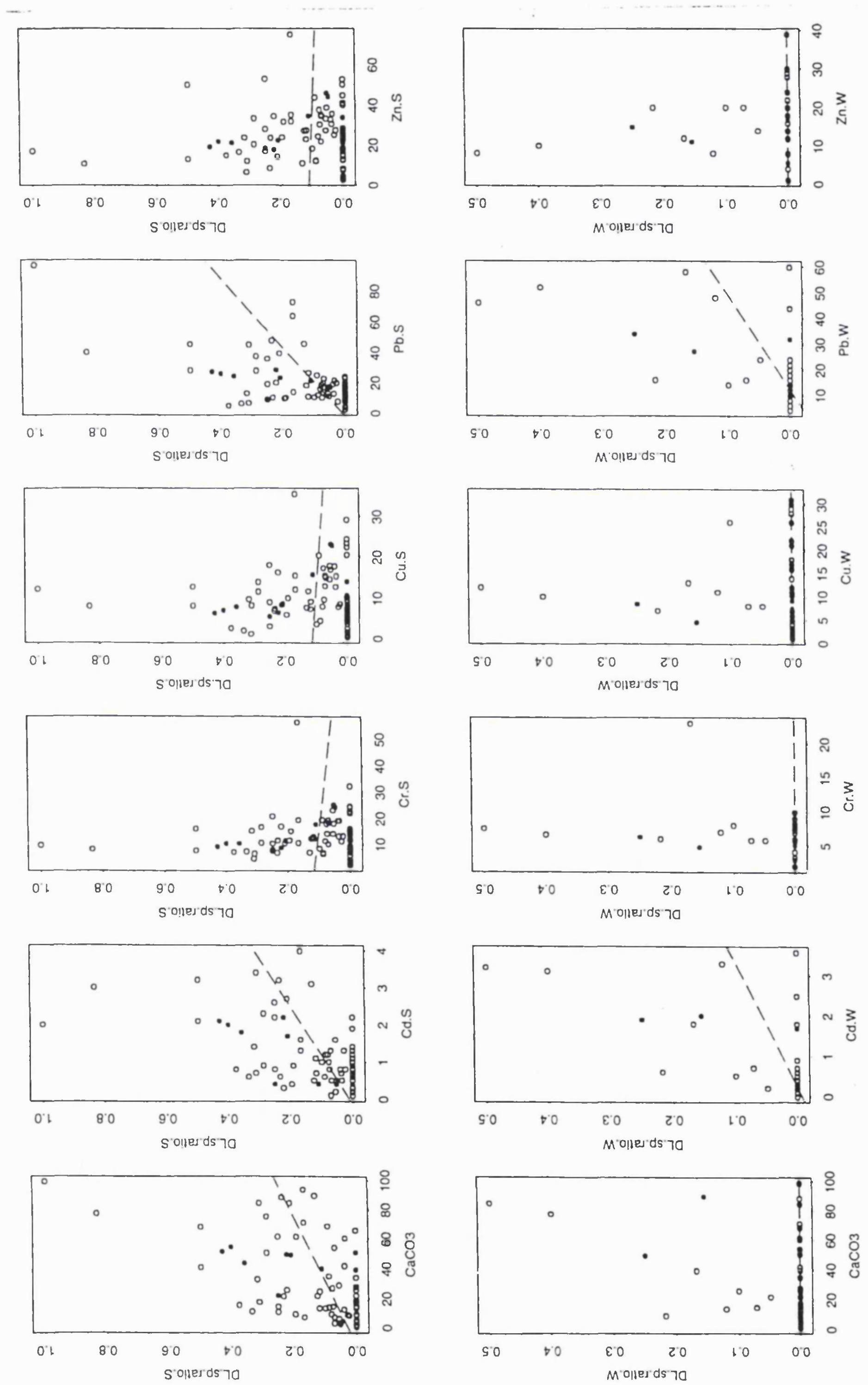


Figure 4.21. Number of deformed living species (S and W) as function of geochemistry; open point, estimated.

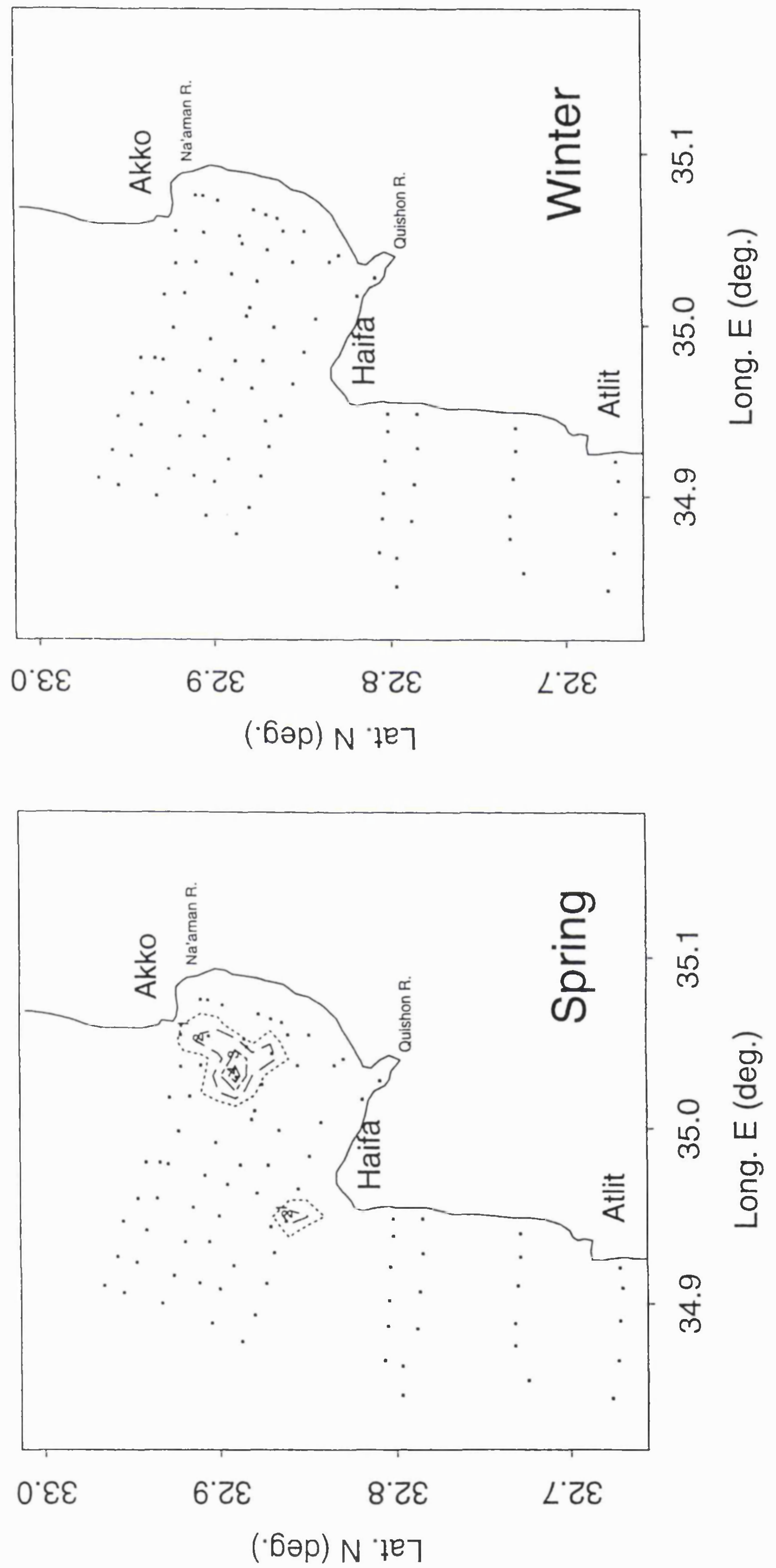


Figure 4.22. The spatial distribution of extra large size deformed living tests count (S & W).

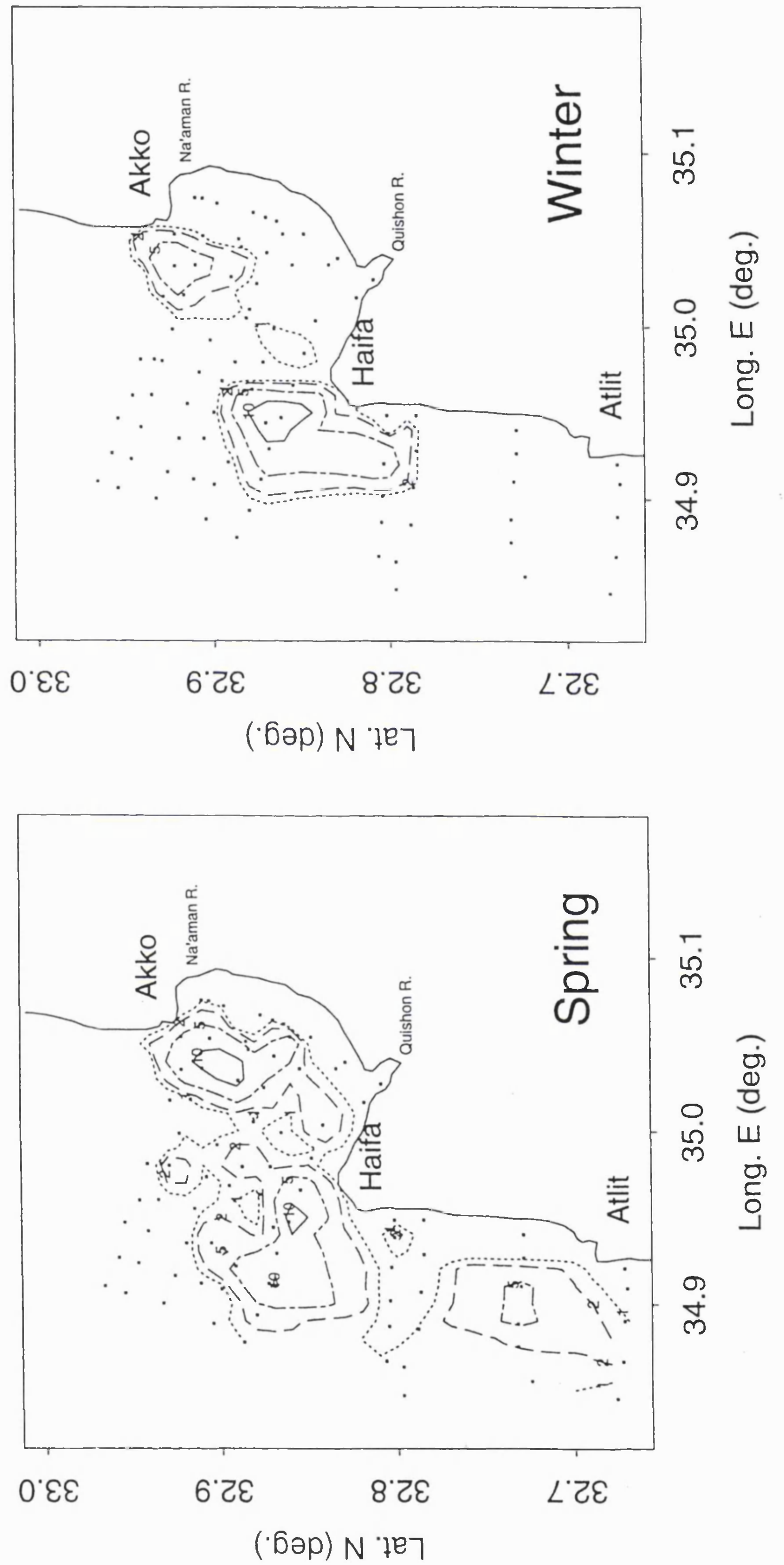


Figure 4.23. The spatial distribution of large size deformed living tests count (S and W).

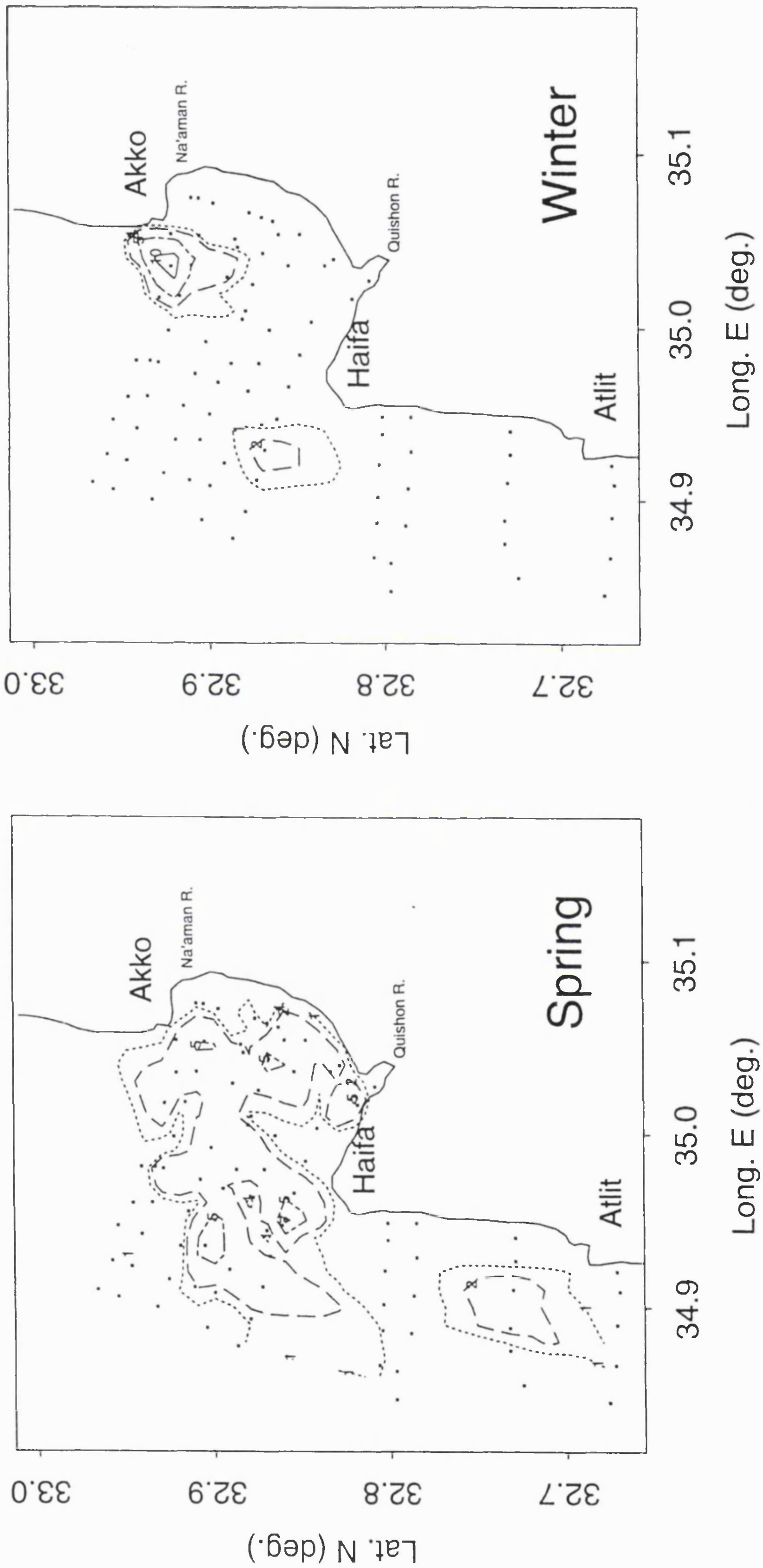


Figure 4.24. The spatial distribution of medium size deformed living tests count (S and W).

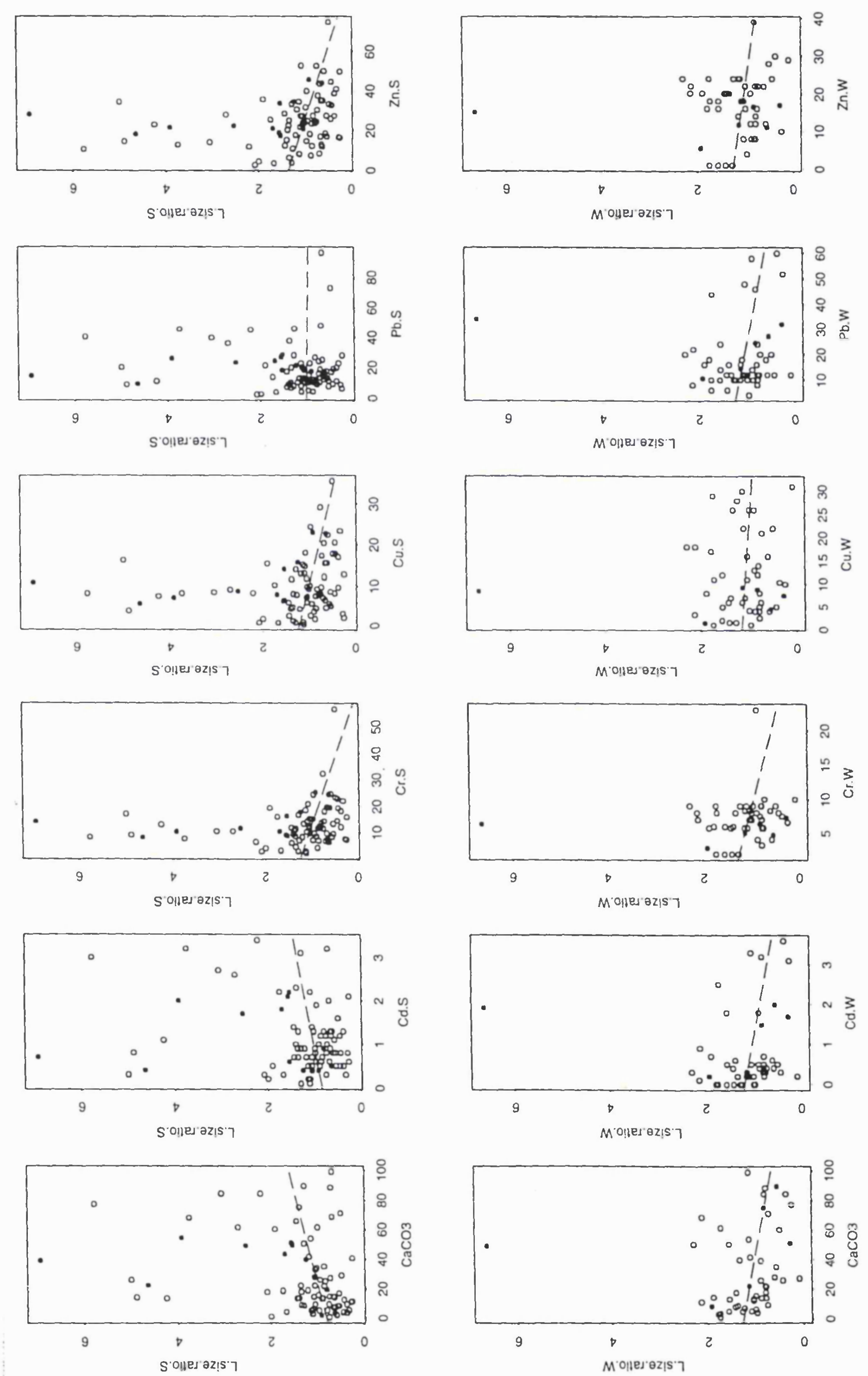


Figure 4.25. The deformed living test size ratio (XL + L) / (M + S), (S and W) as function of geochemistry; open point, estimated.

on only very few data points. However, the fact that the same trends are shown by the Robust regression in both season make it more credible. Could there be some biological reason why increasing Cd and Pb pollution increases the apparent proportions of larger tests e.g. because small tests do not exist / survive in the region of higher pollution? In winter the same trend exists. Figure 4.25 shows the ratio of large deformed living tests to smaller tests as a function of $CaCO_3$ and different concentrations of heavy metals. Cd and Pb seem to be the two elements which are related to increased occurrences of deformation.

4.3.8. Species which are most sensitive to heavy metal pollution.

Of the 168 living foraminiferal species which were encountered in this study, 50 exhibit morphological deformations. *Amphistegina lobifera* has the highest percentage of deformed tests in the study area (38%) of the total defomed living tests. Other deformed species are listed in.

A. *Amphistegina lobifera*

This species is considered the most sensitive species to high levels of heavy metal concentration, and this is reflected in the test deformities. This species represents the highest percentage of the deformed test (38%) of the total living deformed specimens in the study area. The species occurs from 6.5 to 47 m depth in Haifa Bay, and from 7 to 32 m depth in Atlit Bay.

Amphistegina lobifera was found at 23% of the stations, and exhibits morphological deformations at 94% of the stations where it occurs in Haifa Bay. It occurs at 13% of the stations in Atlit Bay, and no deformed tests of this species were found at the relatively unpolluted stations. It represents 90% of the total number of the deformed tests. From the table below, the absolute abundance and the relative abundance do not reflect the effect of heavy metals on the species, but this effect is obvious in the larger amounts of deformed test higher at sites with high concentrations. Additionally, there were no deformed tests at sites with relatively low heavy metal concentrations.

This species is characteristic of hard ground sites (Kurkur ridges). It is dominant at hard ground sites and in large grain-sized substrate (pebble, gravel and coarse sand) and sites with high heavy metal concentrations, especially Cd, Pb and As. The Map in Appendix 9 depicts the spatial distribution of the species in the study area. This species exhibits different types of foraminiferal deformities. some of which might be resulting from heavy metal pollution, or mechanical factors (currents and wave action).

Table 6. The changes of absolute and relative abundance of *A.lobifera* in relation to selected heavy metals (Cd and Pb ppm) in polluted and unpolluted sites.

	polluted site		unpolluted sites	
Station	**12**	**50**	**76**	**78**
A.abundance	16	6	9	29
R.abundance	34	16.4	6.16	21.2
Deformed	6	2	0	0
%Deformed	37.5	33	0	0
Cd ppm	4	1.6	0.2	0.1
Pb ppm	64	73	4	7.3

B. ***Peneroplis pertusus***

This species represents 9% of the deformed tests in Haifa Bay. It was found at 25% of the stations in Haifa Bay and it was encountered as deformed tests at 14% of the stations. In Atlit Bay it occurs at 4.5% of the stations, but no deformed tests were found. It represents 16% of the total number of the deformed tests in the study area. This species is found from 3 to 29 m depth in Haifa Bay, and at 6 m depth at a single station in Atlit Bay. The absolute abundance and the relative abundance are not affected by changes in the concentration of heavy metals.

Table 7. The changes of absolute and relative abundance of *Peneroplis pertusus* in relation to selected heavy melas (Cd and Pb ppm) in polluted and unpolluted sites.

	polluted site	unpolluted site
Station	**11**	**78**
A.abundance	15	3
R.abundance	28.8	2.1
Deformed	4	0
%Deformed	36	0
Cd ppm	2.6	0.1
Pb ppm	36	7.8

The level of pollution by heavy metals where this species exists is not very high, but this species exhibits many morphological deformities. This species prefers fine grained substrate (fine sand and middle size). The Map (appendix 9) shows the spatial distribution of this species in the study area.

C. *Ammonia tepida*

This species is found widespread, occuring from 3 to 72 m depth in Haifa Bay and from 7 to 31 m depth in Atlit Bay. It is a characteristic shallow water species. It occurs at 48% of the stations in Haifa Bay, and it occurs as deformed tests at 29% of the stations where the species was found. It occurs at 14% of the stations in Atlit Bay, but no deformed tests were found. It is dominant at stations where it occurs. The relative abundance decreases with depth and does not have a relation ship with increasing heavy metal concentration. The substrate preference of this species is fine grain sized substrate (very fine sand, fine sand and clay and silt). It represents 15% of the total number of the deformed tests in study area. The Map (appendix 9) gives the spatial distribution of the species in the study area.

Table 8. The changes of absolute and relative abundance of *Ammonia tepida* in relation to selected heavy metals (Cd and Pb ppm) in polluted and unpolluted sites.

	polluted sites	
Station	**1**	**78**
A.abundance	18	9
R.abundance	69.2	6.5
Deformed	6	0
% Deformed	33	0
Cd ppm	2.1	0.1
Pb ppm	28	7.8

D. *Hauerina diversa*

This species is a characteristic shallow water species, encountered from 3 to 44 m depth in Haifa Bay and from 6 m depth at two stations in Atlit Bay. It occurs at 34% of the stations in Haifa Bay. It occurs in 9% of the stations in Atlit Bay, but no deformed tests were found. It occurs as deformed tests at 36% of the station where the species exists. It is dominant in the stations characterised by high concentrations of Cd, Pb and in the sediments. The relative abundance decreases with depth and with increasing heavy metal concentration. The substrate preference of this species is fine grain sizes, (very fine sand, fine sand). It represents 11% of the deformed test in the study area. The Map (appendix 9) shows the spatial distribution of the species in the study area.

Table 9. The changes of absolute and relative abundance of *Hauerina diversa* in relation to selected heavy melas (Cd and Pb ppm) in polluted and unpolluted sites.

	polluted site	unpolluted site
Station	**26**	**78**
A.abundance	6	8
R.abundance	4.6	8
Deformed	2	0
%Deformed	33	0
Cd ppm	3.6	0.1
Pb ppm	47	7.8

4.4 GEOCHEMICAL ANALYSIS OF BENTHIC FORAMINIFERAL TESTS

4.4.1 Microprobe analysis of the foraminiferal tests

Microprobe analysis show that Magnesium and Calcium concentrations within test protoplasm of foraminifera are highly variable. A representative concentration for a sample, therefore, can only be derived by averaging several individual measurements.

The MgO and CaO were measured and converted to ppm.by this formula [(atomic weight of the element / atomic weight of the oxide) * weight% * 10000], atomic weight of the Ca is = 40.08, atomic weight og Mg = 24.35, and atomic weight of O = 15.999.

The Mg / Ca ratio is higher in deformed foraminiferal tests collected from a polluted site (median = 0.7) than the undeformed test collected from the same site (median = 0.01). It is interesting to note is that undeformed *A. lobifera* tests from the polluted site have higher MglCa ratios than the undeformed tests from the unpolluted site (median = 0.003) and the deformed tests collected from unpolluted site (median = 0.005).

Figure (4.26 A) shows the frequency distribution of all spot analyses performed on the four groups of *A. lobifera* test from the two sites, and Figure (4.26. B, C) shows the Magnesium Oxside and Mg/Ca ratio variation in a single test. In total 10 tests were analysed from each site, and 15 spots analysed on each test, giving 150 readings for each group of *A. lobifera*, see Appendix 5

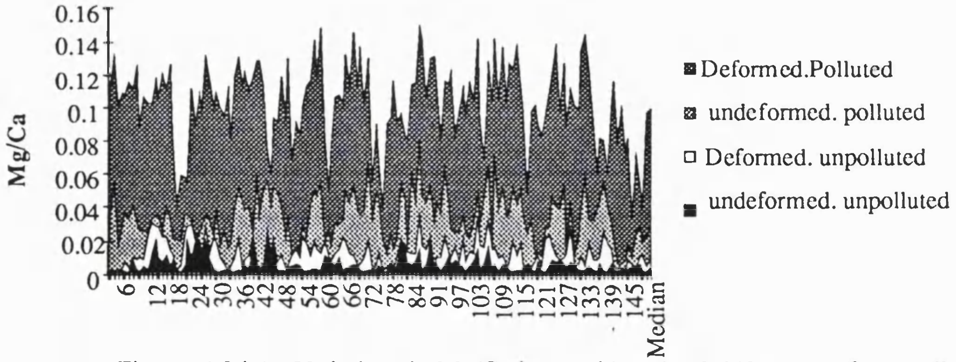


Figure 4.26.A. Variations in Mg/Ca in *Amphistegina lobifera* tests from polluted and unpolluted sites

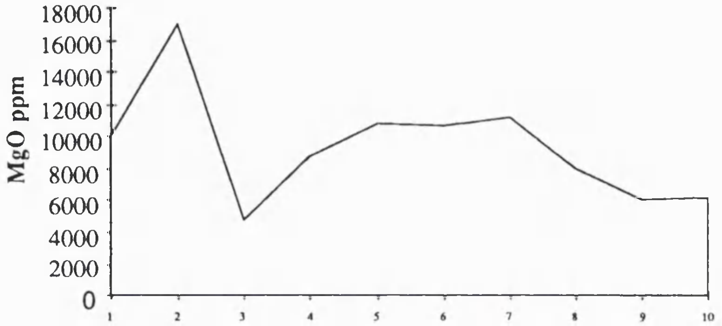


Figure 4.26.B. Variation of MgO in a single test of *A. lobifera* from an unpolluted site

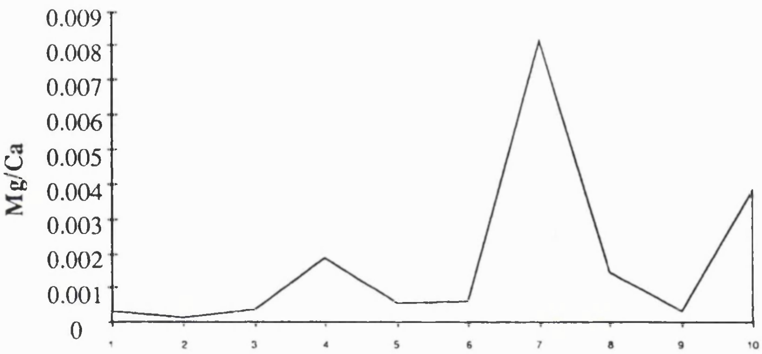


Figure 4.26.C. Variation of Mg/Ca in single test of *A. lobifera* from an unpolluted site.

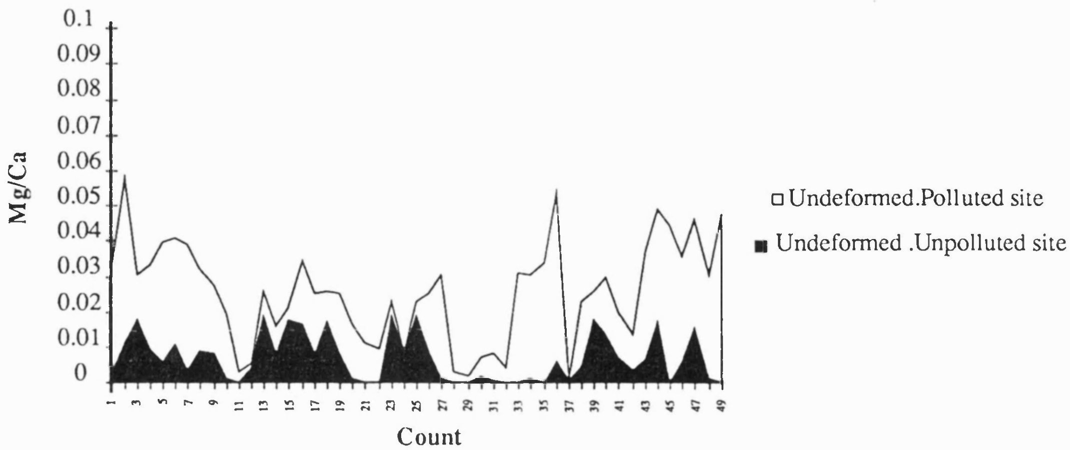


Figure 4.26.D. Variation of Mg/Ca in *Asterigerinata mamilla* from polluted and unpolluted site.

The Mg / Ca ratio is slightly higher in undeformed *Asterigerinata mamilla* collected from the polluted than it is in undefromed from unpolluted site. In total 10 test were anlysed from each site, see appendix 6. Figure (4.26, D) shows the frequency distribution of all spots analyses performed on the two groups of *Asterigerinata mamilla* .

The microprobe analysis have shown that metals Ni, Ti were detected in the deformed tests from a polluted site, but in such small quantities that they do not appear in the spectrograph. Fe is detected in deformed tests from the polluted sites. Figure 4.27 (A, B, C, D, E, F) is a spectrograph showing the changing magnesium/calcium ratio (Mg/Ca) ratios in *A. lobifera* and *Asterigerinata mamilla* tests collected from a polluted site and unpolluted site.

4.5. MORPHOLOGICAL DEFORMITIES OF BENTHIC FORAMINIFERA

The morphological abnormalities of the recovered tests have been recorded. Several foraminiferal specimens that can be related to well known species with 'normal' test morphologies in this study have been observed to display different types of deformations. About fifteen different types of deformation have been recorded for 30 species. One species may exhibit a single type of deformation, whereas other species exhibit more than one type of deformation. These are designated Foraminiferal Deformation Types (FTD) 1 to 13. The descriptions and examples of each of these deformation types are outlined below.

FDT-1 (Twinning)

The FDT-1 is characterised by the 'twinning' or fused pair of specimens. These are fused together laterally such that the apertures of both specimens are either oriented: in the same direction, in opposite directions, or at right angles to each other.

In the first case, i.e. for apertural orientations in the same direction, examples have been observed in specimens of *Adelosina intricata*, *Lachlanella variolata*, *Coscinospira hemprichii*, *Amphistegina lobifera*, and *Adelosina elegans* (Plate 4.1., Figs. 1-11).

For apertural orientations in opposite directions, examples are noted in specimens of *Adelosina brongniartana*, *Adelosina cliarensis*, *A. intricata*, *A. lobifera*, *Ammonia* sp. *C. hemprichii* (Plate 4.2, Figs. 1-8) respectively), while specimens of *Adelosina*

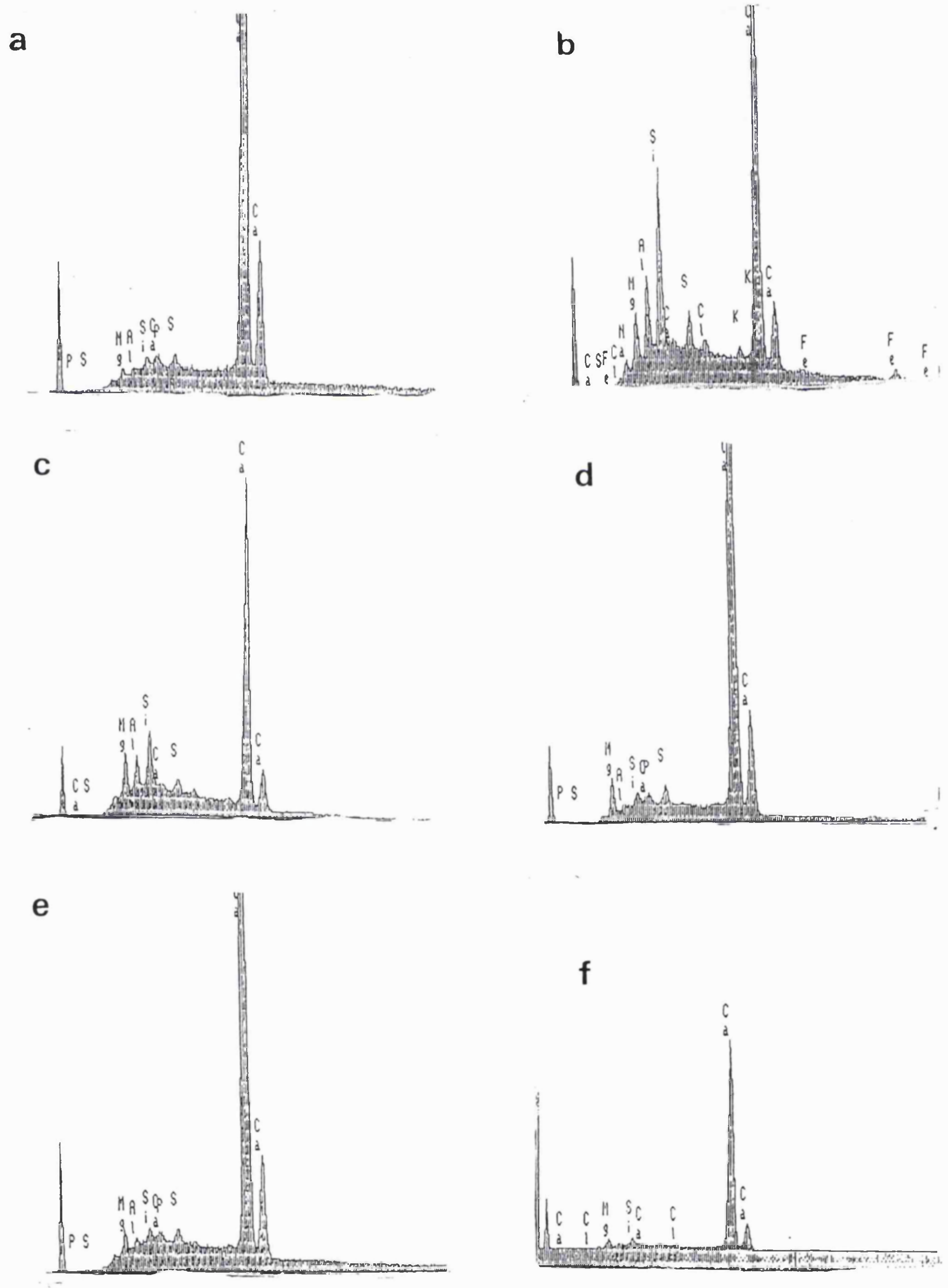


Figure 4.27. Spectrograph showing the changing Magnesium/Calcium ratio (Mg/Ca) in *Amphistegina lobifera* and *Asterigerinata mamilla* from polluted and unpolluted sites. A. Undeformed *A. lobifera* from an unpolluted site. B. Deformed *A. lobifera*from a polluted site. C. Undeformed *A. lobifera* from an unpolluted site. E. Undeformed *A. mamilla* from an unpolluted site. F. Undeformed *A. mamilla* from a polluted site.

mediterranensis (Le Calvez), *A. cliarensis*, *A. brongniartana, C. hemprichii* and *A elegans,* (Plate 4.2) were observed to display apertural orientations at right angles to each other.

Fused pairs or twins are the most common deformation type in the study area. These have been reported by many authors. Stouff *et al* (1999) reported that when the fused pairs are of the same size this type of deformation can result from the fusion of two proloculi or two juveniles that merge inside the parental cyst before calcification and the release of young. If the two young develop synchronously, these tests will be the same size, if one of the young stops its development early it results in a juvenile double test with different size. The specimens may grow in a parallel plane or perpendicular plane.

FTD-2 (Presence of more than one aperture)

This type of deformation refers to the presence of more than one aperture among forms that are known to have only one aperture. Examples are noted in specimens of *A. brongniartana, Quinqueloculina diparilis, Hauerina diversa,* and *Peneroplis pertusus* (Plate 4.3, Figs 1-7).

This type of deformation has been reported in several species by many authors e.g. De Amicis (1895) on *Uvigerina conariensis,* Willems (1974) on *Uvigerina batjesi kaasschieter*, Alve (1991) on *Cribrostomoides kosterensis* and *Bulimina marginata,* and Yanko *et al.* (1994, 1998) on *Quinqueloculina disparalis.*

Sharifi (1986) reported that mechanical breakage of the test can be caused by various methods and as wave action, collision with particles of coarser grain size, strong hydrodynamics or by the action of a predator. Mechanical damaged is common along the marginal area of the test. At the damaged site, protoplasm immediately swells to fill the break and secretes material which tends to heal the injury. The newly constructed portion of the wall is initially very delicate, but this thickens and even regains some of the original ornamentation. It is always possible to distinguish the reconstructed part because it is characterised by abnormal contours of the test, thinner scars and wall.

I believe it is probable that the breakage of the apertural face or last formed chamber took place during the life span of the specimen. The chamber has been repaired and in the process a second aperture was formed. Similar interpretations have been made by previous authors (Setty and Almeida, 1972; Setty, 1983). Alternatively, it might be that one of the pairs masks the smaller test in certain stage of their development and the only part which is exposed is the aperture, or it is a juvenile test that has been masked by the parental test and the aperture was the only exposed part. It is obvious that the new aperture is smaller and sometimes the aperture opening is different from the first one.

FDT-3 (Abnormal chamber enlargement)

This type of deformation refers to the unusually enlarged, inflated and globular features of some of the test chambers in species for which their 'normal' representatives show no inflation. In certain species, the inflation is observed in the last three chambers including the apertural chamber, e.g. *Asterorotalia gaimardii* (Plate 4.3, Fig. 8) and *Elphidium advenum* (Plate 4.3, Fig 9).

Abnormal enlargement of the last three chambers in the last whorl was observed in specimens in this study. This type of deformation was reported by Setty and Nigam (1984), Sharifi (1986), Alve (1991, 1995), and by Yanko *et al.,* (1994, 1998). The enlargement is considered to be pollution-induced in a certain stage of development. This may be some defence mechanism whereby the cytoplasm duplicates or become larger in size accordingly when the chambers are constructed they will be covering larger cytoplasm, and as a result they become larger in size than the previous chambers.

FDT-4 (Presence of residual chambers)

This type of deformation is described by the presence of residual chambers. These are bulbous attachments (probably abandoned chambers) on chambers of a regular whorl. They are frequently found on the apertural chamber but have also been observed on earlier chambers. These features are absent in specimens usually considered as having 'normal' tests. Examples of these features have been observed in specimens of *Ammonia inflata* and and *Rosalina oriantalis* (Plate 4.3, Figs. 10 and 11 respectively), as well as in *Pararotalia spinigera, Asterorotalia gaimardii, Elphidium advenum,* and *Amphistigena lobifera* (Text Plate 4.4, Figs-4).

Some foraminifera found in the study area exhibit protuberances on the spiral side that are known as abnormally protruding chambers (Almogi-Labin *et al.*, 1992; Yanko *et al*, 1994, 1998, Geslin *et al.*, 1998). This type of deformity is represented in this work as residual chambers and extra chambers. Stouff *et al.* (1999) reported that this feature may result from the development of two second chambers from one proloculus, one whorl develops from one of the second chambers. A protuberance corresponding to the other one will remain on the proloculus.

FDT-5 (Chamber size reduction)

This type of deformation represents the reduction in size of certain chambers of the test in contrast with 'normal' specimens in which the chambers are either uniform or gradually increasing in size. Generally, the affected chambers appear to be squeezed or squashed. On the other hand reduction of chamber size may result from tight coiling, or the reduction of the cytoplasm in a certain stage of the development, causing chambers size to also reduce. This feature is commonly observed on the third chamber nearest the aperture as well as on the apertural chamber in specimens of *Astrorotalia gaimardii* (Plate 4.4, Fig 5).

FDT-6 (Addition of extra chambers)

In some cases, certain species display deformations in the form of one or more additional chambers which are otherwise absent in 'normal' specimens. Generally, the extra chambers are added onto the apertural chamber and are completely in discord with the regular chamber alignment. Examples have been observed in specimens of *Sigmoilina edwardsi, Spriroloculina* sp., *Spiroloculina hadai, Triloculina marioni* (Text Plate 4.4, Figs. 7-12 respectively). Also *Edentostomina cultrata, Peneroplis pertusus, Quinqueloculina disparilis, Coscinospira hemprichii, Amphistigena lobifera* and *Adelosina elegens* display this deformity (Plate 4.5, Fig.1-8).

In Plate 4 figures 9 and 11 the specimen is characterised by two terminal chambers instead of the usual one. Both of the last chambers have a terminal aperture. This type of deformation was reported also by Sharifi (1986) on *Miliolinella* sp. The specimens in Plate 4.5, figure 2, 6 is here interpreted as possessing extra chambers. This feature was reported in Stouff's work as resulting from the development of an early chamber from one proloculus, which did not finish its development. The specimens in figures 3, 5, 7 and 8 might represent a fused juvenile test fixed on the parental test.

FDT-7 (Lopsided pseudo-high trochospiral test whorl)

This deformation type is characterised by lopsided and loose trochospiral coiling of tests in forms known to be typically tightly coiled (i.e. a pseudo-high trochospiral appearance of an otherwise low trochospirally coiled form). In such deformed types, successive whorls are off-centred Examples are observed in specimens of *Ammonia inflata* (Seguenza), *Asterorotalia gaimardii*, *Ammonia tepida*, and *Amphistegina lobifera*(Plate 4.6, 1-4), The same type of deformation was reported by Stouff *et al.* (1999) and interpreted as a juvenile test fixed to the parental test. In some forms successive whorls are mal-aligned. Examples are observed in specimens of *Asterorotalia gaimardii*, and *Sorites orbiculus*. In some forms successive whorls are overlap each other. Example are observed in specimens of *Asterorotalia gaimardii*, and *Elphidium crispum* (Plate 4.6, Fig. 7 and 8). Deformations of this kind probably result from rapid growth rates and/or introduction of foreign chemical elements during test construction.

FDT-8 (Lopsided low trochospiral test whorl)

This type of deformation is similar to FDT-7 in showing whorl angulation and lopsidedness which is clearly displayed on the spiral side of the test. However, in this case the test is tight with a low trochospiral coiling. Examples have been observed in specimens of *Elphidium crispum* and *Elphidium* sp. (Plate 4.6, Figs. 9-12).

FDT-9 (Distorted/contorted chambers and overall test outline)

The FDT-9 refers to the deformation feature in which specimens exhibit contorted test outlines in comparison with 'normal' specimens of similar species. This feature is probably related to:

(1) The distorted and highly twisted nature of the chambers. As a result, the chamber edges of certain species appear wavy and crenulated while the overall test shape appears curved or flexured with a sigmoidal appearance. Such curved and wavy features are distinctive when specimens are positioned in lateral view. These have been observed singly or in combination in specimens of *Quinqueloculina disparilis*, and *Elphidium advenum* (Plate 4.7, Figs. 1 and 2).

(2) The presence of chambers that are slightly off-set or displaced from the axis of coiling such that:

(a) The test exhibits simple distortion in which the last whorl is deflected or displaced towards the spiral side, e.g. in specimens of *Peneroplis pertusus* (Plate 4.7, Fig. 3).

(b) The test is highly distorted with chambers formed in an irregular manner, e.g. in specimens of *Ammonia inflata, Adelosina brongniartana, Miliolinella webbiana Planorbulina mediterranensis*, and *Sorites orbiculus* (Plate 4.7, Figs 4-10). The chambers are added in different ways or places around or within the test. The abnormal chambers are often small in size and rarely fully grown. These additional chambers are usually developed in a direction opposite to that of the normal coiling direction (normal growth) and very rarely are they are coiled in the same direction. This type of deformity observed here is similar to those reported from heavy metal pollution by Alve (1991), Yanko (1998), Stouff *et al.* (1999). However, in specimens of *Ammonia tepida* raised in hypersaline culture, this kind of deformity may result from a test having an undetermined number of proloculi. These specimens display such an anarchic disposition of the chambers, that it is impossible to count the proliculi (Stouff, *et al.* 1999)

(c) The apertural chamber is seen to be masking or covering earlier chambers, e.g. in specimens of *Adelosina intricata, Adelosina mediterranensis, Adelosina pulchella, Quinqueliculina* sp, and *Triloculina marioni* (Plate 4.7, Figs 10-12).

(d) The test shows a displaced alignment of the second whorl off the 'normal' spiral trend, e.g. in specimens of *Elphidium* sp;

(f) For miliolid species in which the aperture is 'normally' seen to be flush with the top of the penultimate chamber, the last chamber is displaced upwards in such a manner that the aperture is at a relatively lower position. Examples have been observed in specimens of *Quinqueloculina disparalis* and *Lachlanella variolata* (Plate 4.8, Figs 1 and 2).

FDT-10 (Loose quinqueloculine coiling)

Compared with 'normal' specimens, in this type of deformation, the test is characterised by loose quinqueloculine coiling in which the apertural chamber is detached at the apertural end from earlier chambers, e.g. in specimens of *Adelosina elegans, Spriloculina* sp, and *Spriloculina* sp. (Plate 4.8, Figs. 3-5).

FDT-11 (Very tight quinqueloculine coiling)

In this type of deformation, the test is very tightly coiled such that the initial chamber is disoriented and elevated significantly above the axis of coiling. Examples have been observed in specimens of *Adelosina elegans* (Plate 4.8, Fig. 6).

FDT-12 (Abnormal apertural chamber)

In comparison with 'normal' specimens, this type of deformation refers to the irregularly shaped nature of the apertural chamber. Such irregularities include:

1. Pronounced concave or convex crescent shape, bending or curvature of the apertural chamber in species for which they are otherwise straight, e.g. in specimens of *Quinqueloculina* sp., *Adelosina intricata*, (Plate 4.8, Figs. 7, 8). Some apertural chambers exhibit flexing in which there is a points of bending along the apertural chamber as observed in specimens of *Adelosina intricata, Triloculina* sp, *Spiroloculina* sp, (Plate 4.8, Figs 9-12), *Adelosina elegans* and *Cycloforina* sp. (Plate 4.9, Figs. 1 and 2, respectively).

2. The apertural chamber is in discord with the alignment of the test (Plate 4.9, Fig 3).

FDT 13- (Abnormal apertural shape)

This deformation refers to the abnormal disposition of the aperture in comparison with 'normal' specimens. Often this is in the form of an irregular apertural outline in which the aperture is incompletly dveloped as noted in specimens of *Amphistegina lobifera* (Plates 4.9 and 4.10, all the illustrated specimens have this deformity).

Abnormalities in *Amphistegina lobifera*

This species exhibit different types of morphological deformities for example:

1. Abnormal aperture and having irregular outline (all the specimen possess abnormal aperture) (Plate 4.9 and 10).

2. Double aperture (Plate 4.10, Fig. 6, 7).

3. Extra chambers (Plate 4.10, Fig. 2).

4. Some forms successive whorls off-centred, mal-aligned and overlaping each other. Example are observed in all specimens.

Plate 4.1

FTD 1 : Twinning

A- The apertural openings of the fused pairs in the same direction.

1. *Adelosina intricata* (Terquem); 325 µm, x 220. Pair of tests fused perpendicular to each other. Apertures are in the same direction, they are fused from the first chamber.
2. *Adelosina intricata* (Terquem); 392.8 µm, x 220. One of the pair is fused to the other from the lateral side to the ventral side of the second one.
3. *Adelosina intricata* (Terquem); 391.3 µm, x 90. The pairs are fused from the first chamber, they are parallel to each other.
4. *Lachnalella variolata* (D'Orbigny), 1225 µm, x 72. The pairs are fused from the first chamber. They are parallel to each other.
5. *Coscinospira hemprichii* Ehrenberg; 555.5 µm, x 170. The juvenile test is fixed to the parental test from the spiral side.
6. *Coscinospira hemprichii* Ehrenberg; 522.2 µm, x160.
7. *Coscinospira hemprichii* Ehrenberg; 900 µm, x 105. The pairs in number 6 and 7 are fused from the spiral side and they are parallel to each other. They are in the same size.
8. *Aphistegina lobifera* Larsen, 1125 µm, x 70. The two pairs have the same size. They are fused from the umbilical side, and are perpendicular to each other.
9. *Aphistegina lobifera* Larsen,700 µm, x 93. The two pairs have the same size. They are fused from the apertural side, and are parallel to each other.
10. *Aphistegina lobifera* Larsen, 414 µm, x 200. The juvenile test is fused to the parental test from the aperture, the two tests have offset chambers.
11. *Adelosina elegans* (Williamson); 1428 µm, x 62. The pairs are fused from the second chamber. They are of the same size and are parallel to each other.

Plate 4.1

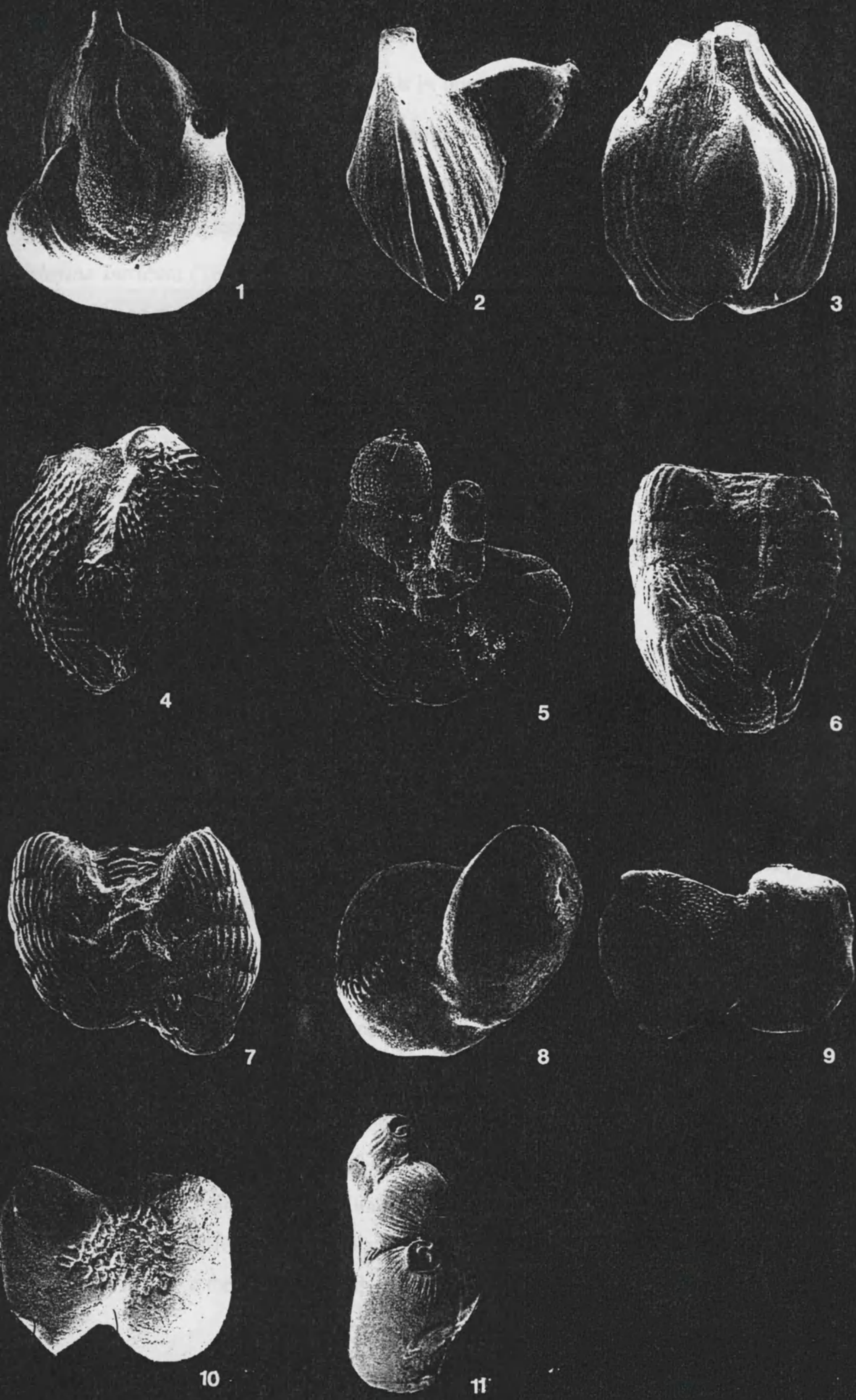


Plate 4.2

FTD 1 : Twinning

B- The apertural openings of the fused pairs is in opposite directions

1. *Adelosina brongniartana* (D'Orbigny) var. *angulata* Wiesner; 1350 µ, x 125.
2. *Adelosina brongniartana* (D'Orbigny) var. *angulata* Wiesner; 1300 µ, x 100
3. *Adelosina cliarensis* (Heron-Allen and Earland); 871.4 µm, x 130.
4. *Adelosina intricata* (Terquem); 588.9 µm, x 125. Figures 1 to 4 are two pairs fused from the second chambers, and the apertural openings are opposite to each other.
5. *Aphistegina lobifera* Larsen; 833.3 µm, x 96. The pairs are fused lateral sides and the apertures are on the same sides but in opposite positions.
6. *Aphistegina lobifera* Larsen; 980 µm, x 96. The juvenile test is attached to the parental test from the umbilical side.
7. *Ammonia* sp, size is 450 µm, x 200. The pairs are fused from the spiral side.
8. *Coscinospira hemprichii* Ehrenberg; 1120 µm, x 105. The pairs are fused from the spiral side.

C- The apertural openings of the fused pairs is in right angles to each other.

9. *Adelosina mediterranensis* (Le Calvez, J and Le Calvez);1218 µm, x 84. The fused pairs are fused from the earlier chamber, they are crossing each other .
10. *Adelosina cliarensis* (Heron-Allen and Earland); 466.7 µx 120. One of the pairs is fused to the other one from the aperture to the first chamber of the other pair.
11. *Adelosina brongniartana* (D'Orbigny) var. *angulata* Wiesner; 945.4 µ, x 70. The fused pairs are attached to gather in a way that each one mask the earlier chamber of the other one an d the apertures are perpendicular to each other.
12. *Coscinospira hemprichii* Ehrenberg; 714.2 µm, x 120. The juvenile pair is attached to the parental test from the earlier chambers that it masks.
13. *Adelosina elegans* (Williamson) var. *separans* Wiesner; 50 µm, x 100. The pairs are fused in such a way that one test is siting on the other and masking part of the test. The chambers have different coiling from the normal quinqueloculine, such that the chambers do not have the proper growth pattern.

Plate 4.2

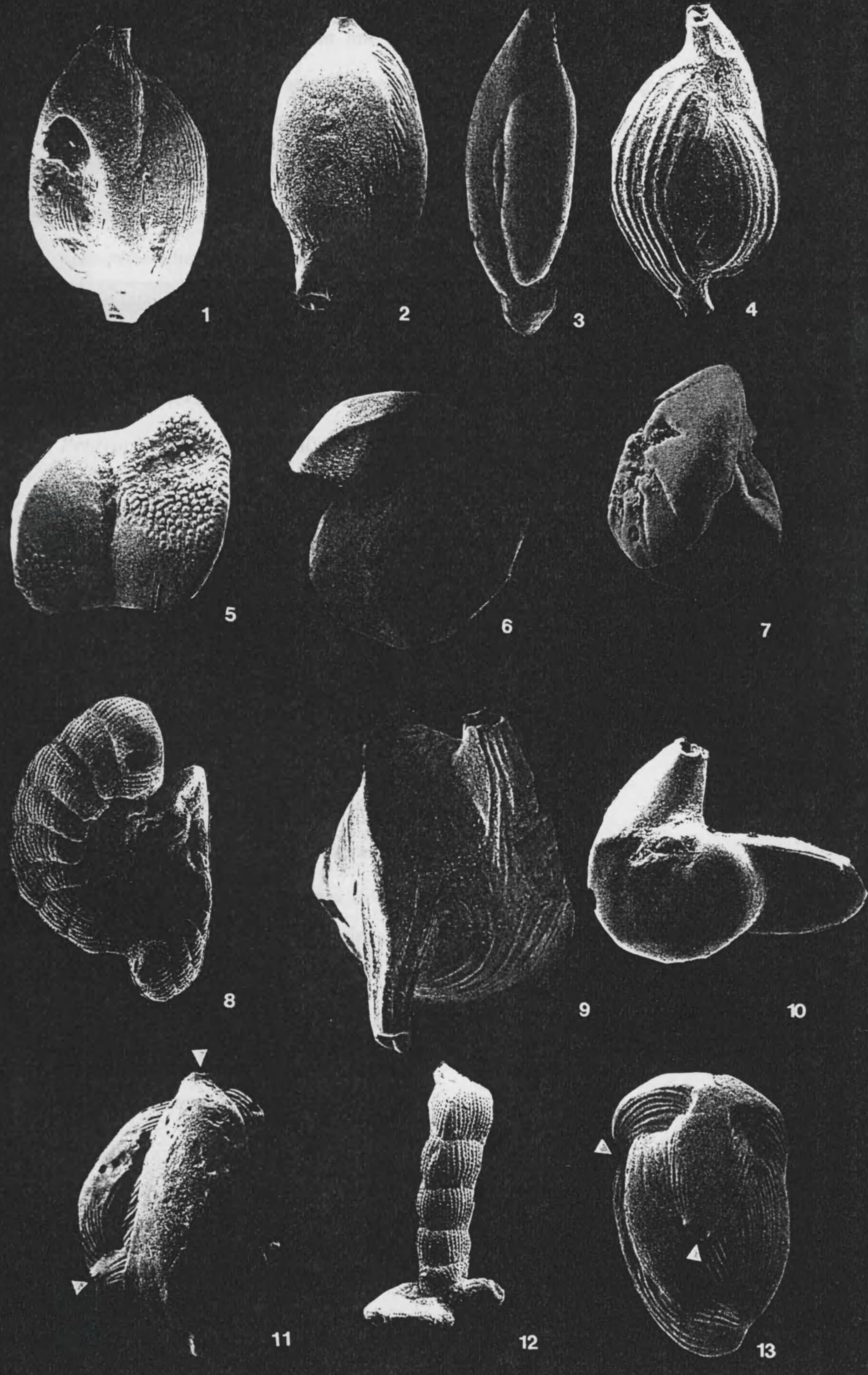


Plate 4.3

FTD- 2 (presence of more than one aperture)

The following specimens possess two apertures, the apertural opening is smaller in the second aperture. The additional apertures are formed in earlier chambers.

1. *Adelosina brongniartana* (D'Orbigny) var. *angulata* Wiesner; 728.5 µm, x 80.
2. *Adelosina elegans* (Williamson), 1100 µm, x928
3. *Quinqueloculina disparilis* D'Orbigny, 757.1 µm, x115.
4. *Quinqueloculina disparilis* D'Orbigny, 981.8 µm, x94.
5. *Hauerina diversa* Cushman, 614 µm, x120
6. *Hauerina diversa* Cushman, 614.2 µm, x190
7. *Peneroplis pertusus* (Forskal), 671 µm, x160

FTD-3 (Abnormal chamber enlargement)

The following specimens have the three last chambers in the last whorl enlarged.

8. *Asterorotalia gaimardii* (D'Orbigny); 600 µm, x 130.
9. *Elphidium transluccens* Natland; 42 µm, x 230, This test exhibits enlargement of the last three chambers in the last whorl
10. *Elphidium* sp. 2, 625 µm, x280.

FDT-4 (presence of residual chambers)

The following specimens have residual chamber attached to the parental test from the umbilical side (they might be fused pairs attached to the parental test and their development had stopped at a certain stage)

11. *Ammonia inflata* (Seguenza), 714.2 µm, x 100. This test exhibit the enlargement of the last three chambers in the last whole, and the off centric of one chamber.
12. *Rosalina orientalis*, 818.2 µm, x 98.

Plate 4.3

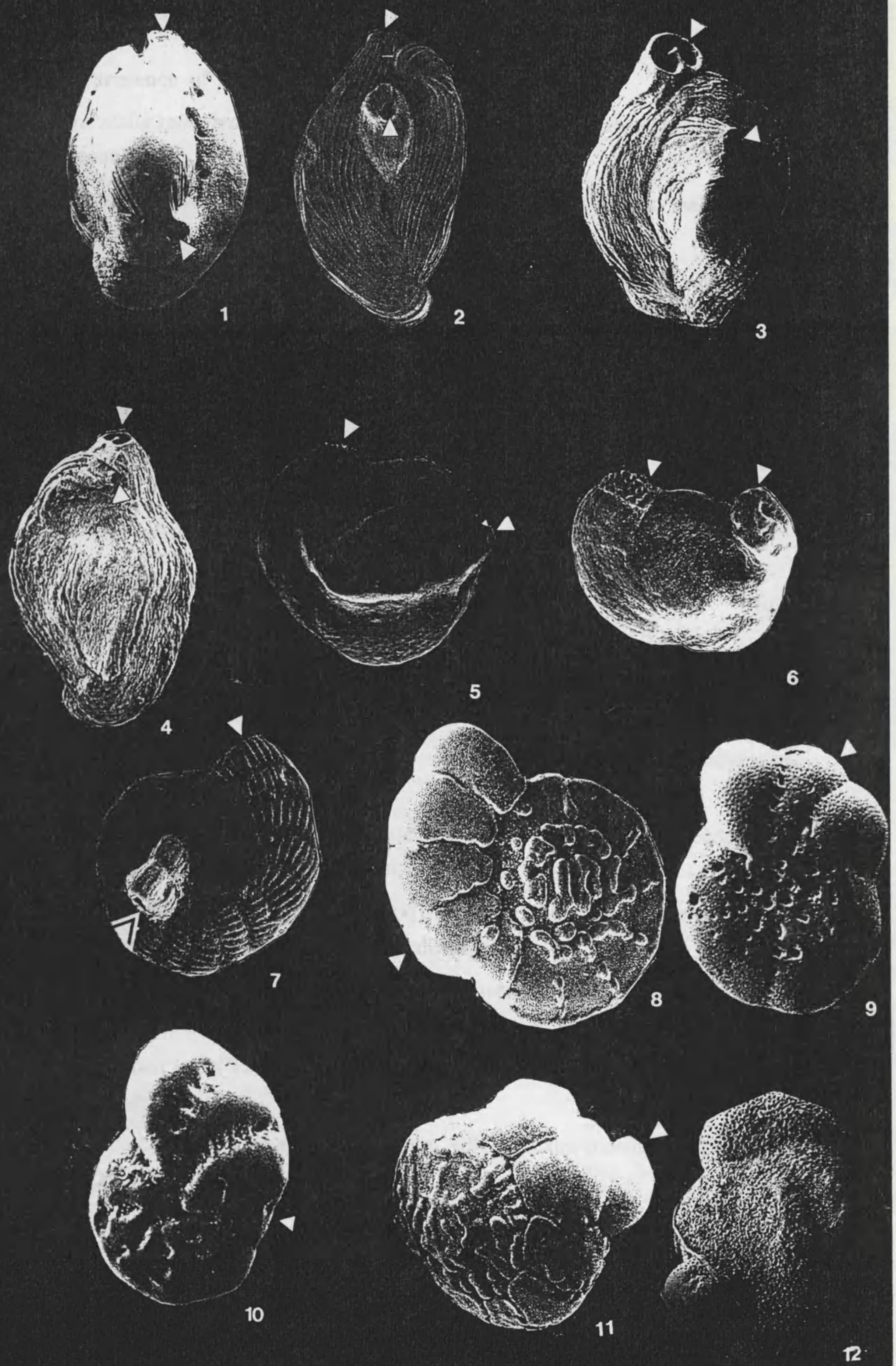


Plate 4.4

FDT-4 (presence of residual chmbers) (continued)

1. *Pararotalia spinigera* Le Calvez; 625 µm, x 130. The residual chamber is attached to the spiral side
2. *Elphidium advenum*, 593 µm, x 200. The chamber are added to the last whorl resulting in double whorls in the last three chamber of the last whorl.
3. *Elphidium advenum*, 625 µm, x 148. The chamber is added on the last whorl near to the apertural chambers.

FTD-5 (Chamber size reduction)

The following specimens display reduction in size of one of the chamber in the last whorl.

4. *Elphidium cf. advenum* (Cushman); 555 µm, x 160. The last three chambers are reduced.
5. *Ammonia inflata*(Seguenza); 850 µm, x 105.
6. *Asterorotalia gaimardii* (D'Orbigny), 671.4 µm, x 92.

FDT-6 (Addition of extra chambers)

The following specimens have an extra chambers are added on to the apertural chamber and are completely in discord with the regular chamber alignment.

7. *Adelosina elegans* (Williamson), 2850 µm, x 64. Two extra chambers are added to the original test.
8. *Adelosina elegans* (Williamson), 2750 µm, x 70. One extra chamber was added to the test masking the apertural part of the test.
9. *Sigmoilina edwardsi* (Schlumberger), 700 µm, x 100. Two extra chamber were added masking most of the test and causing deformed aperture.
10. *Spiroloculina* sp., 783 µm, x 140. An extra chamber has been added to the apertural chamber.
11. *Spiroloculina hadai* Thalmann, 625 µm, x 132. An extra chamber has been added to the apertural chamber.
12. *Triloculina marioni* Schlumberger, 1020 µm, x 84. An extra chamber has been added to the apertural chamber.

Plate 4.4

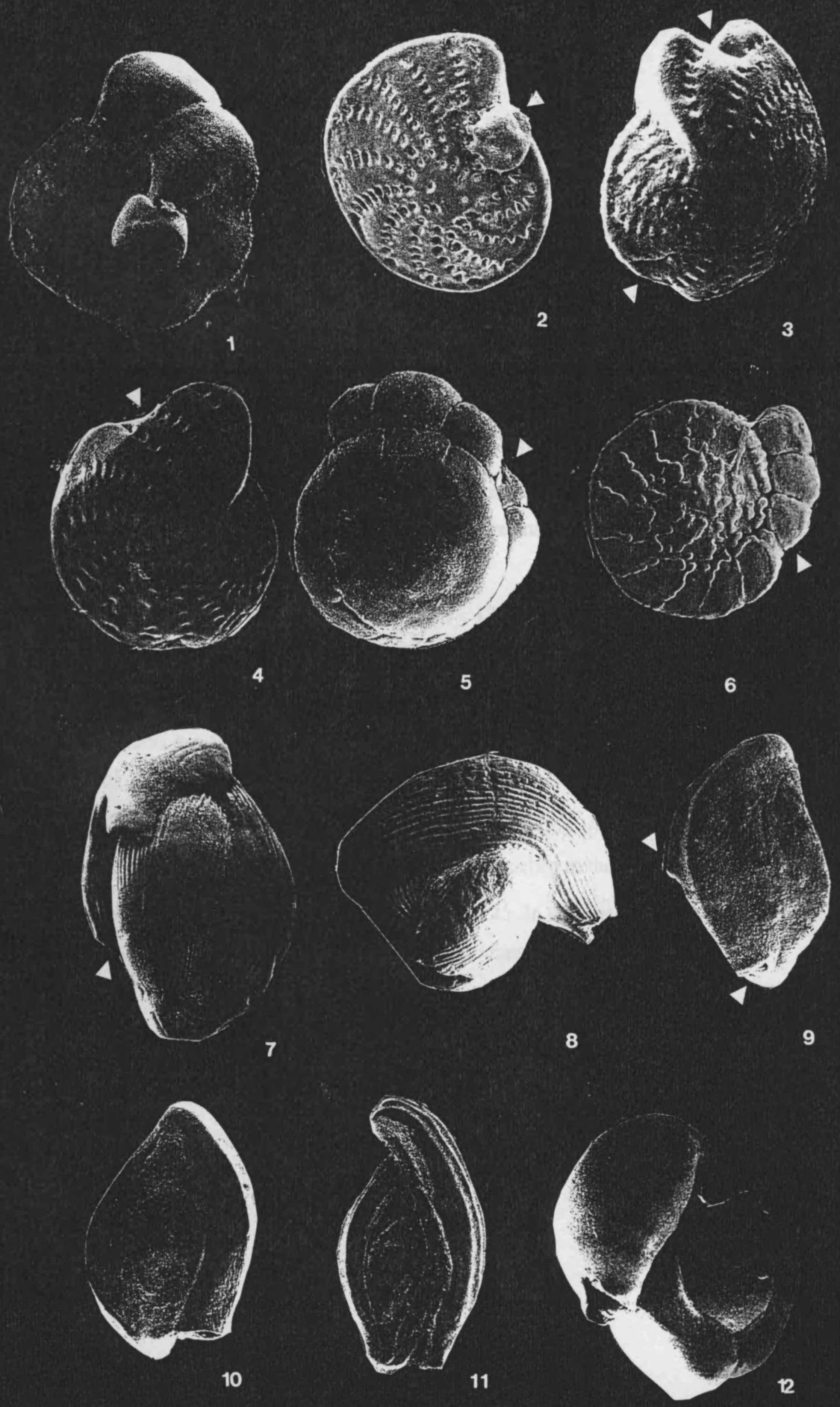


Plate 4.5

FDT-7 (Addition of extra chambers) (continued)

1. *Edentostomina cultrata* (Brady); 960 µm, x 110. An extra chamber is added to the apertural chamber.
2. *Peneroplis pertusus* (Forskål); 637.5 µm, x 130. In this specimen extra chambers are added they might be fused pairs (juvenile test attached to the parental test).
3. *Coscinospira hemprichii* Ehrenberg; 933 µm, x 190. The extra chambers are added to this specimen on the last whorl and their coiling is more simple than the parental test.
4. *Quinqueloculina disparilis* D'Orbigny; 783.3 µm, x 100. An extra chamber is added to the apertural chamber. It has a different aperture and has lost its striations on the extra chamber compared with the original test.
5. *Peneroplis pertusus* (Forskål); 416.6 µm, x 183. In this specimen extra chambers are added, they might be fused pairs (juvenile test attached to the parental test)
6. *Coscinospira hemprichii* Ehrenberg; 558.8 µm, x 180. In this specimen extra chambers are added, they might be fused pairs (juvenile test attached to the parental test)
7. *Amphistegina lobifera* Larsen; 1044 µm, x 48. In this specimen extra chambers are added, they might be fused pairs (juvenile test attached to the parental test).
8. *Adelosina elegans* (Williamson); 625 µm, x 125. In this specimen the extra chambers are added in irregular pattern attached to the earlier chambers.

Plate 4.5

Plate 4.6

TDF-8 (Lopsided pseudo-high trochospiral test whorl)

1. *Ammonia inflata* (Seguenza); 671.4 µm, x 160. This specimen has chambers that are offcentred from the trochospiral plane chambers. This might be a juvenile test attached to the parental test.
2. *Asterorotalia gaimardi* (D'Orbigny); 533 µm, x 170. This specimen has the situation as number one.
3. *Ammonia tepida* (Cushman); 683 µm, x film no 5449 no 27. In this specimen, one of the chambers in the last whorl is off centred.
4. *Amphistegina lobifera* Larsen; 1257 µm, x 96 This specimen has some offcentric chamber from the last whorl.
5. Specimen 5, 7, and 8 have offcentric chamber and the chambers are overlapped as a result they have a malalignment outline.
6. *Asterorotalia gaimardi* (D'Orbigny); 771 µm, x 100.
7. *Asterorotalia gaimardi* (D'Orbigny); 1020 µm, x 80.
8. *Asterorotalia gaimardi* (D'Orbigny); 1080 µm, x 82.
9. *Elphidium crispum* (Linnaeus); 391.7 µm, x 95.

TDF-9 (Lopsided low trochospiral test whorl)

10. *Elphidium crispum* (Linnaeus); 685.7 µm, x 115. The test is tight and results in angulation.
11. *Elphidium* sp, 555.5 µm, x 115. The test is tight and overlapped.
12. *Elphidium crispum* (Linnaeus); 625 µm, x 125. The specimen has a depression in the last whorl which result in forming two keels and elevation of some chamber over the trochospiral plane.
13. *Elphidium crispum* (Linnaeus); 750 µm, x 115. In this specimen part of the last whorl chamber are lopsided forming a depression in the coiling plane.

Plate 4.6

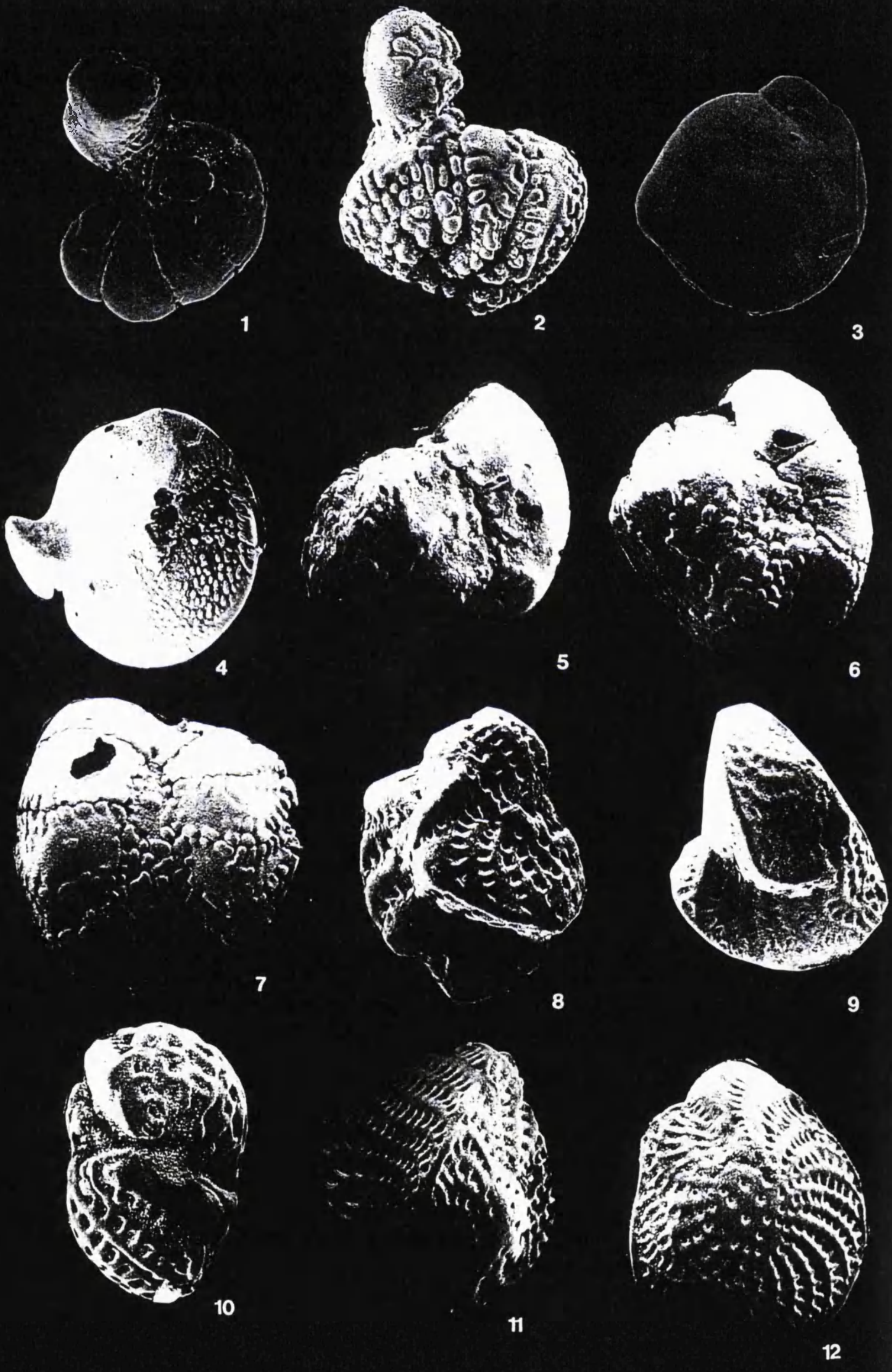


Plate 4.7

TDF-9 (Distorted/contorted chambers and over test outline)

The distorted and the highly twisted nature.

1. *Quinqueloculina disparilis* D'Orbigny; 1000 µm, x 76. The last chamber appears wavy (sigmoid appearance).
2. *Elphidium* cf. *advenum* (Cushman); 700 µm, x 100. The edge of chambers in the last whorl appear crenulated.

Chambers that are slightly of-set or displaced from the axis of the coiling.

3. *Peneroplis pertusus* (Forskål); 783.3 µm, x 100 The chambers in the last whorl are defected and displaced from the coiling plane.
4. The following specimens have tests that are highly distorted, with chambers formed in an irregular manner (4 - 10).
5. *Ammonia inflata* (Seguenza); 430 µm, x 132.
6. *Adelosina brongniartana* (D'Orbigny) var. *angulata* Wiesner; 1125 µm, x 78.
7. *Miliolinella webbiana* (D'Orbigny); 378.5 µm, x 20.
8. *Planorbulina mediterranensis* D'Orbigny; 830µm, x 105.
9. *Sorites orbiculus* Ehrenberg; 1250 µm, x 132.
10. *Sorites orbiculus* Ehrenberg; 714.2 µm, x 130.
11. *Cibicides refulgens* deMontfort; 916 µm, x 105.

The apertural chamber is seen to be masking or covering earlier chambers.

13. *Adelosina mediterranensis* (Le Calvez, and Le Calvez); 600 µm, x 60
14. *Adelosina pulchella* D'Orbigny; 525 µm, x 125.
15. *Adelosina intricata* (Terquem); 510 µm, x, flim no 5446 no 24.
16. *Triloculina marioni* Schlumberger; 571.4 µm, x 105.

Plate 4.7

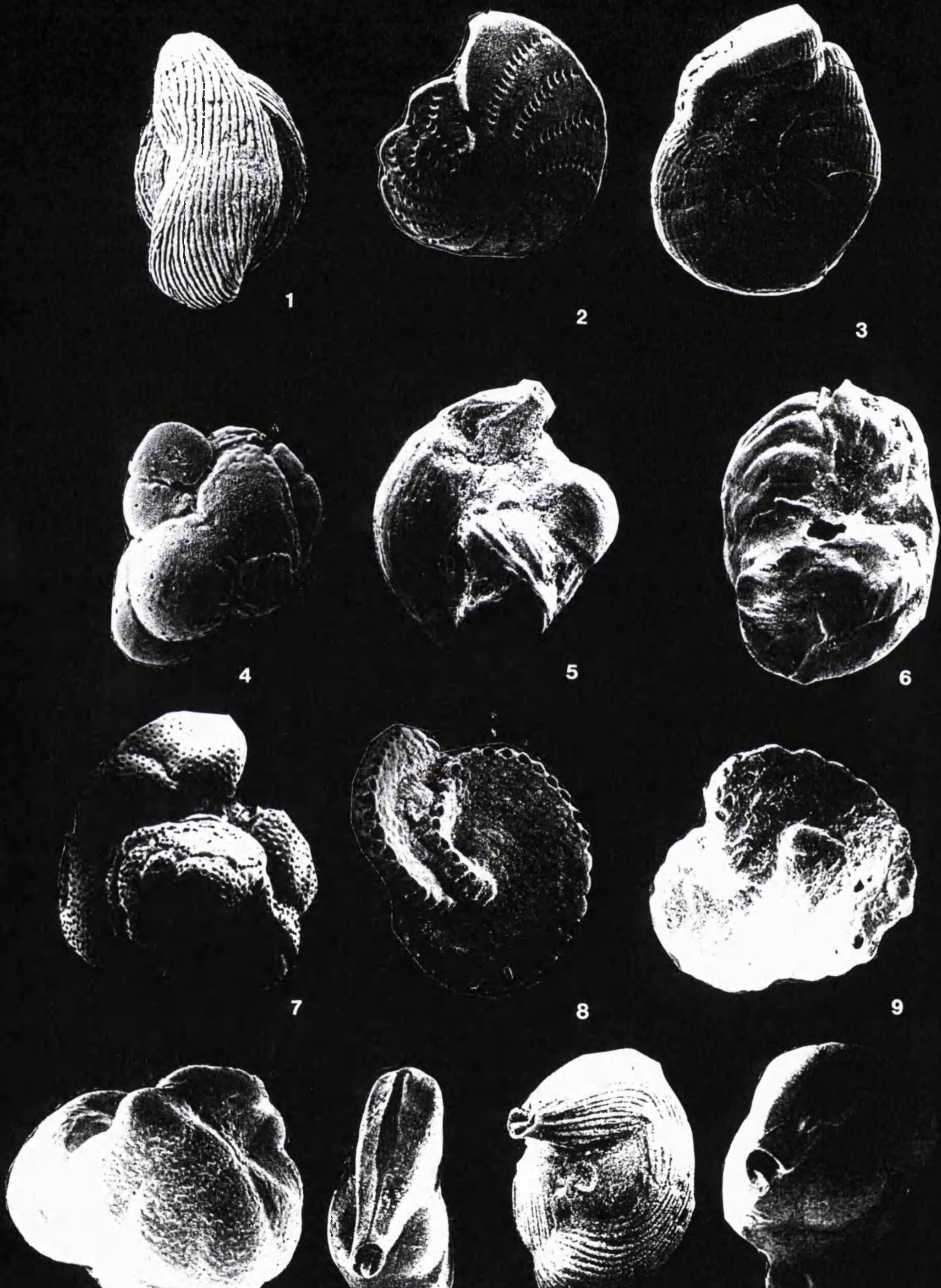


Plate 4.8

TDF-9 (Distorted/contorted chambers and over test outline).

Chambers that are slightly of-set or displaced from the axis of the coiling.

The apertural chamber is displaced downwards.

1. *Quinqueloculina disparilis* D'Orbigny; 416 μm, x 60.
2. *Lachlanella variolata* (D'Orbigny); 500 μm, x 72.

FDT - 10 (Loose quinqueloculine coiling).

The apertural chamber is detached at the apertural end from earlier chambers

3. *Adelosina elegans* (Williamson); 1150 μm, x 69.
4. *Spriloculina* sp. 1044 μm, x 86
5. *Spriloculina* sp. 980 μm, x 52

FDT - 11 (Very tight quinqueloculine coiling).

6. *Adelosina elegans* (Williamson); 945.4 μm, x 69. The second and initial chambers are disoriented and the initial chamber is elevated.

FTD12 - (Abnormal apertural chamber).

A pronounced concave or convex crescent shape, bending or curvature of the apertural chamber (7-8)

7. *Adelosina intricata* (Terquem); 822.2 μm, x 150.
8. *Adelosina intricata* (Terquem); 907 μm, x 90.
9. *Adelosina intricata* (Terquem); 611.1 μm, x 60.

Flexing in which there is a points of bending along the apertural chamber (10-12)

10. *Adelosina intricata* (Terquem); 544.4 μm, x 120.
11. *Triloculina* sp.; 336.3 μm, x 120.
12. *Spiroloculina* sp.; 800 μm, x 820.

Plate 4.8

Plate 4.9

FTD-12 (Abnormal apertural chamber) (continued)

1. *Adelosina elegans* (Williamson); 1540 µm, x 48. This specimen has a combination of deformities; it has apertural chamber flexing at one point, and tight quinqueloculine coiling where the second and the third chambers are elevated.
2. *Cycloforina* sp.; 463.6 µm, x 48. This specimen has a flexing at one point in the apertural chamber.
3. *Sigmoilina edwardsi* (Schlumberger) var. *acuta* Chapman and Parr; 445.4 µm, x 130. The apertural chamber is in discord with the coiling plane of the test sited of pointing upwards it is lying on the earlier chambers.

Abnormalities in *Amphistegina lobifera* Larsen.

This species has a lot of combined deformities in each single test, all the specimens have abnormal apertural shape and exhibit contorted test outlines, off-centred, in some forms successive whorls are mal-aligned, in other forms the successive whorl are overlapping each other, some showing whorl angulation and lopsidedness which is clearly displayed on the spiral side such that the test slightly off-set or displaced from the axis of coiling and exhibits simple distortion in which the last whorl is deflected or displaced towards the spiral side.

4. *Amphistegina lobifera* Larsen; 783 µm, x 115.
5. *Amphistegina lobifera* Larsen; 1250 µm, x 70.
6. *Amphistegina lobifera* Larsen; 1428 µm, x 70.
7. *Amphistegina lobifera* Larsen; 360 µm, x 74.
8. *Amphistegina lobifera* Larsen; 1457 µm, x 90.
9. *Amphistegina lobifera* Larsen; 1428 µm, x 70.
10. *Amphistegina lobifera* Larsen; 642.8 µm, x153 .
11. *Amphistegina lobifera* Larsen; 900 µm, x 90 .
12. *Amphistegina lobifera* Larsen; 1228 µm, x 68 .
13. *Amphistegina lobifera* Larsen; 1285 µm, x 64.

Plate 4.9

Plate 4.10

Abnormalities in *Amphistegina lobifera* Larsen (continued).

1. *Amphistegina lobifera* Larsen; 1342.8 µm, x 84.
2. *Amphistegina lobifera* Larsen; 900 µm, x 90.
3. *Amphistegina lobifera* Larsen; 1342.8 µm, x 64.
4. *Amphistegina lobifera* Larsen; 1300 µm, x 56.
5. *Amphistegina lobifera* Larsen; 700 µm, x 105.
6. *Amphistegina lobifera* Larsen; 1125 µm, x film 5590 no 28
7. *Amphistegina lobifera* Larsen; 980 µm, x film 5590 no 5
8. *Amphistegina lobifera* Larsen; 500 µm, x 160.
9. *Amphistegina lobifera* Larsen; 1114 µm, x 96.
10. *Amphistegina lobifera* Larsen; 1685 µm, x 88.

Plate 4.10

Chapter 5
Taxonomy

5.1 Introduction

Core top samples from the eastern Mediterranean (Levantine Basin from 3 to 210 m depth) were studied for their foraminiferal content. A total of 87 and 52 Stations were sampled in spring 1993 and in winter 1995 respectively. Both living and dead foraminifera populations have been studied. Living foraminifera were used mainly for environmental monitoring and dead foraminifera were studied for taxonomic purposes and to identify the general multi-annual trends in faunal density and the distribution of taxa. A total of 168 species of living foraminifera from 35 families were recorded. Agglutinated foraminifera belonging to 2 families are represented by 7 species. The Miliolina is represented by 6 families and 88 species. The Rotaliina is represented by 22 families and 70 species. The Lagenina is represented by 5 families and 16 species.

5.2 Materials and methods

The samples for microfaunal analysis were preserved in a 4% formalin and sea water solution buffered with sodium borate (20 g of $NaBO_4$ per liter). This can prevent dissolution of calcium carbonate (Boltovskoy and Wright, 1976) and prevent the degeneration of the cytoplasm of living foraminifera.

Foraminifera were studied by standard methods. Rose Bengal stain was added to the preserved sample to differentiate living from the dead foraminifera. The samples were stained for 48 hr, then washed with distilled water using a 0.063 mm sieve to remove the surplus stain, then gently dried. The potential limitations of Rose Bengal stain method has been discussed (Boltovskoy and Wright, 1976). The samples were sieved on meshes of 0.063 mm - 0.5 mm and microscopically analysed in the laboratory. In specimens that were alive at the time of collection, the protoplasm is stained bright red, whereas the test wall remains either unstained or takes on a light pink colouration. However, it is necessary to check that the red colour is not caused by a cluster of bacteria or other organisms using the test as a refuge. The hyaline test, many agglutinated tests, and thick porcelaneous tests may obscure the stain when dry. This problem can be overcome by wetting such test with a moistened brush (Murray, 1991). The test morphology was assessed using the SEM and standard binocular microscope.

Some of the taxonomic identification was carried out by direct comparison with the type collection of V. Yanko, and with the aid of the Ellis and Messina Catalogue, and monographs by Hottinger *et al* (1993), Cimerman and Langer (1991), Sgarrella and

Moncharmont (1993), Loeblich and Tappan (1994), Boltovskoy *et al.* (1980), Piller and Haunold (1998), Albani and Barbero (1990), and Jones, 1994.

5.3 Taxonomy of benthic foraminifera in the study area.

Class Foraminifera Lee, 1990

ORDER TEXTULARIINA Delage and Hérouard, 1896, emend Loeblich and Tappan (1989)

FAMILY Valvulinidae Berthelin, 1880

Genus *Clavulina* D'Orbigny, 1826

Clavulina cf. *C. multicamerata* Chapman, 1937

Plate 5.1, figure 1

1937 *Clavulina multicamerata* Chapman. - Cushman, p. 24, pl. 3, figs. 13, 14.
1937 cf. *Clavulina multicamerata* Chapman. - Cushman, p. 24, pl. 3, fig. 15, 16.
1993 *Clavulina* cf. *C. multicamerata* Chapman. - Hottinger *et al.*, p. 42, pl. 22, figs. 1-6.

Occurrence. This species is a rare species and has low relative abundance in both seasons It was found at 4 stations in spring (16 to 56 m). In winter it was found at 3 stations (24 to 56 m).

FAMILY TEXTULARIIDAE, Ehrenberg, 1838

Genus *Bigenerina* D'Orbigny, 1826

Bigenerina nodosaria D'Orbigny, 1826

Plate 5.1, figure 2

1826 *Bigenerina nodosaria*, D'Orbigny, p. 261, pl. 2, figs. 9 -10.
1922b *Bigenerina nodosaria* D'Orbigny. - Cushman, p. 24, pl. 3, fig. 24.
1958 *Bigenerina nodosaria* D'Orbigny. - Le Calvez, Y., p. 153.
1974 *Bigenerina nodosaria* D'Orbigny. - Colom, p. 87, figs. 6 a - k.
1979 *Bigenerina nodosaria* D'Orbigny. - Alfirevic, p. 64, pl. 4.
1987 *Bigenerina nodosaria* D'Orbigny. - Loeblich and Tappan, p. 172, pl. 191, figs. 1, 2.
1991 *Bigenerina nodosaria* D'Orbigny. - Cimerman and Langer, p. 21, pl. 9, figs. 1 -6.

Occurrence. The species is very rare, found at one station (station 69 at depth 82 m) in the spring.

Genus *Textularia* Defrance, 1824

Textularia agglutinans D'Orbigny, 1839

Plate 5.1, figure 3

1839 *Textularia agglutinans* D'Orbigny, p. 144, pl. 1, figs. 17, 18, 32-34.
1880 *Textularia agglutinans* D'Orbigny. - Möbius, pl. 9, figs. 1- 8.
1884 *Textularia agglutinans* D'Orbigny. - Brady, pl.43, fig.1, 2.

1949 *Textularia agglutinans* D'Orbigny. - Said, p. 5, pl. 1, fig. 3.
1977 *Textularia agglutinans* D'Orbigny. - Le Calvez, p. 13- 14, fig. 1.
1979 *Textularia agglutinans* D'Orbigny. - Pereira, pl. 2, figs. n -p.
1981 *Textularia agglutinans* D'Orbigny. - Banner and Pereiera, p.93, pl. 1, figs. 6-7, pl. 2, fig. 1.
1991 *Textularia agglutinans* D'Orbigny - Hottinger *et al.*, p. 36, pl. 13, figs. 1-9.

Occurrence. The species is found at 2 stations in winter (47 and 34 m depth). In spring it is found at 4 stations (6.5 to 48 m respectively).

Textularia bocki Höglund, 1947

Plate 5.1, figures 4, 5

1947 *Textularia bocki* Höglund, p. 171, pl. 12, figs. 5, 6.
1932 *Textularia agglutinans* D'Orbigny. - Lacroix, p. 16, fig. 13.
1958 *Textularia bocki* Höglund. - Le Calvez, Y., p. 150, pl. 1, fig. 4.
1991 *Textularia bocki* Höglund. – Cimerman and Langer, p 21, pl. 10, fig 3 - 6.

Occurrence. This species is the most abundant and widespread agglutinated species, generally the relative abundance increases with depth. It occurs from 7 to 82 m depth.

Textularia conica D'Orbigny, 1839

Plate 5.1, figure 6

1839 *Textularia conica* D'Orbigny, p.143, pl. 1, figs 19, 20.
1899 *Textularia conica* D'Orbigny. - Flint, p. 285, pl. 29, fig. 6.
1923 *Textularia conica* D'Orbigny. - Cushman, p. 11, pl. 2, figs. 8-10.
1977 *Textularia conica* D'Orbigny. - Le Calvez, Y., p. 18, figs, 1, 2.
1991 *Textularia conica* D'Orbigny. – Cimerman and Langer, p. 22, pl. 10, figs 7 - 9.

Occurrence. This is relatively rare species. It occurs at 9 stations, from 16 to 48 m depth in spring. In winter it was found at 2 stations, at depths of 34 and 47 m.

Textularia truncata Höglund, 1947

Plate 5.1, figure 8

1947 *Textularia truncata* Höglund, p. 175, pl. 12, fig. 8, 9, text figs. 147-149.
1958 *Textularia truncata* Höglund. - Le Calvez, Y., p. 149, pl. 1, fig. 5.
1991 *Textularia truncata* Höglund. - Cimerman and Langer, p. 22, pl. 12, figs 1 - 3.

Occurrence. This species occurred at 8 stations from 16 to 48 m depth in spring and winter, but all the collected specimens of this species were not stained, so it was not included with the count of the living species.

Siphenotextularia concava (Karrer, 1868)

Plate 5.1, figure 7

1868 *Plecanium concavum* Karrer, p. 192, pl. 1, fig. 3.
1932 *Textularia concava* (Karrer). - Lacroix, p. 14, figs. 10 -12.
1960 *Siphenotextularia concava* (Karrer). - Barker, pl. 42, figs. 13 - 14.

1991 *Siphenotextularia concava* (Karrer). - Cimerman and Langer, p. 23, pl. 12, figs 4 - 6..

Occurrence. This species has a wide depth range. It was found in winter at 7 stations (7 to 102 m depth) and in spring in at 16 stations (6.5 to 102 m depth).

Order MILIOLINA Delage and Herouard, 1896

FAMILY Hauerinidae Schwager, 1876

Genus *Parrina* Cushman, 1981

Parrina bradyi (Millett, 1898)

Plate 5.1, figure 9

1898 *Nubecularia bradyi* Millett, p. 261, pl. 5, figs. 6 a, b (fide Ellis and Messina, 1940)
1923 *Miliolina hibrida* (Terquem). - Wiesener, p. 71, pl. 14, figs. 172-175.
1960 *Parrina bradyi* (Millett). - Baker, pl. 1, figs. 5, 6.
1970 *Parrina bradyi* (Millett). - v. Daniels, p. 78, pl. 4, fig 3.
1987 *Parrina bradyi* (Millett). - Loeblich and Tappan, p. 35, figs. 16 - 18.
1991 *Parrina bradyi* (Millett). – Cimerman and Langer p. 49, pl. 47, fig 6 - 7.

Occurrence. This species is very rare. It occurs at 4 stations (3 to 43 m depth). It was not found in the samples collected in winter.

Genus *Articulina* D'Orbigny, 1826

Articulina pacifica Cushman, 1944

Plate 5.1, figure 10

1944 *Articulina pacifica* Cushman, p. 17, pl. 4, fig. 14 -18.
1949 *Articulina pacifica* Cushman. - Said, p. 16, pl. 2, fig. 4.
1984 *Articulina pacifica* Cushman. - Reiss and Hottinger, fig. G 26 m, n, o.
1993 *Articulina pacifica* Cushman. – Hottinger *et al.*, p.48, pl. 31, figs. 5 - 9.

Occurrence. The species was not found in the winter samples. In spring it was found at 4 stations from 16 to 32 m depth. It has low abundance.

Articulina carinata (Wiesner, 1923)

Plate 5.1, figure 11

1923 *Articulina sagra* D'Orbigny var. *carinata* Wiesner, p. 74, pl. 19, fig. 188.
1970 *Articulina pacifica* Cushman. - v. Daniels, p. 78, textfig. 53.
1991 *Articulina carinata* Wiesner. – Cimerman and Langer, p. 48, pl. 47, figs. 1 - 5

Occurrence. The species was found at one station in the spring (38 m depth) and at two stations in winter (27 m and 32 m depth respectively).

Genus *Cycloforina* Luczkowska, 1972

Cycloforina tenuicollis (Wiesner, 1923)

Plate 5.2, figure 1

1923 *Miliolina tenuicollis* Wiesner, p. 48, pl. 6, fig, 66.
1909 *Miliolina ferussacii* D'Orbigny. - Sidebottom, p. 17, pl. 5, fig. 7.
1991 *Cycloforina tenuicollis* (Wiesner). – Cimerman and Langer, p.33, pl. 28. figs. 6 - 5.

Occurrence. This species has a scattered occurrence in spring, in few numbers at 4 stations from 25 to 35 m depth. In winter it is found at one station at 32 m depth.

Cycloforina quinquecarinata (Collins, 1958)

Plate 5.2, figure 2

1958 *Quinqueloculina quinquecarinata* Collins, p. 360, pl. 2, fig. 8.
1987 *Quinqueloculina quinquecarinata* Collins. - Baccaert, p. 103, pl. 48, figs. 1, 2.
1988 *Quinqueloculina quinquecarinata* Collins - Haig, p. 234, pl. 7, figs. 21 - 25.
1993 *Cycloforina quinquecarinata* (Collins). - Hottinger *et al.*, p. 49, pl. 33, figs. 7 - 15.

Occurrence. This species was found in spring at station 22 (at 29 m depth).

Cycloforina sp.

Plate 5.2, figure 3

1991 *Cycloforina* sp. – Cimerman and Langer, p. 33, pl. 28. figs. 10 - 12.

Occurrence. This species found in one station (20, 32 m depth) at spring.

Genus *Quinqueloculina* D'Orbigny, 1826

Quinqueloculina jugosa Cushman, 1944

Plate 5.2, figures 4-5

1878 *Quinqueloculina costata* Terquem, p. 63, pl. 6, figs. 3, 5.
1944 *Quinqueloculina seminulum* Linne var. *jugosa* Cushman, p. 13, pl. 2, fig. 15.
1958 *Quinqueloculina seminulum* Linne var. *jugosa* Cushman. - Le Calvez, J. and Le Calvez, Y., p. 178, pl. 4, figs. 20, 21.
1991 *Quinqueloculina jugosa* Cushman. - Cimerman and Langer, p. 37, pl. 33, figs. 12 - 14.

Occurrence. Found in low numbers at 6 to 32 m depth In spring and winter (in 2 and 3 stations respectively).

Quinqueloculina bosciana D'Orbigny, 1839

Plate 5.2, figure 6

1839 *Quinqueloculina bosciana* D'Orbigny, p.191, pl. 11, figs, 22 - 24.
1991 *Quinqueloculina bosciana* D'Orbigny. – Cimerman and Langer, p.36, pl. 33. figs. 5 - 7.

Occurrence. The species was found at 7 stations in winter from 20 to 51 m depth. In spring, it was found at 2 stations at depths of 27 and 34 m.

Quinqueloculina disparilis D'Orbigny, 1826

Plate 5.2, figure 7-8

1826 *Quinqueloculina disparilis* D'Orbigny, p. 302, no. 21.
1893 *Quinqueloculina disparilis* D'Orbigny. - Schlumberger, p. 212, pl. 2, fig. 55-57.
1923 *Quinqueloculina disparilis* D'Orbigny. - Wiesner, p. 47, pl. 6, fig. 60, 61.
1958 *Quinqueloculina disparilis* D'Orbigny. - Le Calvez, J. and Y., p. 180, pl. 4, fig. 26, 27.
1974 *Quinqueloculina disparilis* D'Orbigny. - Colom, p. 200, fig. 55 a-g.
1991 *Quinqueloculina disparilis* D'Orbigny.– Cimerman and Langer, p.36, pl. 33. figs. 1 - 4.

Occurrence. This species is a widespread species occurring 19 stations at spring (6.5 to 82 m depth) and occurs in 7 stations at winter (19 to 51 m depth).

Quinqueloculina seminula (Linnaeus, 1758)

Plate 5.2, figure 9

1758 *Serpula seminula* Linne', p. 786, pl. 2, figs. 1 a-c (fide Ellis and Messina, 1940)
1893 *Quinqueloculina seminula* (Linne'). - Schlumberger, p. 208, pl. 4, fig. 80, 81.
1923 *Milionila seminulum* (Linne'). - Wiesner, p. 66, pl. 12, fig. 148.
1960 *Quinqueloculina seminula* (Linne'). - Barker, pl. 5, fig. 4.
1970 *Quinqueloculina seminula* (Linne'). - v. Daniels, p. 75, pl. 3. fig. 4.
1991 *Quinqueloculina seminula* (Linne'). – Cimerman and Langer, p. 38 pl. 34. figs. 9 - 12.

Occurrence. This species is found at 34 m to 43 m depth in spring and winter (6 and 2 stations respectively).

Remarks. It has four visible chambers, but one chamber is hardly visible from one side, and it is not visible from the other side.

Quinqueloculina stelligera Schlumberger, 1893

Plate 5.2, figure 10

1893 *Quinqueloculina stelligera* Schlumberger, p. 210, pl. 2, figs. 58, 59.
1923 *Miliolina schlumbergeri.* Wiesner, p. 49, pl. 6, fig. 73.
1985 *Quinqueloculina stelligera* Schlumberger. - La Calvez, J. and La Calvez, Y., p. 174, pl. 11, figs. 125, 126.
1970 *Quinqueloculina stelligera* Schlumberger. - Haake, p. 196, pl. 1, fig. 3, 4.
1991 *Quinqueloculina stelligera* Schlumberger.– Cimerman and Langer, p 38, pl. 34, figs. 13 - 15.

Occurrence. *Quinqueloculina stelligera* is widespread species that occurred at a depth ranges of 6 to 210 m (20 stations) in spring. It is found in winter from 16 to 68m (in 11 stations).

Quinqueloculina laevigata D'Orbigny, 1839

Plate 5.2, figure 11

1839 *Quinqueloculina laevigata* D'Orbigny, p. 143, pl. 3, figs. 32 - 33.
1823 *Miliolina laevigata* (D'Orbigny). - Wiesner, p. 55, pl. 8, fig. 94-96.
1958 *Quinqueloculina laevigata* D'Orbigny. - Le Cavez, J. and La Calvez, Y., p. 184, pl. 10, fig. 112-114.
1929 *Quinqueloculina laevigata* D'Orbigny. - Cushman, p. 30, pl. 4, fig. 3.
1991 *Quinqueloculina laevigata* D'Orbigny. – Cimerman and Langer, p. 37 pl. 33. figs. 8 - 11.

Occurrence. occurred in few numbers at 28 to 38 m depth in both seasons (in 3 stations in spring and 2 stations in winter).

Quinqueloculina parvula Schlumberger, 1894

Plate 5.2, figure 12

1894 *Quinqueloculina parvula* Schlumberger, p. 255, pl. 3, figs. 8,9.
1958 *Quinqueloculina parvula* Schlumberger - Le Calvez, J. and Y., p. 184, pl. 10, figs. 131-133.
1991 *Quinqueloculina parvula* Schlumberger – Cimerman and Langer, p.37 pl. 34. figs. 6 - 8.

Occurrence. This species is very rare it occurs at one station in spring and winter (station 49 at 44 m depth).

Quinqueloculina cf. Q. multimarginata Said, 1949

Plate 5.2, figure 13

1949 cf. *Quinqueloculina cf. Q. multimarginata* Said, p. 10, pl. 1, fig. 34.
1979 *Quinqueloculina crassicarinata* Collins. - Zheng, pl. 6, fig. 4 (non *Q. crassicarinata* Collins).
1993 *Quinqueloculina cf. Q. multimarginata* Said. - Hottinger *et al*, p. 59, pl. 55, figs. 7 - 10.

Occurrence. This species was encountered at one station at 6.5 m depth in spring.

Quinqueloculina pseudobuchiana Luczkowska, 1974

Plate 5.2, figure 14

1974 *Quinqueloculina pseudobuchiana* Luczkowska, p. 58, pl. 5, figs, 1 - 4.
1991 *Quinqueloculina pseudobuchiana* Luczkowska. - Cimerman and Langer, p. 38, pl. 35, figs. 1 - 4.

Occurrence. This species found at one station (station 85), at 6.5 m depth, in spring.

Quinqueloculina cf. *Q. limbata* D'Orbigny, 1826

Plate 5.2, figure 15

1994 *Quinqueloculina* cf. *limbata* D'Orbigny. - Loeblich and Tappan, p. 49, pl. 78, fig. 10 - 12.
1998 *Quinqueloculina* cf. *limbata* D'Orbigny. - Piller and Haunold, p. 17, pl. 4, fig. 11.

Occurrence. This species was found at one station in spring (station 49 at 44 m depth).

Genus *Triloculina* D'Orbigny, 1826

Triloculina marioni Schlumberger, 1893

Plate 5.3, figures 1, 2

1893 *Triloculina marioni* Schlumberger, p. 204, pl. 1, figs. 38 - 41.
1958 *Triloculina marioni* Schlumberger. - Le Calvez, J. and La Calvez, Y., p. 191, pl. 6, fig. 54-56.
1991 *Triloculina marioni* Schlumberger. – Cimerman and Langer, p. 46, pl. 43, figs 1 - 5.

Occurrence. This species is dominant in the area and is the most widespread *Triloculina* species. It occurs at a depth range from 7 to 210 m at 51 stations in spring. It was found in winter at 26 stations.

Triloculina schreiberiana D'Orbigny, 1839

Plate 5.3, figure 3

1839 *Triloculina schreiberiana* D'Orbigny, p. 174, pl. 9, figs, 20 - 22.
1893 *Triloculina schreiberiana* D'Orbigny. - Schlumberger, p. 204, pl. 1, fig. 42-44.
1923 *Miliolina schreiberiana* (D'Orbigny). - Wiesner, p. 60, pl. 9, fig. 114.
1958 *Triloculina schreiberiana* D'Orbigny. - Le Calvez, J. and La Calvez, Y., p. 194, pl. 7, fig. 67.
1977 *Triloculina schreiberiana* D'Orbigny. - Le Calvez, La Calvez, Y., p. 121, fig. 1-3.
1991 *Triloculina schreiberiana* D'Orbigny. – Cimerman and Langer p. 46, pl. 44, fig 1 - 2.

Occurrence. This species is relatively widespread. It occurs from 19 to 102 m depth in both seasons (in 21 stations in spring and 11 stations in winter).

Triloculina plicata Terquem, 1878

Plate 5.3, figures 4

1878 *Triloculina plicata* Terquem, p. 61, pl. 6, figs. 2a, b.
1923 *Triloculina plicata* Terquem. - Wiesner, p. 62, pl. 11, figs. 129, 130.
1958 *Triloculina plicata* Terquem. - Le Calvez, J. and La Calvez, Y., p.198, pl. 14, figs. 162, 163.
1991 *Triloculina plicata* Terquem.– Cimerman and Langer p. 46, pl. 43, figs 8 - 10.

Occurrence. This species occurs at from 6 to 102 m depth in both seasons was found at 18 stations in spring and 13 stations in winter.

Triloculina asymmetrica Said, 1949

Plate 5.3, figure 5

1949 *Triloculina asymmetrica* Said, p.18, pl. 2, fig. 11.
1993 *Triloculina asymmetrica* Said. – Hottinger *et al.*, p. 64, pl. 66, figs. 4 - 9.

Occurrence. This species is found at depth ranges from 6.5 to 75 m depth (in 15 stations) in spring. It was found in winter from 35 to 71 m depth (in 11 stations).

Triloculina serrulata McCulloch, 1977

Plate 5.3, figures 6-8

1977 *Triloculina serrulata* McCulloch, p. 558, pl. 225, figs. 1, 2, 4..
1993 *Triloculina serrulata* McCulloch. – Hottinger *et al.*, p. 65, pl. 67, figs. 1 - 9.

Occurrence. This species relatively widespread in the north region the area. It was found at 26 stations (at 6.5 to 82 m) depth in spring and in 11 stations (at 16 to 75 m) depth in winter.

Triloculina tricarinata D'Orbigny, 1826

Plate 5.3, figure 9, 10

1826 *Triloculina tricarinata* D'Orbigny, p. 299.
1884 *Triloculina tricarinata* D'Orbigny. - Brady, pl. 3, fig.17.
1949 *Triloculina terquemiana (*Brady) var. *laevis* Said, p. 10, pl. 2, fig. 15.
1991 *Triloculina tricarinata* D'Orbigny. - Cimerman and Langer p. 46, pl. 44, figs 3-4.

Occurrence. This species was found at 2 stations (at 45 and 53 m depth) in spring. And 4 stations in winter (at 26 to 184 m).

Triloculina affinis D'Orbigny, 1852

Plate 5.3, figure 11

1852 *Triloculina affinis* D'Orbigny, p. 161.
1905 *Triloculina affinis* D'Orbigny in Fornasini, pl. 1, fig. 1.
1959 *Triloculina affinis* D'Orbigny. - Graham and Militante, p. 52, pl. 7, figs. 5, 6.
1993*Triloculina affinis* D'Orbigny. - Hottinger *et al.*, p. 64, pl. 66, figs. 1 - 3.

Occurrence. This species was found at depth range from 19 and 82 m (in 25 stations) in spring. It was found in winter from 24 to 200 m depth (in 11 stations).

Triloculina ornata Le Calvez, and Le Calvez, 1958

Plate 5.3, figure 12

1958 *Triloculina ornata* Le Calvez, J., and Le Calvez, Y, p. 190, pl. 14, fig. 160, 161.
1991 *Triloculina ornata* Le Calvez, J. & Le Calvez, Y. - Cimerman and Langer p. 46, pl. 44, figs 6-7.

Occurrence. This species occurs from 7 to 36 m depth in 3 stations in spring and 3 stations in winter.

Genus *Biloculinella* Wiesner, 1931

Biloculinella labiata (Schlumberger, 1891)

Plate 5.4, figure 1

1891 *Biloculina labiata* Schlumberger, p. 556, pl.9, fig. 60 -62, text figs. 13 -14.
1923 *Biloculina labiata* Schlumberger var. *simplex*. Wiesner, p. 89, pl. 18, fig. 261.
1958 *Biloculina labiata* Schlumberger var. *simplex*. Wiesner - Le Calvez, J. and La Calvez, Y., p. 202, pl. 16, figs. 193 - 194.
1987 *Biloculina labiata* (Schlumberger). - Loeblich and Tappan, p. 337, pl. 348, figs. 1 - 4.
1991 *Biloculina labiata* (Schlumberger). - Cimerman and Langer, p. 40, pl. 36, fig. 12.

Occurrence. This species was found from 7 and 75 m depth in spring and winter (in 16 and 11 stations) respectively.

Biloculinella globula (Bornemann, 1855)

Plate 5.4, figure 2

1855 *Biloculina globulus* Bornemann, p. 349, pl. 19, fig. 3a,b.

1891 *Biloculina globulus* Bornémann. - Schlumberger, p. 575, pl. 12, fig. 97-100.
1991 *Biloculina globulus* Bornemann. - Cimerman and Langer, p. 40, pl. 36, fig. 1-2.

Occurrence. This species found at 9 stations in spring at 6.5 m to 36 m depth, it was found from 13 to 36 m depth at 5 stations in winter.

Genus *Massilina* Schlumberger, 1893

***Massilina secans* (D'Orbigny, 1826)**

Plate 5.4, figure 3, 4

1826 *Quinqueloculina secans* D'Orbigny, p. 303, no. 43.
1958 *Massilina secans* (D'Orbigny). - Le Calvez, J. andLa Calvez, Y., p. 204, pl. 7, fig. 66.
1971 *Massilina secans* (D'Orbigny). - Murray, p. 67, pl. 25, fig. 1-6.
1987 *Massilina secans* (D'Orbigny). - Loeblich and Tappan, p. 335, pl. 344, fig. 1-3.
1991 *Massilina secans* (D'Orbigny). – Cimerman and Langer p 35, pl. 30, figs 7 - 12.

Occurrence. This species occurs in 7 stations in spring (at 6.5 to 36 m depth). It was found in winter in 2 stations at 3 and 36 m depth.

Genus *Pseudomassilina* Lacroix, 1938

***Pseudomassilina reticulata* (Heron-Allen and Earland, 1915)**

Plate 5.4, figure 5

1915 *Massilina secans* var. *reticulata* Heron-Allen and Earland, p. 582, pl. 45, fig. 1 - 4.
1993 *Pseudomassilina reticulata* (Heron-Allen and Earland). – Hottinger *et al.*, p. 54, pl. 42, figs. 1 - 8.

Occurrence. This species was found in spring at 16 to 36 m depth, at 10 stations. In winter it was found at 28 to 35 m depth, at 4 stations.

Genus *Lachlanella* Vella, 1957

***Lachlanella undulata* (D'Orbigny, 1826)**

Plate 5.4, figures 6, 7

1826 *Quinqueloculina undulata* D'Orbigny, p. 302, no. 27.
1893 *Quinqueloculina undulata* D'Orbigny. - Schlumberger, p. 213, pl. 2, figs. 60, 61.
1923 *Miliolina undulata* (D'Orbigny). – Wiesner, p.53, pl. 7, fig.81.
1985 *Quinqueloculina undulata* D'Orbigny. - Le Calvez, J., and Y., p. 179, pl. 13, figs. 146-148.
1958 *Quinqueloculina undulata* D'Orbigny. - Le Calvez, Y., p.159.
1974 *Quinqueloculina undulata* D'Orbigny. - Colom, p. 202, fig. 58 h-k.
1991 *Lachlanella undulata* (D'Orbigny). – Cimerman and Langer, p. 34, pl. 30, figs. 3 - 6.

Occurrence. This species is very rare, it is found in one station in winter (at 37 and 27 m depth). In spring it was found (at 2 stations at 27 and 33 m depth).

***Lachlanella variolata* (D'Orbigny, 1826)**

Plate 5.4, figures 8, 9

1826 *Lachlanella variolata*, D'Orbigny, p. 302, no. 26.
1839 *Triloculina carinata* D'Orbigny, p. 179, pl. 10, fig. 15-17.
1923 *Miliolina reticulata* (D'Orbigny). - Wiesner, p. 52, pl. 7, fig. 78.
1923 *Miliolina reticulata* (D'Orbigny) var *carinata*D'Orbigny. - Wiesner, p. 54, pl. 8, fig. 88.
1970 *Quinqueloculina reticulata* D'Orbigny. - Cherif, pl. 9, fig. 1
1974 *Quinqueloculina reticulata* D'Orbigny. - Colom, p. 201, fig. 56a-d.
1977 *Quinqueloculina reticulata* D'Orbigny. - Le Calvez, Y.,p. 102, fig. 15-17.
1993 *Lachlanella variolata* D'Orbigny. – Cimerman and Langer p. 35, pl. 31, figs 1 - 12.

Occurrence. This species is rare found in winter at one station (at 33 m). In spring it is found in 2 stations at 27 and 33 m.

Genus *Pseudotriloculina* Cherif, 1970

Pseudotriloculina laevigata **(D'Orbigny, 1826)**

Plate 5.4, figure 10

1826 *Triloculina laevigata* D'Orbigny, p. 300, no. 15.
1923 *Milionila laevigata* (D'Orbigny). - Wiesner, p 55, pl. 8, figs. 94 - 96.
1958 *Triloculina laevigata* D'Orbigny. - Le Calvez, J. and La Calvez, Y., p. 19, pl. 6, fig. 62 - 64.
1991 *Pseudotriloculina laevigata* (D'Orbigny). – Cimerman and Langer p. 43, pl. 39, fig. 8 - 12.

Occurrence. This species is the widespread species in *Pseudotriloculina* species. It occurs in spring at 14 stations, from 16 to 200 m depth. In winter it occurs at 10 stations from 19 to 67 m depth.

Pseudotriloculina oblonga **(Montagu, 1803)**

Plate 5.4, figure 11

1803 *Vermiculum oblonga* Montagu, p. 522, pl. 14, fig. 9 (fide Ellis and Messina).
1839 *Triloculinaaoblonga* (Montagu). - D'Orbigny, p. 175, pl. 10, fig. 3,5.
1958 *Triloculina oblonga* (Montagu). - Le Calvez, J. & Le Calvez, Y., pl. 6, fig. 60, 61.
1958 *Triloculina oblonga* (Montagu). - Le Calvez, Y., p. 115, fig. 1, 2.
1991 *Pseudotriloculina oblonga* (Montagu). – Cimerman and Langer p. 37, 34, pl. 40, figs.1 -4.

Occurrence. This species was found in winter in 6 stations at 19 from 67 m depth. In spring it was found at 14 stations from 6.5 to 67 m.

Pseudotriloculina rotunda **(D'Orbigny, 1826)**

Plate 5.4, figure 12

1826 *Triloculina rotunda* D'Orbigny, p. 299, no. 4.
1893 *Triloculina rotunda* D'Orbigny. - Schlumberger, p. 206, pl. 1, figs. 48 - 50.
1923 *Miliolina routunda* (D'Orbigny). - Wiesner, p. 55, pl. 8, fig. 97.
1958 *Triloculina rotunda* D'Orbigny. - Le Calvez, J. and Y., p. 192, pl. 6, figs. 57, 58.
1974 *Triloculina rotunda* D'Orbigny. - Colom, p. 204, fig. 59, n, o.
1991 *Pseudotriloculina rotunda* (D'Orbigny). – Cimerman and Langer, p. 43, pl. 40, figs. 5 - 6.

Occurrence. This species is rare. It occurs at 2 stations from 47 and 68 m depth. In spring it occurs at 5 stations from 20 to 68 m depth.

Pseudotriloculina sp.

Plate 5.4, figure 13

1993 *Pseudotriloculina* sp. Hottinger *et al*, p. 56. pl. 49, figs. 1 - 7.

Occurrence. This species was found in spring at 6.5 to 102 m depth, in 20 stations. In winter it was found at 14 to 102 m depth, in 6 stations.

Pseudotriloculina subgranulata (Cushman, 1918)

Plate 5.4, figure14

1918 *Triloculina subgranulata* Cushman, p. 290, pl. 96, fig.4.
1993 *Triloculina subgranulata* Cushman. - Hottinger *et al*, p. 56. pl. pl. 47, fig.8 - 13, Plate 5.48, fig 1 -8

Occurrence. This species occure in 7 stations at 6.5 to 36 m depth in spring. In winter it occues in 2 stations at 35 and 36 depth.

Genus *Pseudopyrgo* Rasheed, 1971

Pseudopyrgo milletti (Cushman, 1917)

Plate 5.4, figures 14, 15

1898 *Miliolina durrandi* Millett, p. 268, pl. 6, figs. 8, 9.
1917 *Biloculina milletti* Cushman, p. 81, pl. 34, figs. 4, 5.
1932 *Pyrgo milletti* (Cushman). - Cushman, p. 66, pl., 15, figs. 4, 5
1959 *Edentostomina milletti* (Cushman). - Collins, p. 371
1988 *Edentostomina milletti* (Cushman). - Zheng, pl. 2, fig. 1.
1971 *Pseudopyrgo milletti* (Cushman). - Rasheed, p. 42, pl. 14, fig. 2.
1987 *Pseudopyrgo milletti* (Cushman). - Loeblich and Tappan, pl. 351, figs. 17, 18.
1994 *Pseudopyrgo milletti* (Cushman). - Loeblich and Tappan, p. 53, pl. 89, figs. 10, 11.

Occurrence. This species is occurs from 7 to 47 m depth in 13 stations in spring. In winter it occurs at 5 stations from 24 to 102 m depth.

Genus *Pyrgo* Defrance, 1824

Pyrgo anomala (Schlumberger, 1891)

Plate 5.5, figure 1

1891 *Biloculina anomala* Schlumberger, p. 182, pl. 11, fig. 84, 86, pl. 12, fig. 101.
1917 *Biloculina anomala* Schlumberger. - Cushman, p. 79, pl. 32, fig. 1.
1923 *Biloculina anomala* Schlumberger. - Wiesner, p. 88, pl. 17, fig. 254, pl. 18, fig. 255.
1958 *Pyrgo anomala* (Schlumberger). - Le Calvez, J. and Le Calvez, p. 200, pl. 7, fig. 77.
1991 *Pyrgo anomala* (Schlumberger). – Cimerman and Langer, p. 44, pl. 41, figs. 3 - 5.

Occurrence. This species occurred at 5 stations in both seasons, at a depth from 24 to 102 m.

Pyrgo elongata (D'Orbigny, 1826)

Plate 5.5, figure 2

1826 *Biloculina elongata* D'Orbigny, p. 298, no. 4.
1891 *Biloculina elongata* D'Orbigny. - Schlumberger, p. 571, pl. 11, figs. 87, 88, pl. 12, fig., 89, textfig. 35, 36.
1917 *Biloculina elongata* D'Orbigny. - Cushman, p.78, pl. 31, fig. 1, textfig.. 40.
1923 *Biloculina elongata* D'Orbigny. - Wiesner, p. 87, pl. 17, fig. 247.
1929 *Pyrgo elongata* (D'Orbigny) - Cushman, p.70, pl. 19, fig. 2, 3.
1958 *Pyrgo elongata* (D'Orbigny) - Le Calvez, J. and Le Calvsez, Y., p. 200.
1974 *Pyrgo elongata* (D'Orbigny) - Colom, p. 204, fig. 57 n, o.
1991 *Pyrgo elongata* (D'Orbigny). – Cimerman and Langer, p. 44, pl. 41, figs. 6 - 8.

Occurrence. The species has wide depth range from 6 to 102 m. It occurs in spring in 7 stations. No living test was found in the winter samples.

Remarks. The tooth is wider in the specimen than the specimen figured by Cimerman.

Pyrgo striolata (Brady, 1884)

Plate 5.5, figures 3 - 5

1884 *Biloculina ringens* (Lamarck) var. *striolata* Brady, p. 143, pl. 3, fig. 7, 7.
1921 *Biloculina denticulata* Brady var. *striolata* Brady. - Cushman, 477, pl. 98, fig. 2.
1993 *Pyrgo striolata* (Brady). - Hottinger, p. 57, pl. 51, figs. 5 - 11
1994 *Pyrgo striolata* (Brady). – Loeblich and Tappan, p. 54, pl. 92, figs. 9 - 15.

Occurrence. This species found at 6 to 43 m depth in both seasons (in 5 stations in spring and 4 stations in winter).

Genus *Miliolinella* Wiesner, 1931

Miliolinella dilatata (D'Orbigny, 1839)

Plate 5.5, figure 6, 7

1839 *Quinqueloculina dilatata* D'Orbigny, p. 192, pl. 11, figs. 28 - 30.
1893 *Quinqueloculina dilatata* D'Orbigny - Schlumberger, p.217, pl.3, figs. 70 -40.
1977 *Pateoris dilatata* (D'Orbigny) - Le Calvez, Y., p. 72.
1991 *Miliolinella dilatata* (D'Orbigny). – Cimerman and Langer p. 41, pl. 37, figs 9 - 11.

Occurrence. This species is very rare, it was found at two stations in spring, at 33 and 34 m depth.

Miliolinella grata (Terquem, 1878)

Plate 5.5, figure 8

1878 *Quinqueloculina grata* Terquem, p. 75, pl. 9, figs. 4-7.
1991 *Miliolinella grata* (Terquem). – Cimerman and Langer, p. 41, pl. 37, fig 8.

Occurrence. This species occurs in 3 stations from 33 to 82 m depth. It was not found in winter samples.

Miliolinella webbiana (D'Orbigny, 1839)

Plate 5.5, figure 9

1839 *Triloculina webbiana* D'Orbigny, p. 140, pl. 3, figs. 13 - 15.
1923 *Miliolina webbiana* (D'Orbigny). - 72, pl. 14, figs. 13 -15.
1958 *Triloculina webbiana* D'Orbigny. - Le Calvez, J. & Le Calvez, Y., p. 195, pl. 15, figs., 176 - 178.
1974 *Triloculina webbiana* D'Orbigny. - Le Calvez, Y., p. 90, pl. 23, figs. 1- 4.
1991 *Miliolinella webbiana* D'Orbigny. - Cimerman and Langer, p. 42, pl. 39, figs. 1 - 3.

Occurrence. This species occurs at one station (at 32 m depth) in spring.

Miliolinella labiosa (D'Orbigny, 1839)

Plate 5.5, figures 10, 11

1839 *Triloculina labiosa* D'Orbigny, p. 178, pl. 10, figs. 12-14.
1923 *Miliolina labiosa* (D'Orbigny). -Wiesner, p. 71, pl. 134, fig. 172.
1929 *Triloculina lobiosa* D'Orbigny. - Cushman, p. 60, pl. 15, fig. 3.
1958 *Triloculina lobiosa* D'Orbigny. - Le Calvez, J. and La Calvez, Y., p. 196, pl. 14, figs. 168, 169.
1991 *Miliolinella labiosa* (D'Orbigny). – Cimerman and Langer, p. 41, pl. 3 8, figs. 1 - 3

Occurrence. This is the most abundant *Miliolinella* species. It was found at 10 stations from 16 to 32 m depth in spring and at 3 stations from 16 to 34 m depth in winter.

Miliolinella subrotunda (Montagu, 1803)

Plate 5.5, figure 12, Plate 5.6, figure 1

1803 *Vermiculum subrotunda* Montagu, p. 521 (fide Ellis and Messina, 1940).
1923 *Miliolinella subrotunda* (Walker and Boys). - Wiesner, p. 69, pl. 13, figs. 165 - 169.
1970 *Miliolinella subrotunda* (Walker and Boys). - v. Daniels, p. 77, pl. 4, fig. 2, textfig. 52.
1991 *Miliolinella subrotunda* (Montagu). – Cimerman and Langer p. 42, pl. 38, figs. 4 - 9.

Occurrence. This species is very rare, it was found at two stations in spring (at 16 and 27 m depth). It was not found in winter samples.

Genus *Sigmoilinita* Seiglie, 1965

Sigmoilinita costata (Schlumberger, 1893)

Plate 5.6, figures 2, 3

1893 *Sigmoilina costata* Schlumberger, p. 203, pl. 1, figs. 51, 52.
1958 *Sigmoilina costata* Schlumberger. - LeCalvez, J. and La Calvez, Y., p. 20, pl. 7, figs. 69, 70.
1991 *Sigmoilinita costata* (Schlumberger). – Cimerman and Langer, p. 47, pl. 45, figs. 1 - 6.

Occurrence. This species was found in spring at 13 stations (19 to 184 m depth). In winter it was found at 6 stations at depth m from 28 to 47 m.

Genus *Sigmoilina* Schlumberger, 1887

Sigmoilina edwardsi (Schlumberger) var. *acuta* Chapman and Parr, 1937

Plate 5.6, figure 4

1937 *Sigmoilina edwardsi* (Schlumberger) var. *acuta* Chapman and Parr, 1937, p. 132; pl. 9, fig. 33.

Occurrence. This species was found at one station in winter (35 at depth 28 m). Whereas in spring it was found at 5 stations (at 3 to 34 m).

Genus *Siphonaperta* Vella, 1957

***Siphonaperta agglutinans* (D'Orbigny, 1839)**

Plate 5.6, figures 5, 6

1839 *Quinqueloculina agglutinans* D'Orbigny, p. 195, pl. 12, fig. 11,12.
1958 *Quinqueloculina agglutinans* D'Orbigny. - Le Calvez, J. and Y., p. 166, pl. 9, fig.103, 104.
1977 *Quinqueloculina agglutinans* D'Orbigny. - Le Calvez, Y., p. 54, pl. 7, figs. 1- 4.
1991 *Siphonaperta agglutinans* (D'Orbigny). – Cimerman and Langer, p. 31, pl. 25, fig. 1 - 3.

Occurrence. This species was found in spring and winter at 3 stations from 27 to 34 m depth.

***Siphonaperta dilitata* (Le Calvez, and Le Calvez, 1958)**

Plate 5.6, figure 7

1958 *Quinqueloculina aspera* D'Orbigny var. *dilatata*. - Le Calvez, J, and Le Calvez, J, p. 169, pl. 11, figs. 119 - 121.
1991 *Siphonaperta dilitata* (Le Calvez, J. and Y.). - Cimerman and Langer, p. 31, pl. 26, figs. 1 -3.

Occurrence. This species was found at 2 stations (at 27 and 25 m depth) in spring. It was not found in the winter samples.

***Siphonaperta aspra* (D'Orbigny, 1826)**

Plate 5.6, figure 8

1826 *Quinqueloculina aspra* D'Orbigny, p. 301, no. 11.
1958 *Quinqueloculina aspra* D'Orbigny. - Le Calvez, J. and La Calvez, Y., p. 168, pl. 9, figs. 101, 102.
1991 *Siphonaperta aspra* (D'Orbigny). – Cimerman and Langer, p. 31, pl. 25, figs. 4 - 6.

Occurrence. This species was widspread at spring. It occurrs from 7 to 34 m and at 210 m depth. It is found in 16 stations. It was found in winter at 5 stations from 7 to 34 m depth.

***Siphonaperta osinclinata* (Le Calvez &Le Calvez, 1958)**

Plate 5.6, figure 9

1958 *Quinqueloculina osinclinatum* Le Calvez, J., and Le Calvez, Y, pp.167 - 168, pl. 3, figs. 7 - 8,pl. 9, figs. 95 -97.
1993 *Siphonaperta osinclinatum* (Le Calvez & Le Calvez). - Sgarrela and Moncharmont Zei, p. 185, pl. 8, figs. 6 - 7.

Occurrence. This species was found from 3 to 32 m depth at 3 station in spring. In winter it was found at one station at a depth of 43 m.

Genus *Hauerina* D'Orbigny, 1839

***Hauerina diversa* Cushman, 1946**

Plate 5.6, figure 10

1932 *Hauerina bradyi* Cushman, p. 44, pl. 10, figs. 12 - 15.
1946 *Hauerina diversa* Cushman, p. 11, pl. 2. figs. 16 - 19.
1946 *Hauerina diversa* Cushman. - Said, p. 17, pl. 2, fig. 6.
1987 *Hauerina circinata* Brady. - Baccaert, p. 144, pl. 62, figs. 4, 5.
1993 *Hauerina diversa* Cushman. – Hottinger *et al.*, p. 50, pl. 36, figs. 1 - 7.

Occurrence. This species is widespread in the northern part of the study area. It was found at depths from 6.5 to 44 m in both seasons (it was found at 24 stations in spring and at 10 stations in winter).

FAMILY Spiroloculinidae Wiesner, 1920

Genus *Adelosina* D'Orbigny, 1826

***Adelosina dubia* (D'Orbigny, 1826)**

Plate 5.6, figure 11

1826 *Triloculina dubia* D'Orbigny, p. 300, no. 24.
1923 *Adelosina dubia* (D'Orbigny). - Wiesner, p. 77, pl. 14, figs.193.
1958 *Triloculina dubia* D'Orbigny - Le Calvez, J. and La Calvez, Y., p. 197, pl. 14, figs. 164 - 166.
1991 *Adelosina dubia* (D'Orbigny). - Cimerman and Langer, p. 27, pl. 18, figs. 5 - 7.

Occurrence. This species occurs in one station at 21 m depth in spring.

***Adelosina cliarensis* (Heron-Allen and Earland, 1930)**

Plate 5.6, figure 12

1930 *Quinqueloculina cliarensis* Heron Allen and Earland, p. 58, pl. 3, figs. 26, 31.
1958 *Quinqueloculina cliarensis* Heron Allen and Earland. - Le Calvez, J. and, La Calvez, Y., p. 186, pl. 5, figs. 40, 41.
1958 *Quinqueloculina cliarensis* Heron Allen and Earland. - Le Calvez, Y., p. 157, pl. 1, figs. 10,11..
1991 *Adelosina cliarensis* (Heron-Allen and Earland). – Cimerman and Langer, p. 26, pl. 18, figs. 1 - 4.

Occurrence. This species occurs mostly in the northern part of the study area. In spring it was found at 6.5 to 184 m depth (at 32 stations). It was found at 7 to 68 m depth (in 13 stations) in winter.

***Adelosina duthiersi* Schlumberger, 1886**

Plate 5.6, figure 13 - 15

1886 *Adelosina duthiersi* Schlumberger, p. 553, pl. 16, figs. 16 - 18; p. 554, text - fig. 9.
1923 *Adelosina duthiersi* Schlumberger. - Wiesner, p. 38, pl. 16, figs. 232 - 234.
1958 *Quinqueloculina duthiersi* (Schlumberger). - Le Calvez, J. & Le Calvez, Y., p. 175, pl. 3, fig. 11.
1974 *Quinqueloculina (Adelosina) duthiersi* (Schlumberger) - Colom, p. 187, figs. 53 h - m.
1991 *Adelosina duthiersi* Schlumberger. - Cimerman and Langer, p. 27, pl. 18, figs. 8.
1993 *Adelosina duthiersi* Schlumberger. - Sgarrella and Moncharmont, p. 178, pl. 7, fig. 12.

Occurrence. This species was at depth ranges from 3 to 35 m (in 18 stations). It was found at 7 to 57 m (in 11 stations) in winter. It has greater abundance in shallow locations.

Adelosina pulchella D'Orbigny, 1846

Plate 5.7, figures 1 - 4

1846 *Adelosina pulchella* D'Orbigny, p. 203, pl. 20, figs, 25-30.
1958 *Quinqueloculina pulchella* (D'Orbigny) - Le Calvez, J. & La Calvez, Y., p. 175, pl. 3, fig. 12 - 14.
1991 *Adelosina pulchella* D'Orbigny. – Cimerman and Langer, p. 28 pl. 20, figs. 9 - 10.

Occurrence. This species is relatively widespread. It occurs from 7 to 82 m depth (at 26 stations) in spring. It was found from 7 to 68 m depth (at 18 stations) in winter.

Adelosina partschi (D'Orbigny, 1846)

Plate 5.7, figure 5

1846 *Quinqueloculina partschi* D'Orbigny, p. 293, pl. 10, figs. 4 - 6.
1958 *Quinqueloculina partschi* D'Orbigny. - Le Calvez, J. and La Calvez, Y., p. 186, pl. 10, figs. 109 - 111.

Occurrence. This species is very rare. It was found during both seasons at one station at a depth of 34 m.

Adelosina mediterranensis (Le Calvez, and Le Calvez, 1958)

Plate 5.7, figures 6 - 8

1958 *Quinqueloculina mediterranensis* Le Calvez, J., and La Calvez, Y.p. 177, pl. 4, figs, 29 - 31.
1991 *Adelosina mediterranensis* (Le Calvez, J. and La Calvez, Y.). – Cimerman and Langer, p. 28 pl. 19, figs. 1-16.
1993 *Adelosina mediterranensis* (Le Calvez, J. and La Calvez, Y.). - Sgarrella and Moncharmont, p. 179, pl. 7, figs. 9 -11.

Occurrence. The species was found at 19 to 71 m and at 200 m in both seasons (in 10 stations in spring and 11 stations in winter). The abundance increases at shallower locations.

Adelosina intricata (Terquem, 1878)

Plate 5.7, figure 9, 10

1878 *Quinqueloculina intricata* Terquem, p. 73, pl. 8, figs. 16-21.
1923 *Adelosina intricata* (Terquem). - Wiesner, p. 48, pl. 16, fig. 236 - 238.
1958 *Quinqueloculina intricata* Terquem. - Le Calvez, J. and La Calvez, Y, p. 176, pl. 5, figs. 38, 39.
1991 *Adelosina intricata* (Terquem). – Cimerman and Langer, p. 27, pl. 18, figs. 9 - 10.
1993 *Adelosina intricata* (Terquem). - Sgarrella and Moncharmont, p. 178, pl. 8, figs. 4 - 5.

Occurrence. This species occurred widely in the study area. It was found from 6 to 102 m depth (at 43 stations in spring and 23 stations in winter).

Adelosina brongniartana (D'Orbigny) var. *angulata* Wiesner, 1923

Plate 5.8, figure 2

1923 *Adelosina brongniartana* (D'Orbigny) var. *angulata* Wiesner, pp. 79 and 81.

Occurrence. This species occurs at 7 to 71 m depth (in 16 stations) in spring. It is found from 27 to 63 m depth (in 12 stations) in winter.

Adelosina elegans (Williamson, 1858)

Plate 5.8, figure 4

1858 *Miliolina bicornis* Walker and Jacob var. *elegans* Williamson, p. 88, pl. 7, fig. 195.
1991 *Adelosina elegans* (Williamson). – Cimerman and Langer, p. 27, pl. 20, figs. 5 - 6.

Occurrence. This species occurs at 20 to 71 m depth (in 16 stations in spring and 12 stations in winter).

Adelosina elegans (Williamson) var. *angulata* Wiesner, 1923

Plate 5.8, figure 3

1923 *Quinqueloculina elegans* D'Orbigny, p. 301.
1878 *Quinqueloculina elegans* D'Orbigny. - Terquem, p.64, pl. 6, figs. 7 - 9.
1923 *Adelosina elegans* (Williamson) var. *angulata* Wiesner, pp. 79, 81, pl. 15, fig. 215.

Occurrence. This species occurs from 29 to 71 m depth in both seasons (at 16 stations in spring and 10 stations in winter).

Adelosina elegans (Williamson) var. *separans* Wiesner, 1923

Plate 5.8, figure 1

1923 *Adelosina elegans* (Williamson) var. *separans* Wiesner, pp. 80, 84, pl. 16, fig. 235.

Occurrence. This species occurs at 4 stations (from 7 to 43 m depth) in winter and at 2 stations (at 21 and 32 m depth) in spring.

Adelosina elegans (Williamson,) var. *zigzag* Wiesner, 1923

Plate 5.8, figure 5

1923 *Adelosina elegans* (Williamson) var. *zigzag* Wiesner, pp. 81, pl. 15, fig. 214.

Occurrence. This species occurs at 6.5 to 67 m in spring (in 9 stations). In winter it occurs at 27 to 63 m (in 1 stations).

Adelosina sp. 1

Plate 5.8, figure 6

Occurrence. This species was found at 2 stations at 47 and 48 m at spring and winter.

Remarks. Test is ovate in outline, periphery subrounded and ornamented by distinctly visible, thick and elevated costae. Chambers increase in size as added. The aperture is rounded produced on a short neck, bordered by a thickened cicular rim and provided with a bifit tooth.

Adelosina sp. 2

Plate 5.8, figure 7

Occurrence. This species was found in spring at 12 stations at 7 and 34 m. In winter it was found at 6 stations at 7 and 34 m depth.

Remarks. The periphery of the test ornated by a distictly thick, elevated costae forming an acute shoulders. The aperture is produced on a short bordered by a circular rim provided with a short simple tooth.

Genus *Spiroloculina* D'Orbigny, 1920

Sproloculina costifera Cushman, 1917

Plate 5.8, figure 8

1917 *Sproloculina* cf. *S. costifera* Cushman, no. 71, p. 34.

Occurrence. This species is very rare species. It was found at 2 stations in spring at 20 and 34 m depth. It was found at one station in winter (at 19 m depth).

Spiroloculina angulosa Terquem, 1878

Plate 5.8, figure 9

1878 *Spiroloculina angulosa* Terquem, p. 53, pl. 5, fig. 7.
1958 *Spiroloculina angulosa* Terquem. - Le Calvez, J. and Le Calvez, Y., p. 204, pl. 8, fig. 92.
1991 *Spiroloculina angulosa* Terquem. – Cimerman and Langer, p. 29, pl. 21, figs. 10 - 13.

Occurrence. This species was found at 3 stations (at 20 to 34 m depth) in spring. It is found in winter in 6 stations (at 6 to 23 m).

Spiroloculina depressa D'Orbigny, 1826

Plate 5.8, figure 10, 11

1826 *Spiroloculina depressa* D'Orbigny, p. 298, no. 1.
1944 *Spiroloculina depressa* D'Orbigny. - Cushman and Todd, p. 28, pl. 1, figs. 1, 6, pl. 5, figs 1 - 9.
1974 *Spiroloculina depressa* D'Orbigny. - Colom, p. 208, figs. 62a, b.
1987 *Spiroloculina depressa* D'Orbigny. - Loeblich and Tappan, p. 33, pl. 340, figs. 2 - 5.
1991 *Spiroloculina depressa* D'Orbigny. – Cimerman and Langer, p. 29 pl. 22, figs. 9 - 12.

Occurrence. This species was mostly found in northern part of the study area. It was found at 24 stations, at 6 to 47 m depth in spring. It was found at 8 stations in winter from 7 to 43 m depth.

Spiroloculina ornata D'Orbigny, 1839

Plate 5.8, figure 12

1939 *Spiroloculina ornata* D'Orbigny, p. 167, pl. 12, fig. 7.
1958 *Spiroloculina ornata* D'Orbigny. - Le Calvez J. and Le Calvez, Y., p. 207, pl. 8, fig. 83.
1977 *Spiroloculina ornata* D'Orbigny. - Le Calvez J. and Le Calvez, Y., p. 94, pl. 18, figs. 1 - 4.
1991 *Spiroloculina ornata* D'Orbigny. – Cimerman and Langer, p. 30, pl. 23, figs. 8 - 10.

Occurrence. This species is rare. It occurred at 4 stations from 24 to 29 m depth. It was found at 2 stations at 16 and 20 m depth in winter.

Spiroloculina ornata D'Orbigny var. *tricarinata* Le Calvez, and Le Calvez, 1958

Plate 5.8, figure 13

1958 *Spiroloculina ornata* D'Orbigny var. *tricarinata* Le Calvez, and Le Calvez, p. 207, pl.8, figs. 84, 85
1991 *Spiroloculina ornata* D'Orbigny var. *tricarinata* Le Calvez, and Le Calvez - Cimerman and Langer, p. 30, pl. 23, figs. 4 - 7.

Occurrence. This species has higher abundance at shallower locations. It was found at 20 stations from 6.5 to 36 m depth in spring, at 6 stations from 7 m to 32 m depth in winter.

Spiroloculina antillarum D'Orbigny, 1839

Plate 5.9, figures 1, 2

1839 *Spiroloculina antillarum* D'Orbigny, p. 166, pl. 9, figs. 3, 4.
1986 *Spiroloculina antillarum* D'Orbigny. - Debenay, p. 23, pl. 6, fig. 8.
1993 *Spiroloculina antillarum* D'Orbigny. – Hottinger *et al.*, p.45, pl. 24, figs. 15 - 17.
1994 *Spiroloculina antillarum* D'Orbigny. - Jones, p. 26, pl. 10, fig. 21.

Occurrence. This species was found at 14 stations, from 6.5 to 43 m depth in spring and at 4 stations at 7 to 35 m depth in winter.

Spiroloculina excavata D'Orbigny, 1846

Plate 5.9, figure 4

1846 *Spiroloculina excavata* D'Orbigny, p. 271, pl. 16, figs. 19 - 12.
1893 *Spiroloculina excavata* D'Orbigny. - Schlumberger, p. 201, pl. 3, fig. 68.
1923 *Spiroloculina excavata* D'Orbigny. - Wiesner, p. 34, pl. 5, fig. 23, 24.
1958 *Spiroloculina excavata* D'Orbigny. - Le Calvez, J., and Y., p. 205, pl. 8, fig. 89.
1974 *Spiroloculina excavata* D'Orbigny. - Alfirevic', p. 67, pl. 5, fig. 4.
1991 *Spiroloculina excavata* D'Orbigny. – Cimerman and Langer, p. 30, pl. 23, figs. 1 - 3.

Occurrence. This species is rare. It was found at 7 stations from 20 to 48 m depth, in spring. Also found at one station at 19 m in winter.

Spiroloculina hadai Thalmann, 1931

Plate 5.9, figure 5

1931 *Spiroloculina costata* Hada, p. 84, textfig. 37.
1933 *Spiroloculina hadai* Thalmann, p. 354
1994 *Spiroloculina hadai* Thalmann. – Loeblich and Tappan, p. 43, pl. 66, figs. 11 - 15.

Occurrence. This species was occurred at 5 stations from 16 to 26 m depth in spring. It was found at 5 stations from 7 to 29 m in winter.

Spiroloculina dilatata D'Orbigny, 1846

Plate 5.9, figure 6

1846 *Spiroloculina dilatata* D'Orbigny, p. 271, pl. 16, figs, 16 - 18.
1923 *Spiroloculina dilatata* D'Orbigny. - Wiesner, p. 35, pl. 4, fig. 26.
1991 *Spiroloculina dilatata* D'Orbigny. – Cimerman and Langer, p. 30, pl. 22, figs. 5 - 8.

Occurrence. This species is mostly distributed in northern part of the study area It was found at 21 stations at 6.5 to 82 m depth in spring. Also found at 5 stations in winter from 35 to 75 m depth.

Spiroloculina rostrata Reuss, 1850

Plate 5.9, figure 7

1850 *Spiroloculina rostrata* Reuss, p. 382, pl. 49. fig. 7.
1944 *Spiroloculina rostrata* Reuss. - Cushman and Todd, p. 25, pl. 4, figs. 17 - 21.
1994 *Spiroloculina rostrata* Reuss. – Sgarrella and Moncharmont Zei, p. 169, pl. 5. fig. 5.

Occurrence. This species is very rare. It occurs at 4 stations at depth from 7 to 67 m in both seasons (it was found at 2 stations in winter).

Spiroloculina angulata Cushman, 1917

Plate 5.9, figure 8

1884 *Spiroloculina grata* Terquem. - Brady, pl. 10, figs. 16, 17, 22, 23.
1917 *Spiroloculina grata* var. *angulata* Cushman, pl. 7, fig. 5.
1994 *Spiroloculina angulata* Cushman. - Jones, p. 26, pl. 10, figs. 16, 17, 22, 23.

Occurrence. This species occurs in in spring at 6 stations from 16 to 39 m depth. In winter it wsa found at one station (30) at 32m depth.

Remarks. The specimen figured by Brady is wider and has higher sholders the striations are not interrupted (continous), The specimen in my collection has clear striations on the neck.

Spiroloculina cf _S. cymbium_ (D'Orbigny, 1839)

Plate 5.9 figure 9

cf. 1839 *Spiroloculina* cf *S. cymbium* D'Orbigny 1839, p. 140, pl. 3, figs 5 - 6.

Occurrence. This species was found in spring at 10 stations from 7 to 32 m depth. It was found in winter in 3 stations at 7 to 32 m depth.

Remarks. The specimen has a tritruncate periphery, bicocave in apertural view. The shoulders are wider than in *S.cymbium* D'Orbigny.

Spiroloculina sp. 1

Plate 5.9, figure 3

Occurrence. This species is a rare species. It occurs at 4 stations in spring at 20 to 75 m depth. It was found at one station in winter (at 75 m depth).

Spiroloculina sp. 2

Plate 5.9, figure 10

Occurrence. This species was encountered at one station (21) at 30 m depth in spring. In winter it occurs in two stations at 27 to 30 m depth.

Remarks. This species is porcelaneous, biloculine, test is flat, broadly ovate in lateral view, slightly concave. The surface is rough. Short neck ending with a rounded aperture having two bifid teeth.

FAMILY Soritidae Ehrenberg, 1839

Genes *Amphisorus* Ehrenberg, 1839

Amphisorus hemprichii Ehrenberg, 1849

Plate 5.9, figure 11

1840 *Amphisorus hemprichii* Ehrenberg, p. 130.
1941 *(Marginopora) Amphisorus hemprichii* (Ehrenberg). - Lacroix, p. 17, fig. 22 - 24, 28, 29.
1941 *(Marginopora) Amphisorus hemprichii* (Ehrenberg) *subduplicata* Lacroix, p. 17.
1961 *Amphisorus hemprichii* Ehrenberg. - Lehmann, p. 649, textfig. 40, pl. 10, figs. 6 - 9. pl. 11, figs. 1 - 5.
1977 *Amphisorus hemprichii* Ehrenberg. - Hottinger, p. 99, figs. 10, 22b.
1984 *Amphisorus hemprichii* Ehrenberg. - Reiss and Hottinger, 205, figs. g3, g4.
1993 *Amphisorus hemprichii* Ehrenberg. - Hottinger, p. 71, pl. 81, figs. 1 - 8, pl. 82, figs. 1 - 11.

Occurrence. This species was found at winter in one station (at 28 m depth). But in spring it was found from 7 to 32 m depth at 6 stations.

Genus *Sorites* Ehrenberg, 1839

Sorites orbiculus Ehrenberg, 1839

Plate 5.9, figures 12, 13

1775 *Nautilus orbiculus* - Forskal, p. 125 (fide Ellis and Messina, 1940).
1839 *Sorites orbiculus* Ehrenberg, p. 134.
1852 *Orbiculina complanata.* - Williamson, p. 115.
1961 *Sorites orbiculus* Ehrenberg. - Lehmann, p. 641, pl. 8, figs. 1 - 8.
1977 *Sorites orbiculus* Ehrenberg. - Hottinger, p. 94, figs. 9 b, 30 d, e, 32 b.
1977 Sorites marginalis (Lamarck). - Levy, pl. 8, figs. 1 - 10.
1987 *Sorites orbiculus* Ehrenberg. - Baccaert, pl. 28, figs. 1, 2, pl. 29, fig. 1 a, b.
1987 *Sorites orbiculus* Ehrenberg. - Loeblich and Tappan, p. 382, pl. 419, fig. 4 - 10.
1991 *Sorites orbiculus* Ehrenberg. – Cimerman and Langer, p. 50, pl. 51, figs. 1 - 5.

Occurrence. This species occurs in shallow depths from 3 to 43 m. It occurs in spring at 13 stations and in winter in 8 stations.

FAMILY Peneroplidae Schlultze, 1854

Genus *Peneroplis* deMontfort, 1808

***Peneroplis planatus* (Fichtel and Moll, 1798)**

Plate 5.9, figures 14, 15

1798 *Peneroplis planatus* Fichtel and Moll, p. 91, pl. 16, fig. a - h.
1826 *Peneroplis planatus* (Fichtel and Moll). - D'Orbigny, p. 285, no. 1.
1858 *Peneroplis planatus* (Fichtel and Moll). - Williamson, p. 45, pl. 3, figs. 84, 85.
1960 *Peneroplis planatus* (Fichtel and Moll). - Barker, pl. 13, fig.15.
1974 *Peneroplis planatus* (Fichtel and Moll). - Colom, p. 219, figs. 64, h - i, k.
1987 *Peneroplis planatus* (Fichtel and Moll). - Loeblich and Tappan, p. 371, pl. 391, figs. 7, 8.
1991 *Peneroplis planatus* (Fichtel and Moll). – Cimerman and Langer, p. 50, pl. 50, figs.1 - 6.

Occurrence. This species occurs at shallow depths from 6.5 to 29 m, at 7 stations in spring.

***Peneroplis pertusus* (Forskål, 1775)**

Plate 5.10, figure 1

1775 *Nautilus pertusus* Forskål, p. 125 (fide Ellis and Messina, 1940).
1917 *Peneroplis pertusus* (Forskål). - Cushman, p. 86, pl. 36, fig. 1, pl. 37, figs. 1, 2, 6.
1974 *Peneroplis pertusus* (Forskål). - Colom, p. 219, fig. 64 j.
1991 *Peneroplis pertusus* (Forskål). – Cimerman and Langer, p. 49, pl. 49, figs. 1 - 8.

Occurrence. This species occurs at shallow depths from 3 to 29 m. It was found at 6 stations in winter and 19 stations in spring.

Genus *Coscinospira* Ehrenberg 1839

***Coscinospira hemprichii* Ehrenberg, 1839**

Plate 5.10, figures 2, 3

1839 *Coscinospira hemprichii* Ehrenberg, p. 131, pl. 2, fig. 2.
1972 *Cribrospirolina distinctiva.* - Haman, p. 111, text fig 1, 3.
1987 *Coscinospira hemprichii* Ehrenberg. - Loeblich and Tappan, p. 369, pl. 390, figs. 7 - 10.

1993 *Coscinospira hemprichii* Ehrenberg. - Hottinger *et al.*, p. 69, pl. 77, figs. 1 - 8.

Occurrence. This species occurs at depths from 6 to 29 m, then it again appears at 82 m depth in spring. It was found at 4 stations in winter and 8 stations in spring.

Genus *Monalysidium* Chapman, 1900

***Monalysidium aciculare* (Batsch, 1791)**

Plate 5.10, figure 4

1791 *Nautilus acicularis* Batsch, p. 3, pl. 6, figs. 16 a, b.
1984 *Peneroplis planatus* Fichtel and Moll. - Reiss and Hottinger, pars, p. 242, figs. G 25a.
1987 *Peneroplis pertusus* (Froskal) *acicularis* (Batsch). - Baccaer, p. 59, pl. 18, figs. 1, 2.
1993 *Monalysidium acicularis* (Batsch). - Hottinger *et al.*, p. 70, pl. 78, figs. 1 - 14.

Occurrence. This species is very rare. It occurs at one station in spring and winter (at 6.5 and 29 m depth respectively).

FAMILY Ophthalmidididiidae Wiesner, 1920

Genus *Edentostomina* Collins, 1958

***Edentostomina cultrata* (Brady, 1881)**

Plate 5.10, figure 5

1881 *Miliolina cultrata* Brady, p. 45.
1884 *Miliolina cultrata* Brady, p. 161, pl. 5, figs. 1, 2.
1898 *Miliolina cultrata* Brady. - Millett, p. 269, pl. 6, figs. 11, 12.
1959 *Quinqueloculina cultrata* (Brady). - Graham and Militante, p. 44, pl. 5, fig. 8.
1994 *Edentostomina cultrata* (Brady). – Loeblich and Tappan, p. 40, pl. 63, figs. 8 - 12.
1994 *Edentostomina cultrata* (Brady). - Jones, p..21, pl. 5, figs. 1 - 2.

Occurrence- This species occurs at depth from 4 to 63 m in spring and winter. It was found at 4 stations at winter and 7 stations at spring.

Remaks - The keel around the test is smaller than the one found in the brady, and the it is wider and shorter than the Brady's specimen.

FAMILY Fischerinidae Millett, 1898

Genus *Wiesnerella* Cushman, 1933

***Wiesnerella auriculata* (Egger, 1893)**

Plate 5.10, figure 6

1893 *Planispirina auriculata* Egger, p. 245, pl. 3, figs. 13 -15.
1933 *Wiesnerella auriculata* (Egger). - Cushman, p. 33, fig. 8.
1987 *Wiesnerella auriculata* (Egger). - Baccaer, p. 41, pl. 13, figs. 3 - 5.
1994 *Wiesnerella auriculata* (Egger). - Hottinger *et al.*, p. 43, pl. 24, figs. 1 - 4.

Occurrence. This species was found at one station at 6.5 and no living test were found in winter samples.

Genus *Vertebralina* D'Orbigny, 1826

***Vertebralina striata* D'Orbigny, 1826**

Plate 5.10, figure 7

1826 *Vertebralina striata* D'Orbigny, p. 283.
1871 *Vertebralina striata* D'Orbigny. - Parker, Jones and Brady, fig. 27, fig. zz, after Soldani.
1949 *Vertebralina striata* D'Orbigny. - Said, p. 20, pl. 2, fig. 19.
1984 *Vertebralina striata* D'Orbigny. - Reiss and Hottinger, fig. g, 26 k.
1987 *Vertebralina striata* D'Orbigny. - Baccaert, p. 45, pl. 14, fig. 9 - 11.
1993 *Vertebralina striata* D'Orbigny. – Hottinger *et al.*, p. 43, pl. 23, figs. 8 - 15.

Occurrence. This species is widespread especially in spring. It was found at 32 stations (at 6.5 to 75 m) depth, then it again appears at 200 m and 210 m. In winter it was found at 17 stations (at 7 m to 75 m) depth.

SUBORDER Rotaliina Delage and Hérouard, 1896

FAMILY Planorbulinidae Schwager, 1877

Genus *Planorbulina* D'Orbigny, 1826

***Planorbulina mediterranensis* D'Orbigny, 1826**

Plate 5.10, figures 8, 9

1826 *Planorbulina mediterranensis* D'Orbigny, p. 280, no. 2.
1931 *Planorbulina mediterranensis* D'Orbigny. - Cushman, p. 129, pl. 24, figs. 5 - 8.
1960 *Planorbulina mediterranensis* D'Orbigny. - Barker, pl. 92, figs. 1 - 3.
1991 *Planorbulina mediterranensis* D'Orbigny. –Cimerman and Langer, p. 71, pl. 78, figs. 1-8.

Occurrence. This species occurs in spring at 13 stations from 7 to 63 m depth. It is found in winter from 16 to 63 m depth at 6 stations.

Genus *Planorbulinella* Cushman, 1927

***Planorbulinella larvata* (Parker and Jones, 1865)**

Plate 5.10, figure 10

1865 *Planorbulina vulgaris* D'Orbigny var. *larvata* Parker and Jones, p. 68, pl. 19, fig. 3.
1927 *Planorbulinella larvata* (Parker and Jones). - Cushman, p. 96.
1949 *Planorbulinella larvata* (Parker and Jones). - Said, p. 44, pl. 4, fig. 27.
1977 *Planorbulinella larvata* (Parker and Jones). - Thomas, textfig. 11, p. 187, pl. 1, fig. 1, 2, pl. 2, fig. 3, 4, pl. 3, fig. 1, 2.
1984 *Planorbulinella larvata* (Parker and Jones). - Reiss and Hottigner, p. 249, fig. g 32e, f.
1993 *Planorbulinella larvata* (Parker and Jones). – Hottinger *et al.*, p. 118, pl. 158, figs. 1 - 12.

Occurrence. This species occur from 6 m to 68 m depth (at 7 and 12 stations in winter and spring respectively).

FAMILY Nummulitidae de Blainille, 1827

Genus *Heterostegina* D'Orbigny, 1826

Heterostegina depressa D'Orbigny, 1826

Plate 5.10, figure 11

1826 *Heterostegina depressa* D'Orbigny, p. 305, pl. 17, figs. 5-7.
1949 *Heterostegina depressa* D'Orbigny. - Said, p. 24, pl. 2, fig. 40.
1993 *Heterostegina depressa* D'Orbigny. – Hottinger *et al.*, p. 157, pl. 228, figs. 1 - 11, pl. 229, figs. 1 - 8. pl. 230, fig. 9.

Occurrence. This species occurred in both seasons at the same depth, from 6.5 to 63 m. In spring it was found at 13 stations. In winter it was found at 8 stations.

Genus *Assilina* D'Orbigny, 1839

Assillina ammonoides (Gronovius, 1781)

Plate 5.10, figure 12

1781 *Nautilus ammonoides* Gronovius, p. 282, pl. 19, figs. 5 - 6.
1880 *Operculina complanata* (Defrance). - Möbius, p. 104.
1993 *Assillina ammonoides* (Gronovius). – Hottinger *et al.*, p. 154, pl. 222, figs. 1 - 8, pl. 223, figs. 1 - 14. pl. 224, figs. 1 - 8, pl. 225, figs. 1 - 9.

Occurrence. This species was found at a single station in both seasons (at 71 at 63 m depth).

FAMILY Cibicididae Cushman, 1927

Genus *Lobatula* Fleming, 1828

Lobatula lobatula (Walker and Jacob, 1798)

Plate 5.11, figure 1

1798 *Nautilus lobatulus* Walker and Jacob, (in Kanmacher), p. 642, pl. 14, fig. 36 (fide Ellis and Messina, 1940).
1896 *Truncatulina lobatula* (Walker and Jacob). - Dezelic, p. 87.
1958 *Cibicides lobatulus* (Walker and Jacob). - Le Calvez, Y., p. 188.
1987 *Lobatula lobatula* (Walker and Jacob). - Loeblich and Tappan, p. 583, pl. 637, figs. 10 - 13.
1991 *Lobatula lobatula* (Walker and Jacob). – Cimerman and Langer, p. 71, pl. 75, figs. 1 - 4.

Occurrence. This species has wide depth range in spring from 7 to 200 m depth (in 38 stations). It was found in winter from 32 to 102 m (in 17 stations).

Genus *Cibicides* De Montfort, 1808

Cibicides refulgens deMontfort, 1808

Plate 5.11, figure 2

1808 *Cibicides refulgens* deMontfort, p. 123, fig. 122 (fide Ellis and Messina).
1931 *Cibicides refulgens* deMontfort. - Cushman, p. 116, pl. 21, fig. 2.

1958 *Cibicides refulgens* deMontfort. - Le Cavez, Y., p. 189.
1960 *Cibicides refulgens* deMontfort. - Barker, pl. 92, figs. 7 - 9.
1974 *Cibicides refulgens* deMontfort. - Colom, p. 150, fig.. 31 o - t.
1987 *Cibicides refulgens* deMontfort. - Loeblich and Tappan, p. 582, pl. 634, fig. 1 - 3.
1991 *Cibicides refulgens* deMontfort. – Cimerman and Langer, p. 70, pl. 75, figs. 5 - 9.

Occurrence. This species has a wide depth range, between 6.5 to 200 m. It was found at 13 stations in spring and 6 stations in winter.

Cibicides advenus (D'Orbigny, 1839)

Plate 5.11, figure 3

1839 *Truncatulina advena* D'Orbigny, p. 87, pl. 6. figs. 3 - 5.
1958 *Cibicides advenum* (D'Orbigny). – Le Calvez, Y., p. 197.
1977 *Cibicides advenum* (D'Orbigny). – Le Calvez, Y., p. 122, figs. 1 - 5.
1991 *Cibicides advenum* (D'Orbigny). – Cimerman and Langer, p. 70, pl. 74, figs. 8-10.

Occurrence. This species was found scattered at 11 stations in spring from 6.5 to 102 m depth. It was found in 5 stations at winter from 7 to 36 m depth.

FAMILY Discorbinellidae Sigal, 1952

Genus *Discorbinella* Cushman and Martin, 1935

Discorbinella bertheloti (D'Orbigny, 1839)

Plate 5.11, figure 4

1839 *Rosalina bertheloti* D'Orbigny, p. 135, pl. 1, figs. 28 - 30.
1884 *Discorbinella bertheloti* (D'Orbigny). - Brady, p. 650, pl. 89, fig. 10.
1964 *Discorbinella bertheloti* (D'Orbigny). - Loeblich and Tappan, p. 575, fig. 453 - 3.
1974 *Discorbinella bertheloti* (D'Orbigny). - Le Calvez, p. 59, pl. 14, fig. 1 m- 4.
1993 *Discorbinella bertheloti* (D'Orbigny). – Hottinger *et al.*, p.1114, pl. 150, figs. 1-4.

Occurrence. This is a dominant species occurring at 47 stations at depths from 18 to 200 m in spring. In winter it was found at 27 stations at depths from 6 to 75 m.

FAMILY Cymbaloporidae Cushman, 1927

Genus *Cymbaloporetta* Cushman, 1928

Cymbaloporetta bermudezi (Sellier de Civrieux, 1976)

Plate 5.11, figure 5

1949 *Cymbaloporetta squamosa* (D'Orbigny) - Said, p. 40, pl. 4, fig. 14.
1976 *Tremtophalus bermudezi* Sellier de Civerieux, p. 185, pl. 6, figs. 1 - 6, pl. 7, figs. 4 - 6.
1985 *Cymbaloporetta bermudezi* (Sellier de Civrieux). - Banner, Pereira and Desai, p. 168.
1993 *Cymbaloporetta bermudezi* (Sellier de Civrieux). - Hottinger *et al*, p.119, pl. 159, figs. 7 - 10.

Occurrence. This species occurs at 3 stations (at 19 to 48 m) depth in spring.

FAMILY Acervulindae Schultze, 1854

Genus *Sphaerogypsina* Galloway, 1933

***Sphaerogypsina globula* (Reuss, 1848)**

Plate 5.11, figure 6

1848 *Ceriopora globulus* Reuss, p. 33, pl. 5, fig. 7.
1884 *Ceriopora globulus* (Reuss). - Brady, p. 717, pl. 101, fig, 8.
1954 *Gypsina globulina* (Reuss). - Cushman, Todd, and Post, p. 373, pl. 91, fig. 39.
1992 *Sphaerogypsina globula* (Reuss). - Azazi, pl. 1, figs. 7, 8.
1994 *Sphaerogypsina globula* (Reuss). - Loeblich and Tappan, p. 154, pl. 334, figs. 4 - 6.

Occurrence. There was no living test of this species in spring samples. But is found in winter at 2 stations (at 47 and 67 m).

FAMILY Rotaliidae Ehrenberg, 1839

Genus *Ammonia* Brünnich, 1772

***Ammonia tepida* (Cushman, 1926)**

Plate 5.11, figure 7

1926 *Rotalia beccarii* (Linne') var. *tepida* Cushman, p. 79, pl. 1 (fide Ellis and Messina, 1940).
1931 *Rotalia beccarii* (Linne') var. *tepida* Cushman. - Cushman, p. 61, pl. 13, fig. 3a - c.
1965 *Streblus beccarii* (Cushman). - Todd, p. 29, pl. 6, fig. 1, pl. 7, fig. 2.
1972 *Ammonia beccarii* (Linne') var *tepida* Cushman. - Rosset - Moulinier, p. 174.
1991 *Ammonia tepida* (Cushman). – Cimerman and Langer, p. 76, pl. 87, figs. 10 - 12.

Occurrence. This is a dominant species in the area. It was found at 39 station from 3 to 63 m depth in spring. In winter it was found at 28 stations (from 7 to 45 m depth).

***Ammonia parkinsoniana* (D'Orbigny, 1839)**

Plate 5.11, figures 8, 9

1839 *Ammonia parkinsoniana* D'Orbigny, p. 99, pl. 4, figs. 7 - 9.
1977 *Ammonia parkinsoniana* (D'Orbigny). - Le Calvez, Y., p. 92, pl.. 11, figs. 1 - 3.
1991 *Ammonia parkinsoniana* (D'Orbigny). – Cimerman and Langer, p. 76, pl. 87, figs. 7 - 9.

Occurrence. This species occurs from 6 to 63 m depth (at 20 stations) in spring, whereas in winter it was found from 3 to 63 m depth (at 13 stations).

***Ammonia inflata* (Seguenza, 1862)**

Plate 5.11, figures 10, 11

1862 *Rosalina inflata* Seguenza, p. 106, pl. 1, fig. 6.
1988 *Ammonia beccarri* form *inflata* - Jorissen, p. 52, pl. 6, figs. 1 - 4.
1991 *Ammonia parkinsoniana* (Sequenze). – Cimerman and Langer, p. 76, pl. 87, figs. 5, 6..

Occurrence. This is a dominant species, occuring from 7 to 200 m depth (at 37 and 25 stations in spring and winter respectively).

Genus *Challengerella* Billman, Hottinger and Oesterle, 1980

Challengerella bradyi Billman, Hottinger and Oesterle, 1980

Plate 5.12, figures 1, 2

1949 *Rotalia beccarii* (Linné). - Said, p. 37, pl. 4. fig. 5.
1971 *Ammonia beccarri* (Linné). - Hansen and Reiss (pars), p. 331, pl. 1, figs. 3 - 6, pl. 5, fig. 1 - 4.
1980 *Challengerella bradyi* Billman, Hottinger and Oesterle(pars), p. 91, textfig. 17, pl. 12, fig. 1 - 6, 8 - 10, 13 -14, pl. 13, figs. 7, 12.
1984 *Challengerella bradyi* Billman, Hottinger and Oesterle. - Reiss and Hottinger, p. 244, fig 28 a- d.
1993 *Challengerella bradyi* Billman, Hottinger and Oesterle. – Hottinger *et al.*, p.144, pl. 204, figs. 2 - 7.

Occurrence. This species is dominant, occuring between 7 and 102 m. It was found at 31 and 17 stations in spring and winter, respectively.

Genus *Asterorotalia* Hofker, 1950

Asterorotalia gaimardii (D'Orbigny in Fornasini, 1906)

Plate 5.12, figures 3, 4

1826 *Rotalia (Turbinulina) gaimardii* D'Orbigny, p. 275. (nomen nudum)
1884 *Rotalia papillosa* Brady, p. 708, pl. 106, fig. 9. (non *R. papillosa* D'Orbigny, 1850).
1906 *Turbinulina gaimardii* D'Orbigny in Fornasini, p. 67, pl. 4, fig. 1.
1949 *Rotalia popillosa* Brady. - Said, p. 38, pl. 4, figs. 8 a, b.
1971 *Asterorotalina papillosa* (Brady). - Hofker, p. 27, pl. 71, figs. 1 - 5.
1975 *Rotalia papillosa* Brady. - Saidova, p. 220, pl. 59, figs. 4, 5.
1980 *Asterorotalina gaimardii* (D'Orbigny). - Billmann *et al*, p. 98, figs. 10, 21, 22.
1987 *Rotalinoides gaimardii* (D'Orbigny). - Loeblich and Tappan, p. 666, pl. 773, figs. 1 - 8.
1989 *Pseudorotalia gaimardii* (D'Orbigny). - Inoue, p. 154, pl. 20, figs. 1a-c.
1993 *Asterorotalina gaimardii* (D'Orbigny). - Hottinger *et al.*, p. 143, pl. 202, figs. 8 - 9.

Occurrence. This species occurs from 3 to 47 m depth in spring and winter (at 13 stations and 11 stations respectively).

Genus *Pseudoeponides* Uchio, 1950

Ammoina falsobeccarii Rouvillois, 1974

Plate 5.12, figures 5, 6

1974 *Pseudoeponides falsobeccarii* Rouvillois, p. 4, pl. 1, figs. 1 - 12.
1984 *Pseudoeponides falsobeccarii* Rouvillois. - Levy, Mathieu, Poignant and Rosset-Moulinier, pl. 1 p. 381 - 387.
1993 *Pseudoeponides falsobeccarii* Rouvillois. – Hottinger *et al.*, p.145, pl. 206, figs. 1 - 12.

Occurrence. This species is very widespread in the area. It is dominant and occurs in high abundance. It occurs from 6.5 to 200 m in both seasons (at 32 stations in spring and 18 stations in winter).

Genus *Roshausenia* Bermudez, 1952

Rolshausenia rolshauseni (Cushman and Bermudez, 1946)

Plate 5.14, figures 2, 3

1946 *Rotalia rolshauseni* Cushman and Bermudez, p.119, pl. 19, figs. 11 - 13.
1980 *Rolshausenia rolshauseni* (Cushman and Bermudez). - Boltovskoy *et al.*, p. 49, pl. 31, figs. 3 - 5.

Occurrence. The species occurs in spring at one station, at 6 m depth.

Genes *Pararotalia* Le Cavez, Le Calvez, Y., 1949

Pararotalia spinigera **(Le Calvez) emended Loeblich and Tappan, 1957**

Plate 5.14, figure 9, 10

1949 *Globorotalia spinigera* (Terquem), - LeCalvez, Service Carte Géologique Memoire, p. 39, pl. 6, fig. 97 - 99.
1957 *Pararotalia spinigera* (Le Calvez) emended Loeblich and Tappan. - Ellis and Messina Catalogue, supplement 1961, no.1

Occurrence. This species is a widespread species. It occurs in spring in 26 stations at 7 to 35 m depth. It occured at the same depth in winter in 14 stations.

FAMILY Asterigerinatidae Reiss, 1963

Genus *Asterigerinata* Bermudez, 1949

Asterigerinata mamilla **(Williamson, 1858)**

Plate 5.12, figures 7, 8

1858 *Rotalina mamilla* Williamson, p. 54, pl. 4, figs. 109 -111.
1931 *Rotalina mamilla* (Williamson). - Cushman, p. 23, pl. 5, fig. 11.
1958 *Discorbis mamilla* (Williamson). - Le Cavez, and, Le Calvez, Y, p. 182.
1972 *Asterigerinata mamilla* (Williamson). - Rosset-Moulinier, p. 172, pl. 10, fig. 6, 7, pl. 13, figs. 1 - 9.
1974 *Discorbis mamilla* (Williamson). - Colom, p. 124, fig. 21x, y.
1979 *Asterigerinata mamilla* (Williamson). - Alfirevic', p. 125, fig. 4.
1991 *Asterigerinata mamilla* (Williamson).– Cimerman and Langer, p. 73, pl. 82, figs. 1 - 4.

Occurrence. This species is dominant in the area. and has a wide depth range. It was found in spring at 58 stations from 6.5 to 200 m depth. In winter it was found at 37 stations (at 7 to 200 m in depth).

FAMILY Glabratellidae Loeblich and Tappan, 1964

Genus *Conorbella* Hofker, 1951

Conorbella patelliformis **(Brady, 1884)**

Plate 5.12, figure 9, 10

1884 *Discorbina patelliformis* Brady, p. 647, pl. 89, fig. 1.
1960 *Pileolina patelliformis* (Brady). - Barker, pl. 89, fig. 1.
1974 *Glabratella patelliformis* (Brady). - Colom, p. 137, fig. 22 d - g.
1991 *Glabratella patelliformis* (Brady). - Cimerman and Langer, p. 68, pl. 73, figs. 1 - 3..

Occurrence. The species occurs in spring at 15 stations, from 18 to 67 m depth. It was not found in the samples collected in winter.

FAMILY Trichohylidae Saidova, 1981

Genus *Buccella* Andersen, 1952

***Buccella* sp.**

Plate 5.12, figures 11 - 12.

Occurrence. No stained specimen where found in the tested samples.

FAMILY Rosalinidae Reiss, 1963

Genus *Rosalina* D'Orbigny, 1826

***Rosalina orientalis* (Cushman, 1925)**

Plate13, figure 1

1915 *Discorbis globularis* D'Orbigny. - Heron-Allen and Earland, p. 694, pl. LI, figs. 36 - 39.
1925 *Discorbis orientalis* Cushman, p. 130.
1958 *Rosalina orientalis* (Cushman). - Collins, p. 404.
1987 *Rosalina orientalis* (Cushman). - Baccaert, p. 201, pl. 79, fig. 5, 6.
1993 *Rosalina orientalis* (Cushman). - Hottinger *et al.*, p. 111, pl. 143, figs. 7 - 9, pl. 144, figs. 1 - 2.

Occurrence. The species occurs in spring at 5 stations, from 56 to 102 m depth. In winter it was found at 4 stations from 32 to 67 m depth.

***Rosalina bradyi* (Cushman, 1915)**

Plate 5.13, figure 2

1884 *Discorbina globularis*. - Brady (not D'Orbigny), p. 178, pl. 86, figs. 8a-c.
1915 *Discorbina globularis* (D'Orbigny) var. *bradyi*, Cushman, p. 12.
1951 *Discopulvinulina bradyi* (Cushman). - Hofker, p. 452, fig. 310 a, b.
1954 *Rosalina bradyi* (Cushman). – Hornibrook and Vella, p. 26.
1991 *Rosalina bradyi* (Cushman). – Cimerman and Langer, p. 66, pl. 71. figs. 1 - 5.

Occurrence. This species is widespread. It was found at 25 stations in spring at depths from 3 to 184 m. In winter it was found at 13 stations from 19 to 200 m depth.

***Rosalina macropora* (Hofker, 1951)**

Plate 5.13, figure 3

1951 *Discopulvinulina macropora* Hofker, p. 460, figs. 312, 313.
1960 *Discopulvinulina macropora* Hofker, p. 253, pl. D, fig. 122a - c.
1987 *Rosalina globularis semiporata* (Egger). - Wenger, p. 305, pl. 15, figs. 10 - 12.
1991 *Rosalina macropora* (Hofker). – Cimerman and Langer, p. 67, pl. 71, figs. 6 - 7.

Occurrence. This species is the most widespread *Rosalina* species. It was found at 35 stations in spring at depths from 6.5 to 200 m. In winter it was found at 12 stations from 7 to 200 m depth.

Rosalina globularis D'Orbigny, 1826

Plate 5.13, figure 4

1826 *Rosalina globularis* D'Orbigny, p. 271, pl. 13, figs. 1 - 4.
1994 *Rosalina globularis* D'Orbigny. – Loeblich and Tappan, p. 140, pl. 286, figs. 1- 15.

Occurrence. This species is widespread in the area. It was found at 27 stations in spring at depth from 6 to 200 m. In winter it was found at 9 stations between 12 and 200m depth.

Rosalina pellucida (Said, 1949)

Plate 5.13, figure 5

1949 *Discorbis pellucida* Said, p. 35, pl. 3, figs. 33 a - c.
1993 *Rosalina pellucida* (Said). – Hottinger *et al.*, p. 111, pl. 144, figs. 3 - 6.

Occurrence. This species is widespread It was found at 15 stations in spring at depths of 6 to 75 m. In winter it was found at 8 stations between 27 to 75 m depth, and at 200 m depth.

Genus *Neoconorbina* Hofker, 1951

Neoconorbina terquemi (Rzehak, 1888)

Plate 5.13, figures 8, 9

1876 *Rosalina orbicularis* Terquem, p. 75, pl. 9, figs. 4 a, b (fide Ellis and Messina).
1888 *Discorbina terquemi* Rzehak, p. 228.
1958 *Discorbina orbicularis* (Terquem). - Le Calvez, Le Calvez, Y., p. 183.
1972 *Neoconorbina terquemi* (Rzehak). - v. Daniels, p. 186, pl.9, figs. 29, 30.
1974 *Discorbina orbicularis* (Terquem). - Colom, p. 125, fig. 21 k.
1987 *Neoconorbina terquemi* (Rzehak). - Loeblich and Tappan, p. 560, pl. 609, fig. 8 -10.
1991 *Neoconorbina terquemi* (Rzehak). – Cimerman and Langer, p. 66, pl. 70, figs. 5 - 7.

Occurrence. This species was found at 22 stations, from 6.5 to 72 m depth in spring. It was found at 6 stations at 27 to 53 m depth in winter.

Genus *Gavelinopsis* Hofker, 1951

Gavelinopsis praegeri (Heron-Allen and Earland, 1913)

Plate 5.13 figure 10

1913 *Discorbina praegeri* Heron-Allen and Earland, p. 122, pl. 10, figs. 8 - 10 (fide Ellis and Messina, 1940).
1972 *Gavelinopsis praegeri* (Heron-Allen and Earland). - Rosset - Moulinier, p. 167, pl. 9, figs. 27, 28.
1987 *Gavelinopsis praegeri* (Heron-Allen and Earland). - Loeblich and Tappan, p. 560, pl. 608, fig. 6 - 12.
1991 *Gavelinopsis praegeri* (Heron-Allen and Earland). – Cimerman and Langer, p. 66, pl. 70, figs. 3 - 4.

Occurrence. This species occurred at one station in spring, and was not found in winter samples.

FAMILY Discorbidae Ehrenberg, 1838

Genus *Disconorbis* Sellier de Civrieux, 1977

***Disconorbis bulbosus* (Parker, 1954)**

Plate 5.13, figures 6, 7

1954 *Discorbis bulbosus* Parker, p. 523, pl. 8. figs. 10 -12.
1987 *Disconorbis bulbosus* (Parker). - Loeblich and Tappan, p. 557, pl. 602, figs. 10 - 15.
1991 *Disconorbis bulbosus* (Parker). - Cimerman and Langer, p. 66, pl. 70, figs. 1 - 2..

Occurrence. There were no stained specimens of this species.

FAMILY Eponididae Hofker, 1951

Genus *Eponides* De Montfort, 1808

***Eponides concameratus* (Williamson, 1858)**

Plate 5.13, figures 11, 12

1858 *Rotalina concamerata* Williamson, p. 52, pl. 67, figs. 101-102.
1960 *Eponides concameratus* (Williamson). - Barker, pl. 104, fig. 19.
1979 *Eponides repondance* (Fichtel and Moll) var. *concamerata* (Williamson). - Blanc-Vernet *et al*.., p. 199, figs. 24, 25.
1984 *Eponides repondance* (Fichtel and Moll). - Rögl and Hansen, pl. 3, fig. 4, pl. 4, fig. 1, 2.
1991 *Eponides concameratus* Williamson. – Cimerman and Langer, p. 64, pl. 67, figs. 11 - 14.

Occurrence. The species was found in spring at 22 stations, at 18 to 67 m. In winter it was found at 17 stations from 12 to 75 m depth.

FAMILY Bagginidae Cushman, 1927

Genus *Vavulineria Cushman*, 1926

***Valvulineria bradyana* (Fornasini, 1900)**

Plate 5.14, figure 1

1900 *Discorbina bradyana* Fornasini, p. 393, textfig. 43.
1982 *Valvulincria bradyana* (Fornasini). - Foraminiferi padani (AGIP, S.P.A.), pl.. 39, fig. 3d, p, v.
1984 *Valvulincria bradyana* (Fornasini). - Bizon (in Ecomed), p. 91, fig. 13.
1984 *Valvulincria bradyana* (Fornasini). - Venecpeyre' (in Ecomed), p. 78, pl. 7, fig. 2.
1988 *Valvulincria bradyana* (Fornasini). - Jorissen, p. 26, pl. 4, fig. 1, 2.
1991 *Valvulincria bradyana* (Fornasini). - Cimerman and Langer, p. 64, pl. 67, figs. 8 -11

Occurrence. The species was found in spring at 14 stations, at 6.5 to 72 m. In winter it was found at 8 stations from 7 to 68 m depth.

Genus *Haynesina* Banner and Culver, 1978

***Haynesina depressula* (Walker and Jacob, 1798)**

Plate 5.14, figure 5

1798 *Nautilus depressula* (Walker and Jacob), p. 641, pl. 14, fig, 33.
1972 *Nonion depressulus* (Walker and Jacob). - Rosset - Moulinier, p. 186, pl. 21, fig. 1 - 4, pl. 22, figs. 1, 2.
1976 *Nonion depressulus* (Walker and Jacob). - Hansen and Lykke - Andersen, p. 21, pl. 19, figs. 3, 6.
1978 *Haynesina depressula* (Walker and Jacob). – Banner and Culver, p. 200, pl. 10, fig. 1- 8.
1991 *Haynesina depressula* (Walker and Jacob). – Cimerman and Langer, p. 81, pl. 83, figs. 1 - 4.

Occurrence. The species occurs at spring in 10 stations, at 16 to 72 m. It was found in winter at 8 stations from 16 at 72 m depth.

***Haynesina* sp.**

Plate 5.14, figure 6

1991 *Haynesina* sp. Cimerman and Langer, p. 81, pl. 83, figs. 5 - 8.

Occurrence. There were no stained specimens of this species.

FAMILY Nonionnidae Schultze, 1854

Genus *Astrononion* Cushman and Edwards, 1937

***Astrononion stelliger* (D'Orbigny, 1839)**

Plate 5.14, figures 6, 7

1839 *Nonionina stelliger* D'Orbigny, p. 128, pl. 3, fig. 12.
1930 *Nonionina stelliger* (D'Orbigny). - Cushman, p. 7, pl. 8, fig. 8 - 12, pl. 3, fig. 1- 3.
1991 *Astrononion stelliger* (D'Orbigny). – Cimerman and Langer, p. 74, pl. 84, figs. 13 - 15.

Occurrence. The species was found in spring in 10 stations, from 6 to 66 m. It occurs in winter in 7 stations at 16 to 102 m depth.

Genus *Nonionella* Cushman, 1926

***Melonis affinis* (Reuss, 1851)**

Plate 5.14, figure 8

1851 *Nonionina affinis* Reuss, p. 72, pl. 5, figs. 32a,b.
1884 *Nonionina umbilicatula* Walker and Jacob. - Brady, pl. 109, figs. 8, 9.
1999 *Melonis affinis* (Reuss). - Robertson, p. 226, pl. 91, fig. 3.

Occurrence. The species occurs in spring at 9 stations, at 27 to 210 m. It occurs in winter at 3 stations from 27 to 47 m depth.

***Nonionella turgida* (Williamson, 1858)**

Plate 5.16, figure 1

1858 *Rotalina turgida* Williamson, p. 50, pl. 4, figs. 95 - 97.
1991 *Nonionella turgida* (Williamson). – Cimerman and Langer, p. 74, pl. 84, figs. 6 - 8.

Occurrence. The species occurs in spring at 3 stations, from 20 to 34 m. It occurrs in winter at 2 stations at 12 and 34 m depth.

Nonion sp.

Plate 5.16, figure 2

Occurrence. There was no stained specimens of this species.

Nonionella sp.

Plate 5.16, figure 3

Occurrence. The species occurs at spring in 5 stations, from 25 to 72 m. It occurrs in winter at 2 stations at 32 and 34 m depth.

FAMILY Elphidiidae Galloway, 1933

Genus *Elphidium* De Montfort, 1808

Elphidium crispum (Linnaeus, 1758)

Plate 5.14, figure 11

1758 *Nautilus crispum* Linnaeus, p. 709 (fide Ellis Messina, 1940)
1991 *Elphidium crispum* (Linnaeus). – Cimerman and Langer, p. 77, pl. 90, figs. 1 - 6.

Occurrence. This species is dominant. It was found at spring in 43 stations from 7 to 75 m. It was found in winter at 27 stations from 19 m to 75 m depth.

Elphidium gerthi van Voorthuysen, 1957

Plate 5.14, figure 12

1957 Elphidium gerthi van Voorthuysen, p. 32, pl. 23, fig. 12
1991 Elphidium gerthi van Voorthuysen. - Cimerman and Langer, p. 78, pl. 91, figs. 1-2.

Occurrence. This species was found at 2 stations in spring and winter (from 67 to 75 m depth).

Elphidium macellum (Fichtel and Moll, 1798)

Plate 5.15, figure 1

1798 *Nautilus macellum* var. *beta* Fichtel and Moll, p.66, pl. 19, fig. h - k.
1991 *Elphidium macellum* (Fichtel and Moll). – Cimerman and Langer, p. 78, pl. 89, fig. 9.

Occurrence. This species was found in spring at 11 stations (from 6.5 to 200 m depth). In winter it was found at 4 stations at 36 to 75 m.

Elphidium margaritaceum (Cushman, 1930)

Plate 5.15, figure 2

1930 *Elphidium advenum* (Cushman) var. *margaritaceum.* - Cushman, p. 25, pl. 10, fig.3
1957 *Elphidium margaritaceum.*(Cushman). - Van Voorthuysen, p. 32, pl. 23, fig. 13.
1976 *Elphidium margaritaceum.*(Cushman). - Hansen and Lykke - Andersen, p. 8, pl. 3, fig. 2- 6.
1991 *Elphidium margaritaceum.*(Cushman). - Cimerman and Langer, p. 79, pl. 92, figs 4 - 6.

Occurrence. This species is very rare. It was found at one station in spring and winter at 53 m depth.

Elphidium depressulum (Cushman, 1933)

Plate 5.15, figure 3

1933 *Elphidium advenum* Cushman var *depressulum.* - Cushman p. 51, pl. 12, figs, 4a, b.
1991 *Elphidium depressulum* Cushman. – Cimerman and Langer, p. 78, pl. 90, figs. 7 - 8.

Occurrence. This species was found from 30 to 200 m. It was found at 11 and 9 stations in spring and winter respectively.

Elphidium translucens Natland, 1938

Plate 5.15, figures 4, 5

1938 *Elphidium translucens* Natland, p. 144, pl. 5, figs. 3, 4.
1970 *Cribrononion translucens* (Natland). - v. Daniels, p. 88, pl. 7, figs. 13a, b.
1976 *Elphidium translucens* Natland. - Hansen and Lykke - Andersen, p. 11, pl. 7, figs. 1 - 11.
1991 *Elphidium translucens* Natland. - Cimerman and Langer, p. 79, pl. 92, figs. 7 - 11.

Occurrence. This species was found in spring at 10 stations (from 6.5 to 66 m depth). In winter it is found at 6 stations from 36 to 200 m.

Elphidium jenseni Cushman, 1924

Plate 5.15, figure 6

1924 *Elphidium jenseni* Cushman, p. 49, pl. 16, figs. 4, 6.
1933 *Elphidium jenseni* Cushman. - Cushman, p. 48, pl. 11, figs. 6, 7.
1939 *Elphidium jenseni* Cushman. - Cushman, p. 62, pl. 17, figs. 14, 15.
1991 *Elphidium jenseni* (Cushman). - Cimerman and Langer, p. 78, pl. 92, figs. 1 - 3.

Occurrence. This species is rare. It was found at 3 stations (from 33 to 43 m) in spring. It was found at one station in winter, at a depth of 36 m.

Elphidium striatopunctatum (Fichtel and Moll, 1798)

Plate 5.15, figure 7

1798 *Nautilus striatopunctatum* Fichtel and Moll, p. 61, pl. 9a - c.
1993 *Elphidium striatopunctatum* (Fichtel and Moll). – Hottinger *et al.*, p. 149, pl. 213, figs. 1 - 8, pl. 214, figs. 1 - 6.

Occurrence. This species was found in spring in 8 stations (from 19 to 36 m depth). In winter it was found at 5 stations from 19 to 36 m.

Elphidium cf. *E. advenum* (Cushman, 1922)

Plate 5.15, figure 8

1922 cf. *Polystomella advena* Cushman, p. 56, pl. 9, figs. 11-12.
1991 *Elphidium* cf. *E. advenum* (Cushman). - Cimerman and Langer, p. 77, pl. 89, figs. 5-7.

Occurrence. This species was found from 7 to 75 m (at 14 stations and 9 stations) in spring and winter respectively.

Elphidium cf. *E. limbatum* (Cushman, 1909)

Plate 5.15, figure 9

1909 cf. *Polystomella macella* Fichtel and Moll var. *limbata* Chapman, p. 142, pl. 10, figs. 9 a, b.
1932 cf. *Elphidium macella* (Fichtel and Moll) var. *limbata* (Chapman). - Cushman, p. 50, pl. 11, figs. 9 a,b.
1958 cf. *Elphidium limbatum* (Chapman). - Collins, p. 421.
1979 *Elphidium macella* (Fichtel and Moll). - Pereira, pl. 37, fig. J.
1987 *Elphidium limbatum* (Chapman). - Baccaert, p.255, pl. 103, figs. 7, pl. 104, figs. 1.
1993 *Elphidium limbatum* (Chapman). - Hottinger *et al.*, p. 149, pl. 212, figs. 1 - 9.

Occurrence. This species is rare. It was found in spring and winter at one station at 67m depth.

Elphidium sp. 1

Plate 5.15, figure 10

Occurrence. This species was found at 2 stations, from 45 and 67 m, in spring and witer.

Elphidium sp. 2

Plate 5.15, figure 11

Occurrence. No stained specimens were found of this species.

Genus *Porosononion* Putryra, 1958

Porosononion subgranosus (Egger, 1857)

Plate 5.14, figure 4

1857 *Nonionina subgranosa* Egger, p. 299, pl. 14, figs. 16-18.
1958 *Porosononion subgranosus* (Egger). - Putryra *in* Voloshinova, p. 135, pl. 1, figs 7, 8.

Occurrence. The species occurs in depth ranges from 6.5 to 210 m. It was found in spring at 25 stations. It was found in winter at 16 stations.

FAMILY *Amphisteginidae* Cushman, 1927

Genus *Amphistegina* D'Orbigny, 1826

Amphistegina lessonii D'Orbigny, 1826

Plate 5.16, figure 5

1826 *Amphistegina lessonii* D'Orbigny, p. 304.
1993 *Amphistegina lessonii* D'Orbigny. – Hottinger *et al.*, p.132, pl. 184, figs. 1-11 and 185, figs. 1 - 7.

Occurrence. This species was found in spring at 10 stations from 7 to 48 m depth. In winter it was found at 8 stations (at 7 to 44 m depth).

Amphistegina lobifera Larsen, 1976

Plate 5.16, figures 6, 7

1976 *Amphistegina lobifera* Larsen, p. 4, pl. 3, figs. 1 - 5, pl. 7, fig. 3, pl. 8, fig. 3.
1993 *Amphistegina lobifera* Larsen. – Hottinger *et al.*, p. 133, pl. 186, figs. 1 - 11 and 187, figs. 1 - 7, pl. 188, figs. 1 - 6

Occurrence. This species was dominant in the area. It was found in spring at 20 stations from 7 to 48 m depth. In winter it was found at 14 stations (at 7 to 47 m depth).

FAMILY Reussellidae Cushman, 1933

Genus *Reussella* Galloway, 1933

Reussella spinulosa (Reuss, 1850)

Plate 5.16, figure 8

1850 *Reussella spinulosa* Reuss, p. 374, pl. 47, figs. 5 - 8.
1993 *Reussella spinulosa* (Reuss). – Cimerman and Langer, p. 63, pl. 66, figs. 5 - 8.

Occurrence. This species occurs in deep locations. It was found in spring at 15 stations from 6.5 to 200 m depth. In winter it was found at 8 stations from 7 to 67 m depth.

FAMILY Bolivinidae, Glaessner, 1937

Genus *Bolivina* D'Orbigny, 1839

Bolivina variabilis (Williamson, 1858)

Plate 5.16, figure 11

1858 *Textularia variabilis* Williamson, p. 76, pl. 6, figs. 7 - 8.
1991 *Bolivina variabilis* (Williamson). – Cimerman and Langer, p. 59, pl. 61, figs. 7 - 8.

Occurrence. This species was found in the spring samples at 9 stations from 3 to 210 m depth. whereas in winter it found at two stations, 16 and 56 m depth.

Genus *Brizalina* Costa, 1856

Brizalina striatula (Cushman, 1922)

Plate 5.16, figures 12, 13

1922 *Bolivina striatula* Cushman, p. 27, pl. 3. fig. 10 (fide Ellis and Messina, 1940).
1991 *Brizalina striatula* (Cushman). – Cimerman and Langer, p. 60, pl. 62, figs. 6 - 9.

Occurrence. This species has a wide depth range from 6 to 102 m depth in 7 stations (in spring). It was found in winter at 2 stations, at 32 and 102 m depth.

Brizalina spathulata (Williamson, 1858)

Plate 5.16, figure 14

1858 *Textulariavariabilis* var. *spathulata* Williamson, p. 76, pl. 6, figs. 164, 165.
1991 *Brizalina spathulata* (Williamson). – Cimerman and Langer, p. 60, pl. 62, figs. 3 - 5.

Occurrence. This species has wide depth range in spring from 28 to 210 m at 9 stations, except few numbers at 6.5 depth in two stations. In winter it was found at 5 stations from 32 to 47 m depth.

FAMILY Buliminidae Jones, 1875

Genus *Bulimina* D'Orbigny, 1826

Bulimina elongata D'Orbigny, 1846

Plate 5.16, figure 15

1846 *Bulimina elongata* D'Orbigny, p. 187, pl. 11, figs. 19-20.
1991 *Bulimina elongata* D'Orbigny. – Cimerman and Langer, p. 62, pl. 64, figs. 3 - 8.

Occurrence. This species found at two stations at depths of 6 and 210 m in spring, and, two stations in winter at a depth of 32 m.

Bulimina costata D'Orbigny, 1852

Plate 5.17, figure 1

1852 Bulimina costata D'Orbigny, p. 194.
1991 *Bulimina alazanensis* D'Orbigny. – Sgarrella and Moncharmont Zei, p. 211, pl. 15, fig. 3.

Occurrence. This species is rare. It was found at one station in spring at 184 m. In winter it was found at 3 stations at 24 to 47 m depth.

Bulimina marginata D'Orbigny, 1875

Plate 5.17, figure 2

1875 *Bulimina marginata* D'Orbigny, p. 269, pl. 12, figs. 10-12.
1991 *Bulimina marginata* D'Orbigny. – Cimerman and Langer, p. 62, pl. 64, figs. 9 - 11.
1994 *Bulimina marginata* D'Orbigny. - Jones, p.55, pl. 51, figs 3 - 5.

Occurrence. This species was found in spring at two stations, at 184 and 210 m. In winter it occurs at 5 stations at depth from 32 to 102 m.

Remarks. The specimen has less acute shoulders and fewer pseudospines at the shoulders.

FAMILY Siphogenerinoididae Saidova, 1981

Genus *Rectuvigerina* Matthews, 1945

***Rectuvigerina phlegeri* Le Calvez, 1959**

Plate 5.17, figure 10, 11

1959 *Rectuvigerina phlegeri* Le Calvez - Berthois and Le Calvez, p. 363, pl. 1, fig. 11.
1960 *Rectuvigarina raricosta* Moncharmont Zei, pp. 149 - 150, pl. 4, figs. 18 - 20.
1984 *Rectuvigarina phlegeri* Le Calvez. - Venes - Peyre, pl. 7, fig. 4.
1993 *Rectuvigarina phlegeri* Le Calvez. - Sgarrella and Moncharmont, p. 215, pl. 16, figs. 3, 4.

Occurrence. This species was found at 2 stations in spring (at 82 and 210 m). It was not found in winter samples.

***Rectuvigerina* sp.**

Plate 5.17, figure 12

Occurrence. This species was found at 3 stations in spring (from 184 to 210 m) and at 2 stations in winter (from 32 and 36 m).

Remarks. Test is semi-elongated and rounded in apertural view. Chambers are triserially arranged, become loosely triserial. Chambers increasing in size as added terminating with a big rounded terminal chamber. Aperture produced on a neck and provided with an internal tooth plate. Sutures oblique and depressed, wall is finely perforated. Surface ornamented with longitudinal subrounded costae. It has acute shoulders. One spine at the apical end.

FAMILY Uvigerinidae Haeckel, 1894

Genus *Uvigerina* D'Orbigny, 1826

Uvigerina sp.

Plate 5.17, figure 13

Occurrence. This species occurs from 52 to 200 m depth at 5 stations in spring. In winter it was found at 4 stations from 32 to 56 m depth.

Remarks. Test is elongated, chambers are triserial arranged, later becoming loosely triserial. Chambers become slightly inflated. Sutures are distinct, depressed and oblique. Wall surface finely perforated. It has longitudinal sharp high costae, discontinous at the sutures. The aperture is produced on a short neck and provided with a tooth plate.

FAMILY Fursenkoinidae Loblich and Tappan, 1961

Genus *Fursenkoina* Loblich and Tappan, 1961

***Fursenkoina acuta* (D'Orbigny, 1846)**

Plate 5.17, figure 15

1846 *Polymorphina acuta*, D'Orbigny, p. 234, pl. 13, fig. 4 -5.
1848 *Virgulina schreibersiana* Czjzek, p. 147, pl. 13, fig. 18 - 21.
1972 *Virgulina schreibersiana* Czjzek. - Rosset Moulinier, p. 184.
1985 *Fursenkoina acuta* (D'Orbigny). - Papp and Schmid, p. 82, pl. 75, figs. 1 - 6.
1991 *Fursenkoina acuta* (D'Orbigny). - Cimerman and Langer, p. 64 pl. 67, figs. 1 - 2.

Occurrence. This species very rare. It was found at one station at 210 m depth and at 200 m depth at one station in winter at 200 m depth..

SUBORDER Lagenina Delage and Herouard, 1896

FAMILY Vaginulinidae Reuss, 1860

Genus *Amphicoryna* Schlumberger, 1881

***Amphicoryna* sp.**

Plate 5.16, figure 9

1998 *Amphicoryna* sp. Piller and Haunold, p. 21, pl. 7, fig. 4

Occurrence. This species was found in spring at 9 statiions from 67 to 210 m depth. It was found in winter at 7 stations from 66 to 200 m depth.

Remarks. This specimen consists of one globular chamber and has few costae. The aperture is crown shape and produced at the end of a long neck.

Genus *Lenticulina* Lamarck, 1804

***Lenticulina gibba* (D'Orbigny, 1826)**

Plate 5.16, figure 10

1826 *Cristellaria gibba* D'Orbigny, p. 292, no.17.
1839 *Cristellaria gibba* D'Orbigny, p. 40, pl. 7, figs. 20, 21.
1913 *Cristellaria gibba* D'Orbigny. - Cushman, p.105, pl. 25, fig. 4.
1974 *Robulus gibba* (D'Orbigny). - Colom, p. 96, fig. 11 g.
1977 *Lenticulina gibba* (D'Orbigny). - Le Calvez, Y., p. 25, fig.1.
1991 *Lenticulina gibba* (D'Orbigny). - Cimerman and Langer, p. 51, pl. 53, figs. 7 - 11.

Occurrence. This species was found at deep stations in both seasons from 32 to 200 m depth except for few numbers at 6 m depth. It was found at 4 stations in winter and 9 stations in spring.

FAMILY Polymorphinidae D'Orbigny, 1839

Genus *Polymorphina* D'Orbigny, 1826

***Polymorphina* sp. 2**

Plate 5.17, figure 3

1991 *Polymorphina* sp. 6. – Cimerman and Langer, p. 54 pl. 56, figs. 11 - 12.

Occurrence. This species was found in spring at a single station at 34 m. It was not found in the winter samples.

***Polymorphina* sp. 4**

Plate 5.17, figure 4

1991 *Polymorphina* sp. 5. – Cimerman and Langer, p. 54 pl. 57, figs 5 - 7.

Occurrence. This species occurs in spring in one station at 34 m. In winter it was found at two stations at 7 and 24 m depth.

***Polymorphina* sp. 5**

Plate 5.17, figure 5

1991 *Polymorphina* sp. 7. – Cimerman and Langer, p. 54, pl. 56, figs. 1 - 4.

Occurrence. This species was found in spring at 3 stations at 6.5 and 53 m depth. In winter it was found at two stations at 43 and 52 m depth.

***Polymorphina* sp.**

Plate 5.17, figure 7

1991 *Polymorphina* sp 2, Cimerman and Langer, p. 54, pl. 57, figs. 1 - 4.

Occurrence. This species has wide depth range, it occurs from 6 to 200 m depth at 9 station at spring. In winter it occurs at 4 stations from 7 to 66 m depth.

Genus *Globulina* (D'Orbigny, 1839)

***Globulina gibba* D'Orbigny, 1826**

Plate 5.17, figure 6

1826 *Globulina gibba* D'Orbigny, p. 266.
1994 *Globulina gibba* D'Orbigny. - Loeblich and Tappan, p. 82, pl. 145, figs. 1 - 4.

Occurrence. This species is rare. It occurs at 54 to 66 m depth at 3 station at spring and at two station in winter (at 63 and 66 m).

FAMILY Glandulinidae Reuss, 1860

Genus *Glandulina* D'Orbigny, 1839

***Glandulina laevigata* D'Orbigny, 1826**

Plate 5.17, figure 8

1826 *Nodosaria (Glandulina) Laevigata* D' Orbigny, p. 252, pl. 10, figs. 1 - 3.
1930 *Glandulina laevigata* (D' Orbigny). - Cushman and Ozawa, p. 143, pl. 40, figs. 1 a - b.
1974 *Glandulina laevigata* (D' Orbigny). - Lutze, p. 20, pl. 5, fig. 75.
1993 *Glandulina laevigata* (D' Orbigny). - Hottinger *et al.*, p. 83, pl. 96. figs, 1 - 5, 8.
1998 *Glandulina laevigata* (D' Orbigny). - Piller and Haunold, p. 23, pl. 7, fig. 23.

Occurrence. This species occurs from 45 to 68 m depth at 3 stations in spring. In winter was found at 2 stations at 56 and 68 m depth.

FAMILY Ellipsolagenidae Silvestri, 1923

Genus *Fissurina* Reuss, 1850.

***Fissurina orbignyana* Seguenza, 1862**

Plate 5.17, figure 9

1826 *Fissurina orbignyana* Seguenza, p. 66, pl. 2, figs. 25 - 26.
1940 *Lagena orbignyana* (Seguenza). - Buchner, p. 504, pl. 20, fig. 410 - 412.
1971 *Fissurina orbignyana* Seguenza. - Murray, p. 99, pl. 40, figs. 1 - 5.
1991 *Palliolatella orbignyana* (Seguenza). - Cimerman and Langer, p. 56, pl. 59, figs. 6 - 7.
1993 *Fissurina orbignyana* Seguenza. - Sgarrella and Moncharmont, p. 204, pl. 13, figs. 2 - 3.

Occurrence. This species is very rare. It was found at one station in spring (at 210 m) and 3 stations in winter (at 32 to 47 m).

Remarks. The test has flask shape, it is less rounded than the specimen in Cimerman's book. Its peripheral margin has three subrounded peripheral keels, whereas it is acute in Cimerman's. The figure wall is hyaline and smooth, whereas it is pitted in Cimerman's figure. Aperture is lenticular produced on a short neck bordered by thickened end, phialine rim. An entosolenian tube is present in both specimen but the tube is not continuous in the described specimen, which is continous in Cimerman's specimen.

FAMILY Vaginulinidae Reuss, 1860

Genus *Astacolus* de Montfort, 1808

***Astacolus crepidulus* (Fichtel and Moll, 1798)**

Plate 5.17, figure 14

1798 *Nautilus crepidula* Fichtel and Moll, p. 107, pl. 19, figs. g - i.
1923 *Astacolus crepidulus* (Fichtel and Moll). - Cushman, p. 117, pl. 35, figs. 3, 4.
1970 *Planularia crepidula* (Fichtel and Moll). - Daniels, p. 78, pl. 4, fig. 5.
1971 *Astacolus crepidulus* (Fichtel and Moll). - Murray, p. 77, pl. 29, figs. 5, 6.
1987 *Astacolus crepidulus* (Fichtel and Moll). - Loeblich and Tappan, p. 410, pl. 450, figs. 7, 8.
1991 *Astacolus crepidulus* (Fichtel and Moll). - Cimerman and Langer, p. 52, pl. 54, figs. 10 - 14.
1994 *Astacolus crepidulus* (Fichtel and Moll). - Loeblich and Tappan, p. 72, pl. 130, figs. 1 - 10.

Occurrence. This species was found in spring and winter at one stationm at 27 m depth.

FAMILY Nodosariidae Ehrenberg, 1838

Genus *Nodosaria* Lamarck, 1812

***Nodosaria lamnulifera* Thalmann, 1950**

Plate 5.17, figure 16

1884 *Nodosaria raphanus* (Linne'). - Brady, pl. 64, figs. 6 - 10.
1932 *Nodosaria raphanus* (Linne'). - Thalmann, v. 25, pp. 293 - 312.
1950 *Nodosaria lamnulifera* Thalmann, v. 1, pp. 41 - 45.
1994 *Nodosaria lamnulifera* Thalmann. - Jones, p. 76, pl. 64, figs. 6 - 10.

Occurrence. This species was found in spring at a single station at 75 m. It was not found in winter samples.

Remarks. The aperture of this specimen is off-centred, whereas in Brady's book the specimen has a central aperture.

Genes *Pyramidulina* Fornasini, 1894

***Pyramidulina catesbyi* (D'Orbigny, 1839)**

Plate 5.17, figure 17

1839 *Nodosaria catesbyi* D'Orbigny, p. 16, pl. 1, figs. 8 - 10.
1949 *Nodosaria catesbyi* D'Orbigny. - Said, p. 21, pl. 2, fig. 22.
1959 *Nodosaria catesbyi* D'Orbigny. - Graham and Militante, p. 69, pl. 10, figs. 24, 25.
1977 *Nodosaria catesbyi* D'Orbigny. - LeCalvez, p. 47, figs 1 - 5, 8 - 10.
1994 *Pyramidulina catesbyi* (D'Orbingy). - Loeblich and Tappan, p. 66, pl. 166, figs. 10 - 12.

Occurrence. This species occurs at 2 stations at 45 and 210 m in depth in spring. In winter it was found at a single station at 24 m.

Remarks. The neck in the specimen is shorter than the example in Loeblich and Tappan. The sutures are smaller.

Genus *Pseudonodosaria* Boomgaart, 1951

***Pseudonodosaria comatula* (Cushman, 1923)**

Plate 5.17, figure 18

1923 *Nodosaria comatula* Cushman, p. 83, pl. 14, fig. 5.
1950 *Peudoglandulina comatula* (Cushman). - Cushman and McCulloch, p. 325, pl.42, figs. 5 - 7.
1993 *Peudoglandulina comatula* (Cushman). - Sgarrella and Moncharmont, p. 195, pl. 12, fig. 13.
1994 *Pseudonodosaria discreta* (Cushman). - Loeblich and Tappan, p. 66, pl. 117, figs. 1 - 6.

Occurrence. This species is rare. It was found at a single station in spring (at 58 m depth). In winter it was found at 2 stations at 45 and 102 m depth.

Remarks. The specimen is wider than the examples in Sgarrella and Moncharmont (1993) and Loblich and Tappan (1994). The costae are more numerous and closer to each other, and meet in near the beginning of the neck to the end forming a hexagonl shape. It is less concentric.

Chapter 6
Discussion

A total of 168 species of calcareous and agglutinated benthic foraminifera species recovered during the spring and winter seasons have been distinguished. All the forms have been identified to the species level. The rotaliids make up the highest percentage, followed by miliollids, then the agglutinated forms.

Species of *Lagenina*, however, make up the smallest percentage of the population. This contradicts the observations of De Rijk *et al.*, (1999) who studied deposits between 0 - >1000m of water depth in the Levantine Basin (Mediterranean Sea). These authors observed that the miliollids, represented by *Quinqueloculina* spp. were present in very low percentages in the shallow regimes, and that the microfauna was dominated by *Bulimina* spp., *Cassidulina* spp., and *Brizalina* spp.

In this study, samples were collected from depths of 6 to 200m. The foraminiferal assemblage is composed mainly of shallow water species including miliolids (eg. *Quinqueloculina* sp.) and larger foraminifera (e.g. *Amphistegina lobifera,* Vertebralina *striata* and *peneroplis pertusus*). Species of *Bulimina* and *Brizalina* occur rarely and in small numbers within the assemblage. *Textularia* spp. and *Bigenerina nodosaria* constitute the dominant species among the agglutinated foraminifera. These two species were reported to be found at depths <1000m (de Rijk *et al.*, 1999).

I observed only a small proportion of the species were depth dependant, e.g. *A. tepida* which is known to be a typical shallow water species. Other species show preference to the type of substrate (section 3.4.4.), e.g. *A. lobifera* which appears to prefer hard ground (reef and ridges), coarse, gravel and pebble grain sized substrates. On the other hand, *A. tepida* shows affinity to very fine sand substrates. The deep-water dwellers (outer neritic), such as *Bulimina* spp., also appear to prefer very fine sand substrates. Some species are cosmopolitan and are found living on more than one type of substrate e.g. *A. mamilla*, and *T. marioni*. Hence, the distribution of some species can be explained by the Schmidt theory (1953) which recognises that the type of substrate affects the relative abundance of foraminifera. For the other species, their distribution can be explained by the Phleger theory (1960, 1964) which supposes that sedimentological parameters are not very important for the quantitative distribution of foraminifera.

Whereas some species are clearly widely distributed in the area (see section 3.4.4.), e.g. *A. mammilla*, *T. marioni*, *Elphidium crispum*, others are restricted to particular sites e.g. *A. lobifera*, *Peneroplis pertusus*, and *Heterostigena depresula* which are found at hard ground sites. Some species typical of deeper settings are found to be rare in the area and these include: *Melonis affinis*, *Bolivina variabilis*, *Brizalina spathulata*, *B. striatula* and *Amphicorina sp.* Some other species are observed to occur significantly in Alit Bay but are rare in Haifa Bay e.g. *Asterorotalia gaimardii.*

The statistical assessment (section 3.4) suggests that the distribution of benthic foraminifera in the study area is governed by locally prevalent parameters rather than by one simple factor such as water depth.

Haifa Bay is characterised by low foraminiferal density compared to other basins, for example Karkinitian Bay in the Black Sea (Yanko, 1989). In the Karkinitian Bay, foraminiferal abundance is reported to be 200 times higher than in the Haifa Bay (samples collected in the spring). Although, both Karkinitian and Haifa Bays are quite similar in having an extremely small amount of fresh-water input, the Karkinitian is, however, a eutrophic basin with a high rate of bio-production. Bermen *et al* (1984) reported that the impoverished foraminiferal content in Haifa Bay is as a result of nutrient deficiency typical of oligotrophic basins. Relatively nutrient-rich surface waters enter the Mediterranean through the Straits of Gibraltar (i.e. North Atlantic surface water). During its eastward flow, the salinity and the temperature of this water increases, while its nutrient concentration decreases. This nutrient gradient is expressed in declining primary productivity values from west to east (Antoine *et al.*, 1995). The vertical organic flux reaching the sediment-water interface depends on primary productivity and water depth (Berger and Wafer, 1990). The organic flux will, subsequently, be lower at deep sites in the oligotrophic eastern Mediterranean than at similar depths in the more eutrophic western basin.

Yacobi and Parparov (1996) reported that the average concentration of chlorophyll in the shallower stations in Haifa Bay was 20 times higher than at greater depths. The concentration of phytoplankton was thus found to be higher at shallower depths compared to deeper depths in Haifa Bay. Accordingly, water transparency was lower (i.e. high turbidity) in shallower stations than at deeper offshore stations. It was also noted that the intense proliferation of phytoplankton in Haifa Bay is of a seasonal nature. During the winter month of January 1995, concentrations of chlorophyll were significantly lower with an average of 1.9 µg/l at littoral regimes during winter than at spring time. Hence, a high concentration of chlorophyll in the littoral regime of Haifa Bay is thought to be indicative of intense eutrophic processes. The values reported by Yacobi and Parparov (1996) in deeper stations of the bay, thus approximate that of the open sea. This indirectly confirms the suggestion that eutrophism within the Haifa Bay is initiated by external sources, and is not related to the bay's morphometry. A similar conclusion may be derived from considering the spatial distribution of other variables measured in this study. Based on the obtained ranges of the studied parameters of water quality, we can conclude that the near shore area of Haifa Bay are more eutrophic, while the offshore area of the bay exhibits features of oligotrophy.

There is an observable seasonal variation in the quantitative and qualitative distribution of foraminifera. Foraminifera are more abundant and diverse in samples collected during the spring of 1993 compared with the summer of 1992 (Yanko, 1993) and winter of 1995. The abundance of foraminifera during spring can therefore be related to nutrient enrichment.

The distribution of benthic foraminifera can be influenced by a variety of factors such as temperature, salinity, dissolved Oxygen, pH value, depth, type of substrate, and pollution. Among the above mentioned factors, the last three seem to affect the distribution of the benthic foraminifera, because the other factors do not show any major variations from one station to another. The species diversity, richness, absolute and relative abundance do not show a clear relation to depth, but the distribution of some selected species appear to be affected by depth e.g. *A. tepida* for which its abundance decreases with increase in depth.

The living species richness and diversity increases when very fine sand and clay-silt percentages increase in the substrate and decreases when the percentage of the coarse materials, gravel and pebbles increase. The content of organic matter in the bottom sediment in Haifa Bay increases with increasing clay-silt content, and this increase in the clay-silt content is in turn a function of increase in depth from shore (Yacobi and Paparov, 1996). It seems, therefore, that the number of species (richness) and species diversity are affected by the changes in organic matter. Hence, at relatively deeper stations where there is more food and less turbulence, there is an increase in species richness and diversity.

In the Qishon River harbour, the concentration of organic matter is extremely high despite the shallow near-shore location (Yacobi and Paparov, 1996). This high organic matter content is thought to reflects the amount of industrial pollution because, at these sites, the number of species and the species diversity are very low. These very low species diversity and richness indices suggest significant environmental deterioration near the Akko and Qishon harbours due to the Frutarom factory which discharged pollutants into the bay. An indication of this pollution is the decrease in the abundance of *A. tepida* near the Qishon harbour at sites within the shallow regime which are characterised by clay-silt and very fine sand (features preferred by *A. tepida*).

The absolute abundance increases with increase in fine sand, and decrease with increase in coarse sand, gravel and pebbles. The abundance of foraminifera decreases in sites near the Qishon river harbour (due to the high concentration of toxic organic matter) and in sites which have high concentration of heavy metals in the sediment, e.g. Station 1 (a polluted site) the absolute abundance is less (26 tests / 5g sediment) than at station 76 (146 tests / 5g sediment), a relatively nonpolluted site.

The size of the foraminiferal test is not affected by depth but it is affected by the type of substrate. The percentage of large test sizes is high where the substrate is coarse and pebbly. Where the substrate is clay-silt and fine sand, the majority of tests are smaller. Both seasons are dominated by foraminifera with medium sized tests. The percentage of small sized tests decrease during the winter period (most probably owing to the harsher conditions). Generally, foraminifera reproduce in spring and die back during winter.

The concentration of heavy metals in the sediments is lower in winter than in spring, thus suggesting that less pollutants were released during the period between spring 1993 and winter 1995. For example, the study of Yanko (1994) and Yanko *et al.*, (1998), show that the concentration of Cd in Haifa Bay was 10 times higher than observed in the present study. Alternatively the difference in heavy metal concentration in the sediment in the study area might be due to analytical error (different methods used in extraction), or different sample material - more clay means higher absorption sites and hence higher metal concentration.

The winter period is characterised by harsh environmental conditions such as lower temperature, lower dissolved oxygen, and strong currents which may hasten the mortality of the foraminifera. The availability of food is highly reduced during the winter period relative to the spring, and this may result in the reduction in the abundance of foraminifera.

Compared to the abundant foraminiferal occurrence in Atlit Bay (which is used as the control region) the poor occurrence of foraminifera in the Haifa Bay (polluted region) can be referred to the heavy metal pollution in the area. Even within Haifa Bay, further segregation between sites can be made as regards foraminiferal abundance and changes in heavy metal concentration. Hence, sites of high and low pollution can be distinguished. This was clear in the comparison of two station (1, 78) which have the same features with the only variable being the heavy metal concentration.

The percentage of deformed stained tests is higher at the stations near the outlet of Naaman and Qishon rivers, and in the hard ground region before the 200 m depth where this may result from the contamination from the two river outlets and the dumping of near shore dredged sediments off the coast of the bay. Dredging has been carried out to deepen Qishon harbour and its entrance. The 1.5 million m^3 of sediment removed includes materials that are highly contaminated by trace metals (Kronfeld and Navrot, 1974; Yanko, 1994). Barges were used to transport the sediments for disposal further basinwards at bathymetric depths of about 200m. It is possible that during the removal and subsequent transportation of the sediments for disposal, accidental dumping could have occurred at the southwest portion of the bay closer to the shore. This may explain the contamination in some stations in Atlit Bay where some deformed foraminiferal tests are found and this may also explain why there are relatively unpolluted sites near Qishon river outlets (stations 2, 3 and 4). Wave and current action could, subsequently, have moved the sediment northward as well as backwards towards the bay. Inside the bay there is most probably a current pattern that plays a role in re-distributing the sediment and this may explain the higer concentration of heavy metal toward the sea (e.g. at stations 50 and 40). So disturbance by human activity may be influencing the sediment metals and consequently the foraminiferal test distribution.

The occurrence of Cadmium (Cd), Lead (Pb) and Arsenic (As) correlate with large grain size and $CaCO_3$ distribution as well as with large foraminiferal test size (e.g. stations 12, 37 and 26).

The sediment samples were not analysed for their grain size in winter so the comparison of the distribution of sediment cannot carried out between the spring (1993) and winter

(1995) periods. Nir (1985) reported that in winter, the distribution of sediments is more than in summer because the action of waves is greater. During this season the erosive power of the wave against portions of the submerged ridges should likewise be greater and may be responsible for additional internal sediment supply. Kronfeld and Navrot, (1974) suggested that significant dilution occurs down stream, hence sediments transported from Nahal Gadura River are diluted with uncontaminated sediments especially in winter when currents are stronger and the dispersal of sediments is greater. This may also explain the decline in pollution levels and the decline in foraminiferal abundance during winter. The abundance of some species which are found near the coast line in Haifa Bay are shifted toward the sea in winter.

A geochemical study was carried out on sediments from cores collected at the same sampling sites during the winter and the spring season. The spring season is a quiet period with no rainfall and undisturbed warming of sea water (which is correlated to reduced input of sediments from the land). The winter season is a time of turbulence with much wave action and this leads to some degree of winnowing out of the fine material from near shore and subsequent deposition at greater depths. During these winter periods, there is, however, greater river input from the hinterland. The sediment introduced into the shallower regions of the bay become more subject to the influence of wave action and hence re-distribution.

The absolute heavy metal concentrations though, appear to be slightly greater in the sediments collected during the prior spring season. This may be due to a decrease in the metal pollution over the preceding two years. However, it is more likely that the wave action during the winter would have removed some of the more contaminated clay and organic components from those sample sites (Paencier, 1996), which would explain the decrease in the deformed living test in winter.

Diversity is high where the substrate is clay-silt (see, section 4.3.2.2.). It is well known that the distribution and concentration of trace elements in an aquatic environment depends on different factors (e.g. their mineralogical composition, size of deposited particulate matter, biological activity occurring at the sea bottom) and is strongly influenced by some physical and chemical parameters (salinity, and pH) which control their stability. However, no clear relationship is found in this study between the heavy metal concentration and the physical parameters recorded during sampling.

Although higher levels of heavy elements such as Cadmium and Lead have been observed to favour benthic foraminiferal diversity, an inverse relationship however, exists between the faunal density of the total living foraminifera and such heavy metals. According to Yanko (1993) and Bresler and Yanko (1995a and b), the heavy metals affect the defence system of the foraminifera and disrupt their normal membrane permeability. Under such situations, the organism becomes unable to metabolise food. This in turn results in energy depletion thus inhibiting the organisms normal reproductive cycle. As a result, there is ultimately a decrease in foraminiferal abundance.

The direct relationship between the percentage of living deformed specimens and heavy metal concentration values suggested that the development of abnormal morphologies would be favoured by higher levels of heavy metal concentration. Such observations have, previously, been reported by many others (Stubbles, 1999; Sharifi 1991; Yanko 1994; Yanko *et al.*, 1998).

Fifty species were found to exhibit morphological deformities. Thirteen (13) types of morphological deformities, some of which have been previously reported by other workers, have been described in this study, and some deformities are described for the first time in this study e.g. FDT-7, FDT-8, FDT-9, FDT-10, FDT-11, FDT-12, FDT 13, and different deformaties exhibited by *A. lobifera.* These deformities are thought to result either from mechanical factors (such as currents and wave action), predatory effects, environmental stress, and/or pollution.

These deformity types include: test twinning or test doubles; wrong coiling; double apertures in otherwise single aperture forms and chamber enlargement. Additional morphological deformities noted in this study include a change in the coiling plane, fusion of young which may result from perturbations in the ontogenetic development of the organism (Stouff *et al,* 1999). In this study, the presence of scars has been recognised in many foraminiferal tests, especially tests collected from coastal sites as well as from reef and ridge sites where the substrate is coarse sand and pebbles. It appears that the presence of scars are due to regeneration of tissue subsequent to the partial destruction of the test.

Some foraminifera exhibit small fragmented extensions which appear to be stuck to the test. These fragments could have resulted, initially, from damage to the original test wall. Subsequently, the opening that would have formed from this damage, would create an avenue for the protoplasm to extrude and rebuild a fresh test while the fragmented part still remains partly stuck to the original test wall. In many instances, it is observed that the newly generated parts posses ornamentation that are different from those found on the older part of the test. At times, where new apertures are formed, they are usually of a different shape and size (e.g. oval and smaller and thinner).

The feature of test twining or test doubles was first explained from culture experiments by Stouff (1999), as resulting either from the simultaneous development of two juveniles, one of which developed abnormally during their early stage of calcification, or from the fixation of one juvenile on the test of the parent.

Double tests are often described in literature among test abnormalities. Their presence is often related to ecological causes such as periods of limited food supply and periods when there is an excess of it (Boltovskoy and Wright, 1976). Their presence may also be related to other causes such as fresh water supply which may cause variations in temperature, salinity, pH, turbidity, and changes in the chemical composition of water (Arnal, 1955; Alve, 1991; Almogi-Labin *et al.*, 1992). Pollution has also been cited as one of the probable causes of such aberrant tests (Alve, 1991; Sharifi *et al.*, 1991; Yanko *et al.*, 1994).

Almogi-Labin *et al.* (1992) and Stouff *et al.* (1991a) suggested that salinity fluctuation and/or high salinity may affect the development of foraminiferal test causing morphological deformation. Features of double apertures, loss of segments, deformed outline of tests, presence of scars, pronounced concave/convex crescent shapes, bending or curvature of the apertural chamber such that it is in discord with the alignment of the test are found more frequently in foraminifera within coastal sites and hard grounds or coarse substrate sites. This allows for the suggestion that these types of deformities might be caused by mechanical action e.g. strong currents or waves.

Every species has its threshold of sensitivity to heavy metal concentration, thus exceeding this threshold causes harmful effect on the test. The concentration of some heavy metals in the foraminiferal test depends on the amount of the heavy metal element that can be potentially leached in the sediment. Hence, the concentration of the element in the tests is, generally, directly proportional to the concentration in the surrounding environment. Where the concentration is significantly high, morphological deformations invariably result.

Sharifi (1991) reported that Cd, Cu and Ni in *A. beccarii* causes deformation when concentration within the test reaches a certain limit. He reported that Cu, Zn and Co concentrations in the test of *A. beccarii* do not correlate with the concentration of the same element in the environment. Some elements such as Cu and Ni are considered as significant agents in developing morphological deformities, while others such as Co, Cr and Zn do not seem to be crucial in developing deformations in foraminiferal tests. In the study area different species occur in polluted sites some of them exhibit morphological deformations and some do not. This may be explained by different species having different tolerance to the same elements. *Asterigerinata mamilla*, for example, is widespread in the study area and it occurs in both polluted and unpolluted sites, see Appendix 2. Within both sites, it does not exhibit any kind of morphological deformation and its abundance maybe, therefore not affected by changes in the concentration of heavy metals within the sediment. This species is tolerant to heavy metal pollution. It was observed in this study, that the cosmopolitan species e.g. *Asterigerinata mamilla*, *Vertebralina striata* and *Discorbinella bertheloti* do not show sensitivity to heavy metal pollution, while species which are restricted to certain regions such as *Ammonia tepida*, *Amphistegina lobifera* and *Peneroplis pertusus* tend to show some response to heavy metal pollution reflected in the form of morphological deformation, while being dominant to other species at the site. They are tolerant to or opportunistic in environments exposed to various effluents such as organic mater or heavy metals and various other chemical effluents. It is however, premature to draw any conclusions based on this observation. Perhaps future investigations may be necessary to shed more light on this.

It is known that algae and plankton, which are the principle food sources for the foraminifera, are capable of accumulating heavy metals within their body. According to Nielsen and Anderson (1970); Skarr *et al.*, (1974) and Davies (1978), the concentration of such heavy metals within their body mass have been observed to equal that of the environment in which they thrive. Therefore, symbiotic algae can be deleterious to symbiotic foraminifera such *A. lobifera* which is considered to be very sensitive to heavy metal concentration. This species has the highest percentage of deformed tests observed in this study for both seasons, and its abundance decreases with the increase in heavy metal concentration. The species further shows a direct relationship with Cd and Pb, coinciding with a high percentage of $CaCO_3$. There is also an increase in the species occurrence as well as types of associated deformation. Consequently, this species has been considered a good indicator of heavy metal pollution in this study.

According to Yanko *et al.* (1998), in Haifa Bay *Adelosina cliarensis* is a very sensitive species to salinity changes from 16 - 17‰, and to high concentration of heavy metals e.g. Cd up = 40ppm. In the present study this species comprises 0.6% of the total deformed foraminifera and it is found entirely as deformed specimens in two sites (stations 30 and 45) where the Cd concentration is 1.3ppm. It makes up about 0.8% of the assemblage at station 30 and 0.7‰ at station 45. The absolute abundance of deformed tests of this species at stations 30 and 45 is approximately, one (1) test per 5g of sediment. Hence, in this study, and contrary to the observations of Yanko *et al.* (1998), this species is not considered to be sensitive to heavy metal pollution. Furthermore, this species occurs at stations 50 and 40 (which are considered to have a high concentration of heavy metals such as Cd and Pb) but specimens of the species do not show any deformation. Yanko *et al.* (1998) further reported that this species is sensitive to small changes in salinity. Although probably too small a difference to be significant in the present study, no morphological deformations were observed with salinity changes fo 39‰ at station 50 and 38‰ at stations 54 and 86.

Cibicides advenus was considered by Yanko (1998) as an indicator of Chromium (Cr) contamination. However, in this study, for the entire population from the spring samples, only one (1) deformed test of this species was observed at station 48. Similarly, for the entire population from the winter samples, only one (1) deformed test was also observed at station 23. These two stations are characterised by a low concentration of Chromium (Cr).

A similar conclusion is reached for the species *Pseudotriloculina subgranulata*, which Yanko (1998) considered as a Titanium (Ti) indicator. This species occurs in very small numbers in the study area and no morphological deformations were found in either dead or living specimens of the species. Furthermore, its distribution was not observed to be affected by changes in heavy metals concentrations.

The species *Triloculina marioni* was found to exhibit morphological deformation even in sites with low concentration of heavy metals. This species appears to show no preference to any particular heavy metal contrary to the observations of Yanko, (1998) who cited the species as an indicator of Cd (40 ppm in the sediments).

Deformation and non-deformation of foraminiferal tests are features observed in both polluted and unpolluted sites. With this being the case, there are bound to be several explanations to account for some forms being selectively deformed while others are not within a polluted environment on one hand, and within an unpolluted environment on the other. In order to examine these cases, the following general observations have been made:

1. That the Mg/Ca ratio of foraminiferal tests, whether deformed or non-deformed, is higher in polluted than in unpolluted environments. Thus deformed and non-deformed living foraminiferal tests (e.g. *Amphistegina lobifera*) from polluted sites show a higher Mg/Ca ratio compared to similarly deformed and non-deformed tests of the same species from unpolluted sites (see figure 4.27).

2. In polluted sites where the Mg/Ca ratio is high, the occurrence of deformed tests tend to suggest that heavy metal pollution could be responsible for deformation of tests during shell construction or development. This would probably be effected as a result of the high magnesium content derived from heavy metal pollution which could easily replace much of the normal test building calcium material. On the other hand, the occurrence of non-deformed tests in similar sites, however, tends to suggest that individual organisms may actually posses different threshold limits for uptake of elements from the polluted surroundings in order for such pollutants to be effective in causing the individuals to be deformed. This can also be applied to *Asterigerinata mamilla*, which did not exhibit any deformation in all sites and the difference in Mg/Ca ratio is very small in the living tests from all sites, and it is considered as tolerant to pollution. According to Bresler and Yanko (1996) the occurrence of heavy metals has been known to affect the cytoskeketon which determines the shape of the foraminiferal test.

3. In unpolluted sites where the Mg/Ca ratio is low in the foraminiferal test, the dominant deformation types that have been observed include: abnormal aperture, irregular test outline and double aperture deformations. These features tend to suggest that the deformed tests are due to mechanical abrasion rather than heavy metal pollution. For the non-deformed tests at these sites, their Mg/Ca ratio were found to be within the normal range for single individual tests and they could simply have escaped any mechanical abrasions.

CONCLUSIONS

Based on the present study the following conclusion may be drawn.

1. Haifa Bay is a region polluted by heavy metals whereas Atlit Bay is considered to be an unpolluted area. Atlit Bay was used as a control area against which the Haifa Bay situation is compared. The study area characterised by typical shallow marine foraminiferal species, among which the Rotaliina and the Miliolina represent the highest percentage of the assemblage.

2. Although seasonal changes in the foraminiferal populations are evident, the measured oceanographic parameters have no clear relation to abundance, species diversity, number of species, chemistry, and the morphology of the test, as they are constant through the sample locations. However, certain species show depth and substrate preference.

3. Types of heavy metals found in the region include Cadmium, Chromium, Cobalt, Lead, Arsenic, Vanadium and Lithium. These are assumed to have an adverse on living organisms.

4. The effects of heavy metals are expressed on benthic foraminifera distributions. Generally, their abundance, species diversity and richness tend to be lower in relatively high contaminated sites in comparison with uncontaminated areas. However, certain species appear to be abundant in contaminated sites as they appear to benefit from certain types of heavy metal through increasing growth rate or decreased competition that often result the dominance of the species involved.

5. High percentages of deformed tests are typical in polluted environments. Furthermore, species which dominate the assemblage in polluted sites also tend to have the most deformed tests, for example, deformed *Amphistegina lobifera* is noted at polluted sites.

6. Two basic types of test deformation can be placed under two categories: chemical and mechanical deformation. Both types of deformation reflect the environmental stress.

7. The changes in the chemical composition e.g., Cå/ Mg ratio of the living foraminiferal test, affects the morphology of the test which can be considered as a vital indicator of heavy metal pollution.

8. The sensitivity of certain species to heavy metal pollution (change in the abundance, percentage of morphological deformities) can be used as an indicator of heavy metal pollution in the study area. The present study supports the possibility of studying benthic foraminifera as a technique for *in situ* continuous monitoring for near shore marine pollution.

FUTURE WORK

The research done in this study has given rise to many possible research projects for future investigation. In light of this, the list below describes some of the possible expansions of the research done in this thesis.

1. The trace metal elements are incorporated directly from sea water during shell precipitation. Because of this, the shell composition reflects both the sea water composition and the physical and biological conditions present at the time of precipitation. The next level of study is to relate the effect seen on foraminiferal species to actual levels and types of pollutants.
2. The substitution of Ca in the foraminiferal test by trace metals might be good evidence of heavy metals pollution. Research should be carried out to establish why test composition varies from one individual to another in the same species and to determine what factors influence these variations.
3. It is of great importance to establishing the precise relationship among shell chemistry, sea water composition, and physical, chemical and biological factors.
4. Performing a culture experiment to investigate the effect of inducing certain levels of specific heavy metal elements and their direct effects on specific types of morphological deformation. As a result, an index can be made including different morphological deformities resulting from specific heavy metal concentrations. This index can be used as a proxy for the interpretation and assessment of contamination.
5. Establishing a culture experiment to determine the risk factor (toxicity) of the heavy metal elements in the marine ecosystem.
6. Establish a morphometrical study of deformed and non-deformed tests and performing statistical analysis of detected differences. By using quantitative morphometric analysis to determine the change in the shape of the foraminiferal test, it is possible to determine inter-species natural variations and distinguish them from the morphotypes resulting from environmental stress.

7. Establishing the critical stage at which the pollutant induced morphological deformation occurs during the foraminiferal life cycle.

8. Investigating whether or not heavy metal pollution affects nucleic acid in the foraminiferal cell and if this pollution results in morphological deformation. All the previously mentioned work has to be performed in a culture experiment where the factors affecting the organism can be controlled.

9. It is necessary to have complete time series of samples, and collect the samples during different times in the year, in order to establish the natural yearly fluctuations in oceanographic parameters, pollution levels, and species composition and abundance.

10. Explore the possibility that historical samples from the study area are preserved somewhere which could be used as a baseline to assess the "before and after" scenario of a contaminated site.

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Plate 5.1

1. *Clavulina* cf. *C. multicamerata* Chapman; 1014.2 μm, x 65, station 69.

2. *Bigenerina nodosaria* D'Orbigny; 1333.3 μm, x 65, station 60.

3. *Textularia agglutinans* D'Orbigny;1039.65 μm, x 78 station 62.

4. *Textularia bocki* Höglund; 533.3 μm, x 120, station 62.

5. *Textularia bocki* Höglund; 533.3 μm, x 145, station 62.

6. *Textularia conica* D'Orbigny; 585.5 μm, x 160, station 47.

7. *Siphenotextularia concava* (Karrer); 807.5 μm, x 115, station 69.

8. *Textularia truncata* Höglund; 416.9 μm, x 210, station 69.

9. *Parrina bradyi* (Millett); 494 μm, x 120, station 47.

10. *Articulina pacifica* Cushman;720 μm, x 120, station 38.

11. *Articulina carinata* (Wiesner), 313.3 μm, x 200, station 38.

Plate 5.1

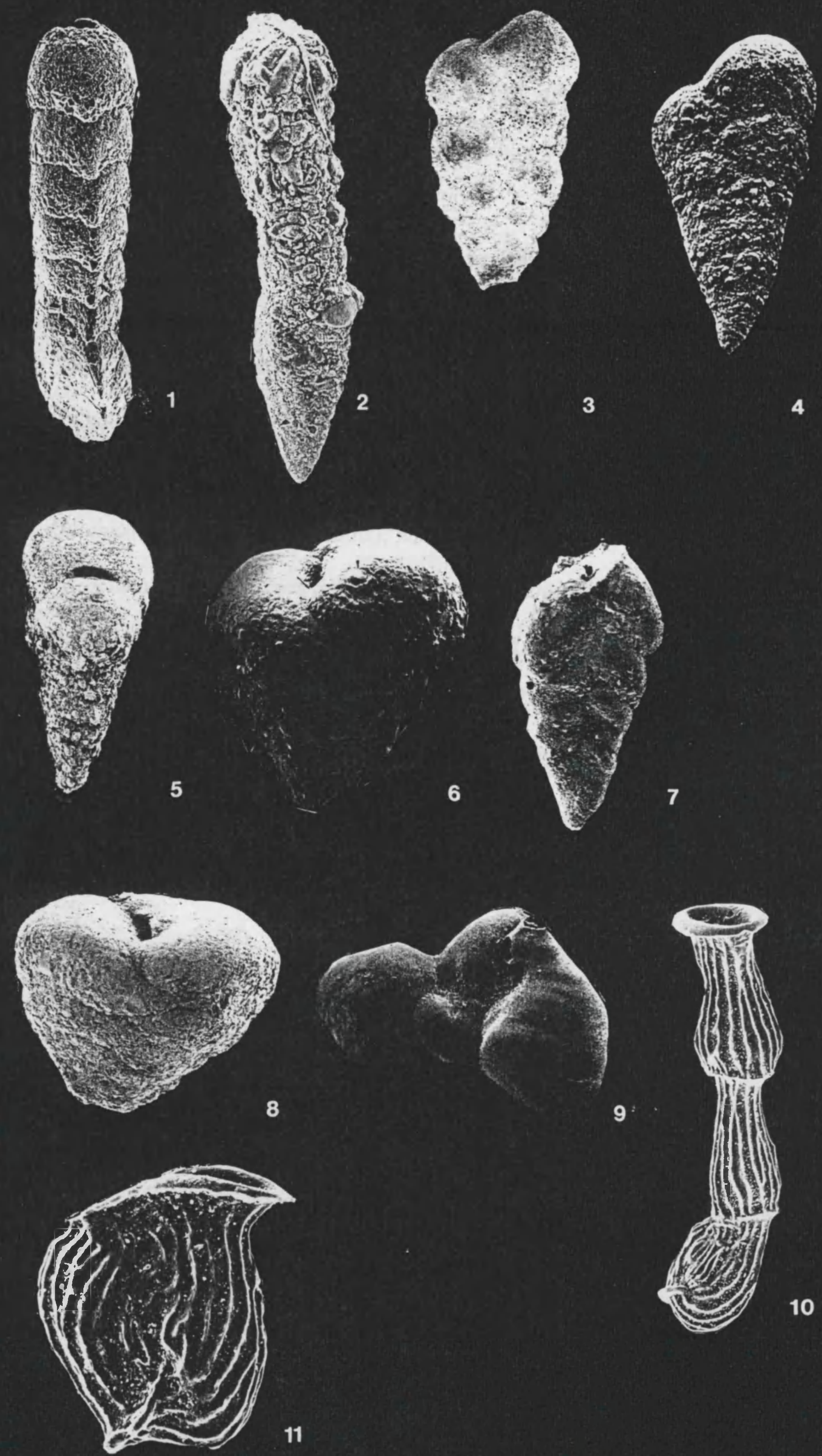


Plate 5.2

1. *Cycloforina tenuicollis* (Wiesner); 750 µm, x130, station 20.
2. *Cycloforina quinquecarinata* (Collins); 425 µm, x 140, station 22.
3. *Cycloforina* sp.; 609.4 µm, x 55, station 20.
4. *Quinqueloculina jugosa* Cushman; 800 µm, x 100, station 30.
5. *Quinqueloculina jugosa* Cushman; apertural view; 544.4 µm, x 165, station 30.
6. *Quinqueloculina bosciana* D'Orbigny; 272 µm, x 175, station 37.
7. *Quinqueloculina disparilis* D'Orbigny; 950 µm x 100, station 33.
8. *Quinqueloculina disparilis* D'Orbigny; 1145 µm, x 74, station 33.
9. *Quinqueloculina seminula* (Linné); 562.5 µm, x 150, station 40.
10. *Quinqueloculina stelligera* Schlumberger; 403.2 µm, x 210, station 30.
11. *Quinqueloculina laevigata* D'Orbigny; 454.5 µm, x 90, station 38.
12. *Quinqueloculina parvula* Schlumberger; 500 x 110, station 49.
13. *Quinqueloculina* cf. *Q. multimarginata* Said; 450 µm, x 200, station 85.
14. *Quinqueloculina pseudobuchiana* Luczkowska; 433.3 µm, x 220, station 85.
15. *Quinqueloculina* cf. *Q. limbata* D'Orbigny; 566.7 µm, x 120, station 2.

Plate 5.2

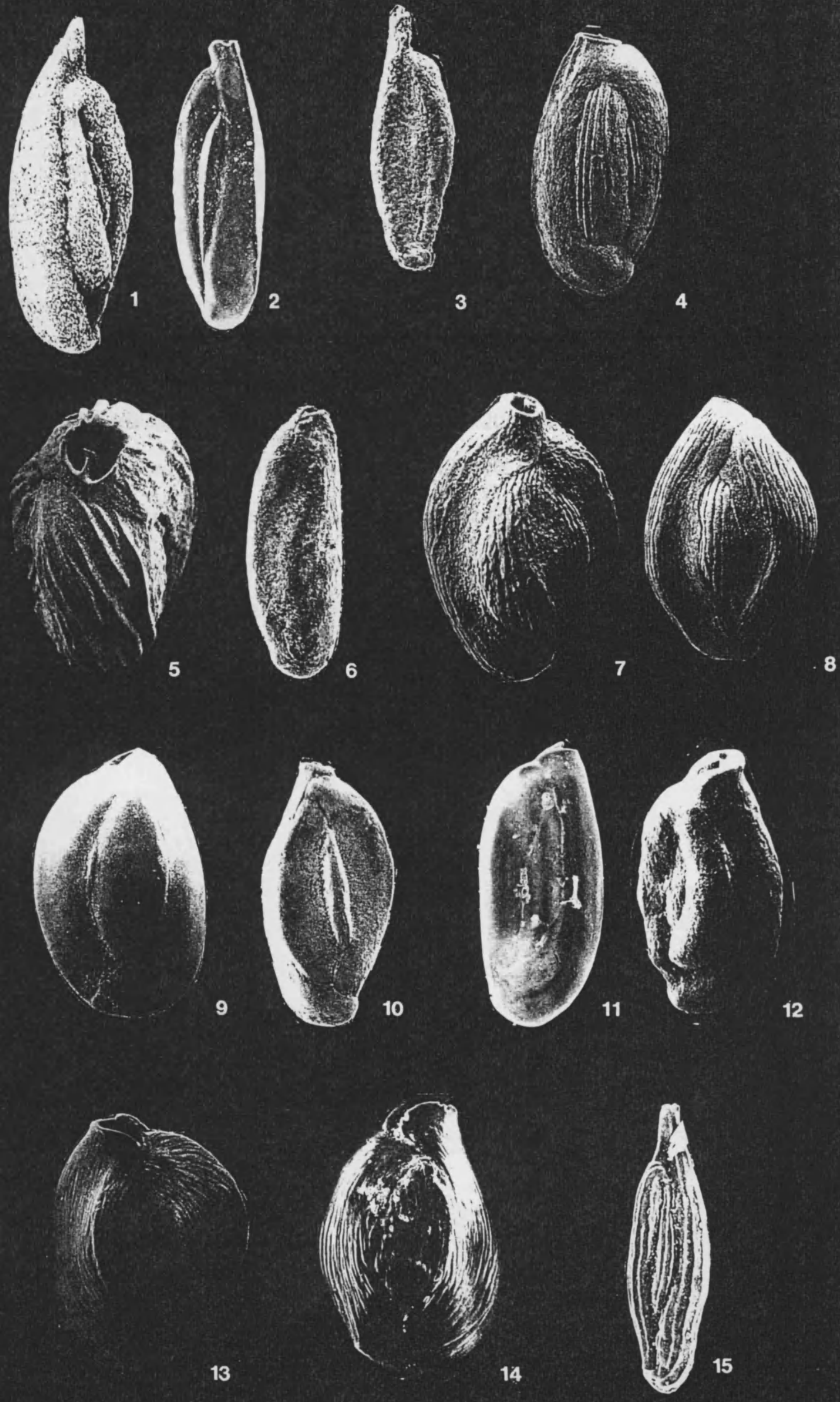


Plate 5.3

1 *Triloculina marioni* Schlumberger; 500 µm x 120, station 61.

2 *Triloculina marioni* Schlumberger; 500 µm x 120, station 61.

3 *Triloculina schreiberiana* D'Orbigny; 671 µm x 120, station 61.

4 *Triloculina plicata* Terquem; 728.5 µm, x 135, station 61.

5 *Triloculina asymmetrica* Said; 393 µm, x 130, station 61.

6 *Triloculina serrulata* McCulloch; 532 µm, x 120, station 61.

7 *Triloculina serrulata* McCulloch; 532 µm x 120, station 61.

8 *Triloculina serrulata* McCulloch; 340 µm x 180, station 61.

9 *Triloculina tricarinata* D'Orbigny; 511 µm x 175, station 61.

10 *Triloculina tricarinata* D'Orbigny; 559 µm x 169, station 61.

11 *Triloculina affinis* D'Orbigny; 614.1 µm x 145, station 61.

12 *Triloculina ornata* Le Calvez and Le Calvez, 565 µm, x 260, station 61.

Plate 5.3

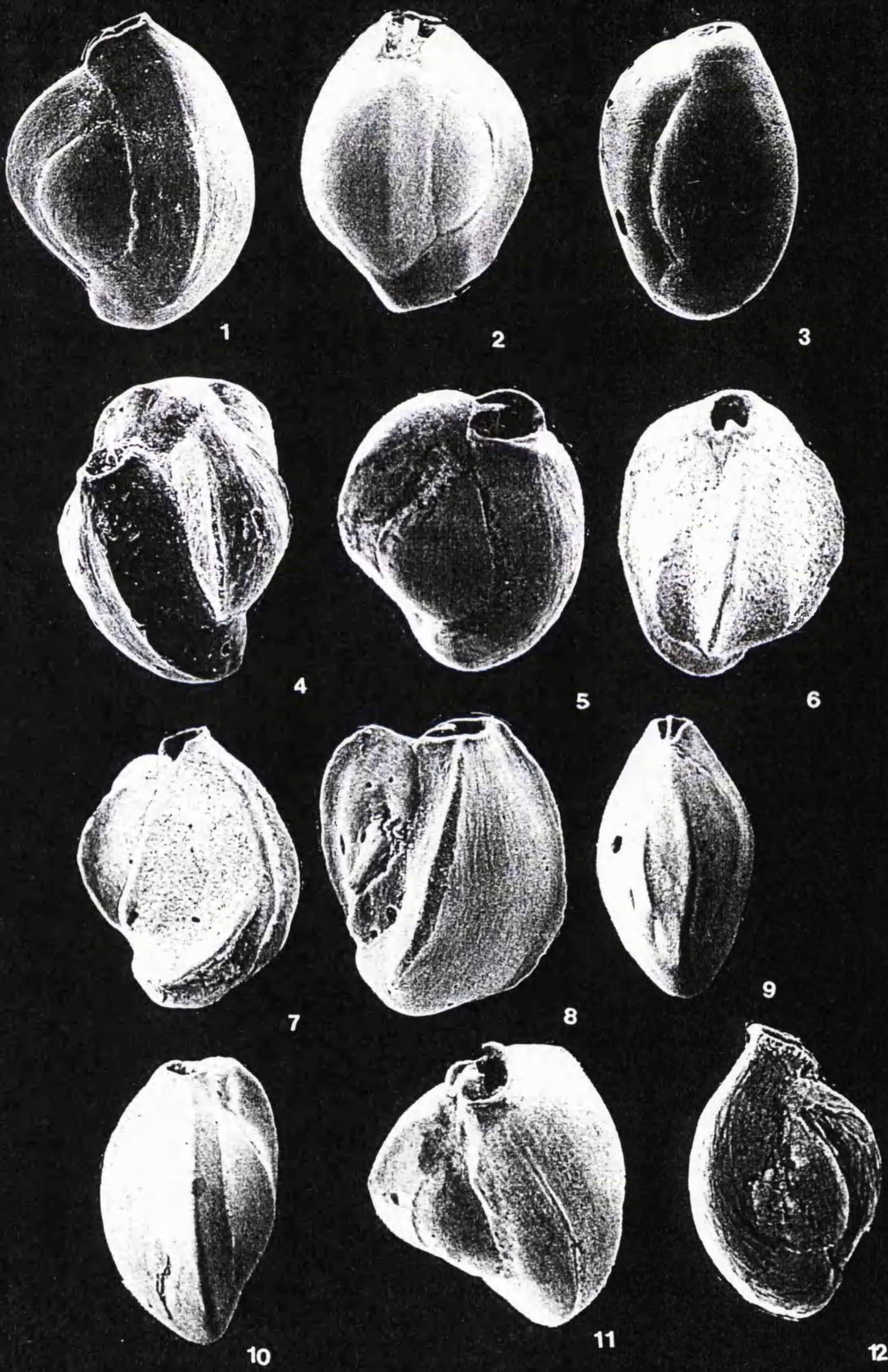


Plate 5.4

1. *Biloculinella labiata* (Schlumberger); 383.3 µm, x 210, station 61.
2. *Biloculinella globula* (Bornemann); 340.1 µm, x 240, station 61.
3. *Massilina secans* (D'Orbigny); 250 µm, x 320, station 35.
4. *Massilina secans* (D'Orbigny); 906 µm, x 120, station 35.
5. *Pseudomassilina reticulata* (Heron-Allen and Earland); 799 µm, x 78, station 35.
6. *Lachlanella undulata* (D'Orbigny); 647 µm, x 130, station 37.
7. *Lachlanella undulata* (D'Orbigny); apertural view, 750 µm, x 100, station 37.
8. *Lachlanella variolata* (D'Orbigny); 1088.9 µm x 74, station 37.
9. *Lachlanella variolata* (D'Orbigny); apertural view;783.3 µm, x 110, station 37.
10. *Pseudotriloculina laevigata* (D'Orbigny); 1392 µm, x 70station 27.
11. *Pseudotriloculina oblonga* (Montagu);1256 µm, x 66, station 28.
12. *Pseudotriloculina rotunda* (D'Orbigny);100 µm, x 175, station 22.
13. *Pseudotriloculina* sp.; 742.8 µm, x 120, station 27.
14. *Pseudotriloculina subgranulata* (Cushman); 470 µm, x 180, station 22.
15. *Pseudopyrgo milletti* (Cushman); 500 µm, x 100, station 28

Plate 5.4

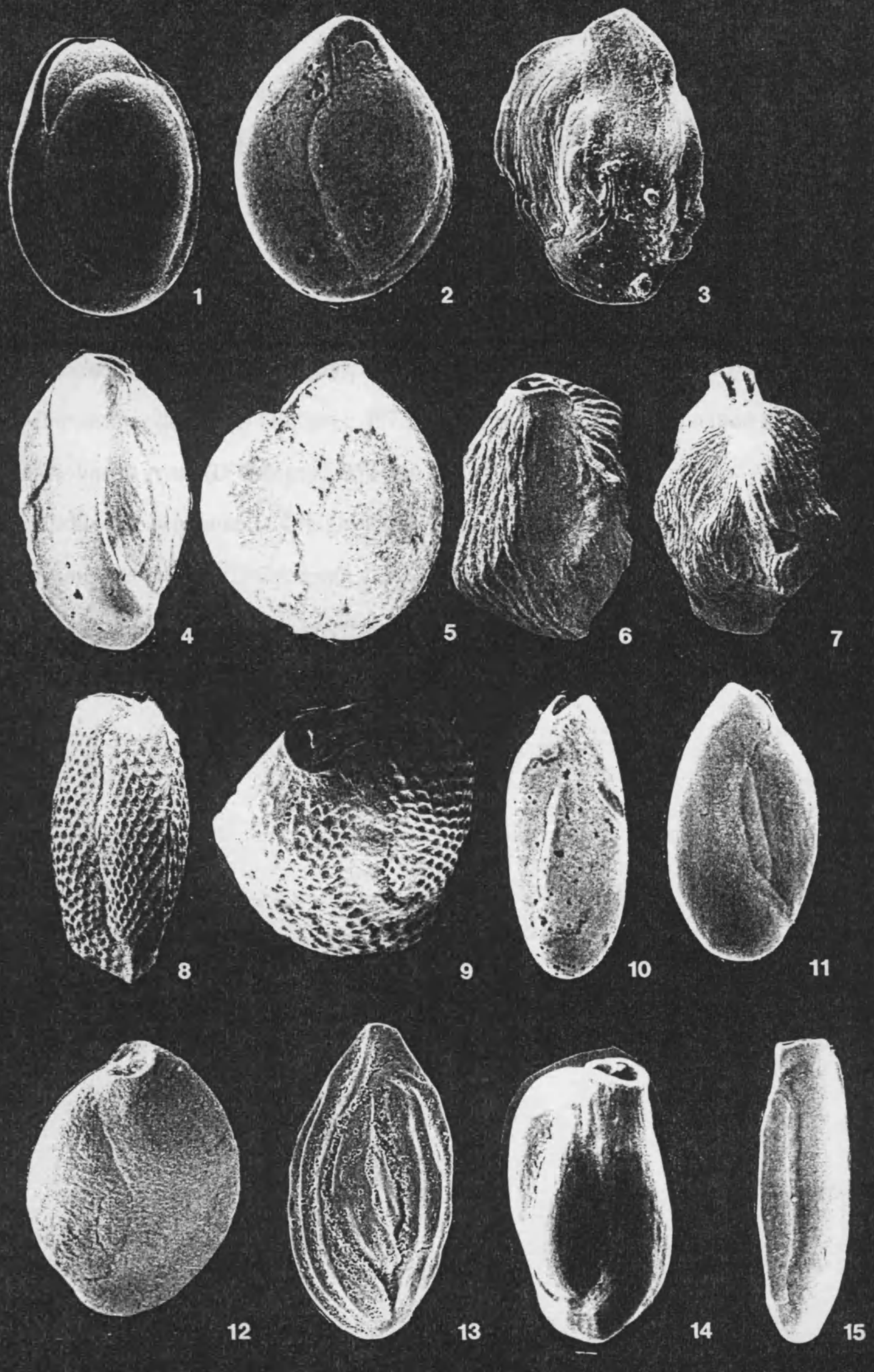


Plate 5.5

1. *Pyrgo anomala* (Schlumberger); 900 µm, x 80, station 43.
2. *Pyrgo elongata* (D'Orbigny); 500 µm, x 130, station 38.
3. *Pyrgo striolata* (Brady); 335.7 µm, x 270, station 38.
4. *Pyrgo striolata* (Brady); 780 µm, x 120, station 38.
5. *Pyrgo striolata* (Brady); lateral view;733 µm, x 100, station 38.
6. *Miliolinella dilatata* (D'Orbigny); 500 µm, x 90, station 41.
7. *Miliolinella dilatata* (D'Orbigny); 357.1 µm, apertural view, x 160, station 41.
8. *Miliolinella grata* (D'Orbigny); 750 µm, x 110, station 41.
9. *Miliolinella webbiana* (D'Orbigny); 671.4 µm , x 130, station 38.
10. *Miliolinella labiosa* (D'Orbigny); 415.3 µm, x 170, station 29.
11. *Miliolinella labiosa* (D'Orbigny); 400 µm, x 160, station 29.
12. *Miliolinella subrotunda* (Montagu); 500 µm, x 185, station 41.

Plate 5.5

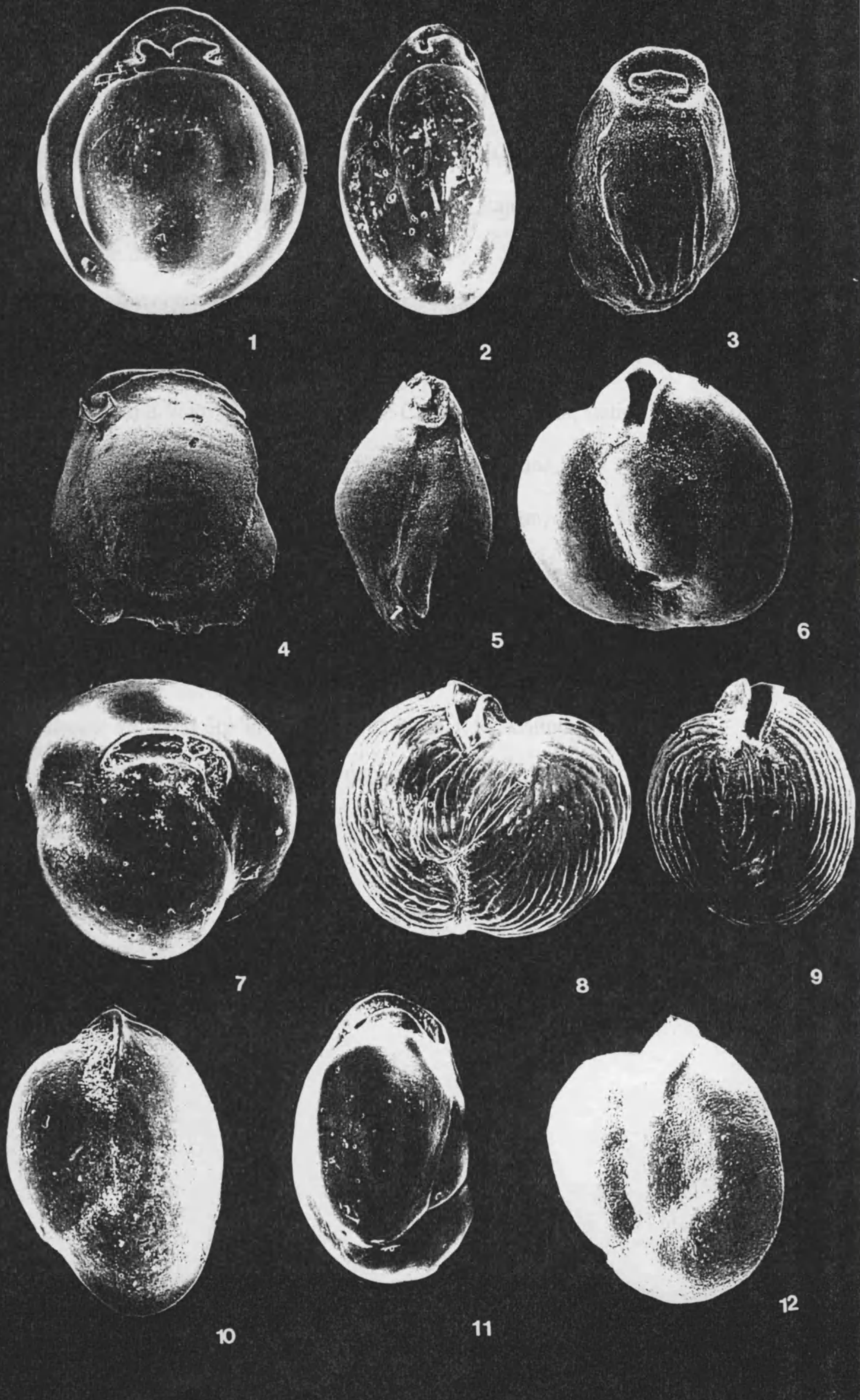


Plate 5.6

1. *Miliolinella subrotunda* (Montagu); 750 µm, x 130, station 41.
2. *Sigmoilinita costata* (Schlumberger); 783.3 µm, x 105, station 32.
3. *Sigmoilinita costata* (Schlumberger); 480 µm, x 110, station 32.
4. *Sigmoilina edwardsi* (Schlumberger) var. *acuta* Chapman and Parr; 739.4 µm, x 120, station 32.
5. *Siphonaperta agglutinans* (D'Orbigny); 766.7 µm, x 200, station 23.
6. *Siphonaperta agglutinans* (D'Orbigny); 766.7 µm, x 105, station 23.
7. *Siphonaperta dilitata* (Le Calvez, and Le Calvez); 714.2 µm, station 23.
8. *Siphonaperta aspra* (D'Orbigny); 671.4 µm, x 115, station 23.
9. *Siphonaperta osinolinata* (Le Calvez, J. and Y.); 500 µm, x 130, station 20.
10. *Hauerina diversa* Cushman; 857.1 µm, x 160, station 2.
11. *Adelosina dubia* (D'Orbigny); 693 µm, x 84, station 29.
12. *Adelosina cliarensis* (Heron-Allen and Earland); 111 µm, x 84, station 29.
13. *Adelosina duthiersi* Schlumberger; 1511.3 µm, x 58, station 28
14. *Adelosina duthiersi* Schlumberger; 960 µm, x 120, station 28.
15. *Adelosina duthiersi* Schlumberger; 1571.4 µm, x 70, station 28.

Plate 5.6

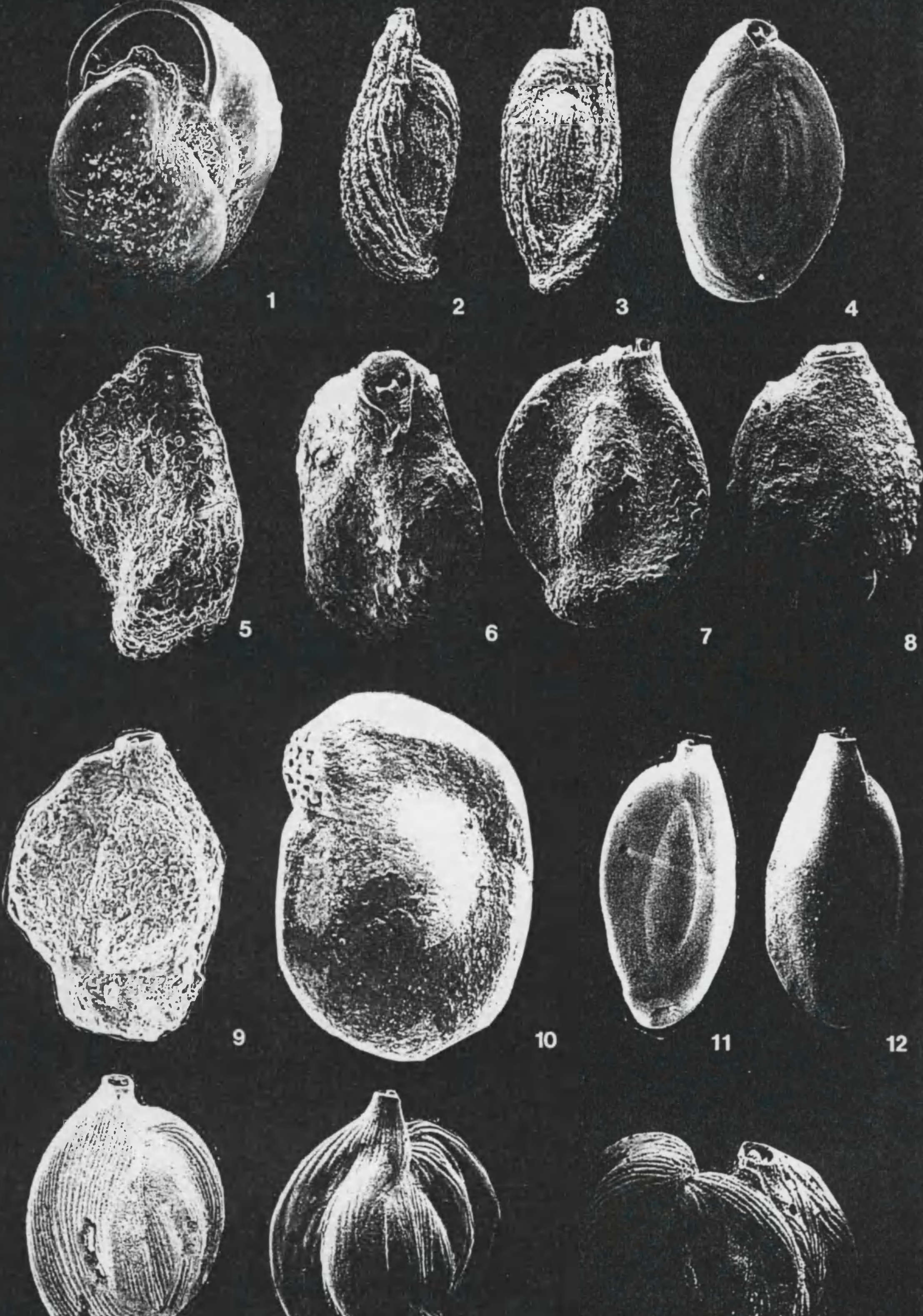


Plate 5.7

1. *Adelosina pulchella* D'Orbigny; 384 µm, x 160, station 28.
2. *Adelosina pulchella* D'Orbigny; 521 µm , x 155, station 28.
3. *Adelosina pulchella* D'Orbigny; 625 µm, x 130, station 28.
4. *Adelosina pulchella* D'Orbigny; 625 µm, x 125, station 28.
5. *Adelosina partschi* D'Orbigny; 1200 µm, x 80, station 28.
6. *Adelosina mediterranensis* (Le Calvez, and Le Calvez), 728.5 µm, x 85, station 29.
7. *Adelosina mediterranensis* (Le Calvez, Le Calvez), 1200 µm, x88, station 29.
8. *Adelosina mediterranensis* (Le Calvez, Le Calvez), 685.7 µm, x 87, station 29.
9. *Adelosina intricata* (Terquem); 587.5 µm, x 150, station 29.
10. *Adelosina intricata* (Terquem); 714 µm, x 85, station 29.

Plate 5.7

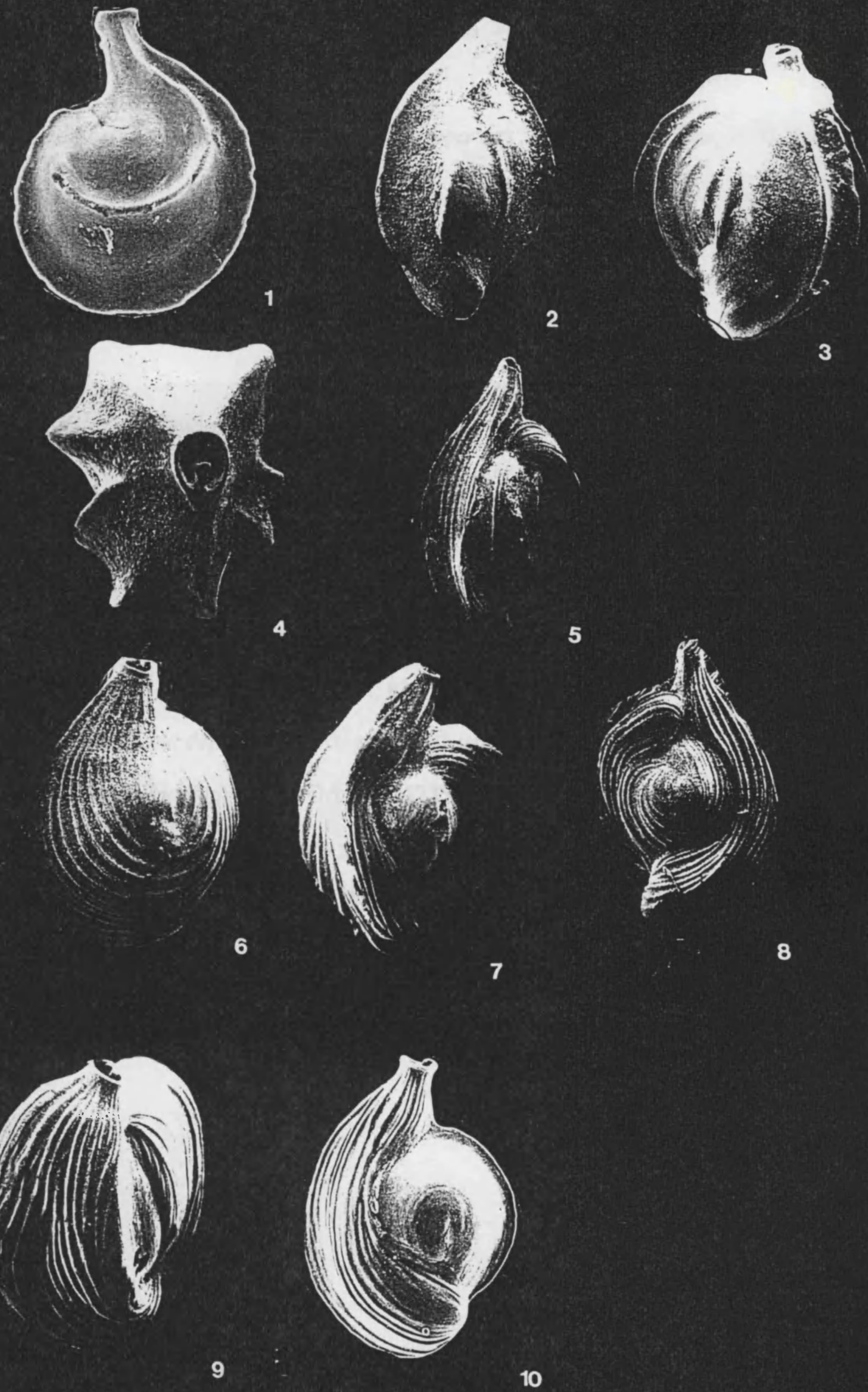


Plate 5.8

1. *Adelosina elegans* (Williamson) var. *separans* Wiesner; 1571 µm, x 60, station 27.
2. *Adelosina brongniartana* (D'Orbigny) var. *angulata* Wiesner; 1250 µm, x 45, station 24.
3. *Adelosina elegans* (Williamson) var. *angulata* Wiesner; 1371 µm, x 62, station 27
4. *Adelosina elegans* (Williamson); 771.4 µm, x 100, station 28.
5. *Adelosina elegans* (Williamson) var. *zigzag* Wieser; 940 µm, x 115, station 24.
6. *Adelosina* sp. 1.; 820 µm, x 105, station 24.
7. *Adelosina* sp. 2.; 562 µm, x 150, station 24.
8. *Spiroluculina costifera* Cushman; 733.3 µm, 100 , station 24.
9. *Spiroloculina angulosa* Terquem; 829.2 µm, x 110, station 29.
10. *Spiroloculina depressa* D'Orbigny; 1233 µm, x 70, station 29
11. *Spiroloculina depressa* D'Orbigny; 1233 µm, x 98, station 29.
12. *Spiroloculina ornata* D'Orbigny; 1068.7 µm, x 84, station 29.
13. *Spiroloculina ornata* D'Orbigny var. *tricarinata* Le Calvez, and Le Calvez, 883.µm, x 84, station 29.

Plate 5.8

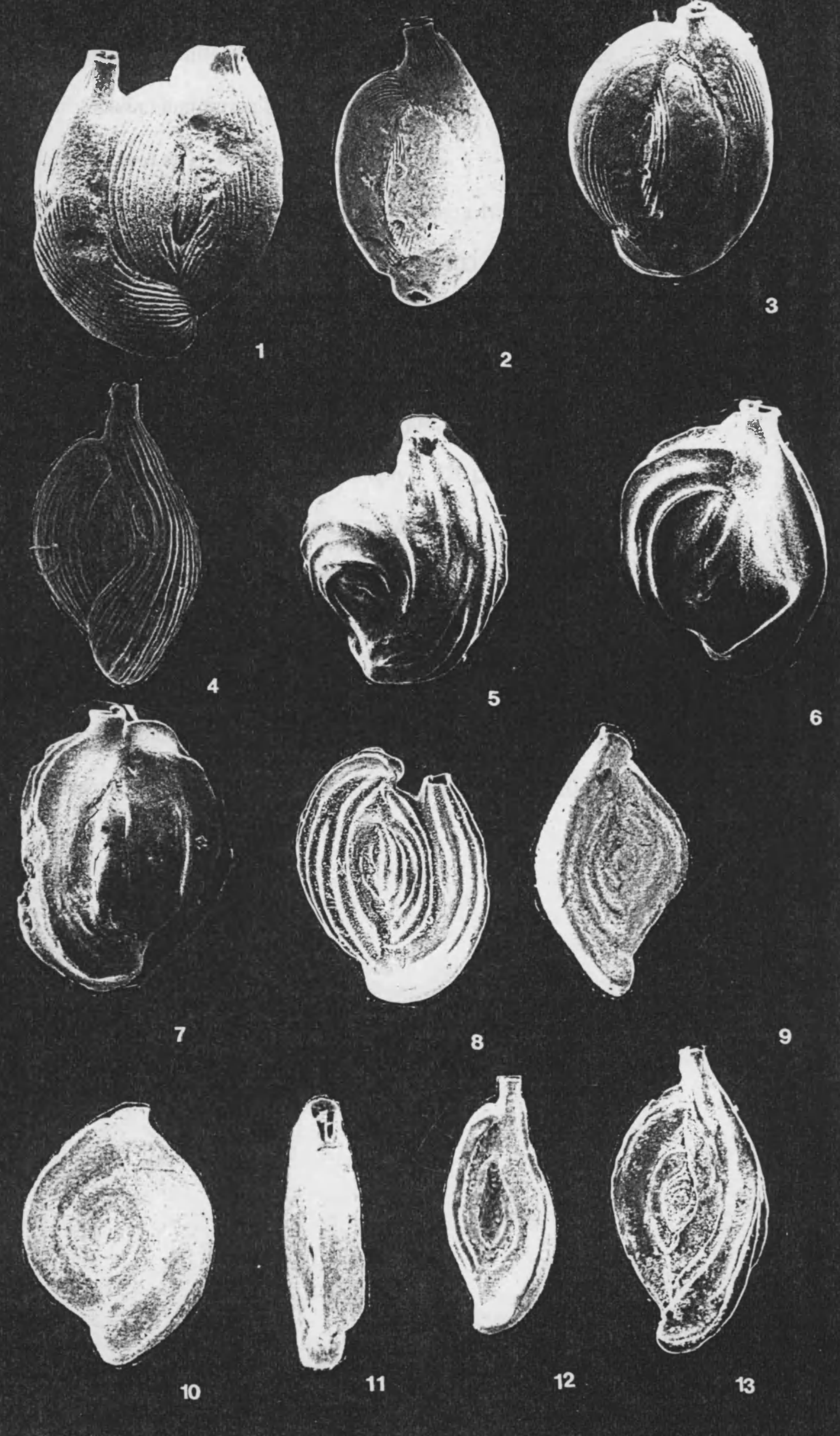


Plate 5.9

1. *Spiroloculina antillarum* D'Orbigny; 714.2 µm, x 85, station 29.
2. *Spiroloculina antillarum* D'Orbigny; 714.2 µm, x 85, station 29.
3. *Spiroloculina* sp.1; 960 µm x 145, station 29.
4. *Spiroloculina excavata* D'Orbigny; 614.2 µm, x 100 station 29.
5. *Spiroloculina hadai* Thalmann; 700.2 µm, x 100.station 29.
6. *Spiroloculina dilatata* D'Orbigny; x 110, station 29.
7. *Spiroloculina rostrata* Reuss; 662 µm, x 95, station 29.
8. *Spiroloculina angulata* Cushman; 993.4 µm, x 145, station 29.
9. *Spiroloculina* cf. *S. cymbium* (D'Orbigny); 920 µm, x 84, station 29.
10. *Spiroloculina* sp. 2; 860 µm x 145, station 21.
11. *Amphisorus hemprichii* Ehrenberg; 1733.3 µm, x 50, station 86.
12. *Sorites orbiculus* Ehrenberg;1633.3 µm, x 52, station 86.
13. *Sorites orbiculus* Ehrenberg; apertural view, 1150 µmx 64, station 86.
14. *Peneroplis planatus* (Fichtel and Moll);1250 µm, x 92, station 85.
15. *Peneroplis planatus* (Fichtel and Moll), apertural view, 920 µm, x 72, station 85.

Plate 5.9

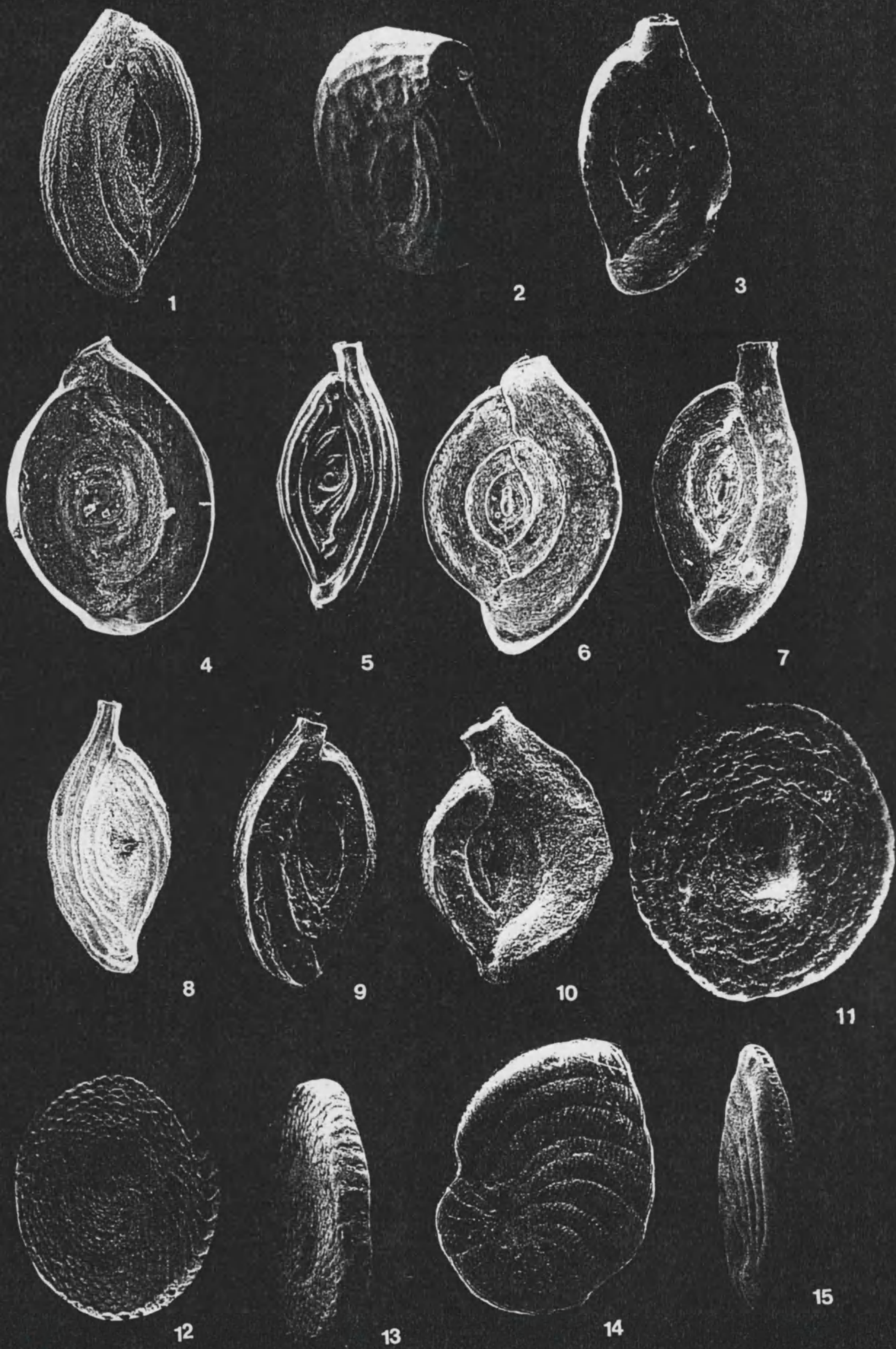


Plate 5.10

1. *Peneroplis pertusus*(Forskål); 625 µm, x 72, station 85.
2. *Coscinospira hemprichii* Ehrenberg; 671 µm, x 90, station 86.
3. *Coscinospira hemprichii* Ehrenberg; 872.7 µm, x 110, station 86.
4. *Monalysium aciculare* (Batsch); 800 µm, x 65, station 85.
5. *Edentostomina cultrata* (Brady); 533.3 µm, x 100, station 84.
6. *Wiesnerella auriculata* (Egger); 335.7 µm, x 220, station 85.
7. *Vertebralina striata* D'Orbigny; 1054 µm, x 130, station 6.
8. *Planorbulina mediterranensis* D'Orbigny; 570 µm, x 120, station15.
9. *Planorbulina mediterranensis* D'Orbigny; 392.8 µm, x 180, station 15.
10. *Planorbulinella larvata* (Parker and Jones); 575 µm, x 100, station 23.
11. *Heterostegina depressa* D'Orbigny; 1337.8 µm, x 60, station 71.
12. *Assilina ammonoides* (Gronovius); 728.5 µm, x 130, station 71.

Plate 5.10

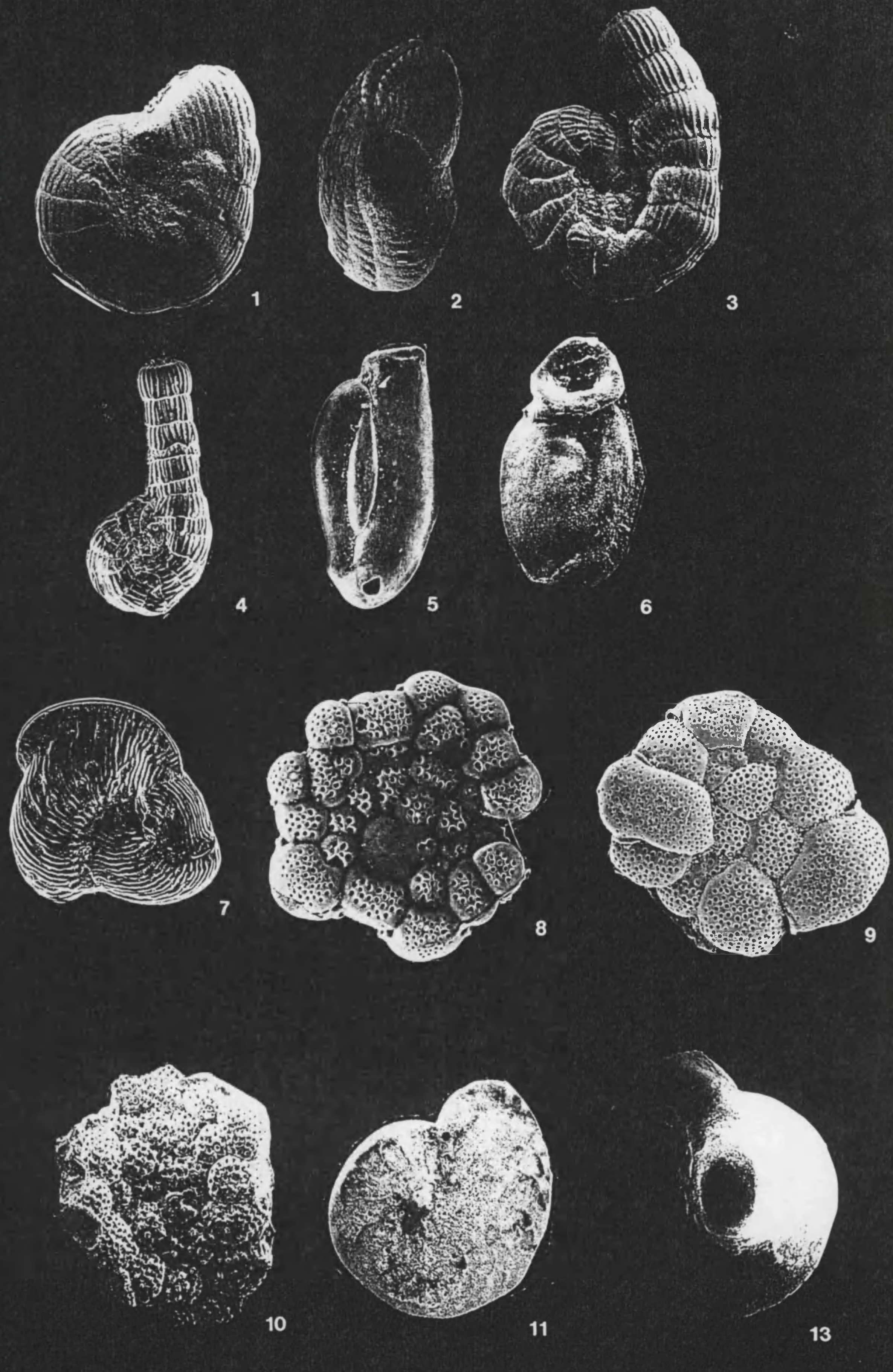


Plate 5.11

1. *Lobatula lobatula* (Walker and Jacob); 742.8 µm, x 85, station 21.
2. *Cibicides refulgens* deMontfort; 305.5 µm, x 230, station 14.
3. *Cibicides advenus* (D'Orbigny); 657 µm, x 125, station 16.
4. *Discorbinella bertheloti* (D'Orbigny); 300 µm, x 170, station 16.
5. *Cymbaloporetta bermudezi* (Sellier de Civrieux); 577 µm, x 170, station 16.
6. *Sphaerogypsina globula* (Reuss); 500 µm, x 84, station 50.
7. *Ammonia tepida* (Cushman); 617.4 µm, x 120, station 13.
8. *Ammonia parkinsoniana* (D'Orbigny); 669 µm, x 135, station 13.
9. *Ammonia parkinsoniana* (D'Orbigny); ventral view, 667 µm, x 135, station 13.
10. *Ammonia inflata* (Seguenza); 661 µm, x 135, station 11.
11. *Ammonia inflata* (Seguenza), ventral view; 600 µm, x 145, station 11.

Plate 5.11

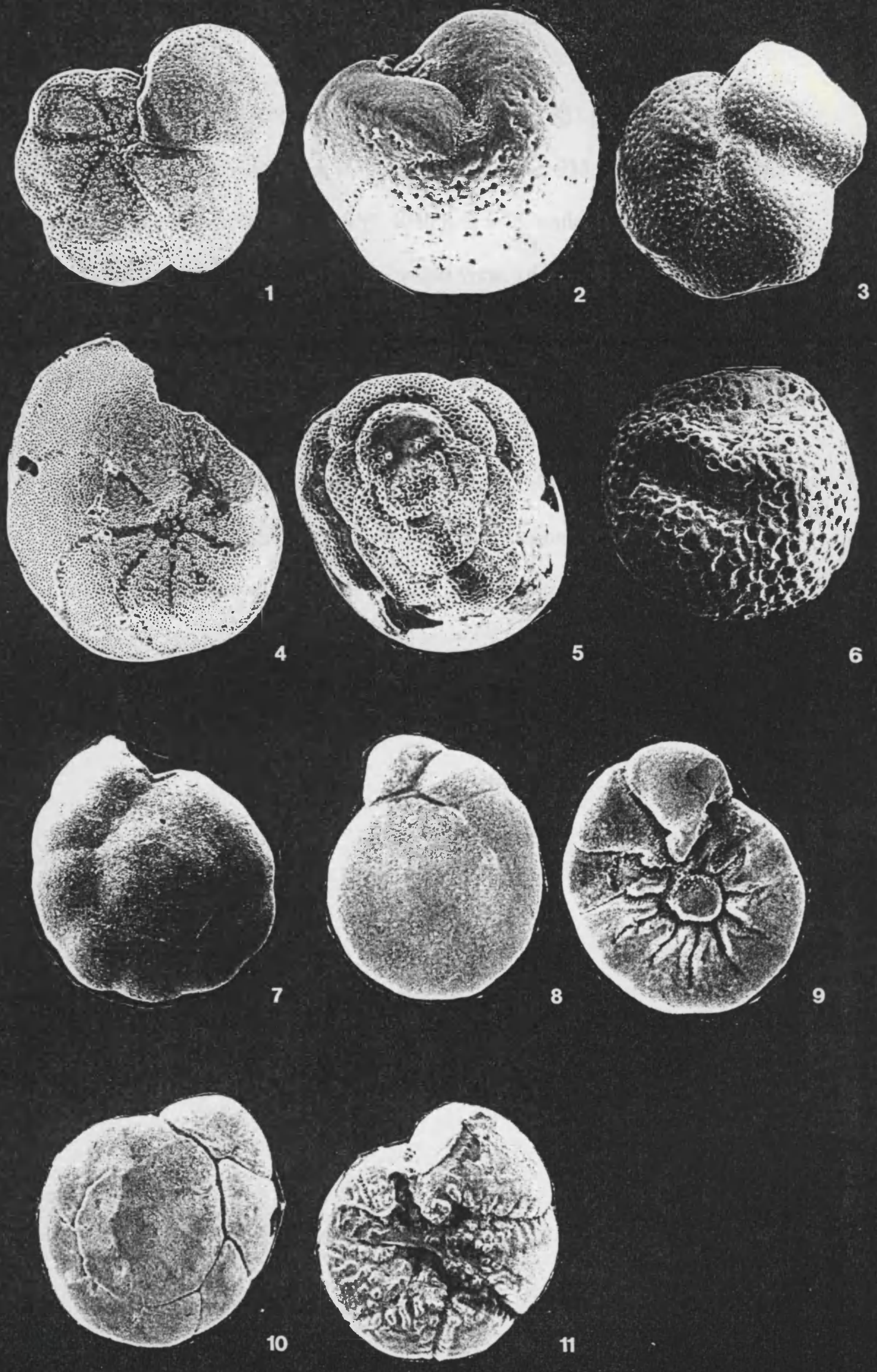


Plate 5.12

1. *Challengerella bradyi* Billman Hottinger and Oesterle; 853 µm, x 96 station 30.
2. *Challengerella bradyi* Billman, Hottinger and Oesterle; 933 µm, x 96, station 30.
3. *Asterorotalia gaimardii* (D'Orbigny); 1040 µm, x 75, station 30.
4. *Asterorotalia gaimardii* (D'Orbigny), ventral view; 742 µm, x 100, station 30.
5. *Ammonia falsobeccarii* Rouvillois; 433 µm, x 160, station 32.
6. *Ammonia falsobeccarii* Rouvillois, 524 µm, x 100, station 32.
7. *Asterigerinata mamilla* (Williamson); 398.4 µm, x 200, station 4.
8. *Asterigerinata mamilla* (Williamson), ventral view; 344.4 µm, x 22, station 4.
9. *Conorbella patelliformis* (Brady); 246 µm, x 300, station 46.
10. *Conorbella patelliformis* (Brady); 275 µm, x 300, station 46.
11. *Buccella* sp. 295 µm, x 280, station 32.
12. *Buccella* sp. ventral view; 221 µm, x 270, station 32.

Plate 5.12

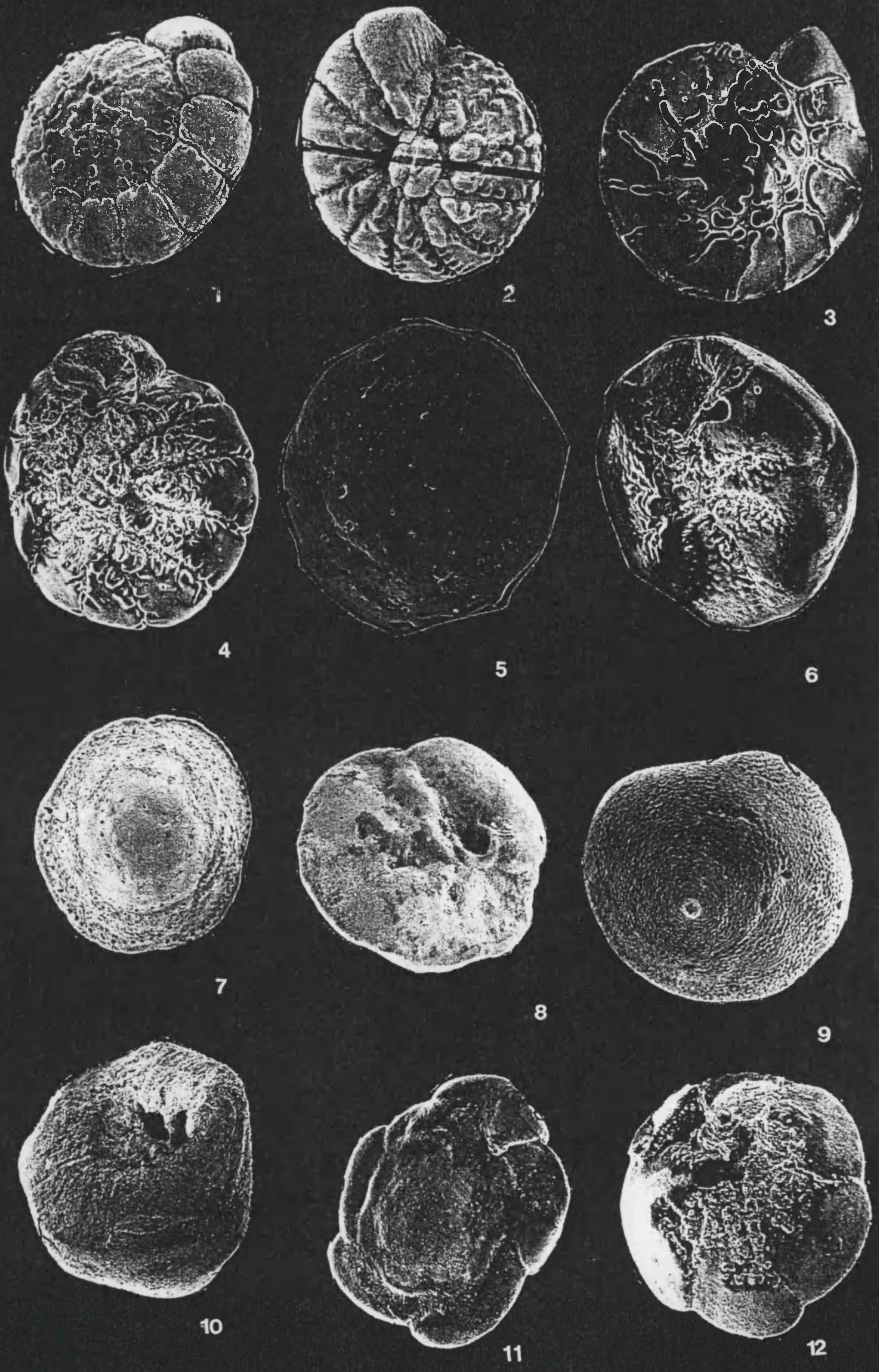


Plate 5.13

1. *Rosalina orientalis* Cushman; 719 µm, x 110, station 63.
2. *Rosalina bradyi* (Cushman); 416 µm, x 165, station 63.
3. *Rosalina macropora* (Hofker); 950 µm, x 150, station 63.
4. *Rosalina globularis* D'Orbigny; 544 µm, x 160, station 63.
5. *Rosalina pellucida* (Said); 500 µm, x 160, station 63.
6. *Disconorbis bulbosus* (Parker); 416 µm, x 160, station 13.
7. *Disconorbis bulbosus* (Parker); umbilical side, 500 µm, x 180, station 13.
8. *Neoconorbina terquemi* (Rzehak); 450 µm, x 160, station 13.
9. *Neoconorbina terquemi* (Rzehak); umbilical side, 642 µm, x 180, station 13.
10. *Gavelinopsis praegeri* (Heron-Allen and Earland); 195 µm, x 300, station 22.
11. *Eponides concameratus* (Williamson); 750 µm, x 100.station 63
12. *Eponides concameratus* (Williamson); umbilical side, 772 µm, x 120, station 63.

Plate 5.13

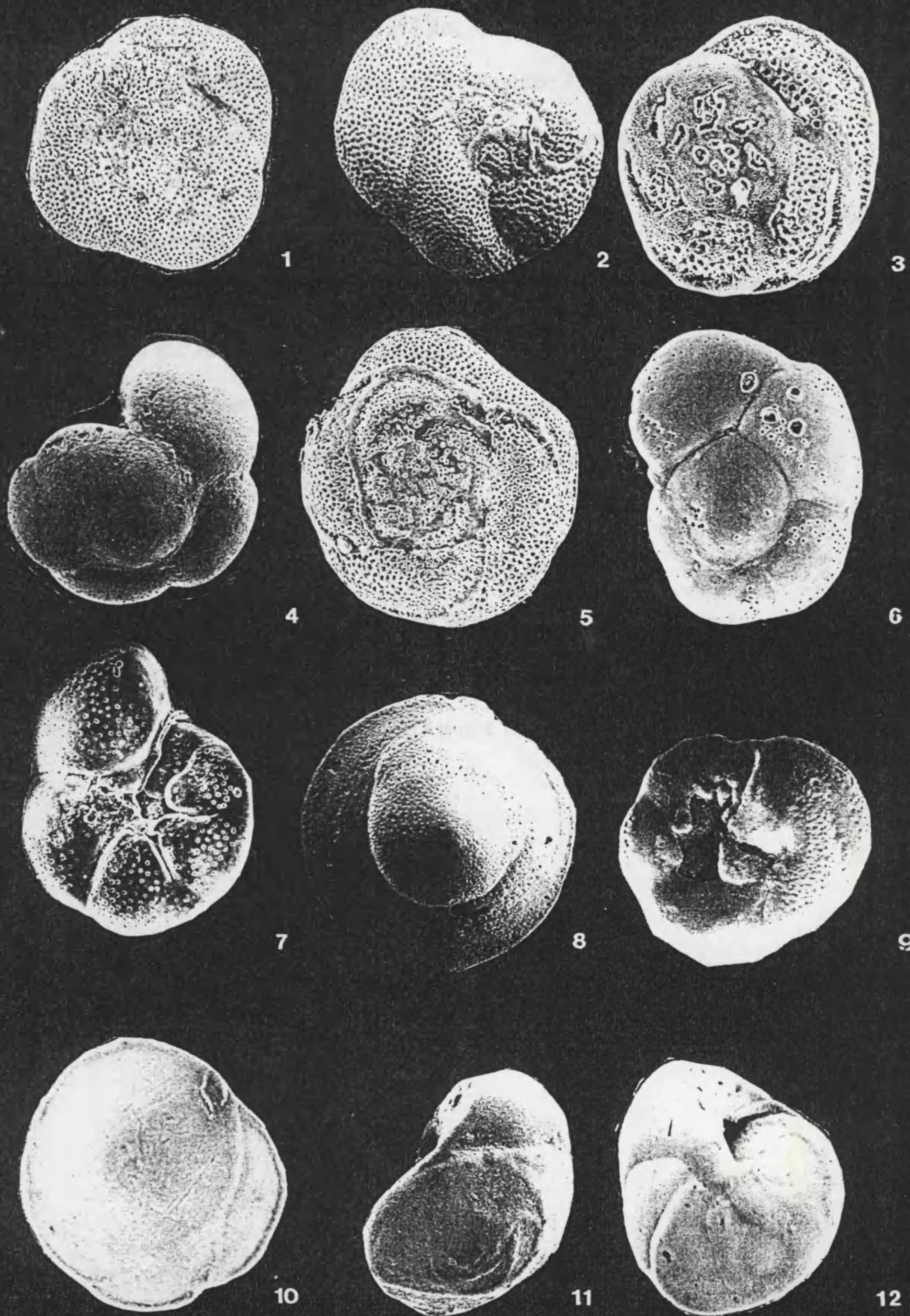


Plate 5.14

1. *Valvulineria bradyana* (Fornasini); 371 µm, x 250, station 43.
2. *Rolshausenia rolshauseni* (Cushman and Bermudez); 333 µm, x 190, station 77.
3. *Rolshausenia rolshauseni* (Cushman and Bermudez); ventral view, 333 µm, x 190, station 77.
4. *Porosononion subgranosus* (Egger); 470 µm, x 130, station 21.
5. *Haynesina depressula* (Walker and Jacob); 321 µm, x 190, station 21.
6. *Haynesina* sp.; 383.3 µm, x 195, station 21
7. *Astrononion stelliger* (D'Orbigny); 458 µm, x 220, station 19.
8. *Astrononion stelliger* (D'Orbigny); 458 µm, x 220, station 21.
9. *Melonis affinis* (Reuss); 500 µm, x 190, station 22.
10. *Pararotalia spinigera* Le Calvez; 426 µm, x 160, station 1.
11. *Pararotalia spinigera* Le Calvez, ventral view, 509 µm, x 185, station 1.
12. *Elphidium crispum* (Linnaeus); 850 µm, x 95, station 47.

12\. *Elphidium gerthi* Van Voorthuysen, 478 µm, x 185, station 52.

Plate 5.15

1. *Elphidium macellum* (Fichtel and Moll); 470 µm, x 195, station 47.
2. *Elphidium margaritaceum* (Cushman), 446 µm, x 200, station 72.
3. *Elphidium depressulum* (Cushman); 535 µm, x 155, station 47.
4. *Elphidium translucens* Natland; 500 µm, x 195, station 47.
5. *Elphidium translucens* Natland; 357 µm, x 240, station 47.
6. *Elphidium jenseni* (Cushman); 714 µm, x 230, station 42.
7. *Elphidium striatopunctatum* (Fichtel and Moll); 1020 µm, x 90, station 22.
8. *Elphidium* cf. *E. advenum* (Cushman), 445 µm, x 95, station 47.
9. *Elphidium* cf. *E. limbatum* (Cushman); 375 µm, x 95, station 52.
10. *Elphidium* sp. 1; 490µm, x 195, station 47
11. *Elphidium* sp. 2; 387 µm, x 180, station 46

Plate 5.14

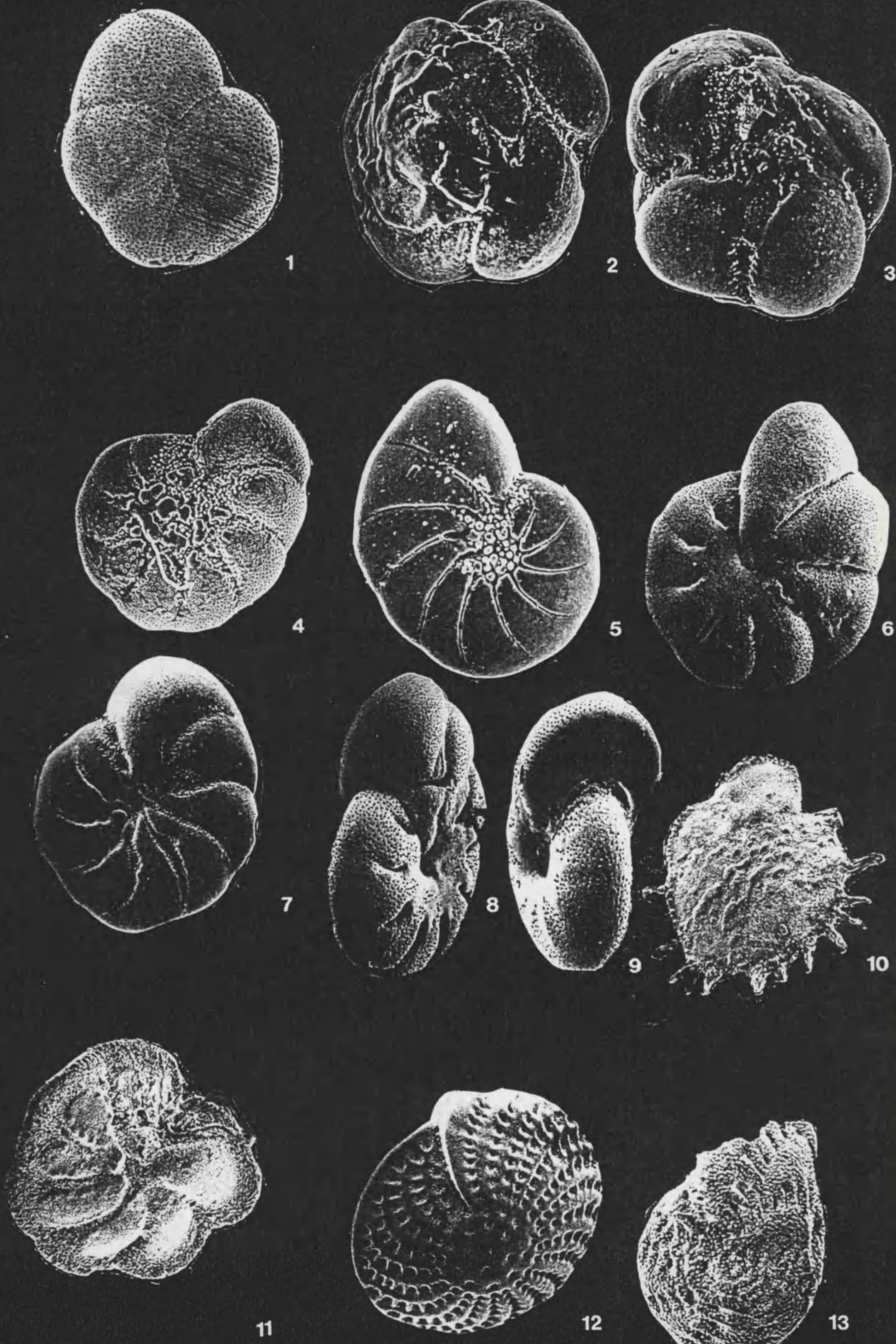


Plate 5.16

1. *Nonionella turgida* (Williamson); 357 µm, x 310, station 21.
2. *Nonion* sp.; 378 µm, x 170, station 21.
3. *Nonionella* sp.; 323 µm, x 170, station 21.
5. *Amphistegina lessonii* D'Orbigny; 656 µm, x 125, station 26.
6. *Amphistegina lobifera* Larsen; 1681 µm, x 52, station 26.
7. *Amphistegina lobifera* Larsen; 1765 µm, x 50, station 26.
8. *Reussella spinulosa* (Reuss); 7167 µm, x 125, station 61.
9. *Amphicoryna sp.*; 400 µm, x 200, station 56.
10. *Lenticulina gibba* (D'Orbigny); 320 µm, x 290, station 57.
11. *Bolivina variabilis* (Williamson); 370 µm, x 250, station 56.
12. *Brizalina striatula* (Cushman);450 µm, x 150, station 56.
13. *Brizalina striatula* (Cushman); 425 µm, x 220, station 56.
14. *Brizalina spathulata* (Williamson); 400 µm, x 240, station 56.
15. *Bulimina elongata* D'Orbigny; 323.2 µm, x 230, station 56.

Plate 5.16

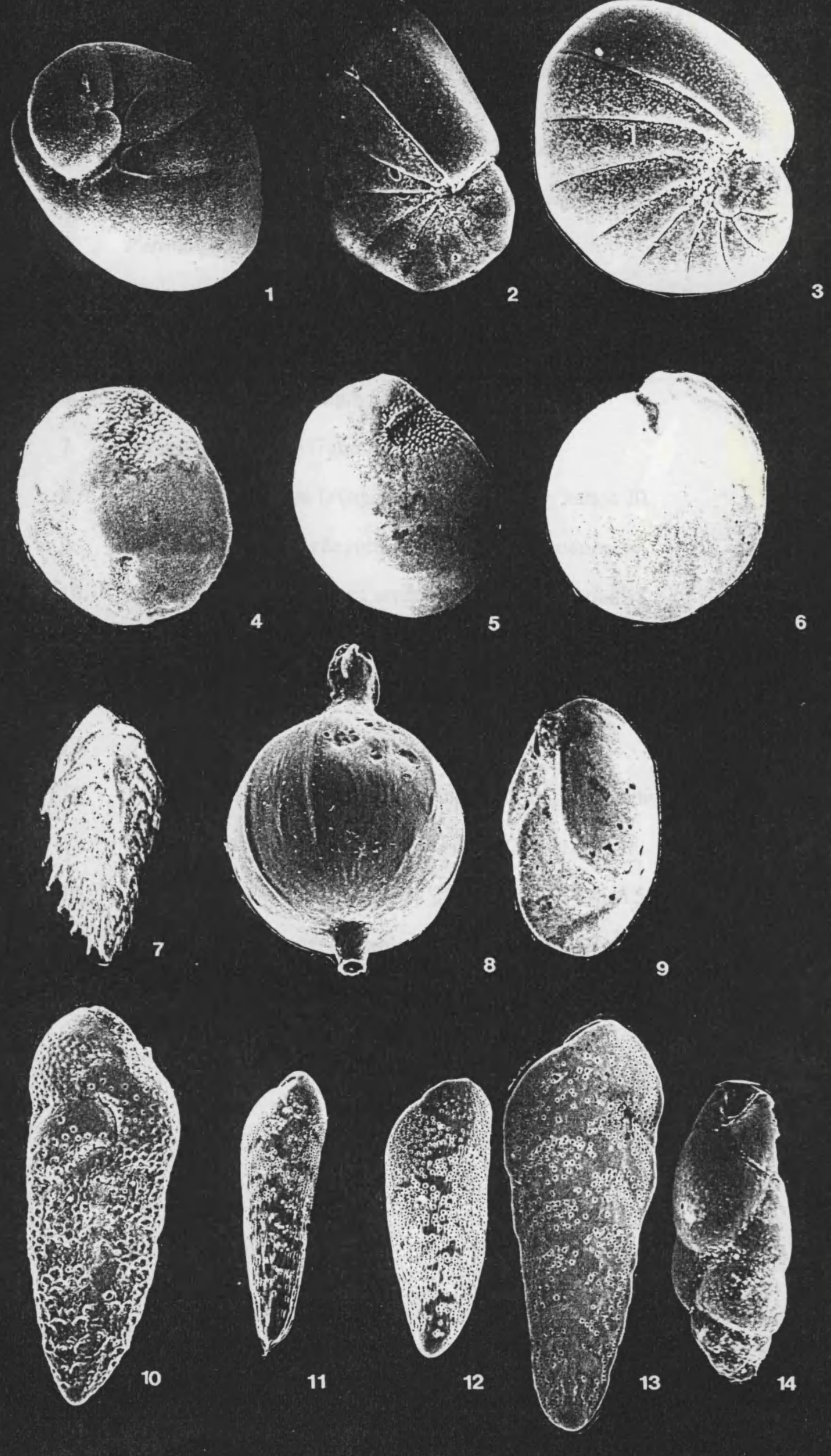
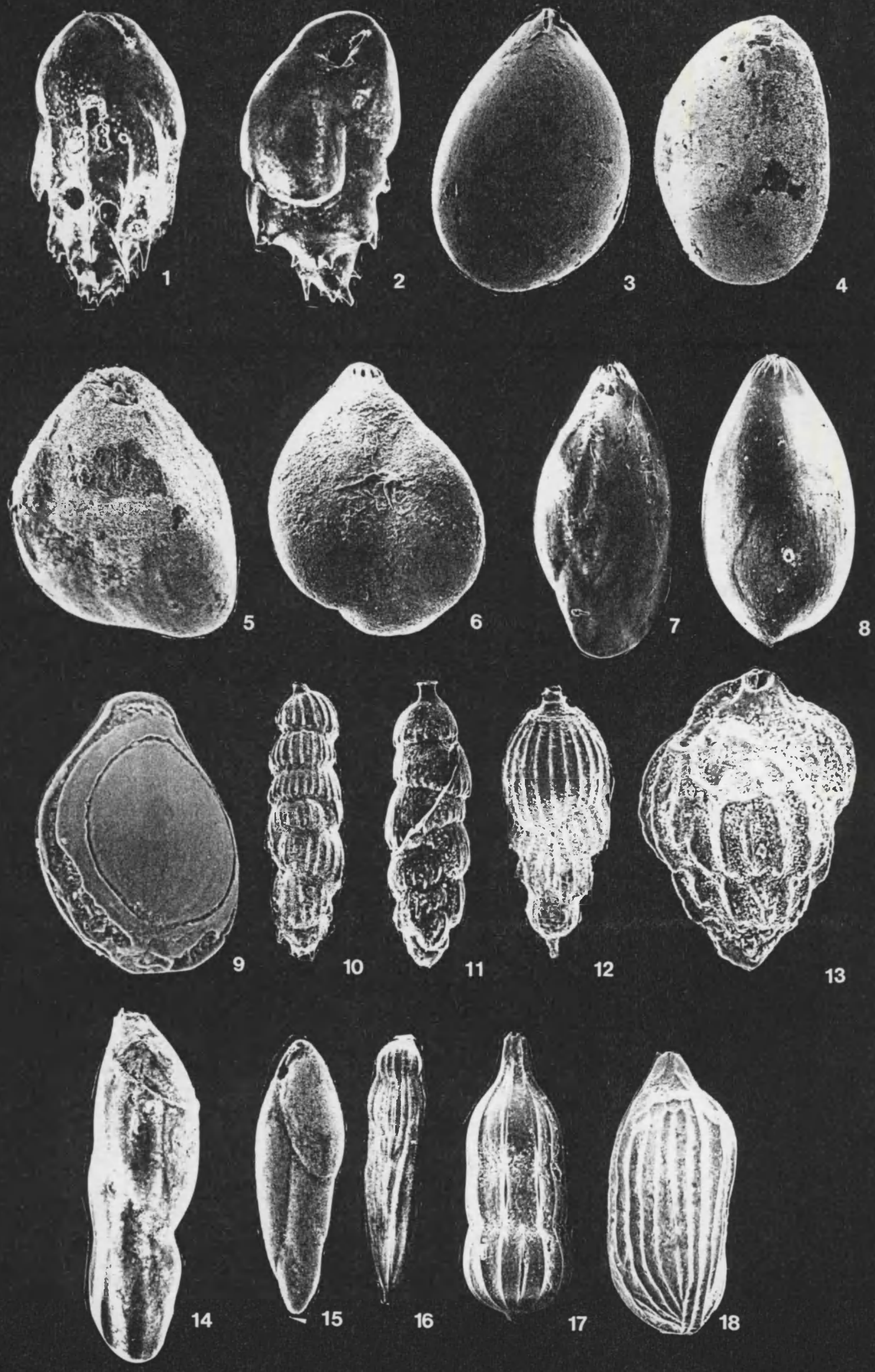


Plate 5.17

1. *Bulimina costata* D'Orbigny; 305 µm, x 220, station 184.
2. *Bulimina marginata* D'Orbigny; 305.8, x 250, station 56.
3. *Polymorphina* sp. 2; 301 µm x 270, station 39.
4. *Polymorphina* sp. 4; 467 µm, x 80, station 74.
5. *Polymorphina* sp. 5; 327 µm , x 280, station 72.
6. *Globulina gibba* D'Orbigny; 306.2 µm, x 58, station 61
7. *Polymorphina* sp.; 357 µm , x 39, station 72.
8. *Glandulina laevigata* D'Orbigny; 433 µm, x 140, station 70.
9. *Fissurina orbignyana* Seguenza; 227 µm, x 270, station 56.
10. *Rectuvigerina phlegeri* Le Calvez; 60 µm, x 195, station 58 .
11. *Rectuvigerina phlegeri* Le Calvez; 472 µm, x 140, station 58.
12. *Rectuvigerina* sp.; 712 µm x 135, station 58.
13. *Uvigerina* sp.; 265 µm, x 250, station 83.
14. *Astacolus crepidulus* (Fichtel and Moll), 775 µm, x 95, station 55.
15. *Fursenkoina acuta* (D'Orbigny); 417 µm, x 210, station 58.
16. *Nodosaria lamnulifera* Thalmann; 3557 µm, x 35, station 58.
17. *Pyramidulina catesbyi* (D'Orbigny); 662.5 µm, x 100, station 56.
18. *Pseudonodosaria comatula* (Cushman); 416 µm, x 140, station 58.

Plate 5.17



APPENDIX 1

Oceanographic, geochemical, sedimentological, and foraminiferal parameters

The location, oceanographic, geochemistry, sedimentology, and foraminiferal population parameters in the study area in spring and winter.

Station	Area	E_S	E_W	N_S	N_W	HD	Depth_S	Depth_W	E_Depth_W	Salin_S	Salin_W	E_Salin_W	Temp_S	Temp_W	E_Temp_W	pH_S	pH_W	Est_pH_W	DO_S	DO_W	Est_DO_W	CaCO3_S	Cd_S	Cd_W	Est_Cd_W	Cr_S	Cr_W	Est_Cr_W	Cu_S	Cu_W	Est_Cu_W	Pb_S	Pb_W	Est_Pb_W	Zn_S	Zn_W	Est_Zn_W	CS	VFS	FS	MS	CS	VCS	G
1	HB	35.02		32.82		0	-7.0		-7.8	39.03		39.15	19.99		17.5	8.3		7.5	10.1		6.3	40.6	2.1		1.0	15.9		9.9	12.8		23.9	28.0		21.0	50.0		29.4	7.5	44.3	42.3	4.9	0.3	0.2	0.3
2	HB	35.04	35.04	32.83	32.83	0	-7.0	-6.5	-7.8	38.92	38.91	39.15	20.41	17.3	17.4	8.9	7.7	7.5	10.1	6.9	6.3	11.3	0.6	0.1	0.1	7.3	8.0	5.8	2.0	3.3	7.0	6.3	8.0	9.4	16.5	20.0	14.4	1.9	54.9	42.5	0.5	0.1	0.1	0.1
3	HB	35.05		32.85		0	-7.0		-7.8	38.92		39.15	20.25		17.5	8.3		7.5	10.3		6.3	10.9	0.8		0.2	7.6		5.9	3.1		7.1	8.8		11.3	16.8		14.6	6.8	48.9	43.6	0.7	0.0	0.0	0.0
4	HB	35.06	35.05	32.86	32.86	0	-7.0	-5.9	-7.8	38.94	38.98	39.15	19.99	17.2	17.5	8.3	7.7	7.5	10.2	7.3	6.3	15.6	0.8	0.2	0.1	7.1	8.0	5.5	2.6	4.2	6.2	4.9	10.0	8.2	14.8	22.0	13.5	0.0	49.6	48.0	1.6	0.4	0.1	0.1
5	HB	35.07		32.88		0	-7.0		-7.8	38.97		39.15	19.98		17.5	8.1		7.5	10.0		6.4	13.4	1.0		0.3	8.5		6.1	3.6		7.9	10.6		12.5	18.4		15.5	0.1	49.8	44.8	3.0	1.5	0.4	0.2
6	HB	35.07	35.07	32.90	32.90	0	-7.0	-6.8	-7.8	38.94	39.12	39.15	20.27	17.7	17.5	8.2	7.3	7.5	7.6	7.0	7.2	25.8	1.9	0.3	0.8	9.6	8.0	7.1	5.6	5.0	11.0	23.0	12.0	18.9	24.9	24.0	18.8	0.0	22.7	78.4	1.9	0.2	0.1	0.0
7	HB	35.08		32.91		0	-6.5		-7.3	39.03		39.15	19.93		17.6	8.2		7.5	8.2		7.0	65.8	1.4		0.5	11.8		7.6	5.8		12.9	17.4		16.3	28.6		20.6	6.3	49.2	40.0	3.2	0.8	0.2	0.2
8	HB	35.05		32.92		1	-13.0		-13.6	39.00		39.15	19.44		17.7	8.2		7.5	8.4		6.9																							
9	HB	35.05	35.05	32.91	32.91	1	-13.0	-13.8	-13.6	39.13	39.14	39.15	19.44	17.8	17.7	8.2	7.7	7.5	8.4	7.4	6.9																							
10	HB	35.05		32.88		0	-13.5		-14.1	39.09		39.15	19.77		17.6	8.1		7.5	9.7		6.5																							
11	HB	35.04	35.04	32.87	32.87	0	-12.5	-12.0	-13.1	39.09	39.00	39.15	19.17	17.4	17.7	8.1	7.4	7.5	9.5	7.2	6.5	61.5	2.6	2.5	1.4	10.4	8.0	7.5	9.0	11.0	12.6	36.0	44.0	24.0	28.0	18.0	20.3	11.7	5.9	19.0	25.1	18.1	7.4	7.7
12	HB	35.04		32.85		0	-13.5		-14.1	39.06		39.15	19.15		17.7	8.1		7.5	8.7		6.8	93.8	4.0	2.2	3.2	10.6	9.0	8.0	12.2	12.0	14.6	64.0	48.0	32.8	32.0	28.0	22.1	4.5	0.4	1.1	5.6	25.5	29.2	25.0
13	HB	35.04	35.04	32.83	32.83	0	-12.0	-12.0	-12.6	16.62	39.13	39.13	19.49	17.5	17.7	8.2	7.3	7.5	9.2	6.8	6.6	14.0	0.8	0.7	0.2	9.0	7.0	5.5	3.7	5.0	6.2	8.8	12.0	11.3	14.7	22.0	13.4	15.6	56.7	25.1	1.3	0.3	0.9	0.1
14	HB	35.00	35.00	32.84	32.84	0	-15.5	-16.0	-16.0	17.42	39.13	39.13	19.05	17.7	17.8	8.1	7.4	7.5	8.8	6.2	6.8	14.0	1.2	0.4	0.3	6.4	4.1	5.0	4.5	4.0	4.9	12.0	10.0	13.3	12.0	8.0	11.8	23.4	54.2	18.4	2.9	0.8	0.2	0.1
15	HB	35.05		32.86		1	-21.0		-21.3	39.16		39.15	19.03		17.8	8.1		7.5	8.6		6.8																							
16	HB	35.03	35.03	32.88	32.87	0	-19.0	-17.0	-19.4	39.14	39.10	39.15	19.16	17.7	17.7	8.2	7.6	7.5	9.0	9.9	6.7	84.5	2.7	3.6	1.6	10.4	7.5	5.4	8.4	10.4	5.9	39.6	60.0	25.3	14.2	30.0	13.1	2.8	0.0	0.2	0.9	4.4	11.3	16.9
17	HB	35.03		32.89		0	-21.0		-21.3	39.13		39.15	19.08		17.8	8.0		7.5	8.7		6.8	68.0	3.2		2.0	7.6		5.2	8.1		5.3	45.3		27.2	12.9		12.3	0.1	0.0	0.2	3.8	45.3	43.9	6.3
18	HB	35.04	35.04	32.91	32.91	0	-19.0	-20.2	-19.4	39.15	39.14	39.15	19.00	18.0	17.8	8.1	7.7	7.5	8.5	6.9	6.9	77.3	3.0	3.1	1.7	8.1	6.6	4.7	8.0	10.0	4.3	40.0	52.0	25.4	10.6	10.0	10.9	3.6	0.1	0.6	6.6	44.7	37.0	7.1
19	HB	35.04		32.92		1	-18.0		-18.4	39.15		39.15	19.03		17.8	8.0		7.5	9.0		6.7																							
20	HB	35.02		32.93		0	-32.0		-32.0	21.97		39.13	18.09		18.0	8.2		7.5	9.6		6.5	61.5	0.9		0.2	15.1		7.9	10.0		14.4	10.3		12.3	31.7		22.0	30.8	63.9	3.7	1.0	0.3	0.2	0.0
21	HB	35.02	35.02	32.92	32.92	0	-30.0	-31.0	-30.1	39.09	39.12	39.15	18.19	18.0	18.0	8.2	7.7	7.5	9.7	6.7	6.5	8.8	1.3	0.6	0.6	11.3	6.0	7.1	8.0	7.0	11.2	20.0	16.0	17.5	25.2	20.0	18.9	35.8	24.1	39.4	0.5	0.1	0.1	0.0
22	HB	35.01		32.88		0	-29.0		-29.1	39.09		39.15	18.19		18.0	8.2		7.5	9.7		6.5	9.4	1.3		0.6	12.0		7.4	9.7		12.3	20.0		17.5	27.5		20.0	59.3	37.3	2.3	0.6	0.2	0.0	0.0
23	HB	35.01	35.01	32.88	32.88	0	-27.0	-27.0	-27.2	39.09	39.14	39.15	18.19	17.9	18.0	8.2	7.4	7.5	9.7	7.2	6.5	14.6	0.8	0.7	0.2	14.2	5.8	7.8	9.7	8.0	13.8	10.2	16.0	12.2	30.5	20.0	21.4	34.8	50.7	11.9	1.7	0.5	0.2	0.2
24	HB	35.00		32.87		0	-25.0		-25.2	39.09		39.15	18.19		18.0	8.2		7.5	9.7		6.5	18.5	2.2		0.4	15.9		7.2	10.2		11.4	13.6		14.2	25.6		19.1	6.2	11.0	51.5	9.3	5.6	4.1	3.9
25	HB	34.98	34.98	32.85	32.85	0	-16.0	-16.5	-16.5	39.09	39.13	39.15	18.19	17.7	18.0	8.2	7.4	7.5	9.7	6.8	6.5	13.5	0.5	3.3	0.1	4.2	7.0	4.0	1.7	11.0	2.9	4.3	48.0	7.7	7.5	8.0	8.7	6.7	49.7	38.6	2.9	1.9	0.2	0.0
26	HB	34.97	34.97	32.86	32.86	0	-19.0	-19.5	-19.4	39.09	93.12	39.15	18.19	17.8	18.0	8.2	7.3	7.5	9.7	6.3	6.5	88.5	3.2	0.5	2.1	6.8	3.3	4.2	7.0	2.5	3.3	47.8	10.0	28.0	8.4	12.0	9.4	1.0	0.3	0.7	3.0	52.2	35.9	6.1
27	HB	34.98		32.87		0	-26.0		-26.2	39.09		39.15	18.19		18.0	8.2		7.5	9.7		6.5	24.7	0.7		0.9	12.3		7.4	9.2		12.4	26.7		20.5	27.6		20.1	20.3	59.9	16.9	2.1	0.6	0.2	0.1
28	HB	34.98	34.98	32.89	32.89	0	-29.0	-29.0	-29.1	39.09	39.13	39.15	18.19	17.9	18.0	8.2	7.4	7.5	9.7	6.4	6.5	13.4	1.1	0.5	0.3	12.9	6.0	6.8	7.4	5.0	10.2	11.0	14.0	12.7	23.1	16.0	17.9	24.6	48.4	20.8	2.5	1.0	0.4	0.7
29	HB	34.99		32.90		0	-30.0		-30.1	39.09		39.15	18.19		18.0	8.2		7.5	9.7		6.5	9.4	1.2		0.5	11.4		7.0	8.0		10.8	16.0		15.5	24.5		18.6	28.8	65.8	4.0	0.9	0.3	0.2	0.0
30	HB	35.00	35.00	32.92	32.92	0	-32.0	-32.0	-32.0	39.09	39.16	39.15	18.19	18.3	18.0	8.2	7.6	7.5	9.7	6.5	6.5	8.3	0.8	0.4	0.2	13.2	5.8	7.4	8.6	6.0	12.4	7.7	12.0	10.5	27.6	20.0	20.1	32.6	61.6	3.5	0.8	0.3	0.1	1.1
31	HB	34.98		32.93		0	-32.0		-32.0	39.09		39.15	18.19		18.0	8.2		7.5	9.7		6.5																	31.0	64.4	3.5	0.7	0.3	0.1	0.1
32	HB	34.98		32.94		0	-34.0		-34.0	39.09		39.15	18.19		18.0	8.2		7.5	9.7		6.5	8.3	1.1		0.3	8.3		6.2	5.6		8.0	13.0		13.9	18.6		15.6	13.6	72.5	8.1	1.9	1.3	1.9	0.8
33	HB	34.98		32.93		0	-32.0		-32.0	39.09		39.15	18.19		18.0	8.2		7.5	9.7		6.5	9.3	0.4	0.3	0.2	11.6	5.8	7.0	5.9	6.0	10.6	9.8	12.0	11.9	24.0	16.0	18.4	11.0	82.4	5.2	0.8	0.3	0.2	0.1
34	HB	34.97		32.91		0	-30.0		-30.1	39.09		39.15	18.19		18.0	8.2		7.5	9.7		6.5	14.6	2.2		0.6	20.8		10.1	18.0		25.5	19.0		17.1	53.0		30.5	12.2	52.7	29.0	4.0	1.6	0.4	0.1
35	HB	34.97	34.97	32.90	32.89	0	-28.0	-28.0	-28.1	39.09	39.13	39.15	18.19	17.9	18.0	8.2	7.6	7.5	9.7	6.6	6.5	35.0	1.2	0.4	0.3	6.9	4.1	5.1	4.4	4.0	5.1	12.0	12.0	13.3	12.3	12.0	12.0	0.0	63.7	30.8	5.6	1.5	0.1	0.0
36	HB	34.96		32.88		0	-28.0		-28.1	39.09		39.15	18.19		18.0	8.2		7.5	9.7		6.5	14.6	0.9		0.5	7.2		5.2	6.4		5.4	16.0		15.5	13.0		12.4	8.1	62.8	24.5	2.9	1.3	0.2	0.1
37	HB	34.95	34.95	32.86	32.86	0	-27.0	-27.5	-27.2	39.15	39.16	39.15	18.29	18.1	17.9	8.2	7.6	7.5	9.7	6.4	6.5	84.5	3.4	3.2	2.0	6.5	7.5	5.0	8.2	12.0	4.9	45.1	46.0	27.1	12.0	8.0	11.8	6.3	0.4	0.4	1.7	9.1	21.1	34.7
38	HB	34.93	34.93	32.87	32.87	0	-31.5	-32.5	-31.5	39.16	29.15	39.15	17.96	18.3	18.0	8.1	7.3	7.5	9.9	6.4	6.4	89.6	3.1		2.0	7.0		4.8	7.8		4.5	45.7		27.3	11.0		11.1	5.2	1.8	1.1	9.0	23.5	22.1	16.8
39	HB	34.94		32.87		0	-34.0		-34.0	39.15		39.15	17.84		18.1	8.2		7.5	9.9		6.4	13.4	1.0		0.2	9.3		5.6	4.3		6.5	9.0		11.4	15.4		13.8	6.3	74.2	16.0	2.2	0.6	0.3	0.3
40	HB	34.95	34.95	32.90	32.90	0	-33.5	-35.0	-33.5	39.13	39.14	39.15	17.77	18.0	18.1	8.2	7.4	7.5	10.0	6.5	6.4	99.0	2.0	0.2	5.6	9.6	5.8	5.9	12.2	6.0	7.2	96.0	10.0	40.7	17.0	14.0	14.7	5.5	1.6	0.4	0.5	3.8	15.0	38.9
41	HB	34.96		32.92		0	-33.0		-33.0	24.09		39.14	17.74		18.1	8.1		7.5	10.0		6.4	16.7	0.5		0.3	9.5		5.9	5.0		7.3	11.2		12.8	17.1		14.8	10.4	71.7	13.9	2.9	0.3	0.1	0.0
42	HB	34.96	34.96	32.94	32.94	0	-36.0	-37.0	-35.9	39.11	39.16	39.15	17.51	18.3	18.1	8.1	7.6	7.5	10.0	6.4	6.4	5.2	1.3	0.2	0.2	13.6	5.8	6.9	7.8	7.0	10.5	9.0	12.0	11.4	23.8	18.0	18.3	26.1	56.2	4.1	1.6	2.0	2.4	4.9
43	HB	34.96		32.95		0	-32.0		-32.0	39.12		39.15	17.62		18.1	8.2		7.5	10.0		6.4	4.0	1.2		0.2	14.4		7.2	8.2		11.6	9.0		11.4	26.0		19.3	50.4	42.7	4.4	1.3	0.5	0.4	0.3
44	HB	34.95		32.96		0	-48.0		-47.5	36.54		39.15	17.24		18.2	8.1		7.5	10.0		6.4	7.3	1.3		0.4	19.4		8.4	15.5		16.2	14.0		14.5	35.2		23.5	81.7	15.8	1.5	0.7	0.2	0.1	0.1
45	HB	34.94	34.94	32.94	32.94	0	-47.0	-46.5	-46.6	39.11	39.17	39.15	17.34	18.2	18.2	8.2	7.6	7.5	10.0	5.2	6.4	7.3	1.3	0.0	0.4	19.4	9.0	8.4	15.5	28.0	16.2	14.0	10.0	14.5	35.2	24.0	23.5	36.5	46.2	9.0	1.9	2.4	1.1	1.5
46	HB	34.94		32.92		0	-45.0		-44.6	27.70		39.14	17.03		18.3	8.3		7.5	9.9		6.4	34.0	1.3		0.3	15.1		7.0	9.3		10.6	12.0		13.3	24.1		18.4	15.7	40.2	16.3	8.7	5.1	3.6	5.4
47	HB	34.94	34.94	32.91	32.91	0	-43.0	-41.0	-42.7	39.12	39.16	39.15	17.29	18.3	18.2	8.3	7.6	7.5	10.2	8.2	6.3	21.6	0.6	0.2	0.2	11.6	5.8	6.9	7.5	8.0	10.4	10.3	24.0	12.3	23.7	14.0	18.2	14.3	58.5	11.8	1.3	5.5	5.3	2.6
48	HB	34.92		32.89		0	-48.0		-47.5	39.15		39.15	17.63		18.1	8.2		7.5	10.1		6.3	33.0	1.4		0.3	15.2		6.9	9.8		10.5	13.0		13.9	23.8		18.3	14.4	46.4	14.9	9.4	4.0	3.4	3.6
49	HB	34.91	34.91	32.87	32.87	0	-44.0	-45.0	-43.7	39.13	39.15	39.15	17.56	18.3	18.1	8.3	7.7	7.5	9.4	6.4	6.6	75.3	2.3		1.5	10.6		6.4	11.6		8.8	37.7		24.6	20.4		16.5	3.5	1.9	1.2	4.3	11.3	17.8	24.2
50	HB	34.89	34.89	32.88	32.88	0	-47.0	-47.0	-46.6	39.10	39.15	39.15	16.88	18.4	18.3	8.3	7.3	7.5	9.0	6.7	6.7	71.1	1.6	0.4	3.8	56.6	10.0	12.0	35.6	21.0	37.4	73.0	20.0	35.2	75.0	22.0	38.2	26.3	4.3	1.8	5.4	16.2	17.9	18.3
51	HB	34.91		32.90		0	-67.0		-66.0	39.08		39.15	16.84		18.3	8.3		7.5	9.1		6.7	28.8	1.6		0.5	23.2		8.1	17.8		15.3	17.0		16.1	33.4		22.7	60.9	7.9	14.3	3.9	2.6	2.4	3.1
52	HB	34.91	34.91	32.91	32.91	0	-67.0	-66.0	-66.0	39.09	39.15	39.15	16.44	18.3	18.4	8.3	7.4	7.5	9.0	6.7	6.7	12.5	0.8	0.5	0.6	19.2	8.3	8.1	17.7	16.0	15.0	19.1	12.0	17.1	32.9	18.0	22.5	63.9	6.7	12.6	4.7	2.6	2.6	3.0

The location, oceanographic, geochemistry, sedimentology, and foraminiferal population parameters in the study area in spring and winter.

Station	Area	E_S	E_W	N_S	N_W	HD	Depth_S	Depth_W	E_Depth_W	Salin_S	Salin_W	E_Salin_W	Temp_S	Temp_W	E_Temp_W	pH_S	pH_W	Est_pH_W	DO_S	DO_W	Est_DO_W
53	HB	34.92		32.93		0	-66.0		-65.0	39.09		39.15	16.43		18.4	8.2		7.5	9.1		6.7
54	HB	34.92	34.92	32.95	32.95	0	-74.0	-76.0	-72.8	38.38	39.16	39.15	16.33	18.3	18.4	8.2	7.3	7.5	9.1	5.2	6.7
55	HB	34.93		32.96		0	-72.0		-70.8	39.10		39.15	16.29		18.4	8.3		7.5	9.2		6.6
56	HB	34.91		32.97		0	-210.0		-204.7	39.07		39.15	15.12		18.7	8.3		7.5	9.0		6.7
57	HB	34.91	34.91	32.96	32.96	0	-200.0	-192.0	-195.0	36.40	39.15	39.15	15.40	18.3	18.6	8.2	7.6	7.5	9.3	6.2	6.6
58	HB	34.90		32.93		0	-184.0		-179.4	39.13		39.15	15.13		18.7	8.2		7.5	9.1		6.7
59	HB	34.89		32.90		0	-82.0		-80.5	39.13		39.15	16.08		18.5	8.3		7.5	10.2		6.3
60	HB	34.88	34.88	32.89	32.89	0	-75.0	-77.0	-73.7	39.11	39.16	39.15	16.10	18.5	18.5	8.4	7.4	7.5	10.3	6.1	6.3
84	HB	35.07		32.91		0	-6.0		-6.8	38.75		39.15	20.70		17.4	8.3		7.5	10.1		6.3
85	HB	35.05		32.88		0	-6.5		-7.3	38.72		39.15	21.31		17.2	8.4		7.5	15.3		4.6
86	HB	35.06		32.87		0	-6.5		-7.3	38.98		39.15	20.98		17.3	8.3		7.5	12.4		5.6
87	HB	35.03		32.81		0	-3.0		-3.9	39.30		39.15	20.90		17.3	8.2		7.5	12.3		5.6
61	AB	34.87		32.81		0	-66.0		-65.0	39.10		39.15	16.39		18.4	8.4		7.5	10.3		6.3
75	AB	34.92		32.67		0	-7.0		-7.8	39.11		39.15	19.99		17.5	8.1		7.5	9.9		6.4
76	AB	34.94		32.73		0	-7.0		-7.8	39.12		39.15	19.63		17.6	8.3		7.5	10.0		6.4
77	AB	34.95		32.79		0	-6.0		-6.8	39.14		39.15	20.09		17.5	8.2		7.5	10.0		6.4
78	AB	34.95		32.80		0	-7.0		-7.8	39.10		39.15	20.00		17.5	8.2		7.5	10.0		6.4
79	AB	34.93		32.79		1	-30.0		-30.1	39.14		39.15	18.70		17.9	8.1		7.5	9.9		6.4
80	AB	34.91		32.79		1	-36.0		-35.9	39.08		39.15	17.78		18.1	8.3		7.5	10.1		6.3
81	AB	34.89		32.79		0	-57.0		-56.3	39.06		39.15	16.66		18.3	8.2		7.5	10.3		6.3
82	AB	34.86		32.80		0	-71.0		-69.8	39.09		39.15	16.32		18.4	8.3		7.5	10.1		6.3
83	AB	34.85		32.80		0	-102.0		-99.9	39.13		39.15	16.19		18.5	8.3		7.5	10.1		6.3
62	AB	34.89		32.81		0	-54.0		-53.4	39.11		39.15	18.24			8.3		7.5	10.1		6.4
63	AB	34.90		32.80		0	-47.0		-46.6	39.11		39.15	18.24			8.3		7.5	10.1		6.4
64	AB	34.92		32.80		1	-31.0		-31.0	39.11		39.15	18.24			8.3		7.5	10.1		6.4
65	AB	34.94		32.80		1	-14.0		-14.6	39.11		39.15	18.24			8.3		7.5	10.1		6.4
66	AB	34.93		32.73		0	-20.0		-20.4	39.11		39.15	18.24			8.3		7.5	10.1		6.4
67	AB	34.91		32.73		0	-35.0		-34.9	39.11		39.15	18.24			8.3		7.5	10.1		6.4
68	AB	34.89		32.73		0	-51.0		-50.4	39.11		39.15	18.24			8.3		7.5	10.1		6.4
69	AB	34.88		32.73		0	-56.0		-55.3	39.11		39.15	18.24			8.3		7.5	10.1		6.4
70	AB	34.86		32.72		0	-68.0		-66.9	39.11		39.15	18.24			8.3		7.5	10.1		6.4
71	AB	34.85		32.68		0	-63.0		-62.1	39.11		39.15	18.24			8.3		7.5	10.1		6.4
72	AB	34.87		32.67		0	-53.0		-52.4	39.11		39.15	18.24			8.3		7.5	10.1		6.4
73	AB	34.89		32.67		0	-37.0		-36.9	39.11		39.15	18.24			8.3		7.5	10.1		6.4
74	AB	34.91		32.67		0	-24.0		-24.3	39.11		39.15	18.24			8.3		7.5	10.1		6.4

Station	CaCO3_S	Cd_S	Cd_W	Est_Cd_W	Cr_S	Cr_W	Est_Cr_W	Cu_S	Cu_W	Est_Cu_W	Pb_S	Pb_W	Est_Pb_W	Zn_S	Zn_W	Est_Zn_W	CS	VFS	FS	MS	CS	VCS	G
53	5.2	0.6		0.4	24.4		8.9	24.4		18.7	14.9		15.0	40.1		25.5	86.6	3.0	4.6	1.7	1.2	0.9	1.1
54	3.5	0.5	0.0	0.3	18.1	9.0	8.7	16.9	29.0	18.0	11.1	10.0	12.8	38.8	24.0	25.0	73.5	23.0	2.1	0.6	0.2	0.1	0.1
55																	76.8	19.5	1.7	0.6	0.2	0.2	0.7
56	0.5	0.3		0.8	32.2		10.1	29.2		25.4	24.2		19.4	52.9		30.5	91.4	7.7	0.8	0.2	0.0	0.0	0.0
57			0.2			10.2			32.0			18.0			20.0								
58	4.2	0.5		0.6	22.8		9.4	20.5		21.1	19.1		17.1	44.8		27.4	68.4	19.8	5.3	2.9	1.8	1.1	0.6
59	5.2	0.3		0.8	22.0		9.0	23.4		19.2	22.9		18.9	41.1		25.9	89.5	4.4	1.8	1.7	0.7	0.4	0.3
60	27.0	1.0	0.2	0.6	17.9	10.0	8.6	17.3	31.0	17.5	18.8	12.0	17.0	37.7	29.0	24.5	45.8	22.3	7.2	9.5	5.5	4.5	4.0
84	2.1	0.8		0.5	24.5		9.9	22.4		21.0	17.7		16.4	50.2		29.5	72.9	21.5	2.1	0.6	0.2	0.2	0.1
85	18.8	0.9		0.2	8.2		6.0	4.2		7.6	10.2		12.2	17.8		15.2	3.0	15.0	77.5	2.3	1.0	0.6	0.5
86	21.9	0.9		0.2	8.5		6.8	4.6		9.9	10.3		12.3	22.6		17.7	10.9	15.7	67.1	2.4	1.0	0.6	0.9
87	13.4	0.7		0.2	6.0		5.1	2.5		5.2	7.4		10.3	12.6		12.1	6.4	82.0	6.3	4.1	0.8	0.2	0.2
61	54.0	0.5	0.3	0.8	18.5	8.3	8.3	15.1	30.0	15.9	22.8	16.0	18.8	34.6	24.0	23.2	38.1	14.4	5.4	8.1	9.5	9.4	9.8
75	17.7	0.3	0.0	0.0	2.9	2.0	2.5	0.7	1.5	0.9	2.3	6.0	5.5	2.7	1.0	4.5	6.4	8.6	83.6	0.9	0.2	0.1	0.0
76	5.0	0.2	0.0	0.1	2.2	2.0	4.2	0.3	1.5	3.2	4.0	10.0	7.4	8.2	1.0	9.2	8.7	9.5	80.9	0.7	0.1	0.0	0.0
77	5.2	0.2	0.0	0.2	2.9	2.0	4.2	0.9	2.0	3.3	7.9	10.0	10.6	8.3	1.0	9.3	0.0	8.2	84.4	0.9	1.2	1.2	0.6
78	8.5	0.1		0.2	2.9		2.9	0.7		1.4	7.8		10.6	3.8		5.6	24.5	12.5	58.2	1.5	0.9	1.0	0.7
79																							
80			1.2			6.0			12.0			24.0			18.0								
81	68.7	0.6	0.9	0.9	19.5	7.0	9.3	20.4	18.0	20.6	25.0	22.0	19.8	43.8	22.0	27.0	14.2	3.1	1.5	2.9	6.2	6.7	7.6
82	25.8	0.3	0.5	0.6	16.9	8.0	8.3	16.2	26.0	15.8	20.1	14.0	17.6	34.5	20.0	23.2	47.7	18.3	9.8	6.8	6.6	5.3	4.4
83			0.2			8.0			26.0			12.0			20.0								
62	60.4	0.5	0.5	0.7	19.2	9.0	8.4	15.4	22.0	16.5	21.4	20.0	18.2	35.8	28.0	23.7	25.5	9.8	3.3	8.7	8.0	9.4	11.8
63	27.8	0.7	0.6	0.3	11.7	8.3	6.8	7.2	16.0	10.0	10.6	18.0	12.5	22.8	22.0	17.8	22.5	48.6	16.4	7.4	2.7	1.5	0.8
64			1.8			23.0			13.0			58.0			12.0		4.3	4.0	3.8	1.9	3.5	5.0	7.2
65																							
66	4.2	0.3	0.0	0.1	3.2	9.0	2.8	0.7	1.0	1.3	3.9	4.0	7.3	3.6	4.0	5.4	4.0	29.7	65.7	0.3	0.1	0.0	0.0
67	17.7	0.7	0.4	0.1	4.6	9.0	3.7	1.2	4.0	2.5	6.7	8.0	9.7	6.4	8.0	7.9	3.6	11.8	77.3	5.6	1.2	0.3	0.2
68	50.5	0.9	0.3	1.0	16.6	9.0	8.1	14.0	18.0	15.3	28.0	20.0	21.0	33.4	24.0	22.7	34.3	17.9	2.9	6.2	8.9	9.2	12.1
69	41.7	0.7	0.2	0.3	13.2	9.0	7.8	12.9	22.0	13.9	12.8	18.0	13.8	30.7	24.0	21.5	34.6	15.8	7.1	8.1	10.0	9.0	11.0
70	22.0	0.5	0.3	0.6	12.4	9.0	7.4	11.8	14.0	12.2	18.3	16.0	16.7	27.3	39.0	19.9	44.3	18.0	6.0	4.3	3.1	2.6	3.1
71	6.3	0.2	0.0	0.3	14.2	7.0	7.4	14.7	26.0	12.3	13.0	12.0	13.9	27.5	16.0	20.0	65.6	21.6	3.2	2.1	1.6	1.6	2.1
72	3.1	0.1	0.0	0.6	10.2	6.0	6.7	13.0	17.0	9.6	20.1	18.0	17.6	21.9	16.0	17.3	66.7	12.1	13.8	3.1	2.0	1.2	0.7
73			0.0			2.0			2.0			6.0			3.0								
74	1.0	0.2	0.0	0.0	4.0	2.0	3.1	1.7	1.0	1.7	2.5	6.0	5.7	4.5	1.0	6.3	26.3	12.8	60.2	0.3	0.2	0.1	0.1

The location, oceanographic, geochemistry, sedimentology, and foraminiferal population parameters in the study area in spring and winter.

Station	P	Tot_sp_liv_S	Tot_sp_liv_W	Living_%_S	Tot_liv_S	Tot_liv_W	S_liv_S	S_liv_W	M_liv_S	M_liv_W	L_liv_S	L_liv_W	XL_liv_S	XL_liv_W	Rel_abund_S	Rel_abund_W	H_S	H_W	Sp_div_S	Sp_div_W	Tot_sp_def_S	Tot_sp_def_W	Tot_def_S	Tot_def_W	S_def_S	S_def_W	M_def_S	M_def_W	L_def_S	L_def_W	XL_def_S	XL_def_W
1	0.1	4		4.2	26		6		15		5		0		0.55		0.92		1.37		2		7		0		7		0		0	
2	0.0	6	6	1.6	35	26	7	0	21	7	6	15	1	0	0.73	1.48	1.09	1.68	2.23	2.57	2	0	4	0	0	0	4	0	0	0	0	0
3	0.0	8		2.6	65		15		36		9		5		1.36		1.59		2.36		2		4		0		4		0		0	
4	0.3	8	7	1.5	61	30	12	0	19	15	21	11	9	4	1.28	1.70	1.77	1.79	2.54	2.97	3	0	6	0	0	0	5	0	1	0	0	0
5	0.2	10		2.4	70		12		25		23		10		1.47		2.01		2.92		1		2		0		2		0		0	
6	0.0	10	8	5.2	59	36	12	0	18	25	20	11	8	0	1.24	2.04	1.91	1.99	3.11	3.13	0	0	0	0	0	0	0	0	0	0	0	0
7	0.1	8			107		0		44		58		5		2.24		1.84		2.18		0		0		0		0		0		0	
8		10			59		0		12		32		15		1.24		1.68		3.11		4		12		0		3		7		2	
9		7	6		51	32	7	0	13	25	22	7	9	0	1.07	1.82	1.42	1.69	2.13	2.19	3	0	19	0	0	0	7	0	9	0	3	0
10		9			58		10		13		35		0		1.22		1.66		3.05		2		16		0		2		10		4	
11	5.1	8	6	5.2	52	41	0	0	14	15	29	16	9	10	1.09	2.33	1.55	1.48	2.17	1.93	2	0	19	0	0	0	7	0	9	0	3	0
12	8.8	6		6.0	47		0		0		30		17		0.99		1.49		1.96		1		6		0		4		2		0	
13	0.0	11	14	2.4	53	52	0	0	9	29	32	16	12	7	1.11	2.95	2.05	2.59	3.99	6.43	0	0	0	0	0	0	0	0	0	0	0	0
14	0.0	34	14	2.1	75	47	2	1	44	24	18	15	11	7	1.57	2.67	3.23	2.56	18.75	7.65	3	0	5	0	0	0	1	0	4	0	0	0
15		14			78		0		29		37		12		1.64		2.36		4.98		5		15		0		4		11		0	
16	63.5	19	9	6.4	61	26	2	2	13	17	29	7	17	0	1.28	1.48	2.59	1.99	9.93	5.33	4	0	6	0	0	0	2	0	4	0	0	0
17	0.3	2		6.9	57		0		12		31		14		1.20		0.49		0.58		1		21		0		4		12		5	
18	0.4	6	5	7.8	61	40	0	0	9	32	37	6	15	2	1.28	2.27	1.31	0.67	1.89	1.67	5	2	15	14	0	0	3	6	12	8	0	0
19		24	4		71	46	0	3	20	3	33	16	18	24	1.49	2.61	2.57	0.31	12.53	1.42	5	1	12	27	0	0	3	15	9	12	0	0
20	0.1	21		4.4	73		10		27		20		16		1.53		2.63		10.91		4		4		0		4		0		0	
21	0.0	36	23	4.5	98	81	6	0	36	34	46	29	10	18	2.06	4.60	3.05	2.99	20.07	9.00	1	5	1	5	0	0	1	2	0	3	0	0
22	0.3	24		4.2	60		3		41		16		0		1.26		2.73		14.07		0		0		0		0		0		0	
23	0.1	40	28	4.7	109	81	8	0	55	28	35	30	11	23	2.29	4.60	3.06	3.25	22.33	16.59	3	2	4	2	0	0	3	1	1	1	0	0
24	8.6	21		2.9	63		0		23		28		12		1.32		2.46		11.12		0		0		0		0		0		0	
25	0.0	38	25	1.9	174	92	16	3	77	42	53	31	28	16	3.65	5.22	3.07	3.02	13.10	13.75	0	3	0	3	0	0	0	1	0	2	0	0
26	0.8	34	34	6.6	130	68	0	0	77	38	32	19	21	11	2.73	3.86	3.12	3.19	14.44	26.44	8	0	14	0	0	0	5	0	9	0	0	0
27	0.0	34		3.9	82		6		39		26		11		1.72		3.09		23.13		4		6		0		4		2		0	
28	1.6	42	26	4.4	89	69	0	2	17	25	56	27	16	15	1.87	3.92	3.27	2.41	31.27	16.19	5	0	7	0	0	0	3	0	4	0	0	0
29	0.0	37		4.0	89		6		45		27		11		1.87		3.27		25.10		3		5		0		4		1		0	
30	0.0	43	33	3.8	118	119	2	0	75	49	33	43	8	27	2.48	6.75	3.31	3.41	25.90	17.78	1	0	1	0	0	0	0	0	1	0	0	0
31	0.0	26			77		0		43		31		3		1.62		2.89		13.59		0		0		0		0		0		0	
32	0.0	19		3.2	67		6		37		23		1		1.41		2.44		9.14		0		0		0		0		0		0	
33	0.1	41	16	3.3	98	51	1	1	47	28	43	19	7	3	2.06	2.89	3.38	1.51	26.05	9.00	8	0	10	0	0	0	6	0	4	0	0	0
34	0.0	8		4.6	31		3		12		16		0		0.65		1.69		3.44		2		4		0		3		1		0	
35	0.8	34	20	3.0	72	65	0	5	39	36	27	15	6	9	1.51	3.69	3.22	2.86	25.30	10.58	3	0	3	0	0	0	2	0	1	0	0	0
36	0.0	28		2.4	79		4		44		26		5		1.66		2.93		16.18		0		0		0		0		0		0	
37	26.3	13	8	1.6	90	62	0	2	28	32	42	19	20	9	1.89	3.52	1.84	1.62	4.24	2.58	4	4	25	20	0	0	8	0	14	20	3	0
38	20.6	23	13	6.2	70	56	0	2	31	34	21	12	18	8	1.47	3.18	2.46	2.24	12.35	5.54	3	2	11	12	0	0	2	3	9	9	0	0
39	0.2	35		2.5	86		2		34		39		11		1.80		3.11		21.50		0		0		0		0		0		0	
40	34.4	27	50	6.9	60	103	4	6	32	42	20	30	4	25	1.26	5.85	2.98	3.51	20.00	36.19	27	0	8	0	0	0	6	0	2	0	0	0
41	0.7	41		2.9	136		8		81		38		9		2.85		3.25		22.14		0		0		0		0		0		0	
42	2.8	43	46	3.5	141	96	3	3	76	43	43	32	19	18	2.96	5.45	3.54	3.52	24.88	33.73	0	0	0	0	0	0	0	0	0	0	0	0
43	0.0	29		3.6	124		3		83		31		7		2.60		3.13		12.26		0		0		0		0		0		0	
44	0.0	12		5.0	71		0		44		24		3		1.49		2.13		4.21		2		1		0		0		1		0	
45	1.3	28	22	5.0	140	67	3	0	82	30	45	21	10	16	2.94	3.80	2.89	2.72	10.54	12.76	2	0	2	0	0	0	1	0	1	0	0	0
46	5.1	11		4.6	114		0		57		37		20		2.39		2.20		3.53		0		0		0		0		0		0	
47	0.8	43	41	4.0	159	84	7	4	79	43	45	30	28	7	3.34	4.77	3.46	3.37	23.76	29.51	10	2	13	2	0	0	8	0	5	0	0	0
48	3.9	19		4.8	114		0		56		37		21		2.39		2.53		6.63		6	0	10	0	0	0	4	0	6	0	0	0
49	35.7	21	21	7.9	109	64	0	3	46	32	34	18	29	11	2.29	3.63	2.68	2.65	8.20	12.19	6		16		0		5		11		0	
50	9.8	18	27	7.9	37	52	0	1	25	29	12	9	0	13	0.78	2.95	2.46	3.04	14.39	22.29	3	0	4	0	0	0	1	0	3	0	0	0
51	4.8	18		7.3	56		2		36		17		1		1.17		2.24		9.12		1		1		0		1		0		0	
52	3.9	25	32	8.1	64	49	2	0	43	24	16	13	3	12	1.34	2.78	2.68	3.30	16.00	49.00	1	0	2	0	0	0	2	0	0	0	0	0

The location, oceanographic, geochemistry, sedimentology, and foraminiferal population parameters in the study area in spring and winter.

Station	P	Tot_sp_liv_S	Tot_sp_liv_W	Living_%_S	Tot_liv_S	Tot_liv_W	S_liv_S	S_liv_W	M_liv_S	M_liv_W	L_liv_S	L_liv_W	XL_liv_S	XL_liv_W	Rel_abund_S	Rel_abund_W	H_S	H_W	Sp_div_S	Sp_div_W	Tot_sp_def_S	Tot_sp_def_W	Tot_def_S	Tot_def_W	S_def_S	S_def_W	M_def_S	M_def_W	L_def_S	L_def_W	XL_def_S	XL_def_W
53	0.9	9		8.9	41		2		19		12		8		0.86		1.62		3.57		0		0		0		0		0		0	
54	0.2	19	16	7.1	34	22	4	0	21	8	9	8	0	6	0.71	1.25	2.62	2.60	18.31	22.00	1	0	1	0	0	0	1	0	0	0	0	0
55	0.3	19			59		4		27		23		5		1.24		2.41		9.60		1		1		0		1		0		0	
56	0.0	19		9.0	87		4		46		23		14		1.83		2.49		7.57		0		0		0		0		0		0	
57		21	18		73	45	5	6	40	27	17	12	11	0	1.53	2.55	2.52	2.69	11.88	11.25	1	0	1	0	0	0	0	0	1	0	0	0
58	0.0	24		8.5	113		5		74		34		0		2.37		2.62		9.69		0		0		0		0		0		0	
59	1.3	23		9.1	50		6		32		11		1		1.05		2.76		15.79		0		0		0		0		0		0	
60	1.1	26	27	7.9	84	60	6	10	43	45	20	5	15	0	1.76	3.41	2.66	2.76	12.55	20.00	2	0	2	0	0	0	1	0	1	0	0	0
84	0.0	18		8.1	24		2		10		4		3		0.94		2.75		36.00		0		0		0		0		0		0	
85	0.1	38		1.7	167		2		74		49		42		6.53		3.22		16.52		0		0		0		0		0		0	
86	1.3	19		1.7	134		4		53		49		28		5.24		2.67		5.58		0		0		0		0		0		0	
87	0.0	13		1.4	102		1		41		33		27		3.99		2.03		4.25		0		0		0		0		0		0	
61	5.2	29	22	7.2	85	47	0	0	40	22	29	17	16	8	3.32	3.96	2.75	2.84	15.00	16.51	2	0	3	0	0	0	2	0	1	0	0	0
75	0.2	22	24	0.6	108	70	0	4	35	25	49	29	24	12	4.22	5.90	2.74	2.90	8.13	13.33	0	0	0	0	0	0	0	0	0	0	0	0
76	0.0	25	28	0.7	146	75	6	9	63	24	45	28	32	14	5.71	6.32	2.80	2.90	9.32	12.21	0	0	0	0	0	0	0	0	0	0	0	0
77	0.0	15	16	0.9	104	77	0	1	49	29	38	32	17	15	4.07	6.49	2.35	2.49	5.47	6.42	0	0	0	0	0	0	0	0	0	0	0	0
78	0.7	18	18	0.8	137	82	0	0	60	28	41	34	36	20	5.36	6.91	2.50	2.46	5.71	7.62	0	0	0	0	0	0	0	0	0	0	0	0
79		18			69		0		34		26		9		2.70		2.57		9.41		0		0		0		0		0		0	
80		11	12		43	23	0	3	17	6	12	8	14	6	1.68	1.94	2.25	2.30	4.78	9.86	0	0	0	0	0	0	0	0	0	0	0	0
81	57.8	11	12	7.8	30	25	0	0	18	8	9	9	3	8	1.17	2.11	2.21	2.29	6.59	9.72	1	0	1	0	0	0	0	0	1	0	0	0
82	1.1	9	10	6.1	36	19	0	1	6	9	21	5	9	4	1.41	1.60	2.09	2.11	3.56	8.14	2	1	2	1	0	0	0	0	2	1	0	0
83		18	20		78	42	4	0	31	18	31	18	12	6	3.05	3.54	2.55	2.60	7.71	14.76	2	0	2	0	0	0	0	0	2	0	0	0
62	23.5	29	15	6.3	58	39	0	3	20	23	22	11	16	2	2.27	3.29	2.89	2.43	22.56	9.15	1	0	1	0	0	0	1	0	0	0	0	0
63	0.1	36	13	3.5	188	50	0	0	92	31	57	19	39	0	7.35	4.21	3.44	2.38	13.28	6.18	0	0	0	0	0	0	0	0	0	0	0	0
64	70.3	11	6		111	53	0	0	14	28	66	16	31	9	4.34	4.47	2.06	1.58	3.43	1.81	0	1	0	10	0	0	0	0	0	10	0	0
65		8	7		79	47	0	0	14	22	33	13	32	12	3.09	3.96	2.02	1.83	2.44	2.27	2	0	3	0	0	0	0	0	3	0	0	0
66	0.2	9	11	0.9	106	65	0	0	39	33	42	23	23	9	4.15	5.48	2.11	2.22	2.16	3.86	0	0	0	0	0	0	0	0	0	0	0	0
67	0.0	29	30	1.5	159	88	0	0	68	49	51	26	40	13	6.22	7.41	4.19	3.14	11.97	16.76	9	0	10	0	0	0	4	0	6	0	0	0
68	8.4	21	23	7.2	116	66	0	0	51	20	39	27	26	19	4.54	5.56	2.89	2.44	7.40	13.52	6	0	9	0	0	0	3	0	6	0	0	0
69	4.5	27	26	5.7	106	76	0	3	49	33	32	29	25	11	4.15	6.40	2.83	2.95	11.78	14.48	1	0	1	0	0	0	0	0	1	0	0	0
70	18.6	24	23	5.8	90	47	0	6	44	20	31	14	15	7	3.52	3.96	2.76	2.93	11.12	20.14	3	0	2	0	0	0	0	0	2	0	0	0
71	2.1	18	18	7.0	75	52	1	1	35	25	31	14	8	12	2.93	4.38	2.59	2.70	7.42	10.65	1	0	0	0	0	0	0	0	0	0	0	0
72	0.3	28	28	7.4	92	67	0	4	44	20	28	25	20	18	3.60	5.64	2.93	3.06	14.98	18.90	2	0	3	0	0	0	1	0	2	0	0	0
73																																
74	0.0	23	27	1.5	114	77	0	0	38	28	61	30	15	19	4.46	6.49	2.87	3.01	8.58	15.77	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX 2

Prediction equations for foraminiferal parameters

Optimum regression models for prediction of foram counts etc., based on Atlit Bay data

Data-scale coefficients

	Tot.sp.lov.S	Tot.liv.S	Sp.div.S	Tot.def.S	Tot.sp.def.S
Intercept	-183.613	-69.787	-91.474	-1.713	-2.207
Depth		0.4191		-0.0450	-0.0543
Temp	2.4712	9.5256	1.1826		
DO	15.4207		7.4800		
CaCO3	0.0239	-0.2347	0.0432		
Clay-sand		-0.3504	0.0412		
Very fine sand		1.3436	-0.0551	-0.0634	-0.0450
Fine sand				0.0336	0.0357
Medium sand	1.6107	4.1456	0.8983	0.2970	0.4346
Coarse sand	-0.4748	-1.6593	-0.2120		
Gravel					
Pebbles	-0.1042		-0.0355	-0.0051	-0.0126
R-squared	0.29	0.48	0.28	0.23	0.24

	Tot.sp.liv.W	Tot.liv.W	Sp.div.W	Tot.def.W	Tot.sp.def.W
Intercept	-357.624	-1185.540	-135.654	-69.715	15.533
Depth		0.1750	-0.1267	0.0361	
Temp	-0.0720			1.7292	0.1303
DO	58.8988	196.8485	22.6815	6.7254	-2.7554
CaCO3		-0.0025		-0.0470	-0.0085
Clay-sand	0.0588		0.0463	-0.0266	
Very fine sand	-0.3187	-0.2838	-0.2230		
Fine sand	0.0578	0.0963	0.0233	-0.0348	-0.0016
Medium sand	0.3817				
Coarse sand					
Gravel				-0.0658	
Pebbles	-0.1681	-0.0229	-0.1007	0.0775	0.0093
R-squared	0.45	0.6	0.37	0.57	0.38

Standardized coefficients

	Tot.sp.lov.S	Tot.liv.S	Sp.div.S	Tot.def.S	Tot.sp.def.S
Depth		0.25		-0.35	-0.52
Temp	0.35	0.27	0.25		
DO	0.18		0.14		
CaCO3	0.06	-0.13	0.18		
Clay-sand		-0.18	0.17		
Very fine sand		0.35	-0.11	-0.22	-0.20
Fine sand				0.39	0.52
Medium sand	0.61	0.31	0.53	0.43	0.37
Coarse sand	-0.21	-0.15	-0.15		
Gravel					
Pebbles	-0.27		-0.14	-0.09	-0.04

	Tot.sp.liv.W	Tot.liv.W	Sp.div.W	Tot.def.W	Tot.sp.def.W
Depth	-0.22	0.20	-0.51	0.34	
Temp				0.20	0.11
DO	0.31	0.39	0.23	0.11	-0.32
CaCO3		-0.03		-0.44	-0.58
Clay-sand	0.17		0.28	-0.23	
Very fine sand	-0.46	-0.15	-0.47		
Fine sand	0.28	0.17	0.23	-0.52	-0.18
Medium sand	0.16				
Coarse sand					
Gravel			-0.25		
Pebbles	-0.48	-0.24	-0.41	0.68	0.59

Prediction equations for Winter from Summer oceanographic data

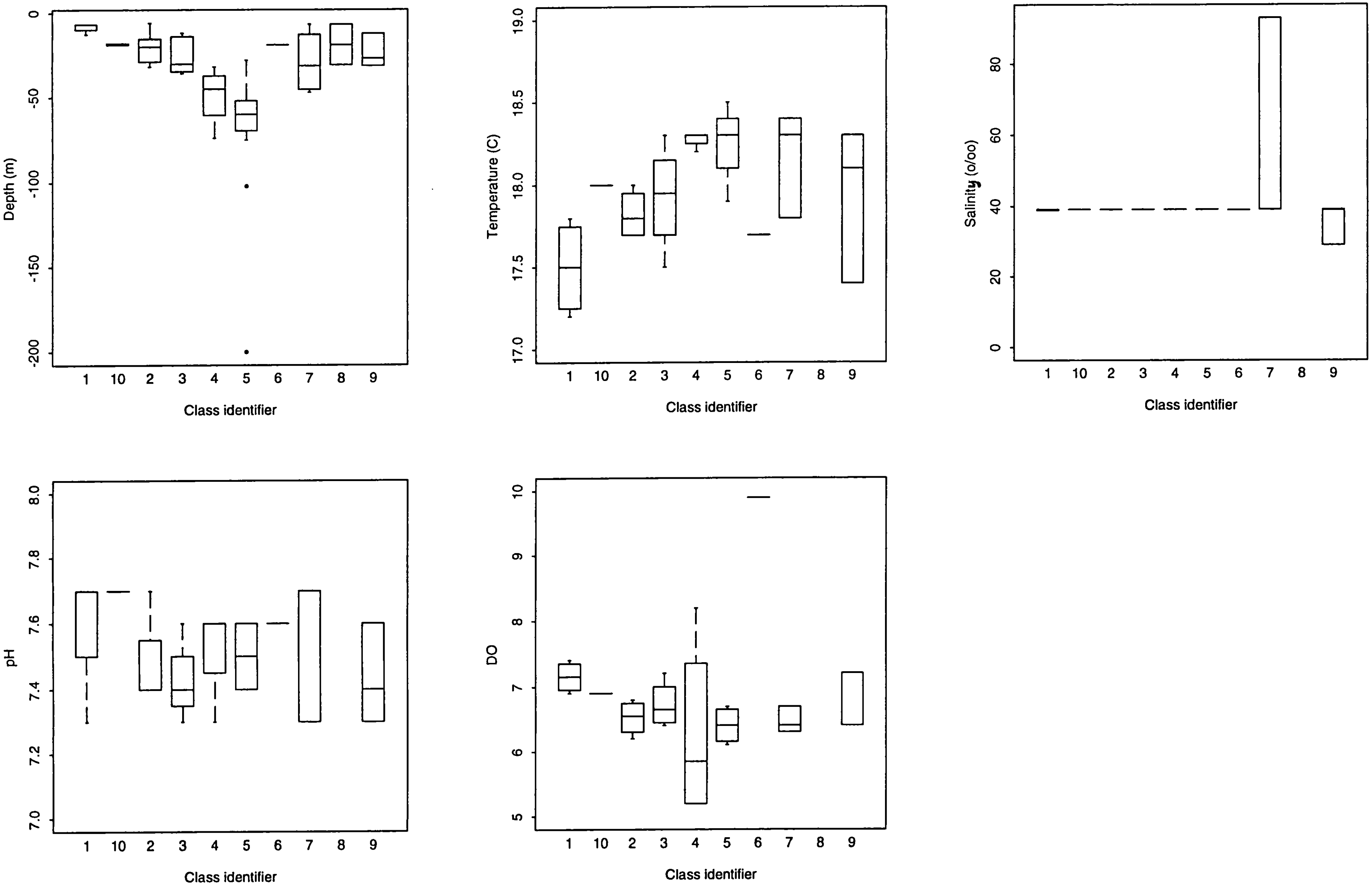
y=b0+b1*x

	b0	b1	x	
Depth.W	-0.9779	0.9699	Depth.S	*
Salinity.W	39.1147	0.000912	Salin.S	*
Temp.W	22.341	-0.2401	Temp.S	*
pH.W	7.5	0	pH.S	*
DO.W	9.7	-0.3333	DO.S	*
log10(Cd.W)	-0.3072	0.7243	log10(Cd.S)	
log10(Cr.W)	0.3905	0.4901	log10(Cr.S)	
log10(Cu.W)	0.2885	0.7748	log10(Cu.S)	
log10(Pb.W)	0.5443	0.5376	log10(Pb.S)	*
log10(Zn.W)	0.3774	0.6423	log10(Zn.S)	*
log10(Cd.S)	-0.7504	0.7263	log10(Pb.S)	
log10(Cd.W)	-2.0233	1.3994	log10(Pb.W)	
log10(Cd.W)	-0.9051	0.4801	log10(Pb.S)	*
log10(Cr.S)	-0.1881	0.9195	log10(Zn.S)	
log10(Cr.W)	0.0455	0.6276	log10(Zn.W)	
log10(Cr.W)	0.1881	0.4745	log10(Zn.S)	*
log10(Cu.S)	-0.9941	1.393	log10(Zn.S)	
log10(Cu.W)	0.1747	0.819	log10(Zn.W)	
log10(Cu.W)	-0.5023	1.1066	log10(Zn.S)	*

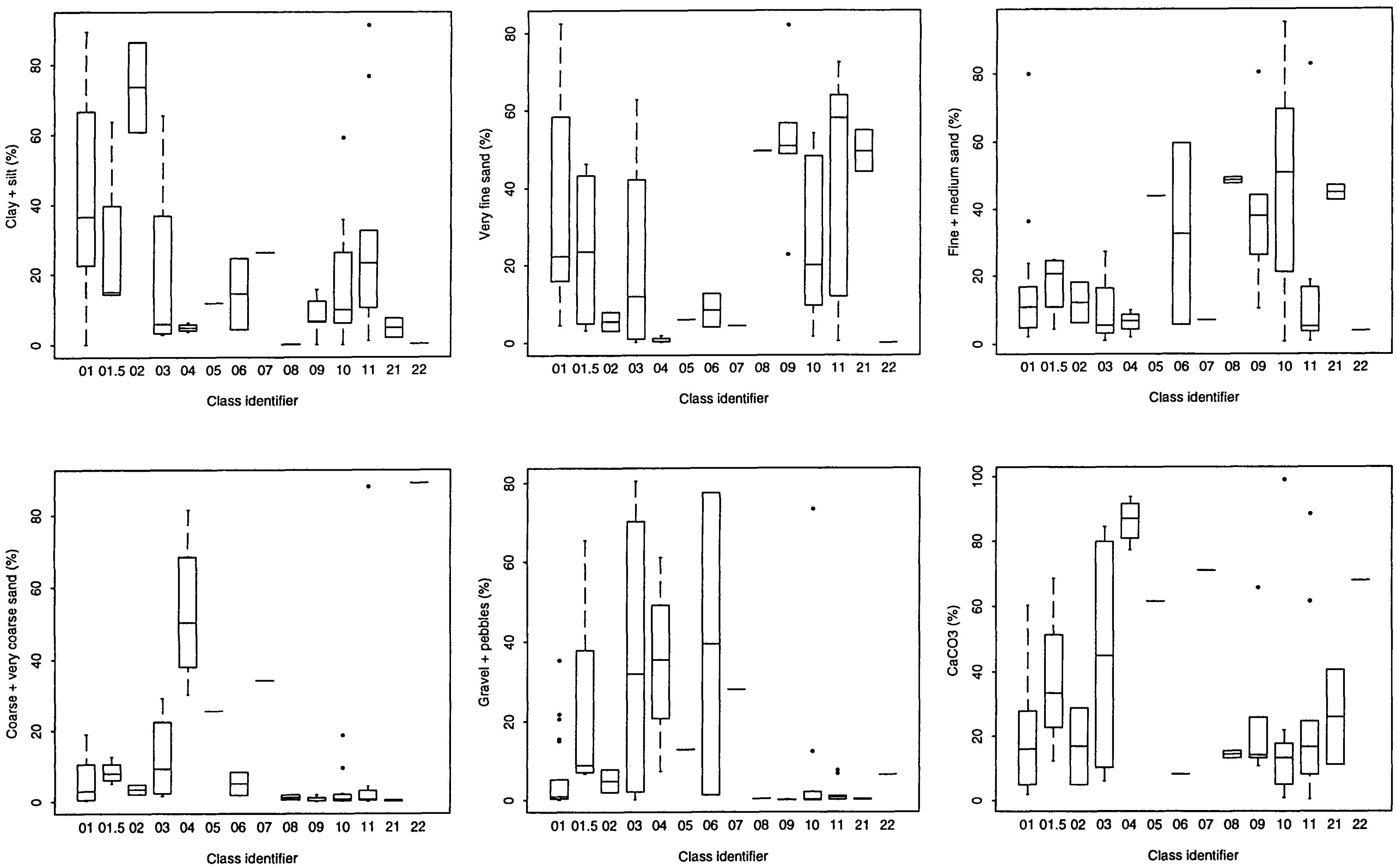
* = used for fill-in

APPENDIX 3

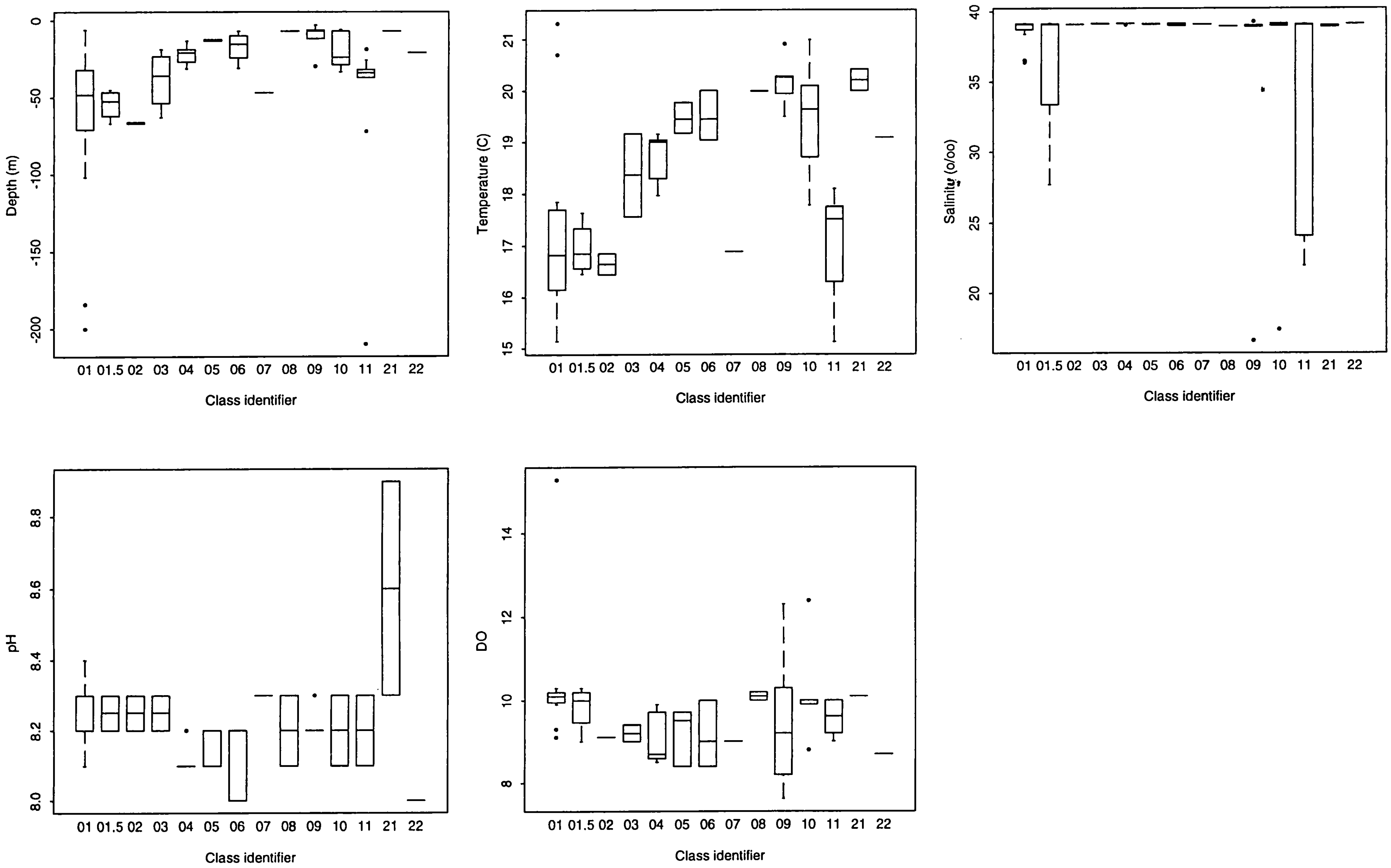
Cluster Analysis parameters



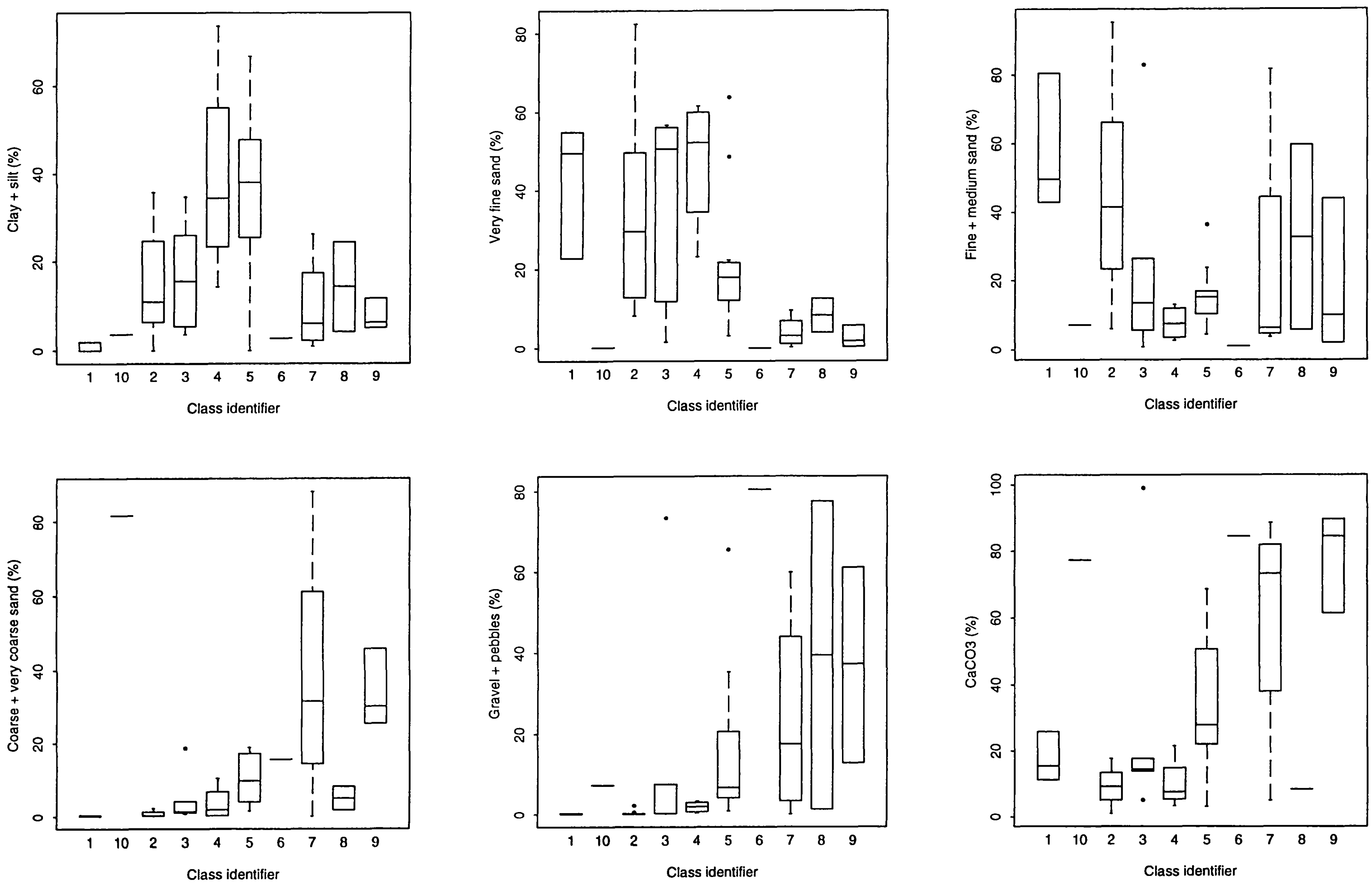
Cluster groups as function of physical parameters (Winter)



Cluster groups as function of sediment composition



Cluster groups as function of physical parameters



Cluster groups as function of sediment composition (Winter)

APPENDIX 4

Results of Principle Components Analysis

percentage variance accounted for	PC1	PC2	PC3	PC4	PC5	PC6
	4.92	**4.54**	**4.19**	**3.59**	**3.28**	**3.05**
Adelosina brongniartana	0.1	-0.1	-0.43	-0.29	-0.16	0.09
Adelosina cliarensis	0.12	0.15	0.03	-0.14	0.18	0.05
Adelosina dubia	0.06	-0.08	0.08	0.23	0.03	-0.08
Adelosina duthiersi	0.09	-0.09	0.12	0.05	0.07	0.14
Adelosina elegans	0.11	-0.04	-0.52	-0.04	-0.25	-0.1
Adelosina elegans var. separans	0.19	0.08	0.19	0.31	0.12	-0.02
Adelosina elegans var. angulata	0.1	-0.05	-0.45	-0.36	-0.25	-0.1
Adelosina elegans var zigzag	-6	0.29	0.22	0.08	-0.34	-0.06
Adelosina intricata	0.17	0.39	-0.38	0.07	0.18	-1.3
Adelosina mediterranensis	0.11	0.08	-0.26	-0.2	-0.17	-0.11
Adelosina partchi	0.02	0	-0.04	-0.07	0.05	0.07
Adelosina pulchella	0.16	0.23	-0.13	-0.25	0.33	-0.08
Adelosina sp1	0.17	0.13	-0.03	0.35	0.06	0.1
Adelosina sp2	0.08	0.02	-0.26	-0.04	-0.02	-0.29
Ammonia inflata	0.15	0.32	-0.04	-0.24	0.09	0.14
Ammonia parkinsoniana	0	-0.25	0.18	0.03	0.07	0.05
Ammonia tepida	-0.02	-0.34	0.29	-0.02	0.07	0.24
Amphicorina sp	-0.6	0.26	-0.02	0.02	-0.18	0.25
Amphisorus hemprichii	0.15	-0.09	0.21	0.07	-0.06	-0.06
Amphistegina lessonii	0.01	-0.28	0.05	0.06	-0.07	-0.48
Amphistegina lobifera	-0.09	-0.48	0.19	0.1	-0.1	-0.3
Articulina carinata	0.04	-0.14	0.08	0.1	0.05	-0.33
Articulina pacifica	0.32	0.16	0.32	0.08	-0.12	0.08
Assillina ammonoides	0.02	0.04	-0.02	0.08	-0.03	-0.06
Astacolus crepidulus	-0.11	0.05	-0.06	-0.04	0.16	0.12
Asterigerinata mamilla	-0.03	0.08	-0.23	0.09	0.17	0.26
Astrononion stelliger	0.15	0.43	0.18	-0.15	-0.19	-0.2
Bigenerina nodosaria	-0.15	0.11	-0.07	-0.02	0	0.14
Biloculinella globula	0.08	-0.01	-0.08	-0.02	0.02	-0.05
Biloculinella labiata	0.14	0.11	-0.15	-0.14	0.04	0.09
Bolivina variabilis	-0.05	0.46	0.3	0.06	-0.23	-0.2
Brizalina striatula	-0.38	0.29	0.11	0.06	-0.06	-0.13
Brizalina spathulata	-0.62	0.42	0.23	0.02	-0.16	-0.14
Bulimina costata	-0.04	0.14	0.11	0.06	-0.23	0.02
Bulimina elongata	-0.49	0.22	0.1	0.08	-0.24	0.03
Bulimina marginata	-0.61	0.29	0.22	0.08	-0.034	-0.06
Challengerella bradyi	0.16	-0.02	-0.4	-0.4	-0.23	-0.12
Cibicides advenus	0.02	-0.05	-0.21	0.13	0.03	-0.12
Cibicides refulgens	-0.03	0.15	-0.07	0.39	-0.24	0.15
Clavulina cf. C. multicamerata	-0.03	-0.08	0.06	-0.05	0	0.09
Conorbella patelliformis	0.02	-0.14	-0.18	-0.15	0.02	-0.22
Coscinospira hemprichii	0.35	0.16	0.39	-0.05	-0.29	0.22
Cycloforina cf. c. quinquecarinata	0.07	0.09	0.09	0.13	0.31	0.03
Cycloforina sp.	0.08	0.13	0.07	0.2	0.2	-0.02
Cycloforina tenuicollis	0.16	0.15	0.16	0.25	0.37	0.07
Cymbaloporetta bermudezi	0.14	0.07	-0.2	-0.06	0.01	-0.3
Disconorbis bulbosus	0.11	0.08	-0.01	-0.05	-0.01	-0.02

percentage variance accounted for	PC1	PC2	PC3	PC4	PC5	PC6
	4.92	**4.54**	**4.19**	**3.59**	**3.28**	**3.05**
Discorbinella berthelotti	-0.05	0.31	-0.26	-0.13	0.23	-0.27
Edentostomina cultrata	-0.14	0.44	0.02	-0.03	0.11	-0.47
Elphidium gerthi	-0.2	0.15	-0.18	-0.16	0.25	0.26
Elphidium jen seni	0.08	0.02	-0.16	-0.04	0.07	-0.07
Elphidium cf. E advenum	0.08	-0.07	-0.35	-0.02	-0.17	0.01
Elphidium cf.limbatum	-0.12	0	-0.14	-0.09	0.05	0.27
Elphidium crispum	0.17	-0.06	-0.19	-0.22	-0.1	-0.28
Elphidium depressulum	-0.02	0.05	-0.13	-0.07	0.08	0.1
Elphidium macellum	-0.17	0.21	-0.34	-0.03	0.17	0.27
Elphidium margaritacum	0.16	-0.21	-0.33	-0.01	-0.12	-0.32
Elphidium sp1	0	-0.09	-0.02	0.01	0.01	-0.87
Elphidium sp2	-0.11	-0.09	-0.45	0.32	0.02	-0.33
Elphidium striatopunctatum	0.07	0.01	0.02	-0.05	0.15	0.08
Elphidium translucens	0.22	0.15	-0.24	-0.05	-0.13	-0.09
Eponides concameratus	0.05	-0.13	-0.25	0.13	0.08	-0.23
Fursenkoina acuta	0.01	0	-0.32	0.22	-0.21	-0.91
Fussurina orbignyana	-0.45	0.51	0.18	0.02	-0.08	-0.41
Gavelinopsis praegeri	0	-0.12	0.09	0.01	-0.03	0.11
Glandulina laevigata	-0.16	0.17	-0.17	-0.15	0.27	0.15
Globulina gibba	0.01	0.05	-0.1	0.04	-0.03	-0.1
Hauerina diversa	0.19	-0.23	0.24	0.17	-0.03	-0.23
Haynesina depressula	-0.09	0.36	0.05	-0.16	0.3	-0.16
Haynesina sp.	0	-0.11	-0.02	-0.98	-0.01	0
Heterostegina depressa	-0.02	-0.37	0.13	0.21	-0.61	-0.35
Lachlanella undulata	0.01	-0.21	0.04	0.03	-0.14	-0.34
Lachlanella variolata	0.01	-0.22	0.07	0.04	-0.17	-0.35
Lenticulina gibba	-0.28	0.08	0.07	-0.01	-0.08	0.09
Lobatula lobatula	-0.16	0.13	-0.24	-0.18	0.19	0.33
Massilina secans	0.09	-0.08	0.14	0.03	-0.02	0.02
Melonis affinis	-0.61	0.28	0.14	0.11	-0.24	0
Miliolinella dilatata	0.09	0.03	-0.14	0.01	0.11	-0.17
Miliolinella grata	-0.16	0.06	-0.1	-0.06	0.03	0.16
Miliolinella labiosa	0.18	-0.01	0.22	0.3	0.06	-0.04
Miliolinella subrotunda	0.23	0.17	0.27	0.09	0.01	0.07
Miliolinella webbiana	0.04	-0.14	0.08	0.1	0.05	-0.33
Monalysidium aciculare	0.12	0.12	-0.24	0.7	-0.26	0.12
Neoconorbina terquemi	0.22	0.2	-0.06	0.13	-0.01	0.02
Nodosaria lamnulifera	0.12	0.01	-0.21	-0.43	-0.02	0
Nonion sp.	-0.31	-0.44	-0.09	-0.01	-0.12	-0.34
Nonionella sp	-0.17	0.31	-0.1	-0.1	0.39	0.04
Nonionella turgida	0.09	0.09	-0.01	-0.06	0.25	-0.04
Pararotalia spinigera	0.07	-0.26	0.37	0.07	0.04	0.29
Parrina bradyi	0.09	-0.01	-0.06	0	0.13	-0.09
Peneroplis pertusus	-0.08	-0.4	0.25	0.04	0.11	0.1
Peneroplis planatus	0.04	-0.18	0.18	0.02	-0.11	0.04
Pesudonodosaria comatula	-0.36	0.14	0.11	0.06	-0.23	0.02
Planorbulina mediterranensis	0.23	0.11	0.24	0.22	-0.04	-0.06

percentage variance accounted for	PC1	PC2	PC3	PC4	PC5	PC6
	4.92	**4.54**	**4.19**	**3.59**	**3.28**	**3.05**
Planorbulinella larvata	0.07	0.58	0.04	0	0.02	-0.32
Polymorphina sp.	0.03	0.23	0.01	0.11	-0.01	-0.23
Polymorphina sp.2	0.15	0.13	-0.1	0	-0.18	10.1
Polymorphina sp.4	-0.11	0.44	0.05	-0.44	0.07	-0.43
Polymorphina sp.5	0.17	0.17	-0.45	0.62	-0.3	0.08
Porosononion subgranosus	-0.1	0.17	-0.17	0.04	0.13	0.15
Ammoina falsobeccarii	0.08	0.05	-0.03	-0.03	0.06	-0.18
Pseudomassilina reticulata	0.38	0.28	0.27	-0.05	0.01	0.14
Pseudotriculina oblonga	0.21	0.05	-0.25	0.38	0.07	-0.08
Pseudotriloculina sp.	0.09	-0.04	-0.09	0.23	0.07	0.03
Pseudotriloculina laevigata	0.06	-0.02	-0.13	0.09	0.23	-0.08
Pseudotriloculina rotunda	0.11	0.1	-0.12	0.04	0.3	-0.08
Pseudotriloculina subgranulata	0.21	-0.12	0.01	0	0.01	-0.21
Pseudopyrgo milletti	0.35	0.3	0.24	-0.06	0.25	-0.03
Pyramidulina catesbyi	-0.09	-0.12	-0.92	-0.08	-0.81	-0.91
Pyrgo anomala	-0.11	0.09	-0.16	-0.07	0.02	0.11
Pyrgo elongata	-0.14	-0.02	-0.02	-0.04	0.15	-0.13
Pyrgo striolata	-0.03	-0.15	-0.13	0.01	0.19	-0.2
Quinqueloculina jugosa	-0.02	-0.06	0.15	0.04	0.03	0.04
Quinqueloculina bosciana	0.11	-0.05	-0.01	0.03	0.25	-0.31
Quinqueloculina cf. Q limbata	0.01	-0.05	0.07	-0.05	-0.03	0.06
Quinqueloculina cf. Q. multimarginata	0.12	0.12	-0.42	0.7	-0.26	0.12
Quinqueloculina disparilis	0.07	-0.03	-0.18	-0.08	0.1	-0.2
Quinqueloculina lavigata	0.08	-0.06	0.1	0.05	-0.01	-0.07
Quinqueloculina parvula	-0.02	-0.04	0	0.09	0.07	-0.05
Quinqueloculina pseudobuchiana	0.12	0.12	-0.24	0.7	-0.26	0.12
Quinqueloculina seminula	0.01	0	-0.1	-0.1	0.06	-0.01
Quinqueloculina stelligera	0.27	0.4	0.27	0.12	0.3	0
Rectouvigenina phlegeri	-0.39	0.22	0.03	0.01	-0.41	0.09
Rectuvigarina sp.	-0.01	-0.3	-0.01	0.03	-0.32	-0.01
Reussella spinulosa	-0.05	0.07	-0.25	-0.09	0.02	0.24
Rosalina pellucida	0.09	0.43	0.14	0.21	0.41	-0.2
Rosalina bradyi	-0.23	0.1	-0.16	0.02	0	0.23
Rosalina globularis	-0.31	0.12	-0.1	-0.02	-0.02	0.24
Rosalina macropora	-0.13	0.1	-0.12	0.14	-0.08	0.2
Rosalina orientalis	-0.23	0.14	-0.1	-0.31	0.02	0.21
Rolshausenia rolashuseni	0.01	-0.03	0.12	0.05	-0.09	-0.06
Sigmoilinita costata	0.26	0.26	0.2	0	0.04	0.05
Sigmoilinita edwardsi	0.12	-0.06	0.17	0.03	0.09	0.08
Siphenotextularia concava	0.2	0.11	-0.02	0.36	0.34	-0.27
Siphonaperta agglutinans	0.05	0.15	0.14	-0.05	0.26	-0.02
Siphonaperta aspera	0.1	0.13	0.27	0.02	0.17	0.16
Siphonaperta dilitata	0.12	0.04	0.11	0.12	0.13	0.09
Siphonaperta osinolinatum	0.11	0.05	0.14	0.06	0.13	-0.03
Sorites orbiculus	-0.03	-0.33	0.25	0.08	-0.03	0.2
Sphaerogypsina globula	0.02	-0.16	0.06	-0.12	0.02	0.05
Spiroloculina angulata	0.13	0.22	0.08	-0.4	-0.27	-0.19

percentage variance accounted for	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
	4.92	**4.54**	**4.19**	**3.59**	**3.28**	**3.05**
Spiroloculina angulosa	0.37	0.32	0.09	-0.23	-0.32	0.03
Spiroloculina antillarum	0.29	0.11	0.2	-0.12	-0.1	0.11
Spiroloculina cf S. cymbium	-0.16	-0.13	-0.45	-0.14	-0.19	0.29
Spiroloculina depressa	0.28	0.39	0.22	-0.15	-0.08	-0.19
Spiroloculina dilatata	0.23	0.09	-0.48	-0.35	-0.41	-0.05
Spiroloculina hadai	0.44	0.29	0.41	-0.03	0.28	0.16
Spiroloculina ornata	0.33	0.25	0.23	-0.25	-0.41	0.12
Spiroloculina ornata var tricarinata	0.26	0.27	0.2	0.11	0.04	0.05
Spiroloculina rostata	0.07	0.1	0.08	-0.1	-0.12	0.25
Spiroloculina sp1	0.35	0.35	0.12	-0.17	-0.37	0.13
Sproloculina costifera	-0.13	0.43	0.22	-0.04	-0.71	-0.11
Sproloculina excavata	0.29	0.24	-0.07	-0.2	-0.16	-0.09
Sproloculina sp2	-0.82	-0.22	0.41	-0.42	-0.32	-0.89
Asterorotalia gaimardii	0.09	-0.02	-0.19	-0.33	0.33	-0.05
Textularia agglutinans	0.14	0.1	-0.44	0.18	-0.18	-0.19
Textularia bocki	0.15	0.45	-0.14	0.18	0.17	-0.41
Textularia conica	0.32	0.09	0.1	0.08	-0.1	-0.27
Textularia truncata	0.11	0.03	-0.19	-0.98	-0.41	0.91
Triloculina affinis	0.23	0.2	-0.13	0.03	0.07	0.12
Triloculina assymmetrica	0.18	0.13	-0.42	-0.15	-0.27	0.09
Triloculina marioni	0.09	0.32	-0.29	-0.1	0.12	0.31
Triloculina ornata	-0.98	-0.44	0.63	0.12	0.22	0.21
Triloculina plicata	0.16	0.16	-0.12	-0.2	-0.09	0.17
Triloculina schreiberiana	0.36	0.3	0.13	-0.02	0.18	0.04
Triloculina serulata	0.29	0.32	-0.08	0.12	0.11	0.11
Triloculina tricarinata	0.93	-0.16	-0.72	-0.65	-0.33	0.81
Valvulincria bradyana	-0.23	-0.11	0	-0.71	0.23	0.71
Vertebralina striata	0.27	0.23	0.08	0.45	0.16	0.12
Wiesnerella auriculata	0.12	0.12	-0.24	0.7	-0.26	0.12

APPENDIX 5

Distribution of species in Spring, 1993

The distribution of the species occurred in the study area in spring (May, 1993).

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Depth / m	7	7	7	7	7	7	6.5	13	13	14	13	14	12	16	21	19	21	19	18	32	30	29	27	25	16	19	26	29	20	32	32	24	32
Species list																																	
Adelosina brongniartana																								2									
Adelosina chiarensis																					2	1							1	3	3	2	2
Adelosina dubia															1																		
Adelosina duthiersi														1										2	2	1		1					2
Adelosina elegans																								1				1					
Adelosina elegans var. separans															1					1							1						
Adelosina elegans var. angulata																							1	1				1					
Adelosina elegans var zigzag																				1	1		1				1	1					
Adelosina intricata																1				2	2	1	1			1		1	1	1	1	2	1
Adelosina mediterranensis																4											1		1				
Adelosina partchi																																	
Adelosina pulchella												1				3			3		1	1	2					1	1	1	2		2
Adelosina sp1																																	
Adelosina sp2																			1							6	1		3			5	
Ammonia inflata	3								1	1	2			3		6				5	1		2					1	9	2	7		2
Ammonia parkinsoniana													8	4	8				2				1	4	2			1		2			
Ammonia tepida	18	23	21	19	12	16	22		8	5	7		14	11					8	5	5	8	7	6	10	5		1				7	
Amphicorina sp																																	
Amphisorus hemprichii			1											1											1								
Amphistegina lessonii												7							7						6	5							
Amphistegina lobifera				8	8			16	19	24	21	16			18		46	31	20							7							
Articulina carinata																																	
Articulina pacifica														1											1		1						1
Assilina ammonoides																																	
Astacolus crepidulus																																	
Asterigerinata mamilla				9	3	2			1	1	1			2	8				2		1	1			2	1	3		8	16		19	11
Astrononion stelliger														2					2							1			4	1			
Bigenerina nodosaria																																	
Biloculinella globula															1									1			1					1	
Biloculinella labiata													1								1									1			1
Bolivina variabilis														1					1				1							5			
Brizalina striatula																														8			
Brizalina spathulata																														1		1	1
Bulimina costata																																	
Bulimina elongata																																	
Bulimina marginata																																	
Challengerella bradyi				3								1									1				2	1		1	1	1	5	2	
Cibicides advenus					2																		1	1									1
Cibicides refulgens						1	1							1												1				1			
Clavulina cf. C. multicamerata	1																								1								
Conorbella patelliformis																3			1														
Coscinospira hemprichii													3	5													4	6	5				
Cycloforina cf. c. quinquecarinata																						1											
Cycloforina sp.																				2													
Cycloforina tenuicollis																				1		1	1	1									
Cymbaloporetta bermudezi																1																	1
Disconorbis bulbosus																																	
Discorbinella berthelotti																8			1	2						1		1	1	1	8		3
Edentostomina cultrata																			2														

Station	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
Depth / m	30	28	28	27	32	34	34	33	36	32	48	47	45	43	48	44	47	67	67	67	45	72	210	200	184	82	75	66	54	20	31	14	20
Species list																																	
Adelosina brongniartana									6				4	1	2														1				
Adelosina chiarensis			2			2	1		2	2		2					1				1				1					4	3		8
Adelosina dubia																																	
Adelosina duthiersi	4	2					1	1				2																					
Adelosina elegans									4	5			6	1	4				1									1	1				
Adelosina elegans var. separans																																	
Adelosina elegans var. angulata							1		3	2			2	1	8			1	1														
Adelosina elegans var zigzag																	1	1															
Adelosina intricata			1			2	1	1	7	2		2		2	6		1	1		2		1				1	1			4			
Adelosina mediterranensis																		1						1					1				
Adelosina partchi							1																										
Adelosina pulchella					1		4	2	2	3	2			3					1		1					1		1	1	6			
Adelosina sp1														1	2																		
Adelosina sp2		1					3	7																							6	8	6
Ammonia inflata		2	5				5	2	3	6	4	3		4				1	1	5	1	1	1	1	1	2		1	1	9			
Ammonia parkinsoniana											5																				12	14	11
Ammonia tepida	11						7	9	5								6					3			1						17		16
Amphicorina sp																		1	1	1		1	3	4	2	2	1						
Amphisorus hemprichii		3	2		1																												
Amphistegina lessonii				9	6				3						8	7																	
Amphistegina lobifera				35	21			7								11	6														38		
Articulina carinata					1																												
Articulina pacifica																																	
Assilina ammonoides																																	
Astacolus crepidulus				1																													
Asterigerinata mamilla	8	4	12			16	8	15	14		19	27					2	13	9	18	7	11		1	1	1	1	7	8	8	6	11	19
Astrononion stelliger																												1	1				
Bigenerina nodosaria																										1							
Biloculinella globula		1			2			2																									
Biloculinella labiata								1		5				1													1	1	1	2			
Bolivina variabilis												1											7		5								
Brizalina striatula												2											5		4								
Brizalina spathulata			1				4					2									1		11		13								
Bulimina costata																									13								
Bulimina elongata																							11	14									
Bulimina marginata																							16		10								
Challengerella bradyi	1	1				3				3			19	6	4													1	1	3			
Cibicides advenus			2												5																		
Cibicides refulgens			1							2		2				1								1	1		1						
Clavulina cf. C. multicamerata																																	
Conorbella patelliformis		1	1	1	1	1							13			1	1	1	1											4	3	9	
Coscinospira hemprichii		3																								1							
Cycloforina cf. c. quinquecarinata																																	
Cycloforina sp.																																	
Cycloforina tenuicollis																																	
Cymbaloporetta bermudezi															2																		
Disconorbis bulbosus																																	
Discorbinella berthelotti		1	1					2	4	4	4	7		6	9	2		1		1	3	2	1	1		1	1	1	1	7	9	12	16
Edentostomina cultrata										4				3																			

The distribution of the species occurred in the study area in spring (May, 1993).

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Depth / m	7	7	7	7	7	7	6.5	13	13	14	13	14	12	16	21	19	21	19	18	32	30	29	27	25	16	19	26	29	20	32	32	24	32
Species list																																	
Elphidium gerthi																																	
Elphidium jenseni																																	
Elphidium cf. E advenum			1			2																											
Elphidium cf.limbatum																																	
Elphidium crispum				1								13				9		3	1						6	8			5	4		3	5
Elphidium depressulum																																	1
Elphidium macellum																									1								
Elphidium margaritacum																																	
Elphidium sp1																																	
Elphidium sp2																																	
Elphidium striatopunctatum																						1	1			1		1					
Elphidium translucens														1																	1		
Eponides concameratus																7			1														
Fursenkoina acuta																																	
Fussiurina orbignyana																																	
Gavelinopsis praegeri													2																				
Glandulina laevigata																																	
Globulina gibba																																	
Haucerina diversa		1					7	1		1	1			2	5				1				1		12	6	7	5					6
Haynesina depressula														2					1		1												
Haynesina sp.																																	
Heterostegina depressa								7		10		9			7		11	14					4										
Lachlanella undulata																																	
Lachlanella variolata																																	
Lenticulina gibba																																	
Lobatula lobatula						1		1													1	1			2	5			2	1	5		2
Massilina secans																																	
Melonis affinis																						1	1							2			
Miliolinella dilatata																																	
Miliolinella grata																																	
Miliolinella labiosa														2	8				1	2	1			1	2		1	1					
Miliolinella subrotunda														1									2										
Miliolinella webbiana																																	
Monalysidium aciculare																																	
Neoconorbina terquemi								1						1	4								2		1	1	1		1	2			2
Nodosaria lamnulifera																																	
Nonion sp.																																	
Nonionella sp																					4			1									
Nonionella turgida																					1												
Pararotalia spinigera	4		8	7	6	9	29		3	4	4		8	6							7	8	7		11		9	7		8			
Parrina bradyi								1																									
Peneroplis pertusus			11	13	15	10	20	21	18	11	15		4	2					9						21			6					
Peneroplis planatus								9					1					10							17			7					
Pesudonodosaria comatula																																	
Planorbulina mediterranensis			2											2	5					2	1		1					1	2	1			1
Planorbulinella larvata																							1					1	1	1			1
Polymorphina sp.																																	1
Polymorphina sp.2																																	
Polymorphina sp.4																																	

Station	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
Depth / m	30	28	28	27	32	34	34	33	36	32	48	47	45	43	48	44	47	67	67	67	45	72	210	200	184	82	75	66	54	20	31	14	20
Species list																																	
Elphidium gerthi																			1								1						
Elphidium jenseni								3	6					2																			
Elphidium cf. E advenum	1					2		7	4					2				1									1	1					
Elphidium cf.limbatum																			1														
Elphidium crispum		3	6		9	11		6	2	2	5	5	15	4			1	1	1		1	1				1	1	1	1	5			
Elphidium depressulum									2	1				2					1					1				1					
Elphidium macellum								1	2					2					1		1			1			1	1					
Elphidium margaritacum																																	
Elphidium sp1																			1		1												
Elphidium sp2																																	
Elphidium striatopunctatum		1							3																								
Elphidium translucens						1			1			3		5														1					
Eponides concameratus		2	1	2	1	2							10			2	1	1	1									1	1	5	4	13	12
Fursenkoina acuta																							2		1								
Fussiurina orbignyana																							3										
Gavelinopsis praegeri																																	
Glandulina laevigata																					1												
Globulina gibba																												1	1				
Haucerina diversa				9	5			9		12				15		12																	
Haynesina depressula							2		2												1	1											
Haynesina sp.																																	
Heterostegina depressa			12	19	9																										7		
Lachlanella undulata				1				1																									
Lachlanella variolata				8				3																									
Lenticulina gibba																				1			2										
Lobatula lobatula		1			2	1	1	2	5	3				7		2	1	8	7	10	1	12		1		5	7	3	6	3			
Massilina secans		10																															
Melonis affinis			1									3											14	11	15								
Miliolinella dilatata								1						3																			
Miliolinella grata								1												1						1							
Miliolinella labiosa																																	
Miliolinella subrotunda																																	
Miliolinella webbiana					1																												
Monalysidium aciculare																																	
Neoconorbina terquemi		1	1			3		2		5	2	3					1				1	1											
Nodosaria lamnulifera																						1											
Nonion sp.																																	
Nonionella sp							1														3	5									2		5
Nonionella turgida							1																							6			
Pararotalia spinigera																																	
Parrina bradyi														4																9			
Peneroplis pertusus			1																														
Peneroplis planatus		1																															
Pesudonodosaria comatula																									1								
Planorbulina mediterranensis					1							4																					
Planorbulinella larvata										2		2		1																			
Polymorphina sp.												2									1	1		1		1		1					
Polymorphina sp.2						1																											
Polymorphina sp.4						1																											

The distribution of the species occurred in the study area in spring (May, 1993).

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
Depth / m	7	7	7	7	7	7	6.5	13	13	14	13	14	12	16	21	19	21	19	18	32	30	29	27	25	16	19	26	29	20	32	32	24	32	30	28	28	27	32	34	34	33	36	32	48	47	45	43	48	44	47	67	67	67	45	72	210	200	184	82	75	66	54	20	31	14	20
Species list																																																																		
Polymorphina sp.5																																							1																											
Porosononion subgranosus																						2	1				1	1		2			1								2													1	1	1	1	1	1		1	1				
Ammonia falsobeccarii														1		5			1						6	12						6			4	4					1							32		1	1	1	2				1	1	1	1	1	1	15			
Pseudomassilina reticulata														1							1	1						1	1	2			1		1							1																								
Pseudotriculina oblonga															6	3					1				1	6		1				2										5					5			1		1										1	7			
Pseudotriloculina sp.													2								1	1	1		1	1	1	1		2	1		1			2																											5	6	3	4
Pseudotriloculina laevigata																					1		1	1	1	7	1													1	1	3					7		9	1		1					1						3			
Pseudotriloculina rotunda																						2																									7			1													5			
Pseudotriloculina subgranulata																									1		1				1				1							1																								
Pseudopyrgo milletti																					2	1	2					1	1	1	2		1					1		1					2		2																			
Pyramidulina catesbyi																																																						1		1										
Pyrgo anomala																																											3									1								1						
Pyrgo elongata																			1							1												1		1																				1						
Pyrgo striolata																			1							1												1		1																				1						
Quinqueloculina jugosa																														8																																				
Quinqueloculina bosciana																																					2		2																											
Quinqueloculina cf. Q limbata		1																																																																
Quinqueloculina cf. Q. multimarginata																																																																		
Quinqueloculina disparilis																		2	2							3							8		5	4				5	15		9			18	9	11	7	9	2								3				7			
Quinqueloculina lavigata																																			5	6		1																												
Quinqueloculina parvula																																																	1																	
Quinqueloculina pseudobuchiana																																																																		
Quinqueloculina seminula																																								2	11	8	12	15																						
Quinqueloculina stelligera					2									2					1	13	15	5	18		20	11	8			13	11	9	7												13											1										
Rectouvigenina phlegeri																																																								1			1							
Rectuvigarina sp.																				2																																				4	7	6								
Reussella spinulosa																									8								2		1				1		1	4		6	3							9					1	1			20	8				
Rosalina pellucida																				3	1	3	1				1	1		1						1			1	1		1					2		3											2						
Rosalina bradyi																					1					7	1	1	1	1					1				3	1	2	4			2				12	1	15	12			11			18			9	4	3			
Rosalina globularis			1					1						1					1		1		1							1					1	2				1	1	1		6			3	2	7	1	5	5					3	9	8	4			5			
Rosalina macropora				1	3	1	8	1	1	1	1			1	5					2				1	4		1	1	1						1			1	3		3	6					3	7	5								12		9	21			11			
Rosalina orientalis																																																				1			1											
Rolshausenia rolashuseni																																																																		
Sigmoilinita costata																					1					1	1	1		2	2	1	3		1	1						2			2													1								
Sigmoilinita edwardsi																					1											1			1																															
Siphonotextularia concava															1	1				1		1	1			1							1					1			1						2		1														2			
Siphonaperta agglutinans																							1							1										1																										
Siphonaperta aspera														1								1	1	1	1	1	1	1		1	1	1		1						1																1										
Siphonaperta dilitata																							1	1																																										
Siphonaperta osinolinata																				1											1																																			
Sorites orbiculus			20		17	12	13						9								6			5	6			4																																						
Sphaerogypsina globula																																																																		
Spiroloculina angulata																									1			1	1	1	1								1																											
Spiroloculina angulosa																													1		1								1																											
Spiroloculina antillarum		2												2							1		1		1				2		1				1	1						2					4																3			
Spiroloculina cf S. cymbium														2											1		1	1	4				2				1																										2			
Spiroloculina depressa		2												1		1					1		1		1		1	1	3		1	1	2		1	1	1		1			2			4		3																			
Spiroloculina dilatata																1					1								7				1						1		1	3	8			8	5	2											1	1		1				
Spiroloculina hadai														1									1		1		1		1																																					

The distribution of the species occurred in the study area in spring (May, 1993).

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Depth / m	7	7	7	7	7	7	6.5	13	13	14	13	14	12	16	21	19	21	19	18	32	30	29	27	25	16	19	26	29	20	32	32	24	32
Species list																																	
Spiroloculina ornata																									1				1				
Spiroloculina ornata var tricarinata					2									2				1						1	3	1	1	1	1		1	1	2
Spiroloculina rostata																											1		1				
Spiroloculina sp1																							1						2				
Sproloculina costifera																													1				
Sproloculina excavata																				1									4		1		
Sproloculina sp2																					1												
Asterorotalia gaimardii																														1	8		
Textularia agglutinans																																	
Textularia bocki																1				2		1	1		1		1			1			1
Textularia conica														2		1										1	1						
Textularia truncata																																	
Triloculina affinis																3								6		3	5	7		3	1	1	1
Triloculina assymmetrica																							1					1	1	1			2
Triloculina marioni		6																		12	9	5	8	5			4	5	7	3	2		2
Triloculina ornata																																	
Triloculina plicata																									2	2	4	3	1	2			1
Triloculina schreiberiana																2					7		9			5	3	5		3	6		8
Triloculina serulata													1	1		1				2	2		2					1		1		2	2
Triloculina tricarinata																											11						
Valvulineria bradyana																								1									
Wiesnerella auriculata																																	
Vertebralina striata						5	7							6						11	13	11	17	20	13	15		3	1	4	3		2
Absolute abundance	26	35	65	61	70	59	107	59	51	58	52	47	53	75	78	61	57	61	71	73	98	59	109	63	174	130	82	89	89	118	77	67	98
Relative abundance	1	1	1	1	1	1	2.2	1.2	1.1	1.2	1.1	1	1.1	1.6	2	1	1	1	1	1.5	2.1	1.2	2.3	1.3	3.7	2.7	1.7	1.9	1.9	2.5	1.6	1.4	2.1
Number of species	4	6	8	8	10	10	8	10	7	9	8	6	11	34	14	19	2	6	24	21	36	23	40	21	38	34	34	42	37	43	26	19	41
H'	1	1	2	2	2	2	1.8	1.7	1.4	1.7	1.5	1.5	2.1	3.2	2	3	0	1	3	2.6	3	2.7	3.1	2.5	3.1	3.1	3.1	3.3	3.3	3.3	2.9	2.4	3.4
Species diversity	1	2	2	3	3	3	2.2	3.1	2.1	3.1	2.2	2	4	19	5	10	1	2	13	11	20	14	22	11	13	14	23	31	25	26	14	9.1	26
Size >500		1	5	9	10	8	5	15	9		9	17	12	11	12	17	14	15	18	16	10		11	12	28	21	11	16	11	8	3	1	7
Size <500>250	5	6	9	21	23	20	58	32	22	35	29	30	32	18	37	29	31	37	33	20	46	16	35	28	53	32	26	56	27	33	31	23	43
Size <250>125	15	21	36	19	25	18	44	12	13	13	14		9	44	29	13	12	9	20	27	36	41	55	23	77	77	39	17	45	75	43	37	47
Size<125>63	6	7	15	12	12	12			7	10				2		2				10	6	3	8		16		6		6	2		6	1

Station	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
Depth / m	30	28	28	27	32	34	34	33	36	32	48	47	45	43	48	44	47	67	67	67	45	72	210	200	184	82	75	66	54	20	31	14	20
Species list																																	
Spiroloculina ornata																																	
Spiroloculina ornata var tricarinata		1		1					1	1																				4			
Spiroloculina rostata																			1														
Spiroloculina sp1						1																					1						
Sproloculina costifera																																	
Sproloculina excavata								1		7					4															8			
Sproloculina sp2																																	
Asterorotalia gaimardii							3		3	3																						9	14
Textularia agglutinans						1								1	3														1				
Textularia bocki		1	1		1	2		1	1				2	2	2	1										1	1		1	2			
Textularia conica					1	1		1						1	1																		
Textularia truncata																																	
Triloculina affinis						2		1	2			4		2												2	3	4	2	3			
Triloculina assymmetrica						2				1																	3	4	3	3			
Triloculina marioni	4	2	3		1	2		2		7		5	17	9		8		1	3		6	3		5	6	4	10	11	7	9			
Triloculina ornata									2																								
Triloculina plicata						1			4																		7	5		6			
Triloculina schreiberiana						1		1	1		3			1		1												1		4			
Triloculina serulata						2		1	1	1				1		1										1	2	1	1	1			
Triloculina tricarinata												19													1								
Valvulineria bradyana	1					2				2		2		1							1	1						1	1				
Wiesnerella auriculata																																	
Vertebralina striata		6	3			8		4	3	7		12		13		15							2	4			9						
Absolute abundance	31	72	79	90	70	86	60	136	141	124	71	140	114	159	114	109	37	56	64	41	34	58	87	73	113	50	84	83	58	183	113	79	111
Relative abundance	0.7	1.5	1.7	1.9	1	2	1	3	3	3	1.5	2.94	2.39	3.34	2.4	2.3	0.8	1.2	1.3	0.9	0.7	1.2	1.8	1.5	2.4	1	1.8	3.2	2.3	7.2	4.4	3.1	4.3
Number of species	8	34	28	13	23	35	27	41	43	29	12	28	11	43	19	21	18	18	25	9	19	18	19	21	24	23	26	28	29	35	12	8	10
H'	1.7	3.2	2.9	1.8	2	3	3	3	4	3	2.1	2.89	2.2	3.46	2.5	2.7	2.5	2.2	2.7	1.6	2.6	2.4	2.5	2.5	2.6	3	2.7	2.8	2.9	3.4	2.1	2	2.1
Species diversity	3.4	25	16	4.2	12	22	20	22	25	12	4.2	10.5	3.53	23.8	6.6	8.2	14	9.1	16	3.6	18	9.6	7.6	12	9.7	16	13	15	23	13	3.5	2.4	2.3
Size >500		6	5	20	18	11	4	9	19	7	3	10	20	28	21	29		1	3	8		5	14	11		1	15	16	16	39	31	32	23
Size <500>250	16	27	26	42	21	39	20	38	43	31	24	45	37	45	37	34	12	17	16	12	9	23	23	17	34	11	20	29	22	57	66	33	42
Size <250>125	12	39	44	28	31	34	32	81	76	83	44	82	57	79	56	46	25	36	43	19	21	27	46	40	74	32	43	40	20	92	14	14	39
Size<125>63	3		4			2	4	8	3	3		3		7				2	2	2	4	4	4	5	5	6	6						

The distribution of the species occurred in the study area in spring (May, 1993).

Station	67	68	69	70	71	72	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Depth / m	35	51	56	68	63	53	24	7	7	6	7	30	36	57	71	102	6	6.5	6.5	3
Species list																				
Adelosina brongniartana	5		1			1	1	3				2	3	5	2					
Adelosina chiarensis			1	1					1										7	
Adelosina dubia																				
Adelosina duthiersi	5						2	3	2		3	2								4
Adelosina elegans	3	4	1	1		1								3	4					
Adelosina elegans var. separans																				
Adelosina elegans var. angulata	6		1			1								3	7					
Adelosina elegans var zigzag					1													2		
Adelosina intricata	9	1	1	1		2	3	2				2	2			1	1	6		
Adelosina mediterranensis		2			2	1									2					
Adelosina partchi																				
Adelosina pulchella	6			1		2	3	2												
Adelosina sp1																				
Adelosina sp2								4												
Ammonia inflata	7	9	9	5		3	5	3				2				3		3		
Ammonia parkinsoniana					5		11	15	21	17	12									28
Ammonia tepida	5						12	19	20	12	9	11							26	21
Amphicorina sp																				
Amphisorus hemprichii																				
Amphistegina lessonii											6									
Amphistegina lobifera									9		29									
Articulina carinata																				
Articulina pacifica																				
Assilina ammonoides					2															
Astacolus crepidulus																				
Asterigerinata mamilla	10	5	7	9		7	3	4	5	3	3	4	7			5		18	13	
Astrononion stelliger		3			3												1			
Bigenerina nodosaria																				
Biloculinella globula													1					1		
Biloculinella labiata	4		1				2	2												
Bolivina variabilis			3														1		1	1
Brizalina striatula																12	1			
Brizalina spathulata																	1		1	
Bulimina costata																				
Bulimina elongata																				
Bulimina marginata																				
Challengerella bradyi	6	4	3			3	3	2			1	1		2	6	3				
Cibicides advenus									3				4			2		2		
Cibicides refulgens																		3		
Clavulina cf. C. multicamerata			1				1													
Conorbella patelliformis																				
Coscinospira hemprichii																			6	
Cycloforina cf. c. quinquecarinata																				
Cycloforina sp.																				
Cycloforina tenuicollis																				
Cymbaloporetta bermudezi																				
Disconorbis bulbosus																				
Discorbinella berthelotti	4	6	3	3		2			3	1	1	2				6	3	7		
Edentostomina cultrata			4		3	2											4			

The distribution of the species occurred in the study area in spring (May, 1993).

Station	67	68	69	70	71	72	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Depth / m	35	51	56	68	63	53	24	7	7	6	7	30	36	57	71	102	6	6.5	6.5	3
Species list																				
Elphidium gerthi																				
Elphidium jen seni																				
Elphidium cf. E advenum			1			1								2				3		
Elphidium cf.limbatum																				
Elphidium crispum	10	6	1	1		1	7	1				9		5						
Elphidium depressulum				1	2	1						5								
Elphidium macellum				1														1		
Elphidium margaritacum						1														
Elphidium sp1																				
Elphidium sp2																				
Elphidium striatopunctatum							3					6								
Elphidium translucens					1									1				1		
Eponides concameratus	4	4				3							6							
Fursenkoina acuta																				
Fussiurina orbignyana																	1			
Gavelinopsis praegeri																				
Glandulina laevigata			1	1																
Globulina gibba					3															
Hauerina diversa										5	11								7	11
Haynesina depressula		6										1					1			
Haynesina sp.																				
Heterostegina depressa					11						17							9		
Lachlanella undulata																				
Lachlanella variolata																				
Lenticulina gibba									7											
Lobatula lobatula	8	11	9						5	3		6				4				
Massilina secans											3									4
Melonis affinis																15				
Miliolinella dilatata																				
Miliolinella grata																				
Miliolinella labiosa																				
Miliolinella subrotunda																				
Miliolinella webbiana																				
Monalysidium aciculare																		1		
Neoconorbina terquemi						5												2		
Nodosaria lamnulifera																				
Nonion sp.																				
Nonionella sp								3												
Nonionella turgida																				
Pararotalia spinigera	17						11	9	17	21	16	8							8	
Parrina bradyi																				2
Peneroplis pertusus											3								9	11
Peneroplis planatus																			11	
Pesudonodosaria comatula																				
Planorbulina mediterranensis					5															
Planorbulinella larvata				1		1											1	1		
Polymorphina sp.									1								1			
Polymorphina sp.2																				
Polymorphina sp.4							2		1								1			

The distribution of the species occurred in the study area in spring (May, 1993).

Station	67	68	69	70	71	72	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Depth / m	35	51	56	68	63	53	24	7	7	6	7	30	36	57	71	102	6	6.5	6.5	3
Species list																				
Polymorphina sp.5						1												5		
Porosononion subgranosus		9	6	11		6	9	10	7	5						7		7	4	
Ammonia falsobeccarii		8	12	11	9	13	9	10	7				7					2		
Pseudomassilina reticulata	3																			
Pseudotriculina oblonga																		8		
Pseudotriloculina sp.													2			3		6	4	
Pseudotriloculina laevigata		2										2	3							
Pseudotriloculina rotunda				3																
Pseudotriloculina subgranulata	3																	1		
Pseudopyrgo milletti								2												
Pyramidulina catesbyi																				
Pyrgo anomala							2									2				
Pyrgo elongata										1						3				
Pyrgo striolata										2										
Quinqueloculina jugosa										7	6									
Quinqueloculina bosciana																				
Quinqueloculina cf. Q limbata																				
Quinqueloculina cf. Q. multimargina																		1		
Quinqueloculina disparilis		7																	4	
Quinqueloculina lavigata																				
Quinqueloculina parvula																				
Quinqueloculina pseudobuchiana																		1		
Quinqueloculina seminula																				
Quinqueloculina stelligera		12	10	7													2			
Rectouvigenina phlegeri																				
Rectuvigarina sp.																	1			
Reussella spinulosa				9					2									2		
Rosalina pellucida																	1			
Rosalina bradyi					8													4	3	1
Rosalina globularis																			4	
Rosalina macropora			16						12									6	7	
Rosalina orientalis			1			1										8				
Rolshausenia rolashuseni										1										
Sigmoilinita costata																				
Sigmoilinita edwardsi																			1	1
Siphenotextularia concava									1							1		1		
Siphonaperta agglutinans																				
Siphonaperta aspera									2			2								
Siphonaperta dilitata																				
Siphonaperta osinolinata																				2
Sorites orbiculus										14	11								12	15
Sphaerogypsina globula																				
Spiroloculina angulata																				
Spiroloculina angulosa																				
Spiroloculina antillarum	3																		6	
Spiroloculina cf S. cymbium							2	2												
Spiroloculina depressa							5	3									1			
Spiroloculina dilatata	7			5										4	6			7		
Spiroloculina hadai																				

The distribution of the species occurred in the study area in spring (May, 1993).

Station	67	68	69	70	71	72	74	75	76	77	78	79	80	81	82	83	84	85	86	87
Depth / m	35	51	56	68	63	53	24	7	7	6	7	30	36	57	71	102	6	6.5	6.5	3
Species list																				
Spiroloculina ornata																				
Spiroloculina ornata var tricarinata	2																	1		
Spiroloculina rostata									4											
Spiroloculina sp1																				
Sproloculina costifera																				
Sproloculina excavata																				
Sproloculina sp2																				
Asterorotalia gaimardii	5		3	3								2		2	2					
Textularia agglutinans																		2		
Textularia bocki				1	1		2	2	1		1						1	2		
Textularia conica																				
Textularia truncata																				
Triloculina affinis	5		3	2		6	3						2							
Triloculina assymmetrica	5					3									4			4		
Triloculina marioni	9	5	6	9		11	13	6	9	5	2	2		3	3	1		11		1
Triloculina ornata								2	2											
Triloculina plicata	3	5			7					7						1		7		
Triloculina schreiberiana	3	6				2										1				
Triloculina serulata	2	1	1			1												1		
Triloculina tricarinata						10														
Valvulineria bradyana				3					2				6					3		
Wiesnerella auriculata																		2		
Vertebralina striata					9			2	2		3							23		
Absolute abundance	159	116	106	90	72	92	114	111	146	104	137	69	43	30	36	78	23	167	134	102
Relative abundance	6.2	4.5	4.1	4	2.8	3.6	4.46	4.3	5.7	4.07	5.4	2.7	1.7	1.2	1.4	3.1	0.9	6.5	5.2	4
Number of species	29	21	27	24	17	28	23	23	25	15	18	18	11	11	9	18	17	38	19	13
H'	4.2	2.9	2.8	3	2.6	2.9	2.87	2.7	2.8	2.35	2.5	2.6	2.2	2.2	2.1	2.5	2.8	3.2	2.7	2
Species diversity	12	7.4	12	11	7.1	15	8.58	8.4	9.3	5.47	5.7	9.4	4.8	6.6	3.6	7.7	35	17	5.6	4.3
Size >500	40	26	25	15	8	20	15	24	32	17	36	9	14	3	9	12	3	42	28	27
Size <500>250	51	39	32	31	31	28	61	49	45	38	41	26	12	9	21	31	4	49	49	33
Size <250>125	68	51	49	44	35	44	38	35	63	49	60	34	17	18	6	31	10	74	53	41
Size<125>63					1				6							4	2	2	4	1

APPENDIX 6

Distribution of species in Winter, 1995

Table 3 The distribution of species in the study area in winter (January, 1995).

Location	2	4	6	9	11	13	14	16	18	19	21	23	25	26	28	30	33	35	37	38	40	42	45	47	49	50	52	54	57	60	61	62	63	64	65	66	67	68	69	70	71	72	74	75	76	77	78	80	81	82	83
Depth /m	7	7	7	13	13	12	16	19	19	19	30	27	16	19	29	32	32	28	27	32	34	36	47	43	44	47	67	45	200	75	66	54	20	31	14	20	35	51	56	68	63	53	24	7	7	6	7	36	57	71	102
Name of species																																																			
Adelosina brongniartana																						2		1							1						1		2			1	1	2				1	1	1	
Adelosina clarensis											3					4	3				1	1	3	1		1							2			3			3	1					1						
Adelosina dubia																																																			
Adelosina duthiersi						3	3							1				3			1																4						3	2	1		1		2		
Adelosina elegans																						1		1			1				2		1				1	3	1	1		1							1	2	
Adelosina elegans var. separans												1												1																					1						
Adelosina elegans var. angulata															2						1	1		1			1										1		2			1							4	1	
Adelosina elegans var zigzag																																				1															
Adelosina intricata								2			3			1	2	3					1	3	2	1		1				1	1		2				4	1	3	1		2	4	1				2			3
Adelosina mediterranensis								3																1								1						1			2	1								4	
Adelosina partchi																					1																														
Adelosina pulchella								2		1	3	3			2	3	3			3	1	3					1				1	1					4			1		1	1	1							
Adelosina sp1											3	3														1															1										
Adelosina sp2						3								1							1														9	4								2							
Ammonia inflata	3			3							3	4			2	5		7			5	3	5	2			1	2	1		3	4	6				4	5	6	3		2	3	2							6
Ammonia parkinsoniana							3					3	4		2	6																		7	10	6					4		7	8	9	10	7				
Ammonia tepida	9	10	8	7			6				3	3	8	5	2		3				4	4				2								9		9	2						8	7	4	6	5				
Amphicorina sp																											2		3	1	1									1										1	1
Amphisorus hemprichii													4					1																																	
Amphistegina lessonii						3							2	5					5	4		1		1	3																						1				
Amphistegina lobifera		2	3	7	18				33	43				7					29	17					7	7								22											10		17				
Articulina carinata													2						1	2																															
Articulina pacifica																																																			
Assillina ammonoides																																									1										
Astacolus crepidulus																			2																																
Asterigerinata mammilla		3	3	3		4	3				3		3	1		5	7	2			4	8	12	3		6	3	1	2	1	4	3	5		9	8	3	2	3	3		4	2	2	2	1	1	4			2
Astrononion stelliger							3							1																	1	1						2			4									1	3
Bigenerina nodosaria																																																			
Biloculinella globula					3				1											1													7															2			
Biloculinella labiata											3															1	1			1	1	1					2		1				1	3							
Bolivina variabilis							3																																1												
Brizalina striatula																3																																			5
Brizalina spathulata																3	3				1		1					1																							
Bulimina costata															1						1		2																												
Bulimina elongata																3	1																																		
Bulimina marginata																3	1						3					1																							2
Challengerella bradyi					3	3							2	1		3									4						1		4				5	1	4			1	4	2			1		4	4	1
Cibicides advenus								3				3						1																											1			2			
Cibicides refulgens			3					4						1									2		1				1	1																					
Clavulina cf. C. multicamerata																	3																						1				1								
Conorbella patelliformis																																																			
Coscinospira hemprichii							1						1		2																														1	1					
Cycloforina cf. c. quinquecarinata																																																			
Cycloforina sp.																																																			
Cycloforina tenuicollis												3																																							
Cymbaloporetta bermudezi																																																			
Disconorbis bulbosus																																																			
Discorbinella berthelotti						7								1	2	3	3	2			1	3	4	3	1			2		1	3		5	4	6	10	1	4	1	1		3			3	3	1				
Edentostomina cultrata						5																																	1		1	3									

Table 3 The distribution of species in the study area in winter (January, 1995).

Location	2	4	6	9	11	13	14	16	18	19	21	23	25	26	28	30	33	35	37	38	40	42	45	47	49	50	52	54	57	60	61	62	63	64	65	66	67	68	69	70	71	72	74	75	76	77	78	80	81	82	83
Depth /m	7	7	7	13	13	12	16	19	19	19	30	27	16	19	29	32	32	28	27	32	34	36	47	43	44	47	67	45	200	75	66	54	20	31	14	20	35	51	56	68	63	53	24	7	7	6	7	36	57	71	102
Name of species																																																			
Elphidium gerthi																											1			1																					
Elphidium jen seni																						2																													
Elphidium cf E. advenum		3																				1		1						1	1		1						1			1							2		
Elphidium cf.limbatum																											1																								
Elphidium crispum									1					8		3		2		5	1	4	2	2		1	1	1		2	2	1	3	3			6	2	1	2		2	6	1					1		
Elphidium depressulum																						1					1	1	1		1									1	3	1									
Elphidium macellum																						1					1			1											1										
Elphidium margaritacum																																										2									
Elphidium sp1																											1	1																							
Elphidium sp2																								1				1			1														1						
Elphidium striatopunctatum														1				3				1																					1								
Elphidium translucens																						1		3					1		1										1								1		
Eponides concameratus					3	3				1								5		2	1				3	2	1			1			8		7	8	3	3				1						2			
Fursenkoina acuta																													1																						
Fussiurina orbignyana																3							1					1																							
Gavelinopsis preageri																																																			
Glandulina laevigata																																							1	1											
Globulina gibba																															1										1										
Hauerina diversa	3						3					3	7	3	2				6	3				8	5																					3	5				
Haynesina depressula							3		1	1	3										1	1																3													
Haynesina sp.																																																			
Heterostegina depressa					11							6							11	6														8							6						9				
Lachlanella undulata																			3																																
Lachlanella variolata																			5																																
Lenticulina gibba																													1																1						
Lobatula lobatula													4	6		3				7	5	3		9	5	3	4			3	5						5	5	7						9	7					7
Massilina secans																																															1				
Melonis affinis												3				3							1																												
Miliolinella dilatata																																																			
Miliolinella grata																																																			
Miliolinella labiosa							3				3		2								1																														
Miliolinella subrotunda																																																			
Miliolinella webbiana																																																			
Monalysidium aciculare															3																																				
Neoconorbina terquemi												3		1							2		1	1		3																4									
Nodosaria lamnulifera																																																			
Nonion sp.																																																			
Nonionella sp																	3				2																				4										
Nonionella turgida						3															2																														
Pararotalia spinigera	5	3	4	3							5	3	4		3																						11						6	5	6	15	6				
Parrina bradyi																																																			
Peneroplis pertusus		6	4	9			7						9		6																																9				
Peneroplis planatus													6																																						
pesudonodosaria comatula																												1																							1
Planorbulina mediterranensis							3				3	3			2	3																									3										
Planorbulinella larvata															2						11		1				1	1												1		1									
Polymorphina sp.																																																			
Polymorphina sp.2																																																			
Polymorphina sp.4																																											1		1						

Table 3 The distribution of species in the study area in winter (January, 1995).

Location	2	4	6	9	11	13	14	16	18	19	21	23	25	26	28	30	33	35	37	38	40	42	45	47	49	50	52	54	57	60	61	62	63	64	65	66	67	68	69	70	71	72	74	75	76	77	78	80	81	82	83
Depth /m	7	7	7	13	13	12	16	19	19	19	30	27	16	19	29	32	32	28	27	32	34	36	47	43	44	47	67	45	200	75	66	54	20	31	14	20	35	51	56	68	63	53	24	7	7	6	7	36	57	71	102
Name of species																																																			
Polymorphina sp.5																									1																				1									
Porosononion subgranosus												3			2	4					2							1	2			4						4	4	4		3	4	6	2	6					3
Ammonia falsobeccarii								8				3	1				5					1		2	3		4	2	5	7						5	8	6	4	8	5	4	2			5			
Pseudomassilina reticulata																		3				1															1															
Pseudotriculina oblonga													2	1			3					1				1	1					1																			
Pseudotriloculina sp.														1		3					1														1	5												1			2
Pseudotriloculina laevigata												3	2	1							1	1			3	1	1													1											1			
Pseudotriloculina rotunda																												1														1												
Pseudopyrgo milletti												3			4						1			3																							1						
Pseutriloculina subgranulata																						1															1															
Pyramidulina catesbyi																																											1							
Pyrgo anomala																								1			1			1														1							2
Pyrgo elongata														1																																				
Pyrgo striolata						3								1							1			1																							3					
Quinqueloculina cf. Q. multimarginata																																																			
Quinqueloculina jugosa																																														5	1				
Quinqueloculina bosciana																		1			1				1	1								5					1										1			
Quinqueloculina cf. Q limbata																																																			
Quinqueloculina disparilis									4						3				3			7			3	4	5															4														
Quinqueloculina lavigata																		4		2																															
Quinqueloculina parvula																									2																									
Quinqueloculina pseudobuchiana																																																			
Quinqueloculina seminula																					1	2		1																												
Quinqueloculina stelligera							3				8	3	9	1		4	3				1		7																	7	6	3												
Rectouvigenina phlegeri																																																			
Rectuvigarina sp.																	3					1																												
Reussella spinulosa																		4			1	4	1				5						6								4					1					
Rosalina pellucida											3	3					3				1	1			1				2	3																					
Rosalina bradyi														1		3		2			1	2	1	1	5	2	1		2			5									6										
Rosalina globularis						3					3										1	1			3	1	1		4	1																					
Rosalina macropora		3	3								3	2		2						1	2			2	1			5	13									9						1					
Rosalina orientalis																	3										1													1			1								
Rolshausenia rolshauseni																																																			
Sigmoilinita costata											3			1	2	3					2	1	1																											
Sigmoilinita edwardsi																		3																																	
Siphenotextularia concava														1							1				1	1				1			1												1						1
Siphonaperta agglutinans												1				2				1																													
Siphonaperta aspera												3		1		3				1																								1					
Siphonaperta dilitata																																																			
Siphonaperta osinolinata																								1																										
Sorites orbiculus			8			6					9				7		6							3																						9	5				
Sphaerogypsina globula																										1	2																							
Spiroloculina angulata																3																																		
Spiroloculina angulosa											1								1																								1		1	1				
Spiroloculina antillarum	3						3						2									1															2														
Spiroloculina cf S. cymbium													2			3																											1	2						
Spiroloculina depressa											3	3			2	3						3		1																				3	2						
Spiroloculina dilatata																						2		1						1							4			3												
Spiroloculina hadai												1			1																				1							1	1						

Table 3 The distribution of species in the study area in winter (January, 1995).

Location	2	4	6	9	11	13	14	16	18	19	21	23	25	26	28	30	33	35	37	38
Depth /m	7	7	7	13	13	12	16	19	19	19	30	27	16	19	29	32	32	28	27	32
Name of species																				
Spiroloculina ornata												1			1					
Spiroloculina ornata var tricarinata	3												2	1						
Spiroloculina rostata																				
Spiroloculina sp1																				
Sproloculina costifera													1							
Sproloculina excavata								1												
Sproloculina sp2											1	1								
Asterorotalia gaimardii																3				
Textularia agglutinans																				
Textularia bocki					3			2										4		
Textularia conica														1						
Textularia truncata																				
Triloculina affinis														1						
Triloculina asymmetrica																6				
Triloculina marioni											3	3				3		3		3
Triloculina ornata																				
Triloculina plicata													2	3		2				
Triloculina schreiberiana														1	2	3				
Triloculina serulata								1							2					
Triloculina tricarinata																				
Valvulineria bradyana						3														
Vertebralina striata						3					8	6	7	3	9	12		7		
Wiesnerella auriculata																				
Absolute abundance	26	30	36	32	41	52	47	26	40	46	80	81	92	68	69	119	51	65	62	56
Relative abundance	1	2	2	2	2	3	3	1	2	3	5	5	5	4	4	6.75	3	4	4	3
Number of species	6	7	8	6	6	14	14	9	5	4	22	28	25	34	26	33	16	20	8	13
H'	2	2	2	2	1	3	3	2	1	0	3	3	3	3	2	3.41	2	3	2	2
Species diversity	3	3	3	2	2	6	8	5	2	1	9	17	14	26	16	17.8	9	11	3	6
Size >0.500mm		4			10	7	7		2	24	18	23	16	11	15	27	3	9	9	8
Size <0.500>0.250mm	15	11	11	7	16	16	15	7	6	16	29	30	31	19	27	43	19	15	19	12
Size <0.250>0.125mm	7	15	25	25	15	29	24	17	32	3	34	28	42	38	25	49	28	36	32	34
Size<0.125>0.63mm							1	2		3			3		2		1	5	2	2

Location	40	42	45	47	49	50	52	54	57	60	61	62	63	64	65	66	67	68	69	70	71	72	74	75	76	77	78	80	81	82	83
Depth /m	34	36	47	43	44	47	67	45	200	75	66	54	20	31	14	20	35	51	56	68	63	53	24	7	7	6	7	36	57	71	102
Name of species																															
Spiroloculina ornata																							1	1							
Spiroloculina ornata var tricarinata		1		1			1										3														
Spiroloculina rostata							1																		1						
Spiroloculina sp1										1																					
Sproloculina costifera																															
Sproloculina excavata																															
Sproloculina sp2																															
Asterorotalia gaimardii	1	5													5	10	2		1	1									5	3	
Textularia agglutinans	1					1																									
Textularia bocki	1	1			1	1	1		1	1		1								2	1		2	1	1		1				
Textularia conica	1					1																									
Textularia truncata																															
Triloculina affinis		2		1			2		5	2							4		2	1		5	1					1			
Triloculina asymmetrica	1			2			1			1	2	2					3	1				1								1	
Triloculina marioni	7			6	5	2	2		6	8	7						5	4	5	4		6	7	4	3	3	1		2	1	1
Triloculina ornata		1																						1	1						
Triloculina plicata	5	3		2				1	3	4							2	2			4					3			1		1
Triloculina schreiberiana	1	1			1		3										3	4				2							1		1
Triloculina serulata	1	1			1					2		1					1	1	1			1									
Triloculina tricarinata			7					5														7									
Valvulineria bradyana			1	1				1			2									1					1			1			
Vertebralina striata	9	11	8	6	9	2				4											5			9	8		10				
Wiesnerella auriculata																															
Absolute abundance	103	95	66	82	64	52	49	22	45	60	47	39	50	53	47	65	88	66	76	47	52	67	77	70	75	76	82	23	25	19	42
Relative abundance	5.8	5	4	5	4	3	3	1	2.6	3	4	3	4	4	4	5	7	6	6	4	4	6	6	6	6	6	7	2	2	2	3.5
Number of species	50	45	21	39	21	27	32	16	18	27	22	15	13	6	7	11	30	23	26	23	18	28	27	24	28	15	18	12	12	10	20
H'	3.5	4	3	3	3	3	3	3	2.7	3	3	2	2	2	2	2	3	2	3	3	3	3	3	3	3	2	2	2	2	2	2.6
Species diversity	36	34	13	29	12	22	49	22	11	20	17	9	6	2	2	4	17	14	14	20	11	19	16	13	12	6	8	10	10	8	15
Size >0.500mm	25	18	16	7	11	13	12	6			8	2		9	12	9	13	19	11	7	12	18	19	12	14	15	20	6	8	4	6
Size <0.500>0.250mm	30	32	21	30	18	9	13	8	12	5	17	11	19	16	13	23	26	27	29	14	14	25	30	29	28	32	34	8	9	5	18
Size <0.250>0.125mm	42	43	30	43	32	29	24	8	27	45	22	23	31	28	22	33	49	20	33	20	25	20	28	25	24	29	28	6	8	9	18
Size<0.125>0.63mm	6	3		4	3	1			6	10		3							3	6	1	4		4	9	1		3		1	

APPENDIX 7

Measurements of Mg/Ca ratios in *A. lobifera*

variations in Mg/Ca ratio in Amphistegina lobifera. a

	Unpolluted site										Polluted site									
Counts			Undeformed test					Deformed test					Undeformed					Deformed		
	MgO	CA(	Mgppm	Ca ppm	Mg/Ca	MgO	CaO	Mg ppm	Ca pp	Mg/Ca	MgO	CaC	Mg ppm	Ca pp	Mg/Ca	MgO	CaO	Mg ppm	Ca pp	Mg/Ca
1	0.02	52	120.842	370276.76	0.0003264	0.11	51.9	664.631	370992	0.0017915	1.67	47	10090.3	332820.2	0.0303176	3.5	38.7	21147.35	276492.38	0.0764844
2	0.01	53	60.421	378854.6	0.0001595	0.11	52.62	664.631	376138	0.00176699	2.8	45	16917.9	321597.5	0.0526058	4.15	47.2	25074.72	337395.04	0.0743186
3	0.02	48	120.842	343113.6	0.0003522	0.1	50.6	604.21	361699	0.00167048	0.8	47	4833.68	336823.2	0.0143508	4.39	44.1	26524.82	315164.14	0.0841619
4	0.1	45	604.21	321669	0.0018784	0.04	51.83	241.684	370491	0.00065233	1.44	46	8700.62	328888.7	0.0264546	4.01	43.2	24228.82	308945.2	0.0784243
5	0.03	49	181.263	350261.8	0.0005175	0.3	42.12	1812.63	301082	0.00602038	1.78	51	10754.9	363771.9	0.0295651	3.69	44.4	22295.35	317380.08	0.0702481
6	0.03	44	181.263	314520.8	0.0005763	0.13	48.94	785.473	349833	0.00224528	1.77	51	10694.5	364558.2	0.0293356	4.62	47.4	27914.5	338538.75	0.0824559
7	0.49	51	2960.63	364558.2	0.0081211	0.09	51.4	543.789	367417	0.00148003	1.86	51	11238.3	364558.2	0.0308272	3.9	47	23564.19	335750.95	0.0701835
8	0.08	48	483.368	343113.6	0.0014088	0.34	47.75	2054.314	341327	0.00601862	1.33	51	8035.99	364701.2	0.0220345	5.04	45.5	30452.18	324957.17	0.0937114
9	0.02	52	120.842	371420.47	0.0003254	0.47	48.8	2839.787	348832	0.00814084	1.01	50	6102.52	357410	0.0170743	3.31	44.4	19999.35	317165.63	0.0630565
10	0.23	51	1389.68	364558.2	0.003812	0.23	49.8	1389.683	355980	0.00390382	1.03	49	6223.36	350547.7	0.0177533	3.96	41.9	23926.72	299795.51	0.0798101
11	0.1	49	604.21	348832.16	0.0017321	1.18	50.51	7129.678	361056	0.01974676	0.13	49	785.473	349832.9	0.0022453	4.01	43.2	24228.82	308945.2	0.0784243
12	0.7	51	4229.47	361055.58	0.0117142	0.99	44.26	5981.679	316379	0.01890667	0.09	51	543.789	367417.5	0.00148	3.69	44.4	22295.35	317380.08	0.0702481
13	0.99	44	5981.68	313805.98	0.0190617	0.49	49	2960.629	350262	0.00845262	0.34	48	2054.31	341326.6	0.0060186	4.62	47.4	27914.5	338538.75	0.0824559
14	0.49	49	2960.63	350261.8	0.0084526	0.99	44.26	5981.679	316379	0.01890667	0.47	49	2839.79	348832.2	0.0081408	3.9	47	23564.19	335750.95	0.0701835
15	0.34	44	2054.31	315235.62	0.0065168	0.79	45.1	4773.259	322384	0.01480614	0.23	50	1389.68	355980.4	0.0039038	5.04	45.5	30452.18	324957.17	0.0937114
16	0.54	45	3262.73	322383.82	0.0101207	0.61	43.53	3685.681	311161	0.01184493	1.1	51	6646.31	361055.6	0.018408	3.9	47	23564.19	335750.95	0.0701835
17	0.21	44	1268.84	311161.15	0.0040778	0.49	51	2960.629	364558	0.00812114	0.99	44	5981.68	316379.3	0.0189067	5.04	45.5	30452.18	324957.17	0.0937114
18	0.49	51	2960.63	364558.2	0.0081211	0.23	51	1389.683	364558	0.00381196	0.49	49	2960.63	350261.8	0.0084526	3.31	44.4	19999.35	317165.63	0.0630565
19	0.08	48	483.368	343113.6	0.0014088	0.02	51.96	120.842	371420	0.00032535	0.99	44	5981.68	316379.3	0.0189067	1.18	50.5	7129.678	361055.58	0.0197468
20	0.02	52	120.842	371420.47	0.0003254	0.23	51	1389.683	364558	0.00381196	0.79	45	4773.26	322383.8	0.0148061	2.1	44.3	12688.41	316379.33	0.0401051
21	0.23	51	1389.68	364558.2	0.003812	0.99	44.26	5981.679	316379	0.01890667	0.61	44	3685.68	311161.1	0.0118449	1.3	49	7854.73	350261.8	0.0224253
22	0.99	44	5981.68	313877.46	0.0190574	0.49	49	2960.629	350262	0.00845262	0.49	51	2960.63	364558.2	0.0081211	1.02	44.3	6162.942	316379.33	0.0194796
23	0.49	44	2960.63	315235.62	0.0093918	0.99	44.26	5981.679	316379	0.01890667	0.23	51	1389.68	364558.2	0.003812	4.01	43.2	24228.82	308945.2	0.0784243
24	0.99	44	5981.68	316665.26	0.0188896	0.02	48	120.842	343114	0.00035219	0.02	52	120.842	371420.5	0.0003254	3.69	44.4	22295.35	317380.08	0.0702481
25	0.99	44	5981.68	315164.14	0.0189796	0.08	48	483.368	343114	0.00140877	0.23	51	1389.68	364558.2	0.003812	4.62	47.4	27914.5	338538.75	0.0824559
26	0.49	49	2960.63	351691.44	0.0084183	0.02	51.96	120.842	371420	0.00032535	0.99	44	5981.68	316379.3	0.0189067	3.9	47	23564.19	335750.95	0.0701835
27	0.99	44	5981.68	315378.58	0.0189667	0.47	48.8	2839.787	348832	0.00814084	0.49	49	2960.63	350261.8	0.0084526	5.04	45.5	30452.18	324957.17	0.0937114
28	0.49	51	2960.63	364558.2	0.0081211	0.23	49.8	1389.683	355980	0.00390382	0.99	44	5981.68	316379.3	0.0189067	4.39	44.1	26524.82	315164.14	0.0841619
29	0.08	49	483.368	350261.8	0.00138	1.18	50.51	7129.678	361056	0.01974676	0.02	48	120.842	343113.6	0.0003522	4.01	43.2	24228.82	308945.2	0.0784243
30	0.02	51	120.842	365201.54	0.0003309	0.99	44.26	5981.679	316379	0.01890667	0.99	44	5981.68	316379.3	0.0189067	3.69	44.4	22295.35	317380.08	0.0702481
31	0.02	49	120.842	350261.8	0.000345	0.49	51	2960.629	364558	0.00812114	0.49	49	2960.63	350261.8	0.0084526	4.62	47.4	27914.5	338538.75	0.0824559
32	0.1	46	604.21	328817.2	0.0018375	0.23	51	1389.683	364558	0.00381196	0.99	44	5981.68	316379.3	0.0189067	3.9	47	23564.19	335750.95	0.0701835
33	0.03	50	181.263	357410	0.0005072	0.02	51.96	120.842	371420	0.00032535	0.79	45	4773.26	322383.8	0.0148061	5.04	45.5	30452.18	324957.17	0.0937114
34	0.02	44	120.842	316665.26	0.0003816	0.23	51	1389.683	364558	0.00381196	0.61	44	3685.68	311161.1	0.0118449	3.31	44.4	19999.35	317165.63	0.0630565
35	0.02	51	120.842	364558.2	0.0003315	0.49	49	2960.629	350262	0.00845262	1.77	51	10694.5	364558.2	0.0293356	3.96	41.9	23926.72	299795.51	0.0798101
36	0.08	48	483.368	343113.6	0.0014088	0.99	44.26	5981.679	316379	0.01890667	1.86	51	11238.3	364558.2	0.0308272	4.01	43.2	24228.82	308945.2	0.0784243
37	0.02	52	120.842	371420.47	0.0003254	0.02	51.96	120.842	371420	0.00032535	2.53	51	15286.5	364701.2	0.0419152	3.69	44.4	22295.35	317380.08	0.0702481
38	0.23	51	1389.68	364558.2	0.003812	0.23	51	1389.683	364558	0.00381196	1.78	50	10754.9	357410	0.0300913	4.62	47.4	27914.5	338538.75	0.0824559
39	0.1	49	604.21	348832.16	0.0017321	0.49	49	2960.629	350262	0.00845262	1.72	49	10392.4	350547.7	0.0296462	3.9	47	23564.19	335750.95	0.0701835
40	1.18	51	7129.68	361055.58	0.0197468	0.11	51.9	664.631	370992	0.0017915	0.13	49	785.473	349832.9	0.0022453	5.04	45.5	30452.18	324957.17	0.0937114
41	0.23	51	1389.68	364558.2	0.003812	0.11	52.62	664.631	376138	0.00176699	2.8	45	16917.9	321597.5	0.0526058	3.9	47	23564.19	335750.95	0.0701835
42	0.02	52	120.842	370991.58	0.0003257	0.1	50.6	604.21	361699	0.00167048	1.8	47	10875.8	336823.2	0.0322893	5.04	45.5	30452.18	324957.17	0.0937114
43	0.23	51	1389.68	364558.2	0.003812	0.04	51.83	241.684	370491	0.00065233	2.44	46	14742.7	328888.7	0.0448259	3.31	44.4	19999.35	317165.63	0.0630565
44	0.99	44	5981.68	316665.26	0.0188896	0.3	42.12	1812.63	301082	0.00602038	1.78	51	10754.9	363771.9	0.0295651	1.18	50.5	7129.678	361055.58	0.0197468
45	0.49	50	2960.63	357410	0.0082836	0.13	48.94	785.473	349833	0.00224528	1.77	51	10694.5	364558.2	0.0293356	0.99	44.3	5981.679	316379.33	0.0189067
46	0.99	44	5981.68	316307.85	0.0189109	0.09	51.4	543.789	367417	0.00148003	1.86	51	11238.3	364558.2	0.0308272	2.44	49	14742.72	350261.8	0.0420906
47	0.02	48	120.842	343113.6	0.0003522	0.34	47.75	2054.314	341327	0.00601862	2.53	51	15286.5	364701.2	0.0419152	2.19	44.3	13232.2	316379.33	0.0418238
48	0.1	46	604.21	328817.2	0.0018375	0.47	48.8	2839.787	348832	0.00814084	1.78	50	10754.9	357410	0.0300913	4.01	43.2	24228.82	308945.2	0.0784243
49	0.03	51	181.263	365273.02	0.0004962	0.13	51	785.473	364558	0.00215459	0.99	44	5981.68	316379.3	0.0189067	3.69	44.4	22295.35	317380.08	0.0702481
50	0.17	51	1027.16	361055.58	0.0028449	0.09	51.96	543.789	371420	0.00146408	1.72	51	10392.4	364558.2	0.0285069	5.04	44.4	30452.18	317165.63	0.0960135
51	0.24	49	1450.1	350261.8	0.0041401	0.34	51	2054.314	364558	0.00563508	0.13	51	785.473	364701.2	0.0021537	3.31	50.5	19999.35	361055.58	0.0553913
52	0.31	44	1873.05	316379.33	0.0059203	0.47	49	2839.787	350262	0.00810761	0.09	50	543.789	357410	0.0015215	3.96	44.3	23926.72	316379.33	0.0756267
53	0.22	44	1329.26	314520.8	0.0042263	0.23	44.26	1389.683	316379	0.00439246	0.34	49	2054.31	350547.7	0.0058603	4.01	49	24228.82	350261.8	0.0691735
54	0.1	49	604.21	350261.8	0.001725	1.18	51.96	7129.678	371420	0.01919571	0.47	49	2839.79	349832.9	0.0081176	3.69	44.3	22295.35	316379.33	0.0704703
55	0.05	44	302.105	315950.44	0.0009562	0.99	51	5981.679	364558	0.01640802	0.23	51	1389.68	367417.5	0.0037823	4.62	43.2	27914.5	308945.2	0.0903542
56	0.09	51	543.789	364558.2	0.0014916	0.49	49	2960.629	350262	0.00845262	1.78	48	10754.9	341326.6	0.0315092	3.9	44.4	23564.19	317380.08	0.074246
57	0.18	48	1087.58	343113.6	0.0031697	0.99	51.9	5981.679	370992	0.01612349	1.77	49	10694.5	348832.2	0.0306581	5.04	47.4	30452.18	338538.75	0.0899518
58	0.11	52	664.631	371420.47	0.0017894	0.79	52.62	4773.259	376138	0.01269017	1.86	50	11238.3	355980.4	0.03157	3.9	47	23564.19	335750.95	0.0701835
59	0.1	56	604.21	400299.2	0.0015094	0.61	50.6	3685.681	361699	0.01018991	2.53	51	15286.5	361055.6	0.0423384	5.04	45.5	30452.18	324957.17	0.0937114
60	0.52	41	3141.89	293076.2	0.0107204	0.49	51.83	2960.629	370491	0.00799109	0.02	44	120.842	316379.3	0.000382	3.31	44.1	19999.35	315164.14	0.0634569
61	0.44	51	2658.52	365273.02	0.0072782	0.08	42.12	483.368	301082	0.00160544	0.99	49	5981.68	350261.8	0.0170777	1.18	43.2	7129.678	308945.2	0.0230775
62	0.32	43	1933.47	307372.6	0.0062903	0.02	48.94	120.842	349833	0.00034543	0.49	44	2960.63	316379.3	0.0093578	3.31	45.5	19999.35	324957.17	0.0615446
63	0.21	51	1268.84	364558.2	0.0034805	0.47	51.4	2839.787	367417	0.00772905	0.99	45	5981.68	322383.8	0.0185545	3.96	44.1	23926.72	315164.14	0.0759183
64	0.53	48	3202.31	343113.6	0.0093331	0.23	47.75	1389.683	341327	0.00407142	0.79	44	4773.26	311161.1	0.0153402	4.01	43.2	24228.82	308945.2	0.0784243
65	0.03	49	181.263	350261.8	0.0005175	1.18	48.8	7129.678	348832	0.02043871	0.61	51	3685.68	364558.2	0.01011	3.69	44.4	22295.35	317380.08	0.0702481
66	0.17	52	1027.16	371420.47	0.0027655	0.99	50.6	5981.679	361699	0.01653773	1.77	51	10694.5	364558.2	0.0293356	4.62	47.4	27914.5	338538.75	0.0824559
67	0.24	51	1450.1	364558.2	0.0039777	0.49	51.83	2960.629	370491	0.00799109	1.86	52	11238.3	371420.5	0.0302576	3.9	47	23564.19	335750.95	0.0701835
68	0.31	49	1873.05	348832.16	0.0053695	0.23	42.12	1389.683	301082	0.00461563	2.53	51	15286.5	364558.2	0.0419316	5.04	45.5	30452.18	324957.17	0.0937114
69	0.22	51	1329.26	361055.58	0.0036816	0.02	48.94	120.842	349833	0.00034543	1.78	44	10754.9	316379.3	0.0339938	3.9	44.4	23564.19	317165.63	0.0742962
70	0.1	56	604.21	400299.2	0.0015094	0.23	51.4	1389.683	367417	0.0037823	1.72	49	10392.4	350261.8	0.0296704	5.04	41.9	30452.18	299795.51	0.1015765
71	0.05	49	302.105	350261.8	0.0008625	0.49	47.75	2960.629	341327	0.00867389	1.67	51	10090.3	364701.2	0.0276673	3.31	43.2	19999.35	308945.2	0.0647343
72	0.09	52	543.789	371706.4	0.001463	0.99	48.8	5981.679	348832	0.01714773	2.8	50	16917.9	357410	0.0473347	3.31	44.4	19999.35	317380.08	0.0630139
73	0.08	51	483.368	361055.58	0.0013388	0.02	51.4	120.842	367417	0.0003289	1.8	49	10875.8	350547.7	0.0310251	1.18	44.1	7129.678	315164.14	0.0226221
74	0.12	55	725.052	393151	0.0018442	0.23	47.75	1389.683	341327	0.00407142	2.44	49	14742.7	349832.9	0.0421422	2.1	43.2	12688.41	308945.2	0.0410701
75	0.22	52	1329.26	371420.47	0.0035789	0.49	48.8	2960.629	348832	0.00848726	1.78	45	10754.9	321597.5	0.0334422	1.3	45.5	7854.73	324957.17	0.0241716
76	0.1	450	604.21	3216690	0.0001878	0.11	51	664.631	364558	0.00182311	0.99	47	5981.68	336823.2	0.0177591	1.02	44.1	6162.942	315164.14	0.0195547
77	0.03	42	181.263	300224.4	0.0006038	0.11	51.96	664.631	371420	0.00178943	0.49	46	2960.63	328888.7	0.0090019	4.01	43.2	24228.82	308945.2	0.0784243
78	0.32	51	1933.47	365273.02	0.0052932	0.1	51	604.21	364558	0.00165738	0.99	51	5981.68	363771.9	0.0164435	3.69	44.4	22295.35	317380.08	0.0702481
79	0.02	47	120.842	335965.4	0.0003597	0.04	49	241.684	350262	0.00069001	0.79	51	4773.26	364558.2	0.0130933	4.62	38.7	27914.5	276492.38	0.1009594
80	0.28	51	1691.79	365273.02	0.0046316	0.3	44.26	1812.63	316379	0.00572929	0.61	50	3685.68	357410	0.0103122	3.9	47.2	23564.19	337395.04	0.0698415
81	0.93	44	5619.15	314520.8	0.0178658	0.13	51.96	785.473	371420	0.00211478	1.78	44	10754.9	316379.3	0.0339938	2.18	44.1	13171.78	315164.14	0.0417934
82	0.81	51	4894.1	364558.2	0.0134247	0.09	51	543.789	364558	0.00149164	1.72	51	10392.4	364558.2	0.0285069	1.99	43.2	12023.78	308945.2	0.0389188
83	0.39	48	2356.42	343113.6	0.0068678	0.34	51.96	2054.314	371420	0.00553097	0.13	51	785.473	364701.2	0.0021537	3.49	44.4	21086.93	317380.08	0.0664406
84	0.21	44	1268.84	311161.15	0.0040778	0.47	51	2839.787	364558	0.00778967	2.8	50	16917.9	357410	0.0473347	2.99	47.4	18065.88	338538.75	0.0533643
85	0.44	51	2658.52	364558.2	0.0072925	0.23	49	1389.683	350262	0.00396756	1.8	49	10875.8	350547.7	0.0310251	4.01	47	24228.82	335750.95	0.0721631
86	0.81	48	4894.1	343113.6	0.0142638	1.18	44.26	7129.678	316379	0.02253522	2.44	49	14742.7	349832.9	0.0421422	3.69	45.5	22295.35	324957.17	0.0686101
87	0.02	52	120.842	371420.47	0.0003254	0.99	51.96	5981.679	371420	0.01610487	1.78	51	10754.9	367417.5	0.0292717	5.04	44.4	30452.18	317165.63	0.0960135
89	0.33	51	1993.89	364558.2	0.0054693	0.49	51	2960.629	364558	0.00812114	1.77	51	10694.5	363771.9	0.029399	3.31	45.5	19999.35	324957.17	0.0615446
90	0.93	44	5619.15	316665.26	0.0177448	0.23	49	1389.683	350262	0.00396756	1.86	51	11238.3	364558.2	0.0308272	3.96	44.1	23926.72	315164.14	0.0759183
91	0.08	49	483.368	350261.8	0.00138	0.02	51.9	120.842	370992	0.00032573	1.78	50	10754.9	357410	0.0300913	5.04	43.2	30452.18	308945.2	0.0985682
92	0.25	44	1510.53	316379.33	0.0047744	0.23	52.62	1389.683	376138	0.00369461	1.72	44	10392.4	316379.3	0.0328479	3.9	44.4	23564.19	317380.08	0.074246
93	0.04	44	241.684	315235.62	0.0007667	0.49	50.6	2960.629	361699	0.00818534	1.67	51	10090.3	364558.2	0.0276782	1.99	38.7	12023.78	276492.38	0.0434868
94	0.32	48	1933.47	343113.6	0.0056351	0.99	51.83	5981.679	370491	0.01614527	2.44	51	14742.7	364701.2	0.0404241	2.99	47.2	18065.88	337395.04	0.0535452
95	0.55	44	3323.16	316379.33	0.0105037	0.02	42.12	120.842	301082	0.00040136	1.78	49	10754.9	350547.7	0.0306804	4.01	47	24228.82	335750.95	0.0721631
96	0.32	51	1933.47	364558.2	0.0053036	0.23	48.94	1389.683	349833	0.00397242	0.99	49	5981.68	349832.9	0.0170987	5.04	45.5	30452.18	324957.17	0.0937114
97	0.44	51	2658.52	365987.84	0.007264	0.49	51.4	2960.629	367417	0.00805794	0.49	51	2960.63	367417.5	0.0080579	3.31	47	19999.35	335750.95	0.059566
98	0.29	48	1752.21	343113.6	0.0051068	0.11	47.75	664.631	341327	0.0019472	0.99	48	5981.68	341326.6	0.0175248	3.96	45.5	23926.72	324957.17	0.0736304

variations in Mg/Ca ratio in Amphistegina lobifera. b

					Unpolluted site									Polluted site							
Counts			Undeformed test					Deformed test					Undeformed					Deformed		
	MgO	CAO	Mgppm	Ca ppm	Mg/Ca	MgO	CaO	Mg ppm	Ca pp	Mg/Ca	MgO	CaO	Mg ppm	Ca pp	Mg/Ca	MgO	CaO	Mg ppm	Ca pp	Mg/Ca
99	0.15	43	906.315	307372.6	0.0029486	0.89	43.32	5377.469	309660	0.01736572	0.79	49	4773.26	348832.2	0.0136835	4.01	44.4	24228.82	317165.63	0.0763917
100	0.39	450	2356.42	3216690	0.0007326	0.34	51	2054.314	364558	0.00563508	0.99	44	5981.68	316379.3	0.0189067	3.9	47	23564.19	335750.95	0.0701835
101	0.21	42	1268.84	300224.4	0.0042263	0.47	49	2839.787	350262	0.00810761	0.49	49	2960.63	350261.8	0.0084526	5.04	45.5	30452.18	324957.17	0.0937114
102	0.44	51	2658.52	365273.02	0.0072782	0.23	44.26	1389.683	316379	0.00439246	0.99	44	5981.68	316379.3	0.0189067	3.9	44.4	23564.19	317165.63	0.0742962
103	0.81	47	4894.1	335965.4	0.0145673	1.18	51.96	7129.678	371420	0.01919571	0.79	48	4773.26	343113.6	0.0139116	5.04	45.5	30452.18	324957.17	0.0937114
104	0.02	51	120.842	365273.02	0.0003308	0.99	51	5981.679	364558	0.01640802	0.61	44	3685.68	316379.3	0.0116496	3.31	44.1	19999.35	315164.14	0.0634569
105	0.33	44	1993.89	314520.8	0.0063395	0.49	49	2960.629	350262	0.00845262	1.78	49	10754.9	350261.8	0.0307054	1.18	43.2	7129.678	308945.2	0.0230775
106	0.93	51	5619.15	364558.2	0.0154136	0.99	51.9	5981.679	370992	0.01612349	1.72	44	10392.4	316379.3	0.0328479	3.31	44.4	19999.35	317380.08	0.0630139
107	0.08	48	483.368	343113.6	0.0014088	0.79	52.62	4773.259	376138	0.01269017	0.13	45	785.473	322383.8	0.0024365	3.96	38.7	23926.72	276492.38	0.0865366
108	0.25	44	1510.53	311161.15	0.0048545	0.61	50.6	3685.681	361699	0.01018991	2.8	44	16917.9	311161.1	0.0543702	4.01	47.2	24228.82	337395.04	0.0718114
109	0.04	51	241.684	364558.2	0.000663	0.49	51.83	2960.629	370491	0.00799109	1.8	51	10875.8	364558.2	0.0298328	3.69	47	22295.35	335750.95	0.0664044
110	0.31	48	1873.05	343113.6	0.005459	0.23	42.12	1389.683	301082	0.00461563	2.44	51	14742.7	364558.2	0.04044	4.62	45.5	27914.5	324957.17	0.0859021
111	0.22	52	1329.26	371420.47	0.0035789	0.02	48.94	120.842	349833	0.00034543	1.78	51	10754.9	364701.2	0.0294897	3.9	47.4	23564.19	338538.75	0.0696056
112	0.1	48	604.21	343113.6	0.001761	0.23	51.4	1389.683	367417	0.0037823	1.77	50	10694.5	357410	0.0299223	5.04	47	30452.18	335750.95	0.0906987
113	0.05	46	302.105	328817.2	0.0009188	0.99	47.75	5981.679	341327	0.0175248	1.86	49	11238.3	350547.7	0.0320593	3.9	45.5	23564.19	324957.17	0.0725148
114	0.09	51	543.789	365273.02	0.0014887	0.49	48.8	2960.629	348832	0.00848726	1.78	49	10754.9	349832.9	0.0307431	5.04	44.4	30452.18	317165.63	0.0960135
115	0.08	51	483.368	361055.58	0.0013388	0.99	50.6	5981.679	361699	0.01653773	1.72	45	10392.4	321597.5	0.032315	3.31	45.5	19999.35	324957.17	0.0615446
116	0.12	49	725.052	350261.8	0.00207	0.02	51.83	120.842	370491	0.00032617	1.78	47	10754.9	336823.2	0.0319305	3.31	44.1	19999.35	315164.14	0.0634569
117	0.22	44	1329.26	316379.33	0.0042015	0.08	42.12	483.368	301082	0.00160544	0.99	46	5981.68	328888.7	0.0181875	1.18	43.2	7129.678	308945.2	0.0230775
118	0.1	44	604.21	314520.8	0.001921	0.02	48.94	120.842	349833	0.00034543	1.72	51	10392.4	363771.9	0.0285685	3.5	44.4	21147.35	317380.08	0.066631
119	0.03	49	181.263	350261.8	0.0005175	0.47	51.4	2839.787	367417	0.00772905	0.13	51	785.473	364558.2	0.0021546	4.15	38.7	25074.72	276492.38	0.0906886
120	0.32	44	1933.47	315950.44	0.0061195	0.23	42.12	1389.683	301082	0.00461563	0.09	51	543.789	363771.9	0.0014949	4.39	47.2	26524.82	337395.04	0.0786165
121	0.02	51	120.842	364558.2	0.0003315	0.23	48.94	1389.683	349833	0.00397242	0.34	51	2054.31	364558.2	0.0056351	4.01	47	24228.82	335750.95	0.0721631
122	0.04	48	241.684	343113.6	0.0007044	1.18	51.4	7129.678	367417	0.01940484	0.47	50	2839.79	357410	0.0079455	3.69	45.5	22295.35	324957.17	0.0686101
123	0.32	52	1933.47	371420.47	0.0052056	0.99	47.75	5981.679	341327	0.0175248	0.23	44	1389.68	316379.3	0.0043925	4.62	47	27914.5	335750.95	0.0831405
124	0.55	56	3323.16	400299.2	0.0083017	0.49	48.8	2960.629	348832	0.00848726	1.78	51	10754.9	364558.2	0.0295013	3.9	45.5	23564.19	324957.17	0.0725148
125	0.32	41	1933.47	293076.2	0.0065972	0.23	51	1389.683	364558	0.00381196	1.77	51	10694.5	364701.2	0.0293241	5.04	44.4	30452.18	317165.63	0.0960135
126	0.44	51	2658.52	365273.02	0.0072782	0.02	51.96	120.842	371420	0.00032535	1.86	50	11238.3	357410	0.0314437	3.31	47	19999.35	335750.95	0.059566
127	0.29	43	1752.21	307372.6	0.0057006	0.23	51	1389.683	364558	0.00381196	2.53	49	15286.5	350547.7	0.0436075	3.96	45.5	23926.72	324957.17	0.0736304
128	0.15	51	906.315	364558.2	0.0024861	0.49	49	2960.629	350262	0.00845262	0.02	49	120.842	349832.9	0.0003454	4.01	44.4	24228.82	317165.63	0.0763917
129	0.39	48	2356.42	343113.6	0.0068678	0.99	44.26	5981.679	316379	0.01890667	0.99	51	5981.68	367417.5	0.0162803	3.69	45.5	22295.35	324957.17	0.0686101
130	0.21	49	1268.84	350261.8	0.0036226	0.02	51.96	120.842	371420	0.00032535	0.49	51	2960.63	363771.9	0.0081387	4.62	44.1	27914.5	315164.14	0.0885713
131	0.09	52	543.789	371420.47	0.0014641	0.23	51	1389.683	364558	0.00381196	0.99	51	5981.68	364558.2	0.016408	3.9	43.2	23564.19	308945.2	0.076273
132	0.08	51	483.368	364558.2	0.0013259	0.49	49	2960.629	350262	0.00845262	1.67	50	10090.3	357410	0.0282317	5.04	44.4	30452.18	317380.08	0.0959486
133	0.12	49	725.052	348832.16	0.0020785	0.11	51.9	664.631	370992	0.0017915	2.8	44	16917.9	316379.3	0.0534734	3.9	38.7	23564.19	276492.38	0.0852255
134	0.22	51	1329.26	361055.58	0.0036816	0.89	52.62	5377.469	376138	0.01429652	0.8	51	4833.68	364558.2	0.013259	5.04	47.2	30452.18	337395.04	0.0902568
135	0.1	56	604.21	400299.2	0.0015094	0.34	50.6	2054.314	361699	0.00567962	1.44	51	8700.62	364701.2	0.0238569	3.31	47	19999.35	335750.95	0.059566
136	0.03	52	181.263	370276.76	0.0004895	0.47	50.6	2839.787	361699	0.00785125	1.78	50	10754.9	357410	0.0300913	1.18	45.5	7129.678	324957.17	0.0219404
137	0.32	53	1933.47	378854.6	0.0051035	0.23	51.83	1389.683	370491	0.00375092	1.77	44	10694.5	316379.3	0.0338028	2.1	47	12688.41	335750.95	0.0377911
138	0.02	48	120.842	343113.6	0.0003522	1.18	42.12	7129.678	301082	0.02368017	1.86	51	11238.3	364558.2	0.0308272	1.3	45.5	7854.73	324957.17	0.0241716
139	0.04	45	241.684	321669	0.0007513	0.99	48.94	5981.679	349833	0.01709867	1.33	51	8035.99	364701.2	0.0220345	1.02	44.4	6162.942	317165.63	0.0194313
140	0.32	49	1933.47	350261.8	0.0055201	0.49	51.4	2960.629	367417	0.00805794	1.01	49	6102.52	350547.7	0.0174085	3.9	47	23564.19	335750.95	0.0701835
141	0.1	44	604.21	314520.8	0.001921	0.11	42.12	664.631	301082	0.00220747	1.03	49	6223.36	349832.9	0.0177895	5.04	45.5	30452.18	324957.17	0.0937114
142	0.05	51	302.105	364558.2	0.0008287	0.11	48.94	664.631	349833	0.00189985	0.13	51	785.473	367417.5	0.0021378	3.9	44.4	23564.19	317165.63	0.0742962
143	0.09	48	543.789	343113.6	0.0015849	0.1	51.4	604.21	367417	0.00164448	0.09	48	543.789	341326.6	0.0015932	5.04	45.5	30452.18	324957.17	0.0937114
144	0.08	52	483.368	371420.47	0.0013014	0.04	47.75	241.684	341327	0.00070807	0.34	49	2054.31	348832.2	0.0058891	3.31	44.1	19999.35	315164.14	0.0634569
145	0.12	51	725.052	364558.2	0.0019889	0.3	48.8	1812.63	348832	0.00519628	0.47	44	2839.79	316379.3	0.0089759	3.31	43.2	19999.35	308945.2	0.0647343
146	0.22	49	1329.26	348832.16	0.0038106	0.13	52.62	785.473	376138	0.00208826	0.23	49	1389.68	350261.8	0.0039676	1.18	44.4	7129.678	317380.08	0.0224642
147	0.1	51	604.21	361055.58	0.0016735	0.09	50.6	543.789	361699	0.00150343	1.1	44	6646.31	316379.3	0.0210074	2.1	38.7	12688.41	276492.38	0.0458906
148	0.32	56	1933.47	400299.2	0.0048301	0.34	51.83	2054.314	370491	0.00554484	0.99	48	5981.68	343113.6	0.0174335	1.3	47.2	7854.73	337395.04	0.0232805
149	0.02	52	120.842	370276.76	0.0003264	0.47	42.12	2839.787	301082	0.00943193	0.49	44	2960.63	316379.3	0.0093578	1.02	47	6162.942	335750.95	0.0183557
150	0.04	53	241.684	378854.6	0.0006379	0.23	48.94	1389.683	349833	0.00397242	0.99	49	5981.68	350261.8	0.0170777	4.01	45.5	24228.82	324957.17	0.07456

APPENDIX 8

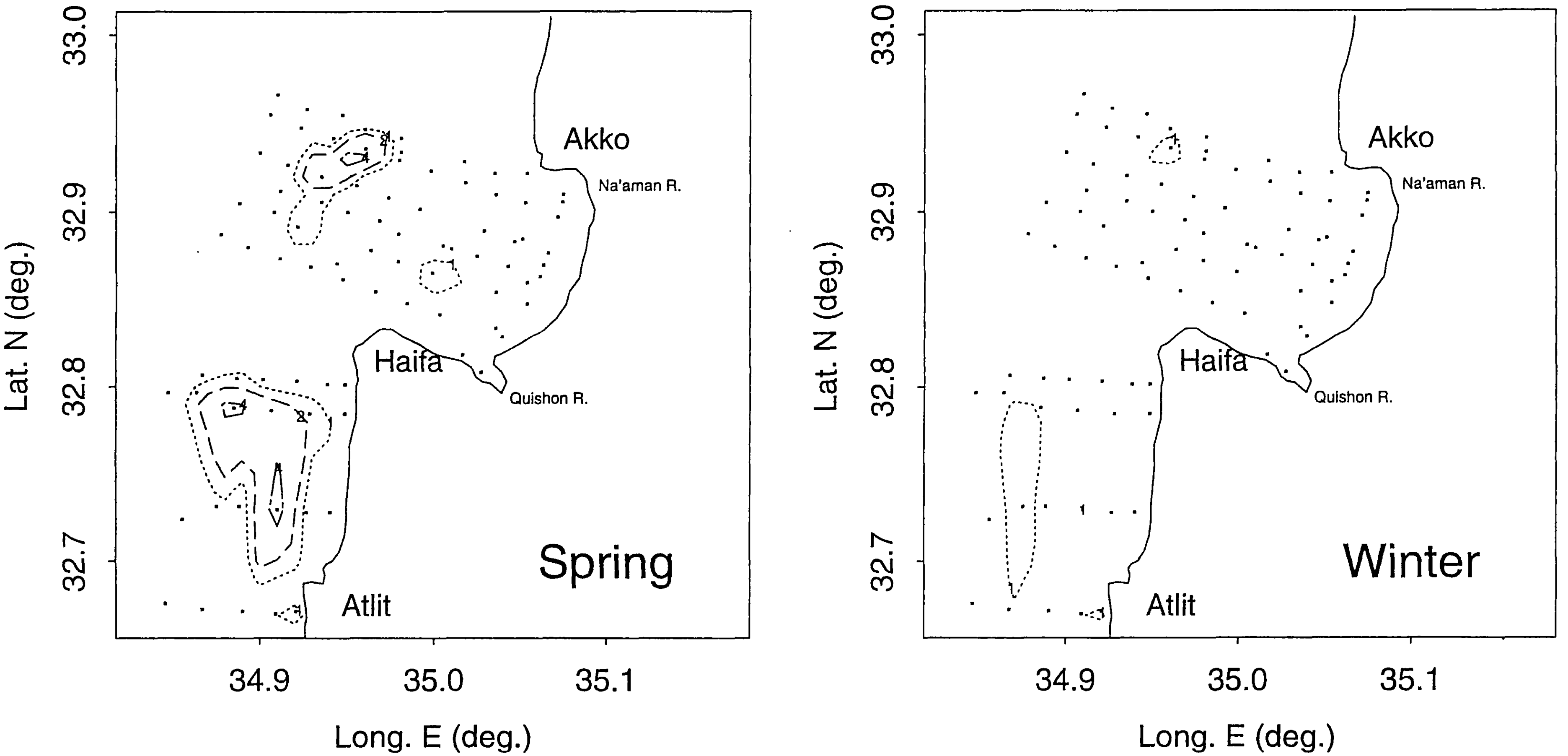
Measurements of Mg/Ca ratios in *A. mamilla*

The variations in Mg/Ca ratio in Asterigerinata mamilla.

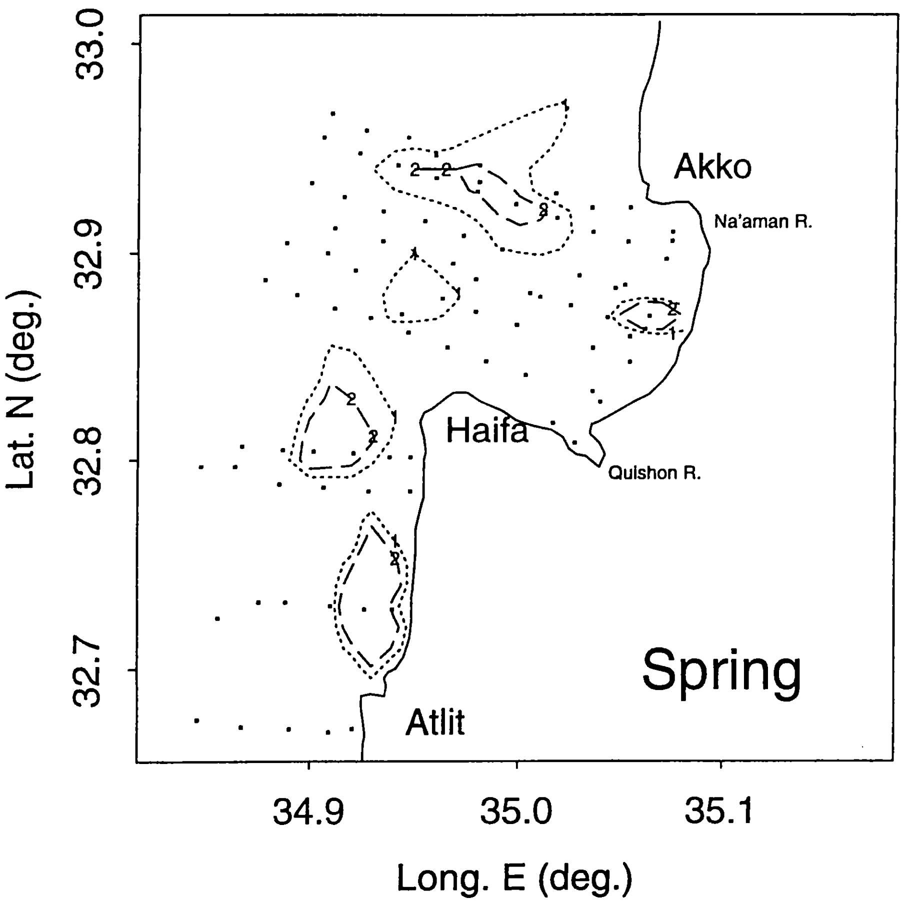
			Unpolluted site						Polluted site	
		Undeformed test						Undeformed test		
Counts	MgO	CaO	Mg ppm	Ca ppm	Mg/Ca	Mg/O	Mg ppm	Ca O	Cappm	Mg/Ca
1	0.23	51.8	604.21	370276.8	0.0016	1.67	10090.3	51	364558.2	0.0277
2	0.1	53	4229.47	378854.6	0.0112	2.8	16917.9	51	364558.2	0.0464
3	0.7	48	5981.679	343113.6	0.0174	0.8	4833.68	51.96	371420.47	0.013
4	0.99	45	2960.629	321669	0.0092	1.44	8700.62	51	364558.2	0.0239
5	0.49	49	2054.314	350261.8	0.0059	1.78	10754.9	44.26	316379.33	0.034
6	0.34	44	3262.734	314520.8	0.0104	1.77	10694.5	49	350261.8	0.0305
7	0.54	51	1268.841	364558.2	0.0035	1.86	11238.3	44.26	316379.33	0.0355
8	0.21	48	2960.629	343113.6	0.0086	1.33	8035.99	48	343113.6	0.0234
9	0.49	51.96	2960.629	371420.5	0.008	1.01	6102.52	44.26	316379.33	0.0193
10	0.49	49	483.368	350261.8	0.0014	1.03	6223.36	49	350261.8	0.0178
11	0.08	46	120.842	328817.2	0.0004	0.13	785.473	44.26	316379.33	0.0025
12	0.02	50	1389.683	357410	0.0039	0.09	543.789	45.1	322383.82	0.0017
13	0.23	44.3	5981.679	316665.3	0.0189	0.34	2054.31	43.53	311161.15	0.0066
14	0.99	51	2960.629	364558.2	0.0081	0.47	2839.79	51	364558.2	0.0078
15	0.49	48	5981.679	343113.6	0.0174	0.23	1389.68	51	364558.2	0.0038
16	0.99	51.96	5981.679	371420.5	0.0161	1.1	6646.31	51.02	364701.16	0.0182
17	0.99	51	2960.629	364558.2	0.0081	0.99	5981.68	50	357410	0.0167
18	0.49	48.8	5981.679	348832.2	0.0171	0.49	2960.63	49.04	350547.73	0.0084
19	0.99	50.51	2960.629	361055.6	0.0082	0.99	5981.68	48.94	349832.91	0.0171
20	0.49	51	483.368	364558.2	0.0013	0.79	4773.26	44.99	321597.52	0.0148
21	0.08	51.9	120.842	370991.6	0.0003	0.61	3685.68	47.12	336823.18	0.0109
22	0.02	51	120.842	364558.2	0.0003	0.49	2960.63	46.01	328888.68	0.009
23	0.02	44.3	5981.679	316665.3	0.0189	0.23	1389.68	50.89	363771.9	0.0038
24	0.99	50	2960.629	357410	0.0083	0.02	120.842	51	364558.2	0.0003
25	0.49	44.25	5981.679	316307.9	0.0189	0.23	1389.68	51	364558.2	0.0038
26	0.99	48	2960.629	343113.6	0.0086	0.99	5981.68	51.02	364701.16	0.0164
27	0.49	46	483.368	328817.2	0.0015	1.72	10392.4	50	357410	0.0291
28	0.08	51.1	120.842	365273	0.0003	0.13	785.473	44.26	316379.33	0.0025
29	0.02	48	120.842	343113.6	0.0004	0.09	543.789	51	364558.2	0.0015
30	0.02	51.96	604.21	371420.5	0.0016	0.34	2054.31	51.02	364701.16	0.0056
31	0.1	48	181.263	343113.6	0.0005	0.47	2839.79	50	357410	0.0079
32	0.03	46	120.842	328817.2	0.0004	0.23	1389.68	49.04	350547.73	0.004
33	0.02	51.1	120.842	365273	0.0003	1.78	10754.9	48.94	349832.91	0.0307
34	0.02	50.51	483.368	361055.6	0.0013	1.77	10694.5	51.4	367417.48	0.0291
35	0.08	49	120.842	350261.8	0.0003	1.86	11238.3	46.56	332820.19	0.0338
36	0.02	44.26	1933.472	316379.3	0.0061	2.53	15286.5	44.99	321597.52	0.0475
37	0.32	44	120.842	314520.8	0.0004	0.02	120.842	47.12	336823.18	0.0004
38	0.02	49	1691.788	350261.8	0.0048	0.99	5981.68	46.01	328888.68	0.0182
40	0.28	44.2	5619.153	315950.4	0.0178	0.49	2960.63	50.89	363771.9	0.0081
41	0.93	51	4894.101	364558.2	0.0134	0.99	5981.68	51	364558.2	0.0164
42	0.81	48	2356.419	343113.6	0.0069	0.79	4773.26	51	364558.2	0.0131
43	0.39	51.96	1268.841	371420.5	0.0034	0.61	3685.68	51.02	364701.16	0.0101
44	0.21	56	2658.524	400299.2	0.0066	1.77	10694.5	50	357410	0.0299
45	0.44	41	4894.101	293076.2	0.0167	1.86	11238.3	49.04	350547.73	0.0321
46	0.81	51.1	120.842	365273	0.0003	2.53	15286.5	48.94	349832.91	0.0437
47	0.02	46	1993.893	328817.2	0.0061	1.78	10754.9	51.4	367417.48	0.0293
48	0.33	51.1	5619.153	365273	0.0154	1.72	10392.4	47.75	341326.55	0.0304
49	0.93	48	483.368	343113.6	0.00141	1.67	10090.3	48.8	348832.16	0.02893
50	0.08	51.96	0	371420.47	0	2.8	16917.9	49.8	355980.36	0.04752

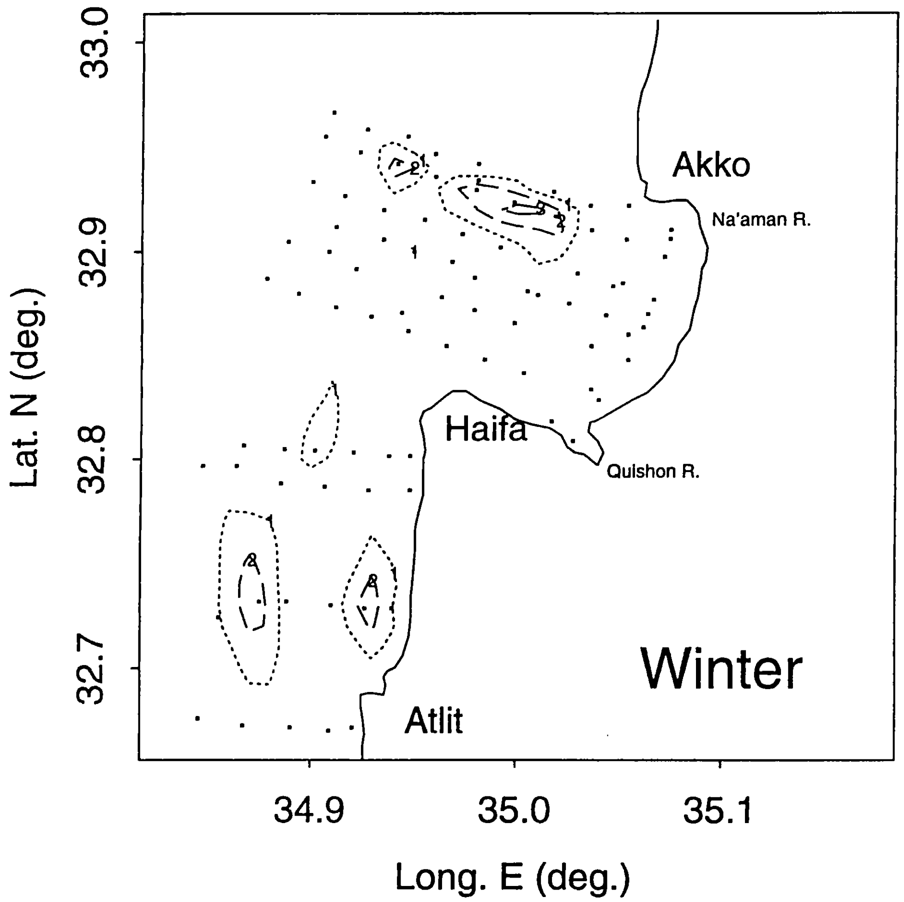
APPENDIX 9

Abundance maps of benthic foraminiferal species

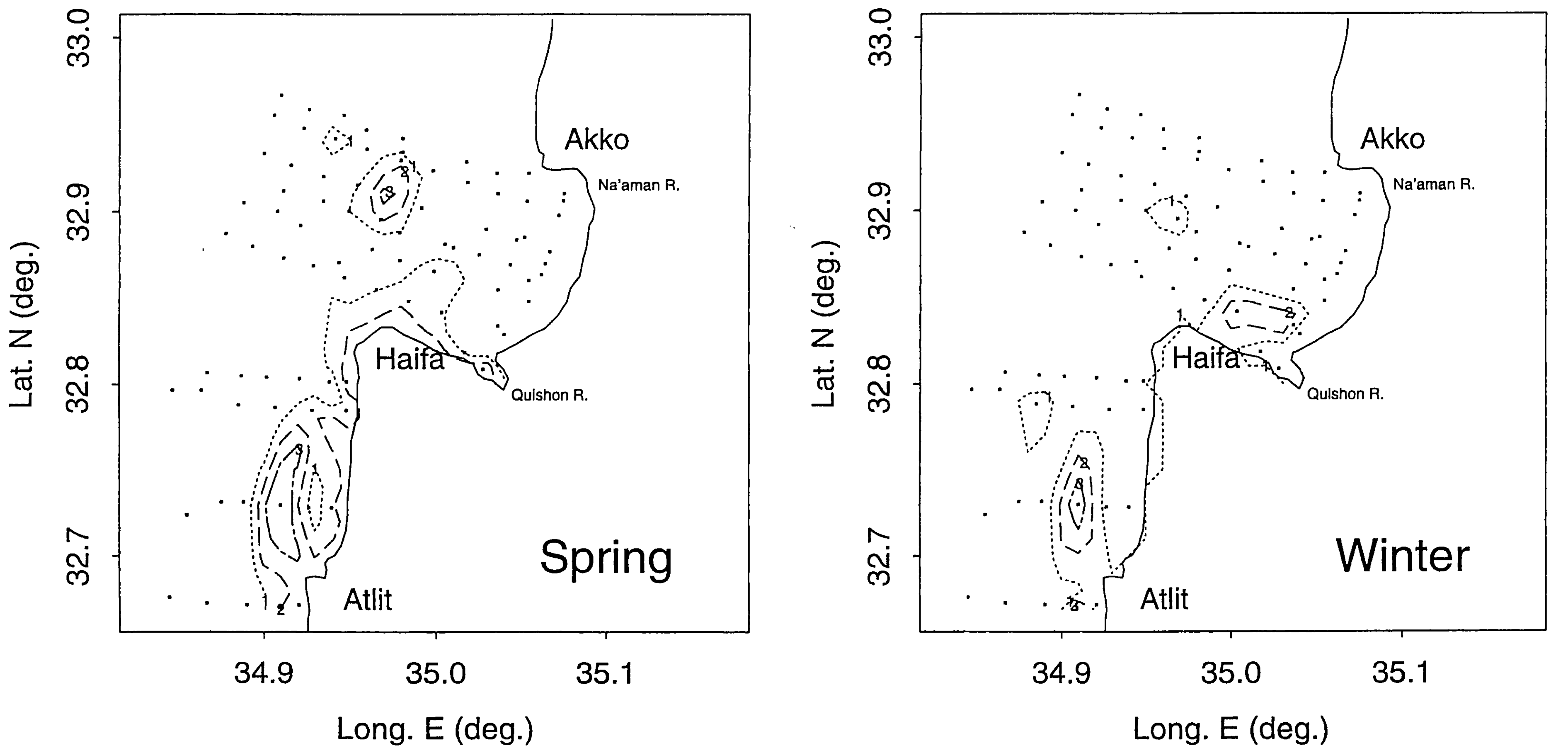


Absolute abundance of Adelosina brongniartana

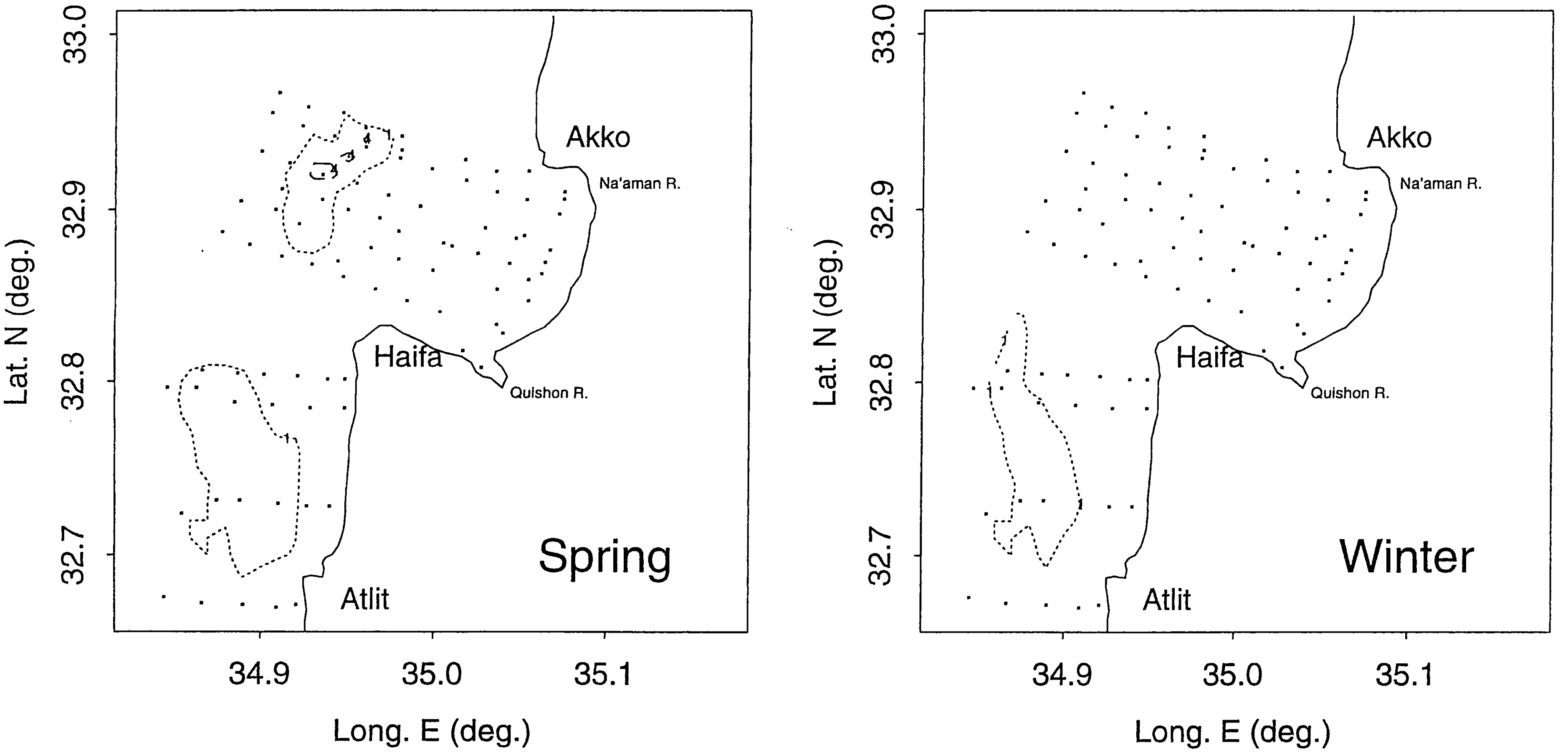




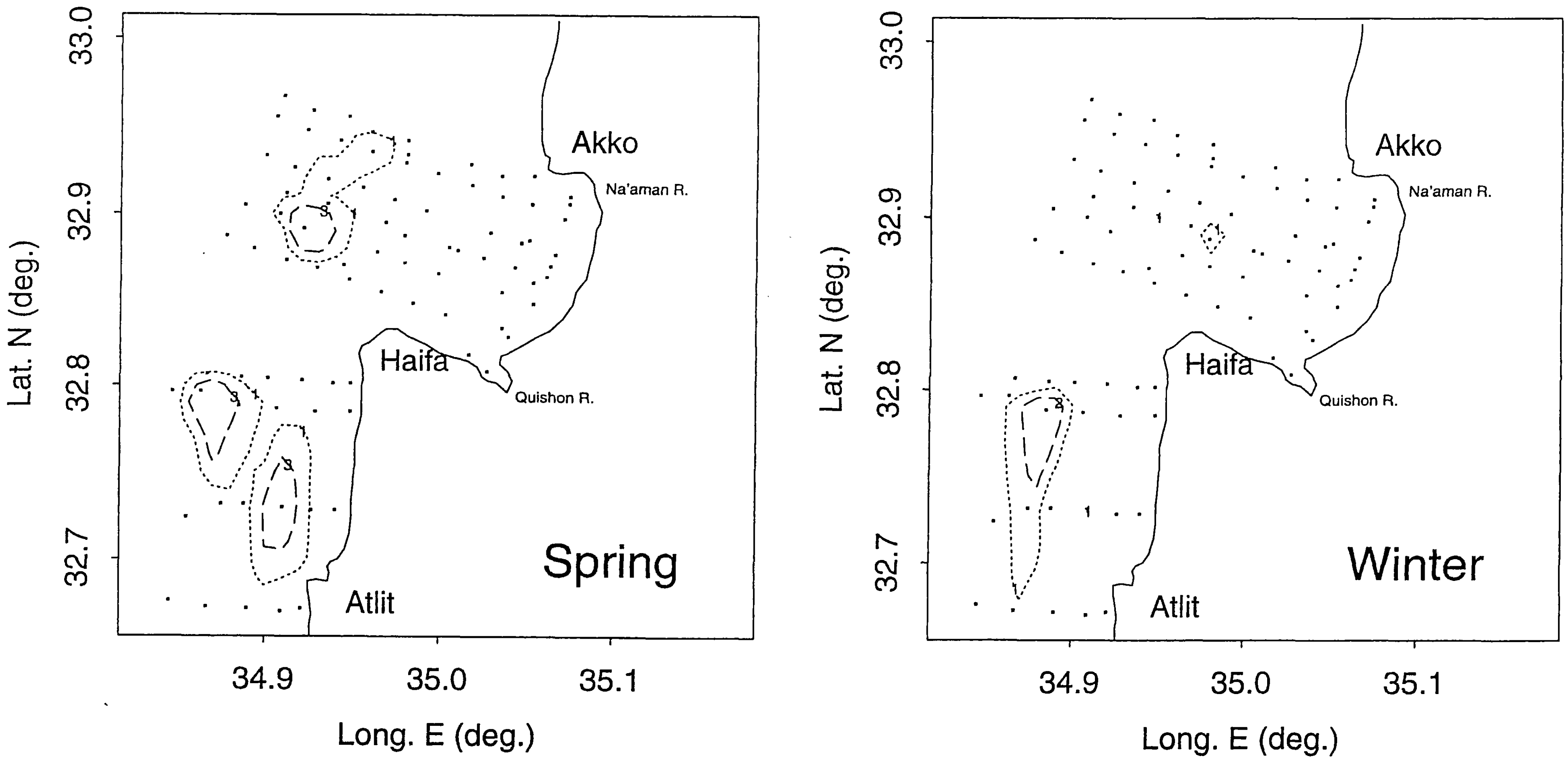
Absolute abundance of Adelosina cliarensis



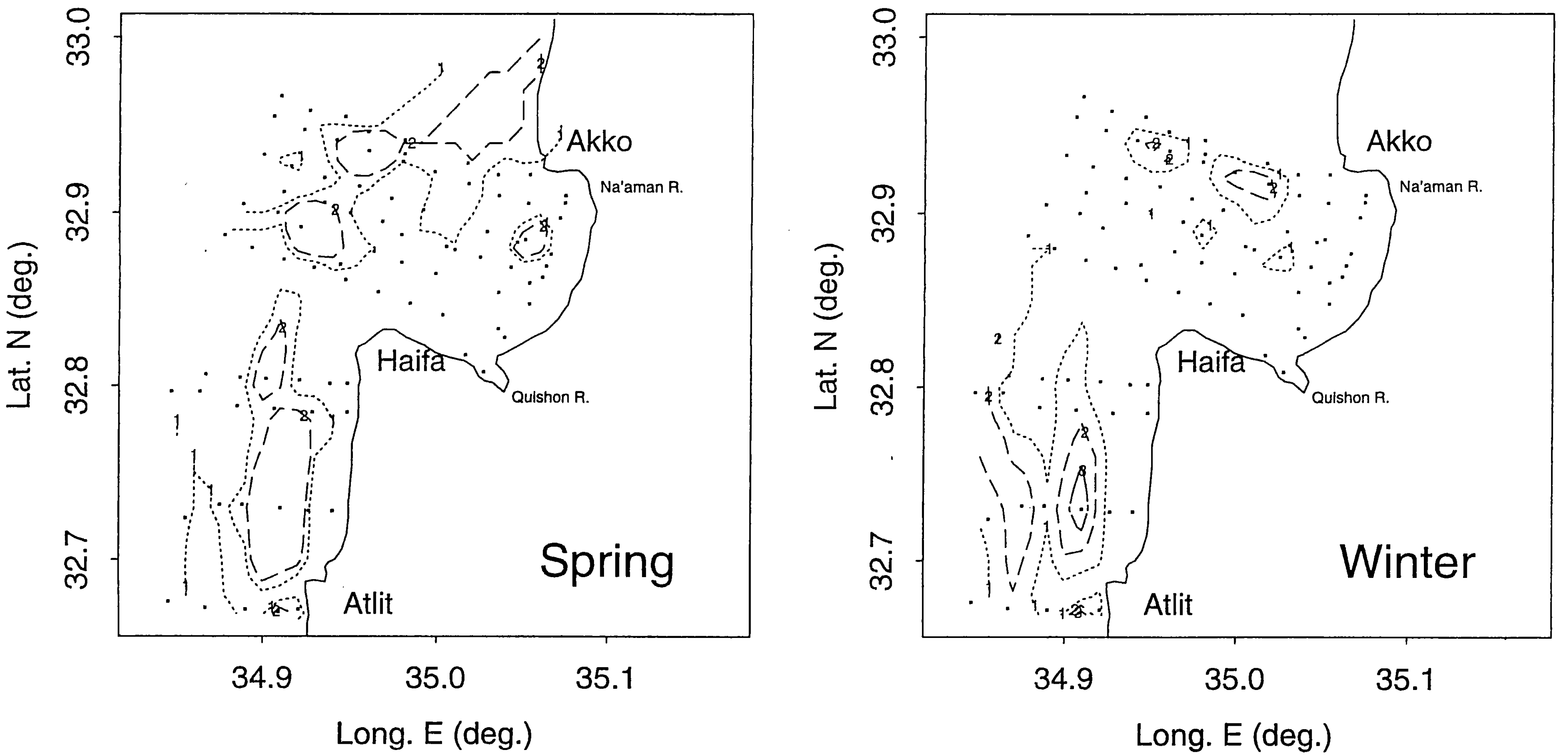
Absolute abundance of Adelosina duthiersi



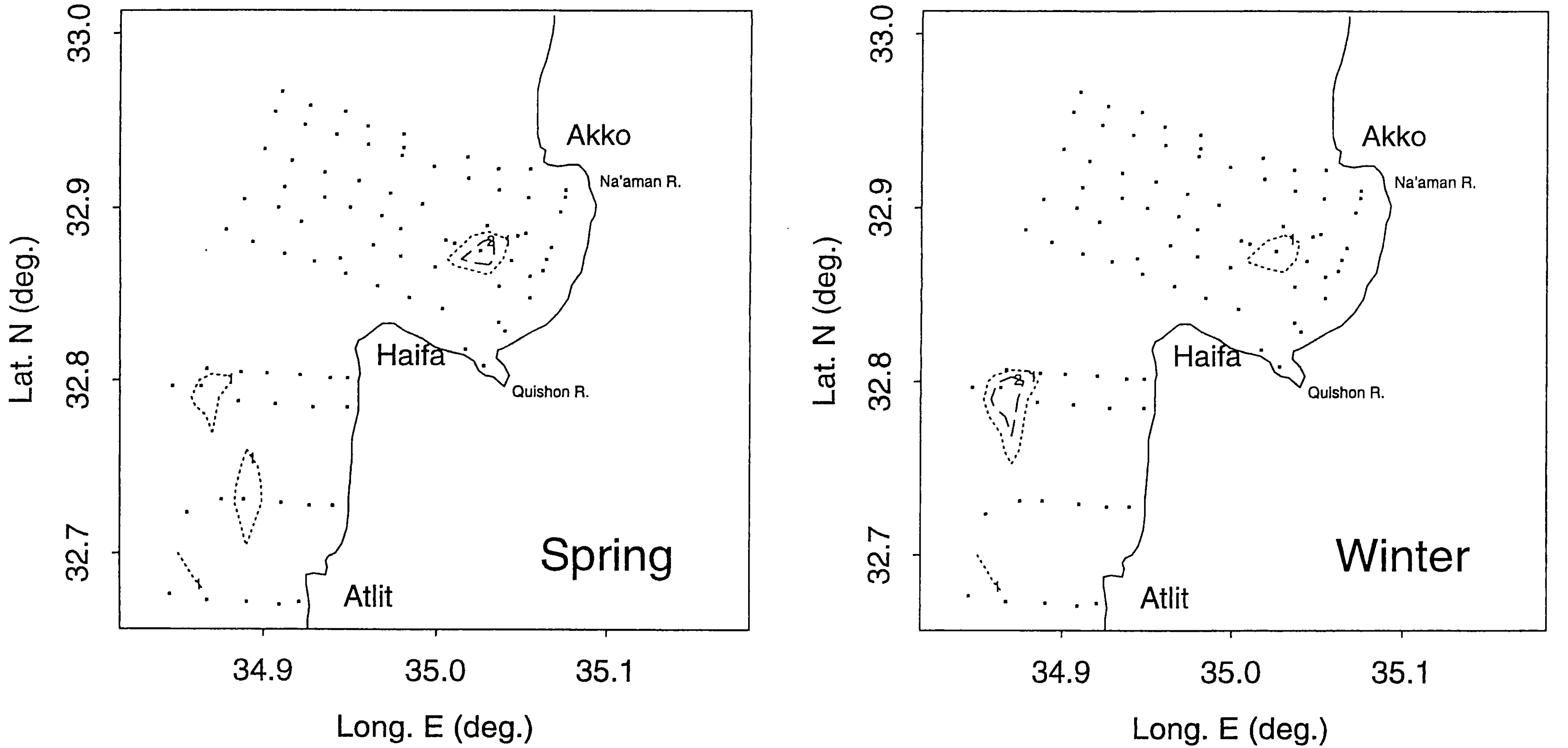
Absolute abundance of *Adelosina elegans*



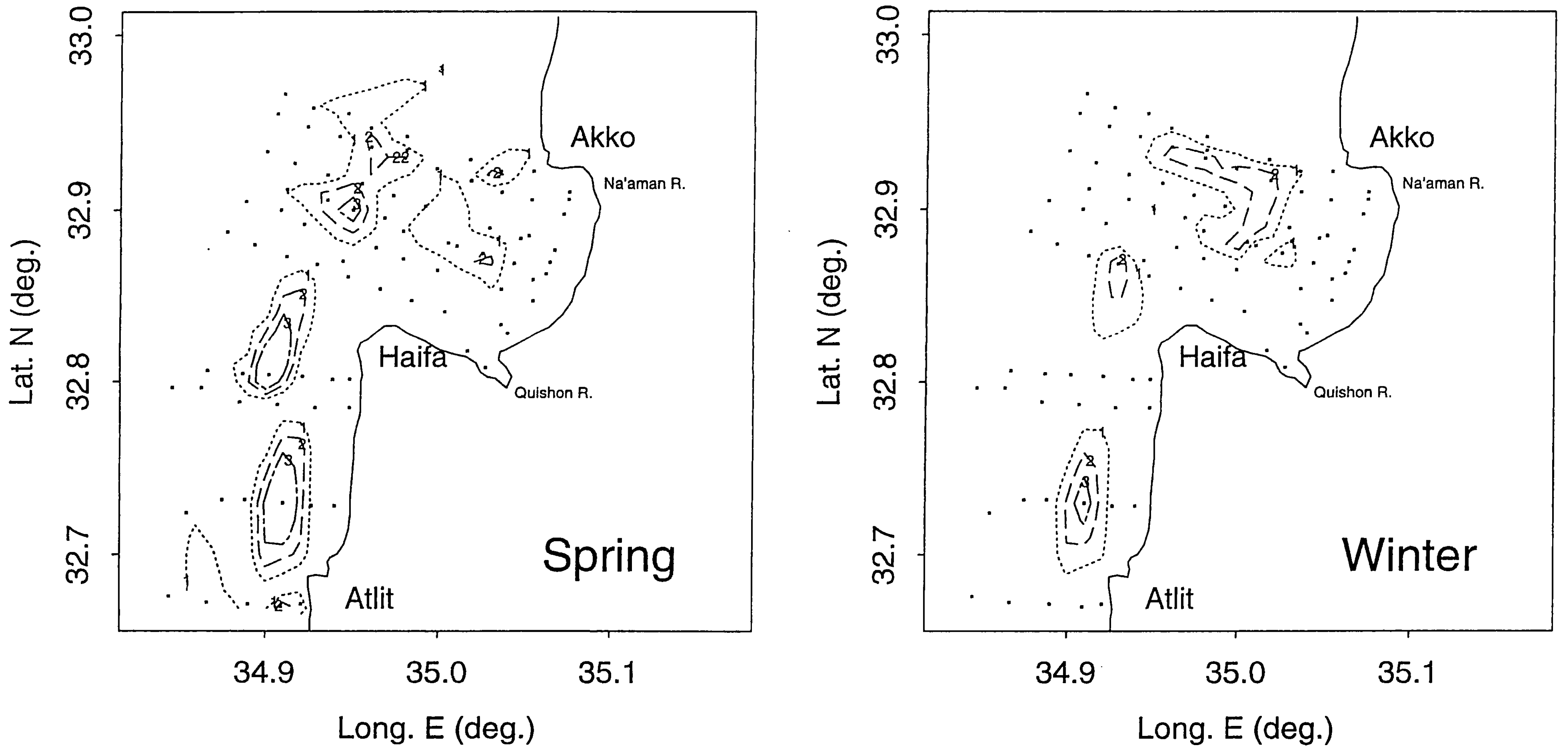
Absolute abundance of Adelosina elegans var anguiata



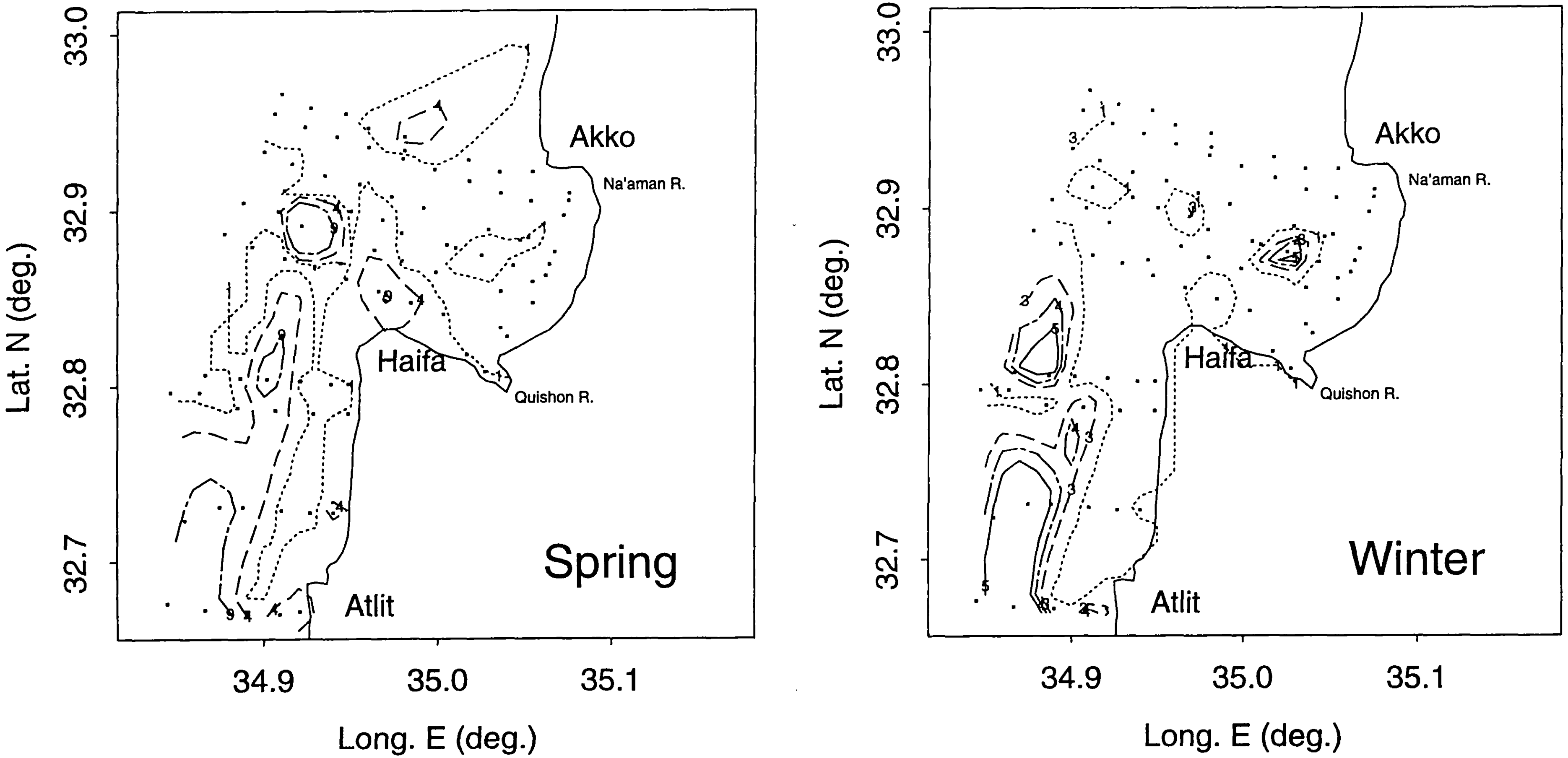
Absolute abundance of Adelosina intricata



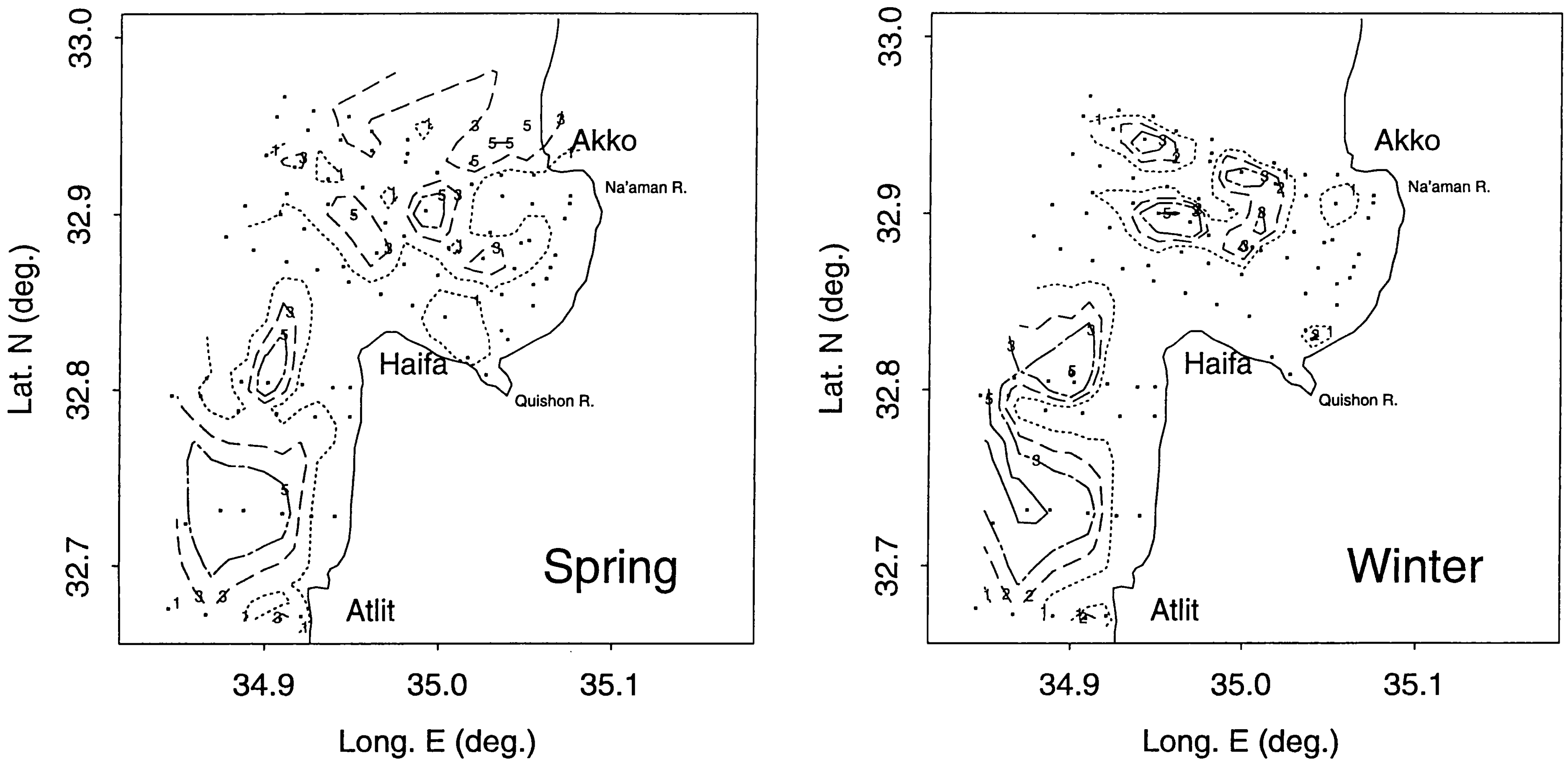
Absolute abundance of Adelosina mediterranensis



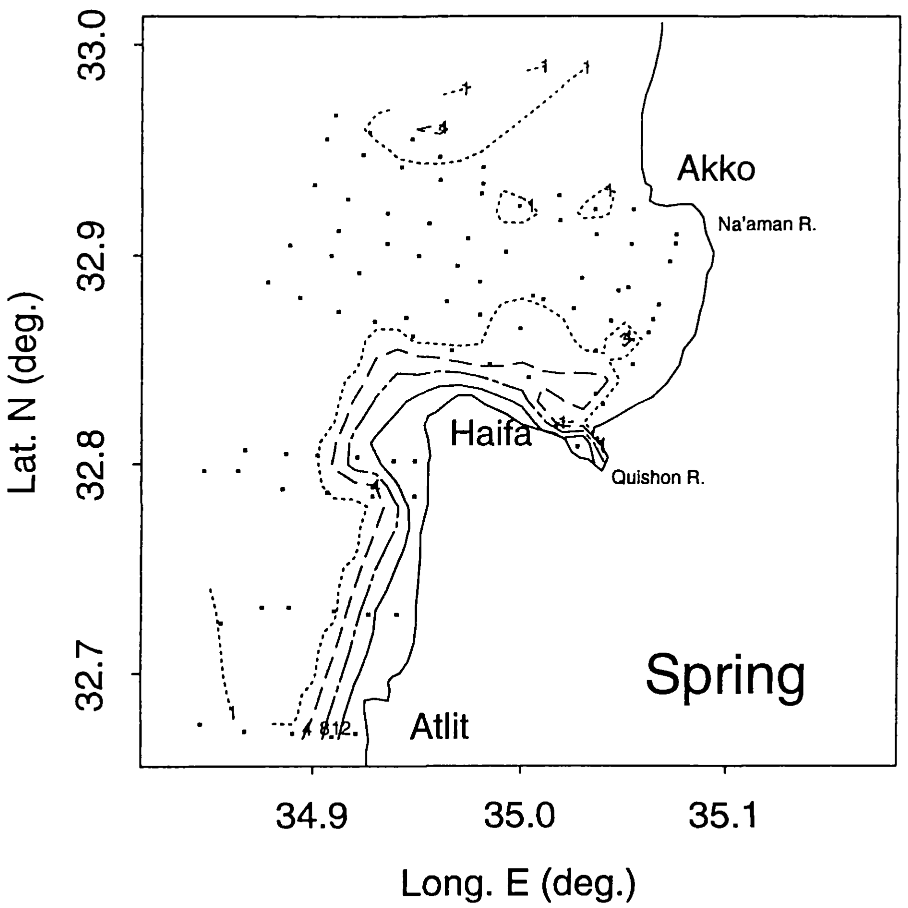
Absolute abundance of Adelosina pulchella

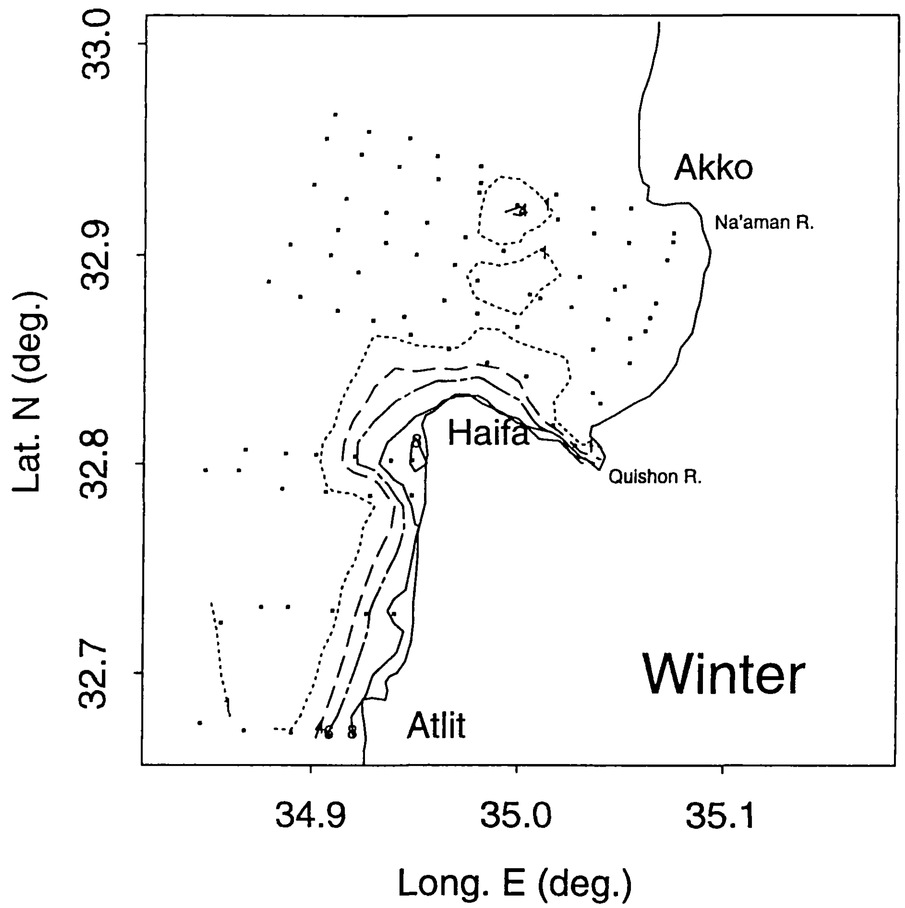


Absolute abundance of Ammonia falsobeccarii

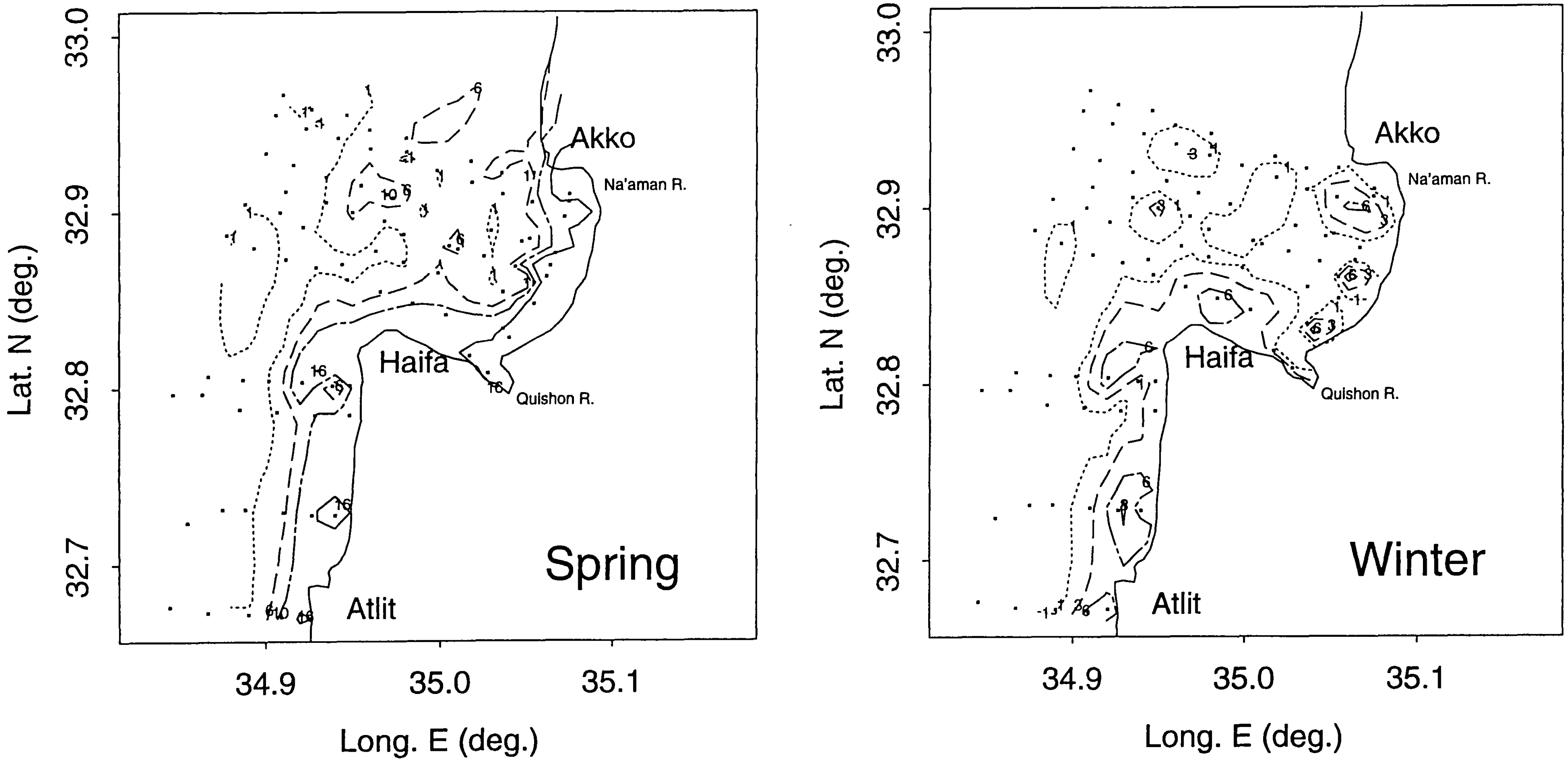


Absolute abundance of Ammonia inflata

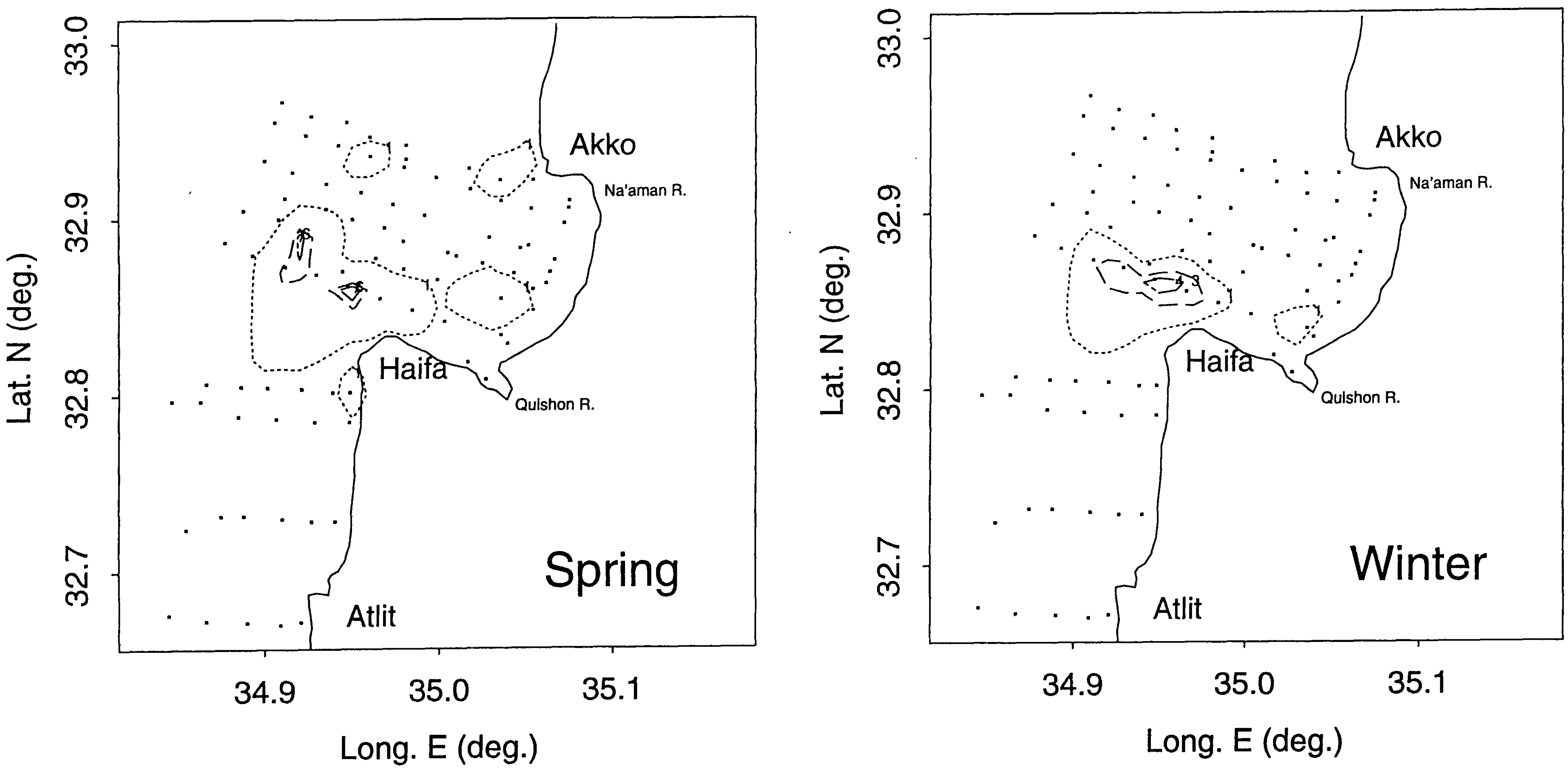




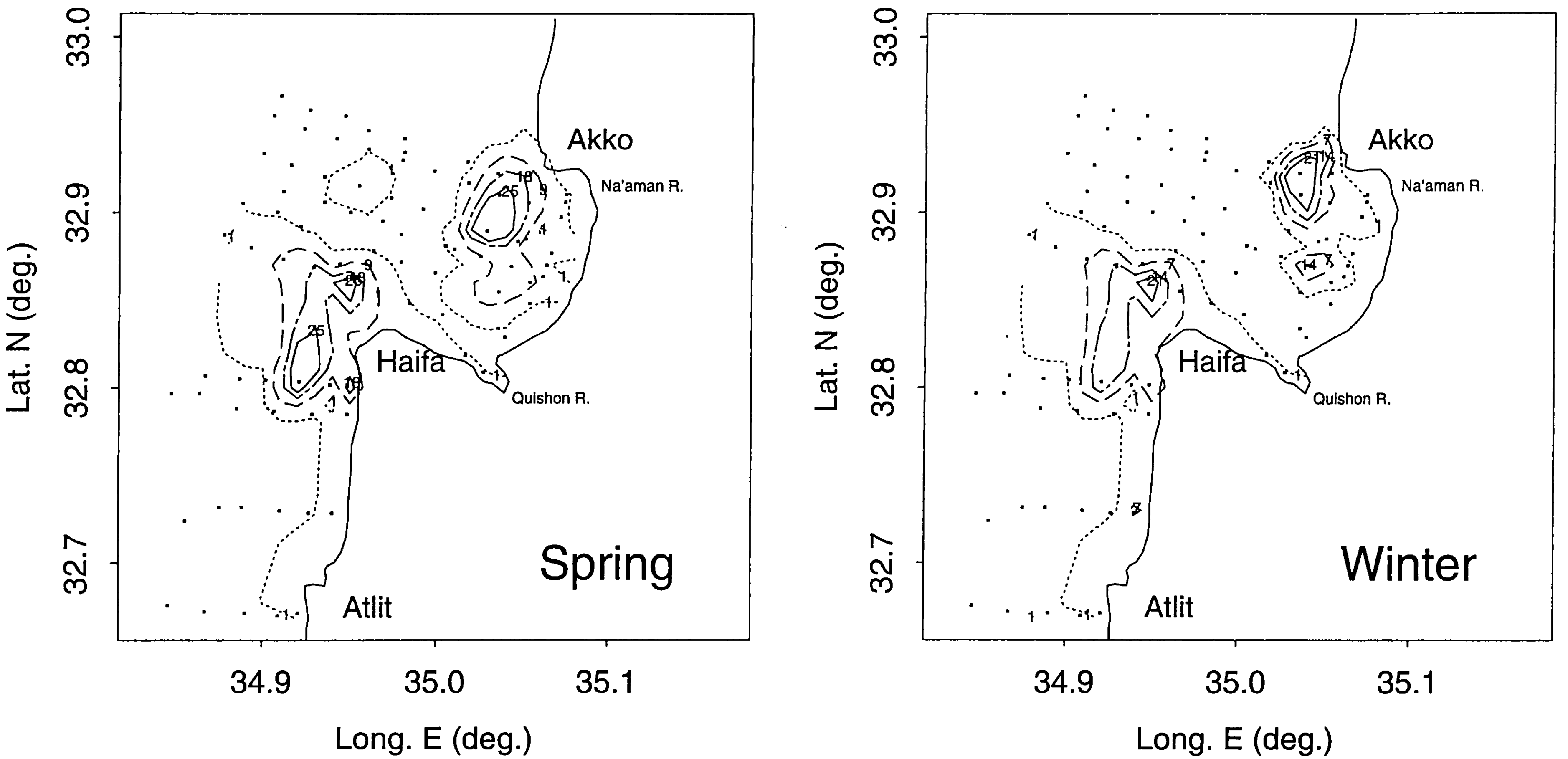
Absolute abundance of Ammonia parkinsoniana



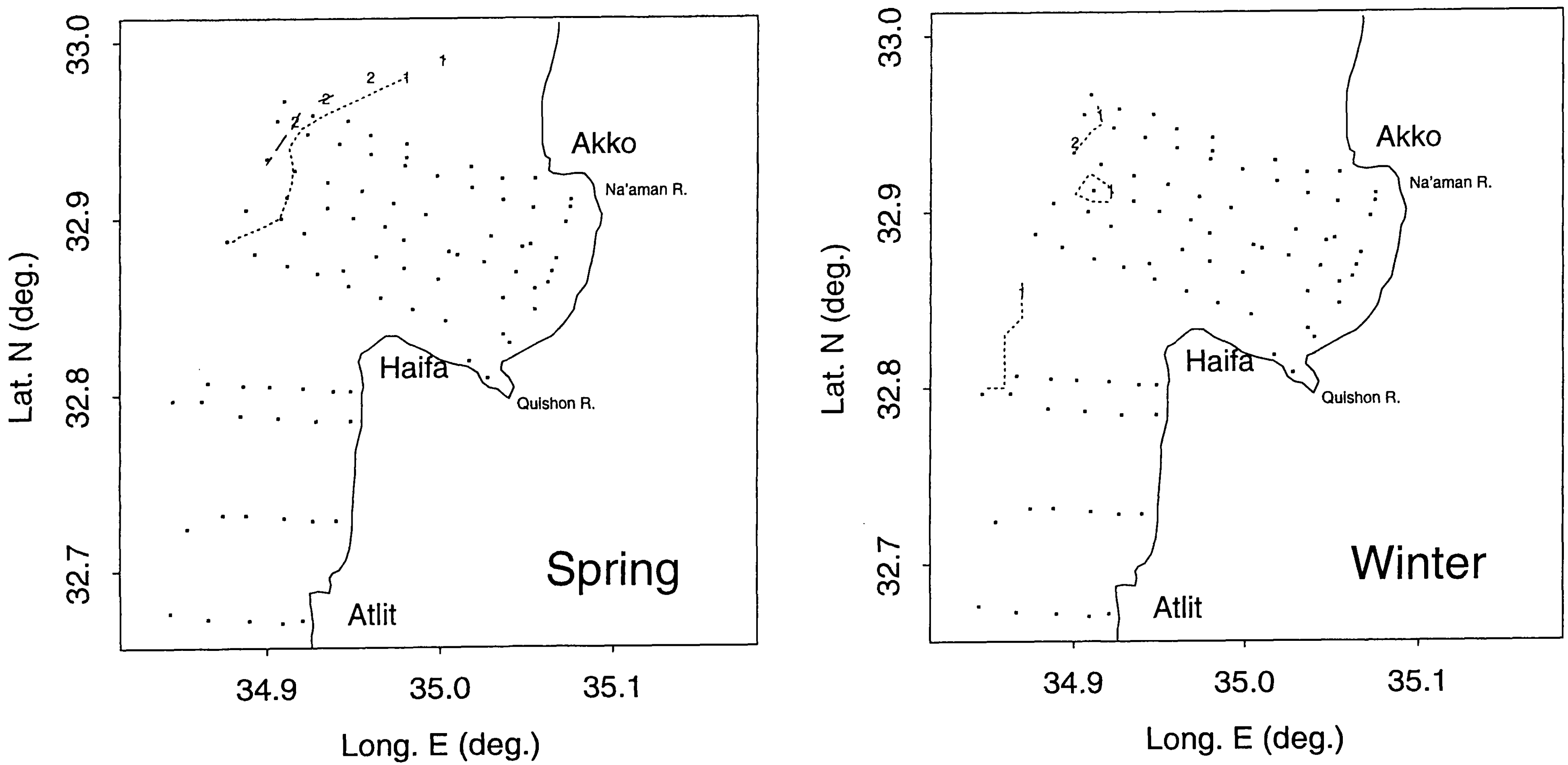
Absolute abundance of Ammonia tepida



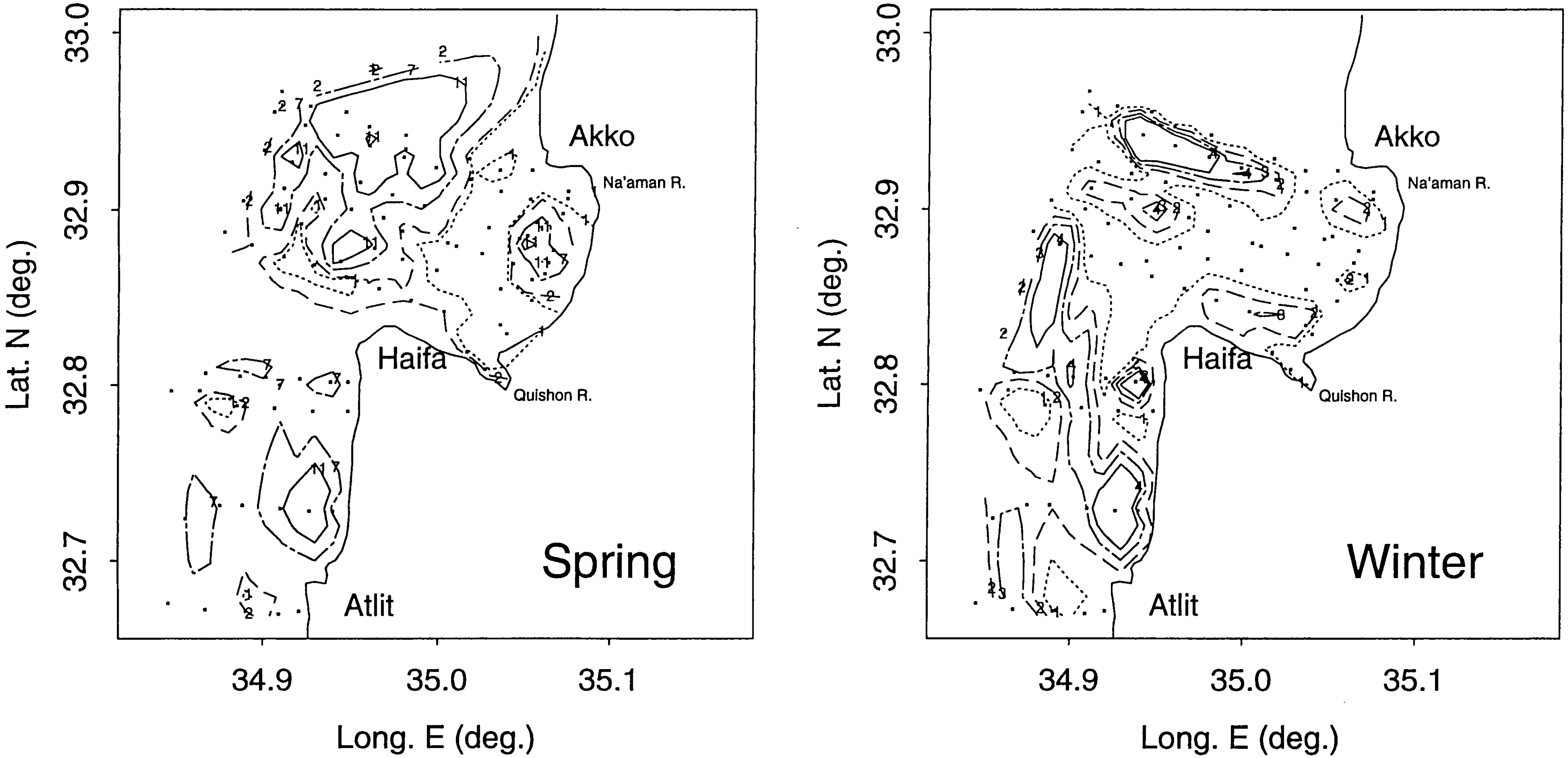
Absolute abundance of Amphistegina lessonii



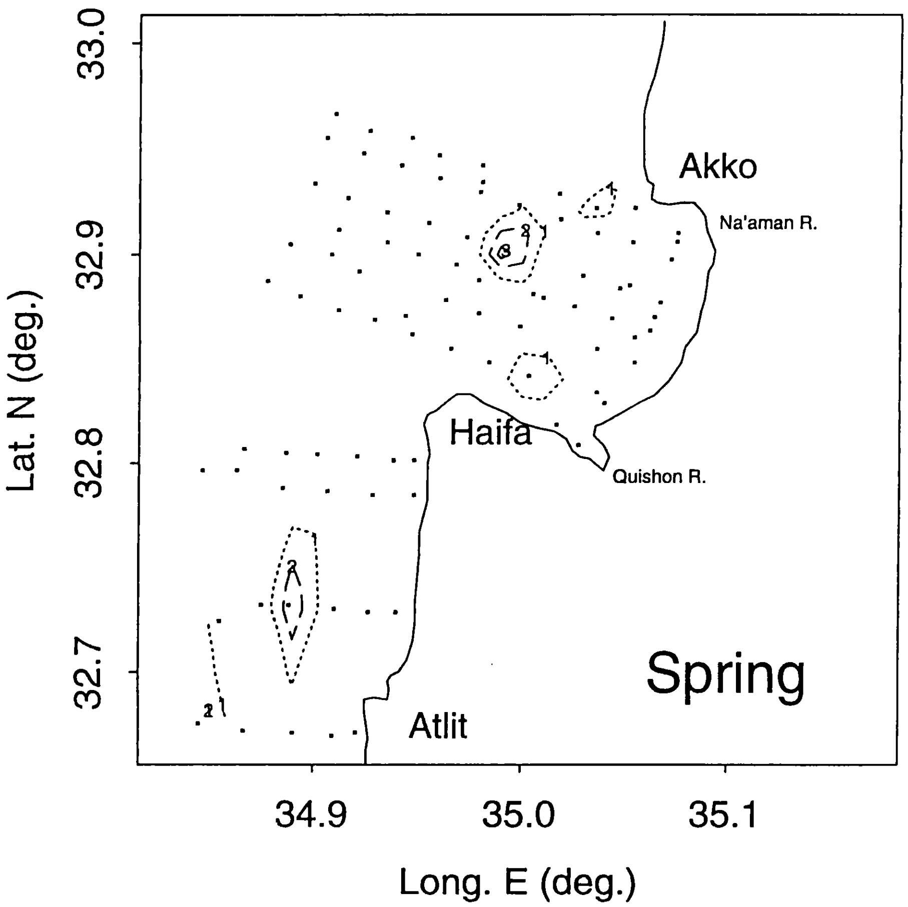
Absolute abundance of Amphistegina lobifera

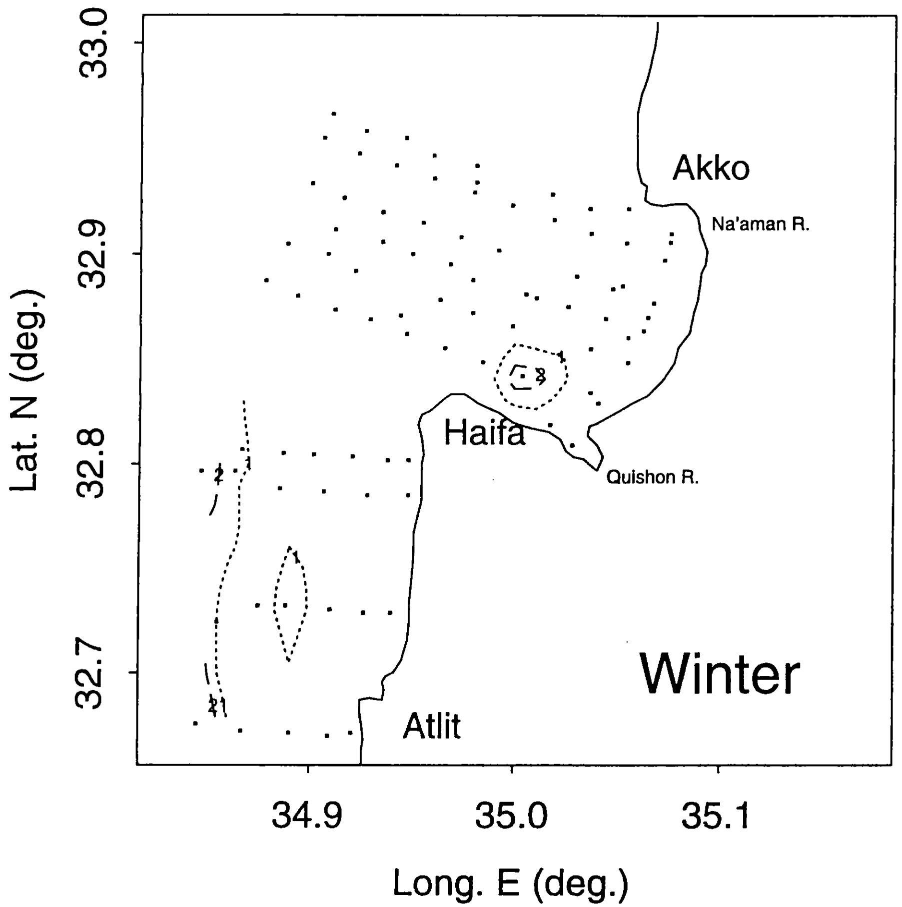


Absolute abundance of Amphicorina sp

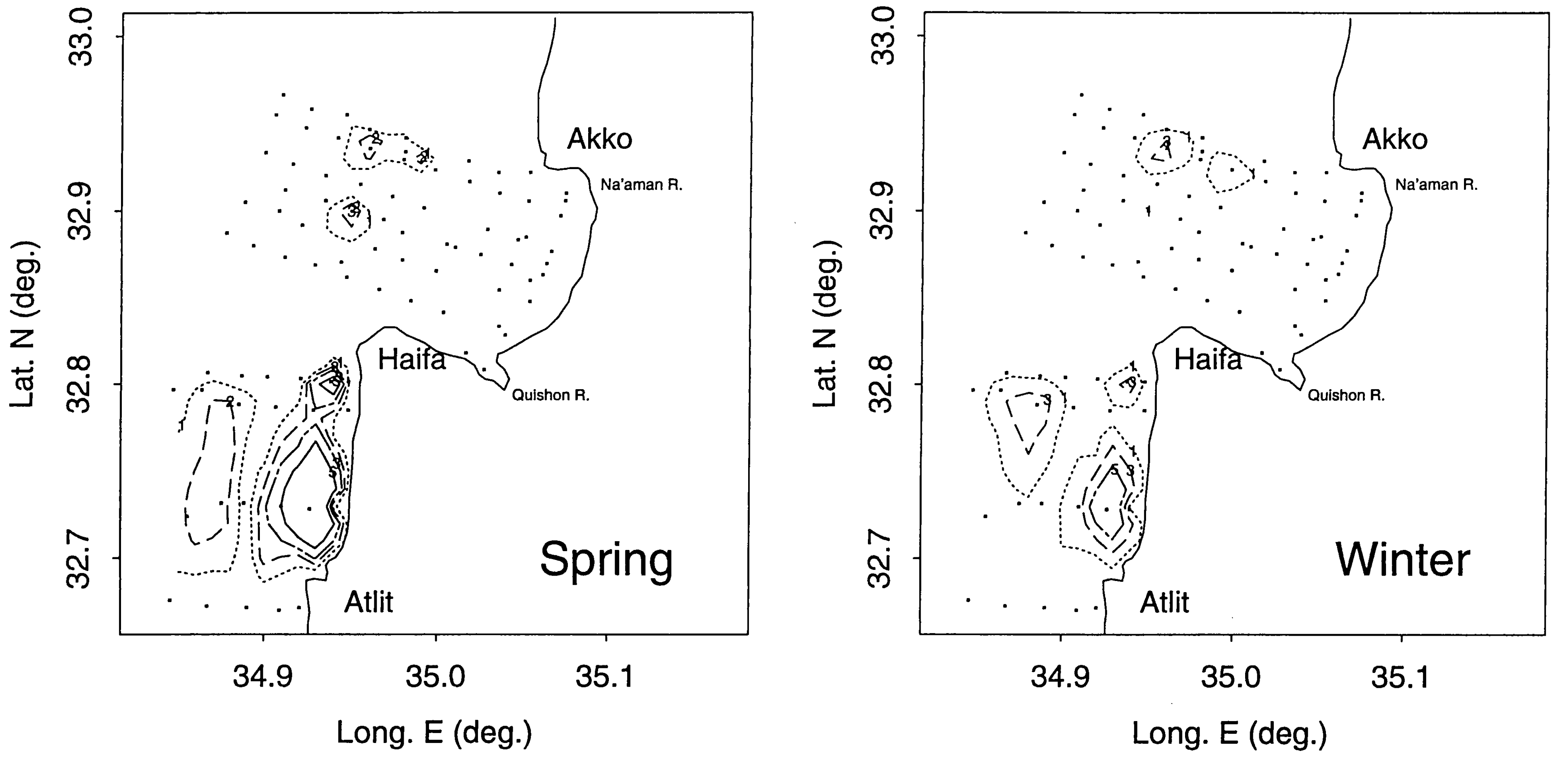


Absolute abundance of Asterigerinata mamilla

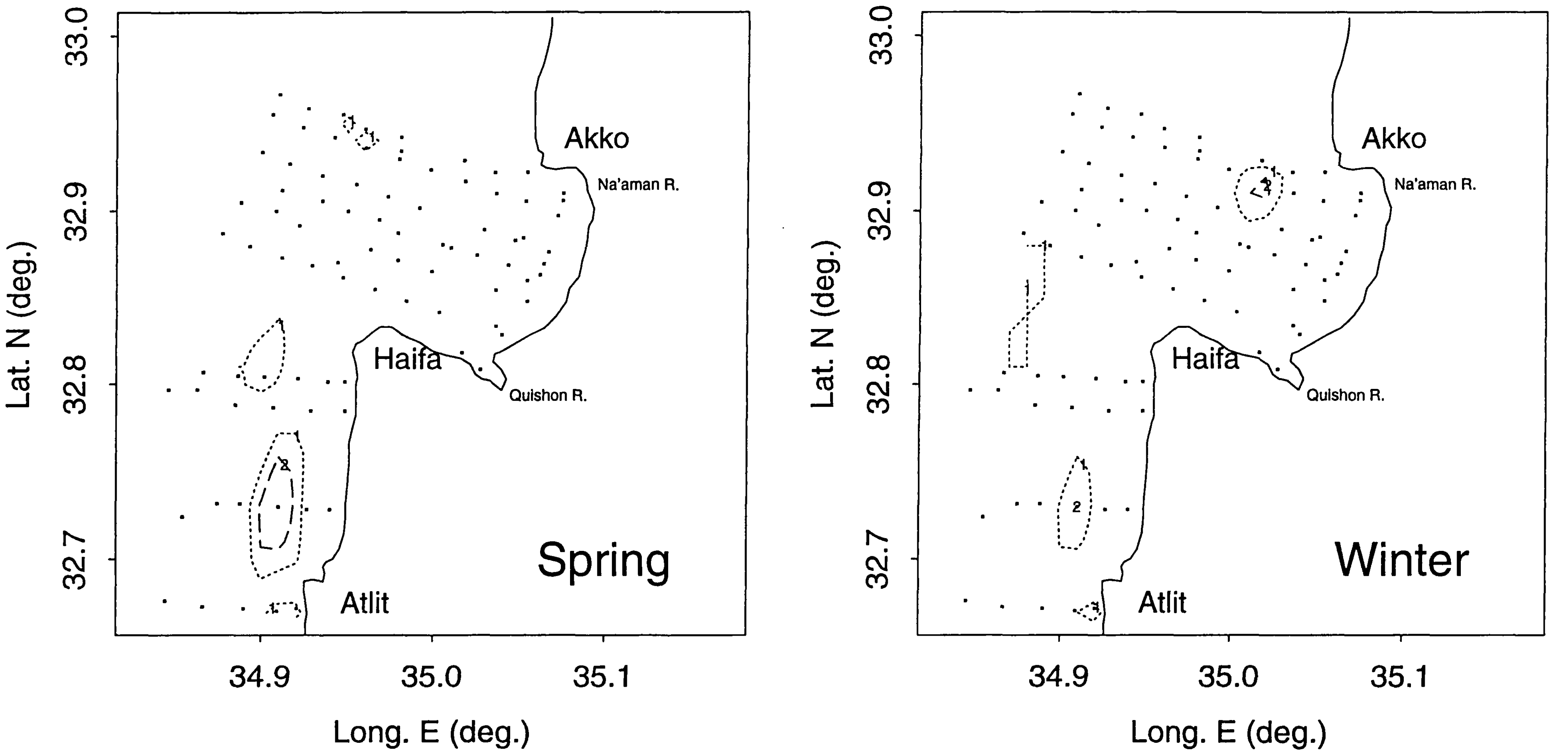




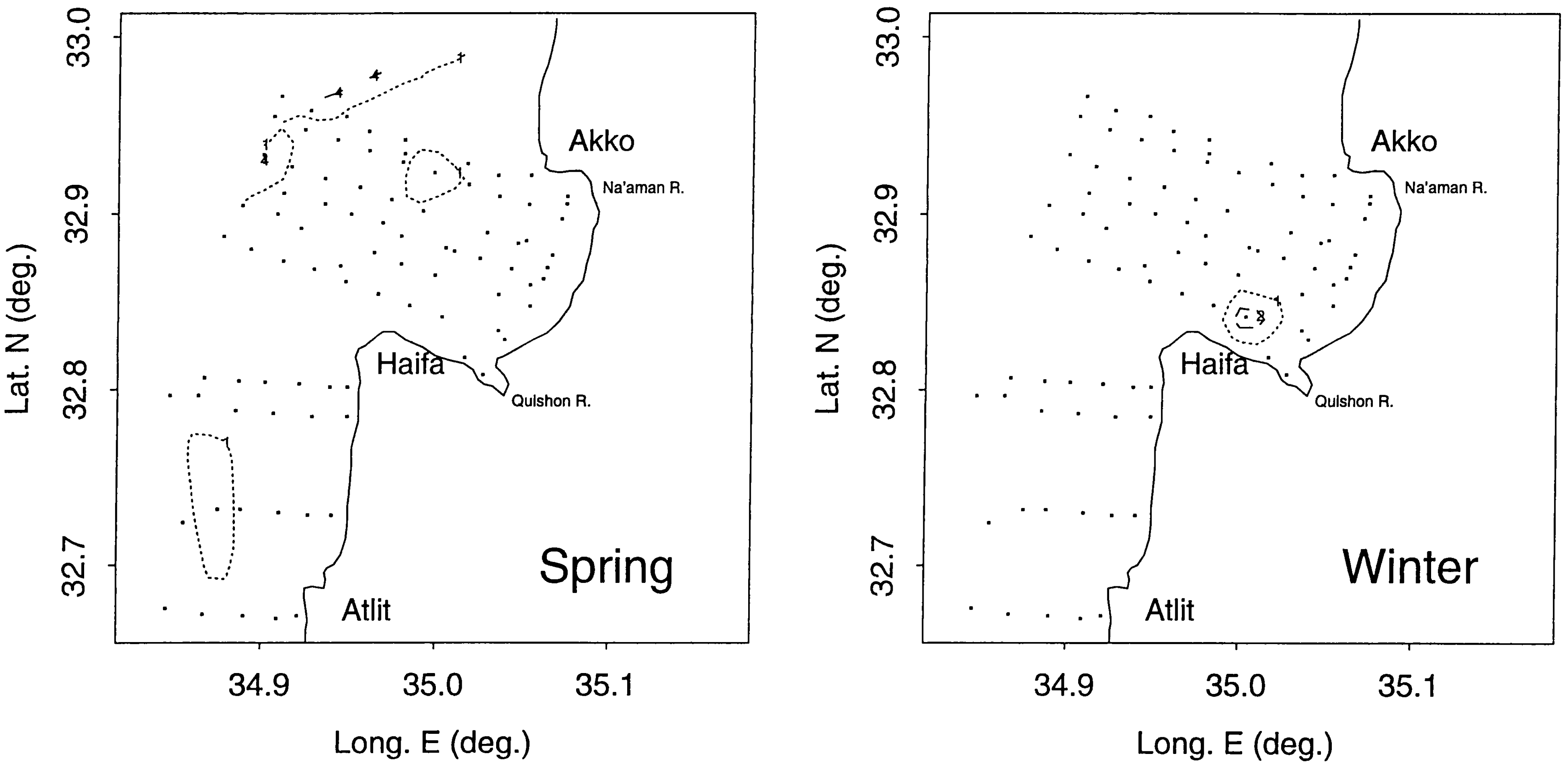
Absolute abundance of Astrononion stelliger



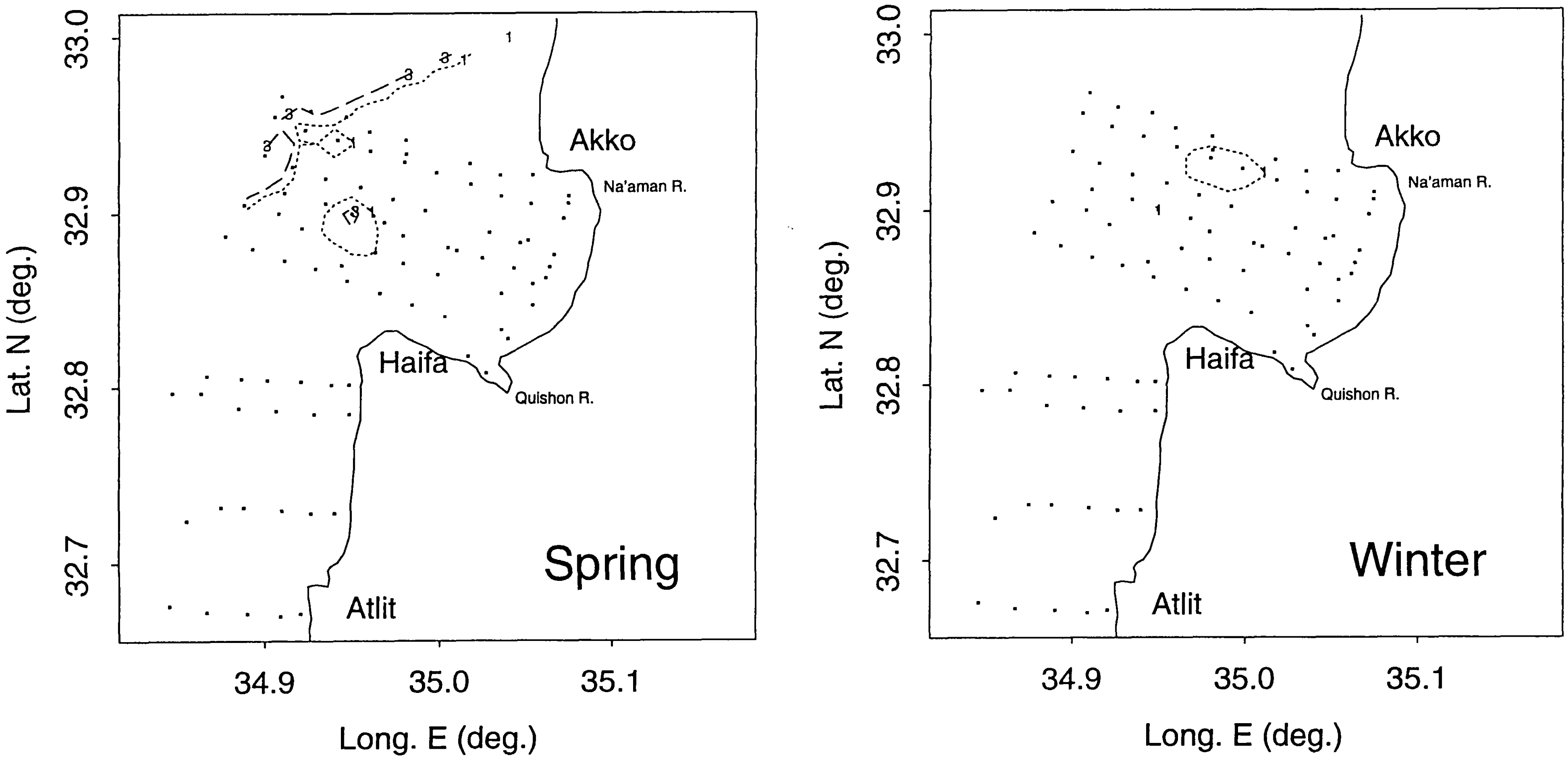
Absolute abundance of Sterorotalia gaimardi



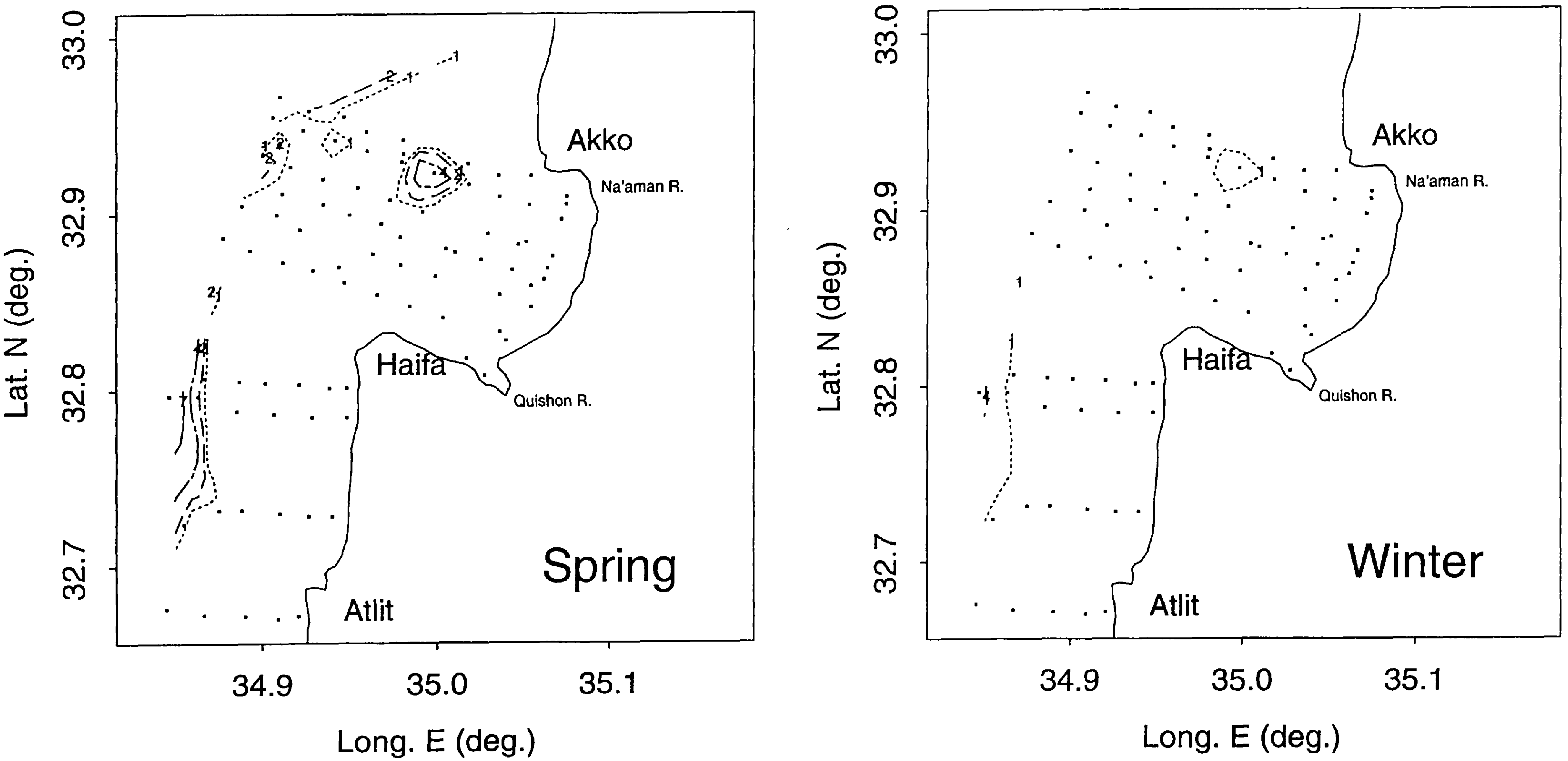
Absolute abundance of Biloculinella labiata



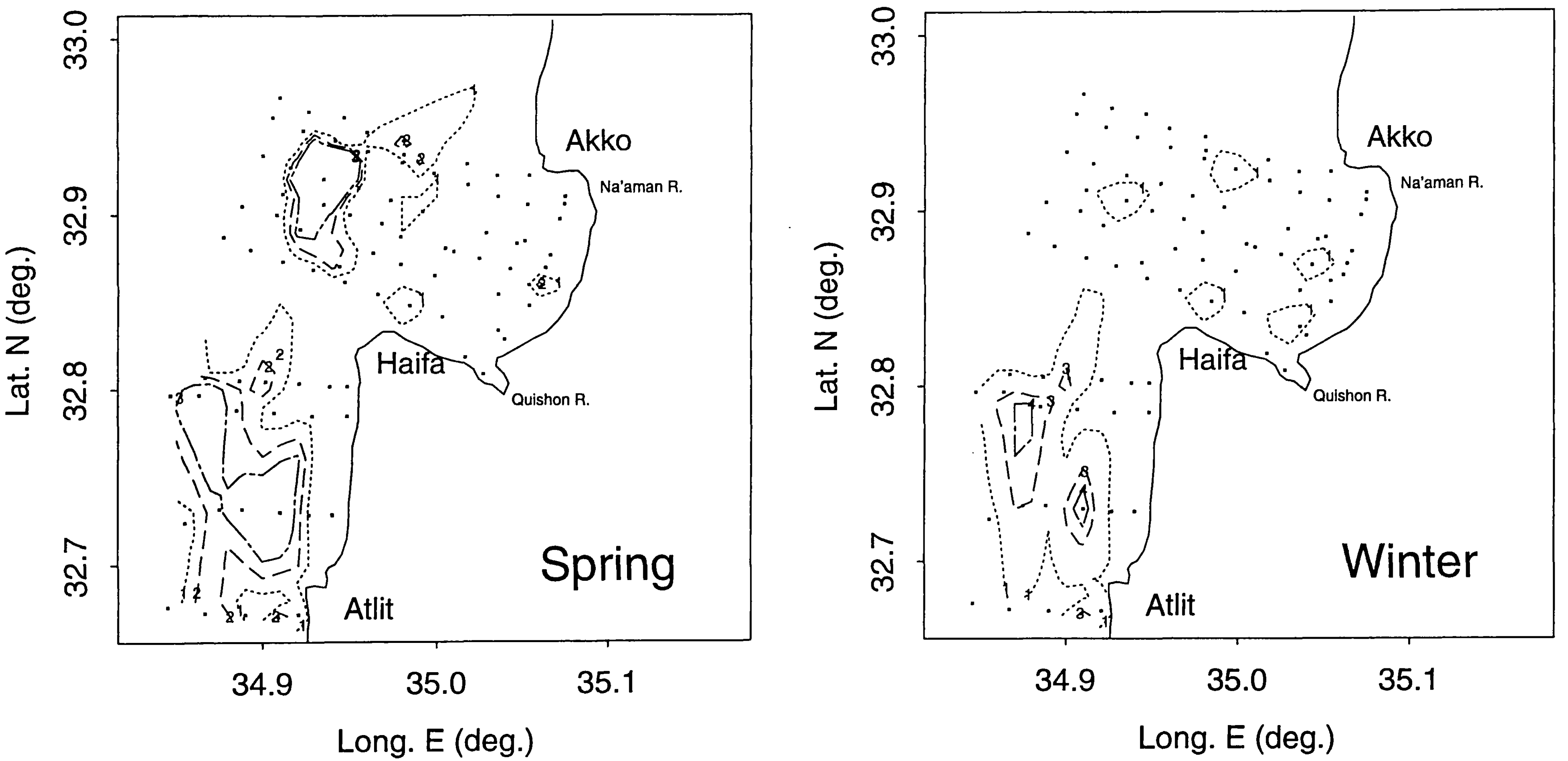
Absolute abundance of Bolivina variabilis



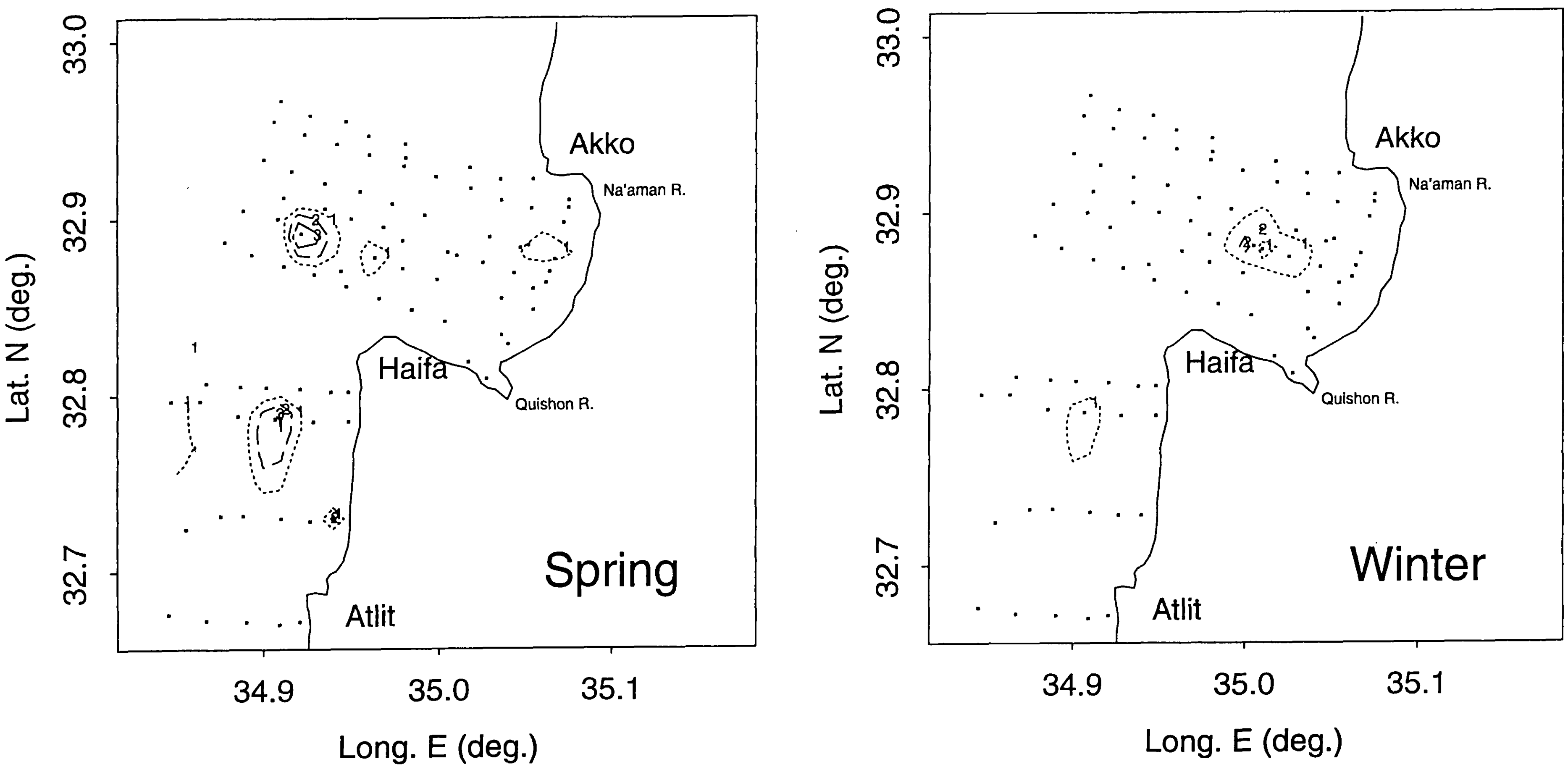
Absolute abundance of Brizalina spathulata



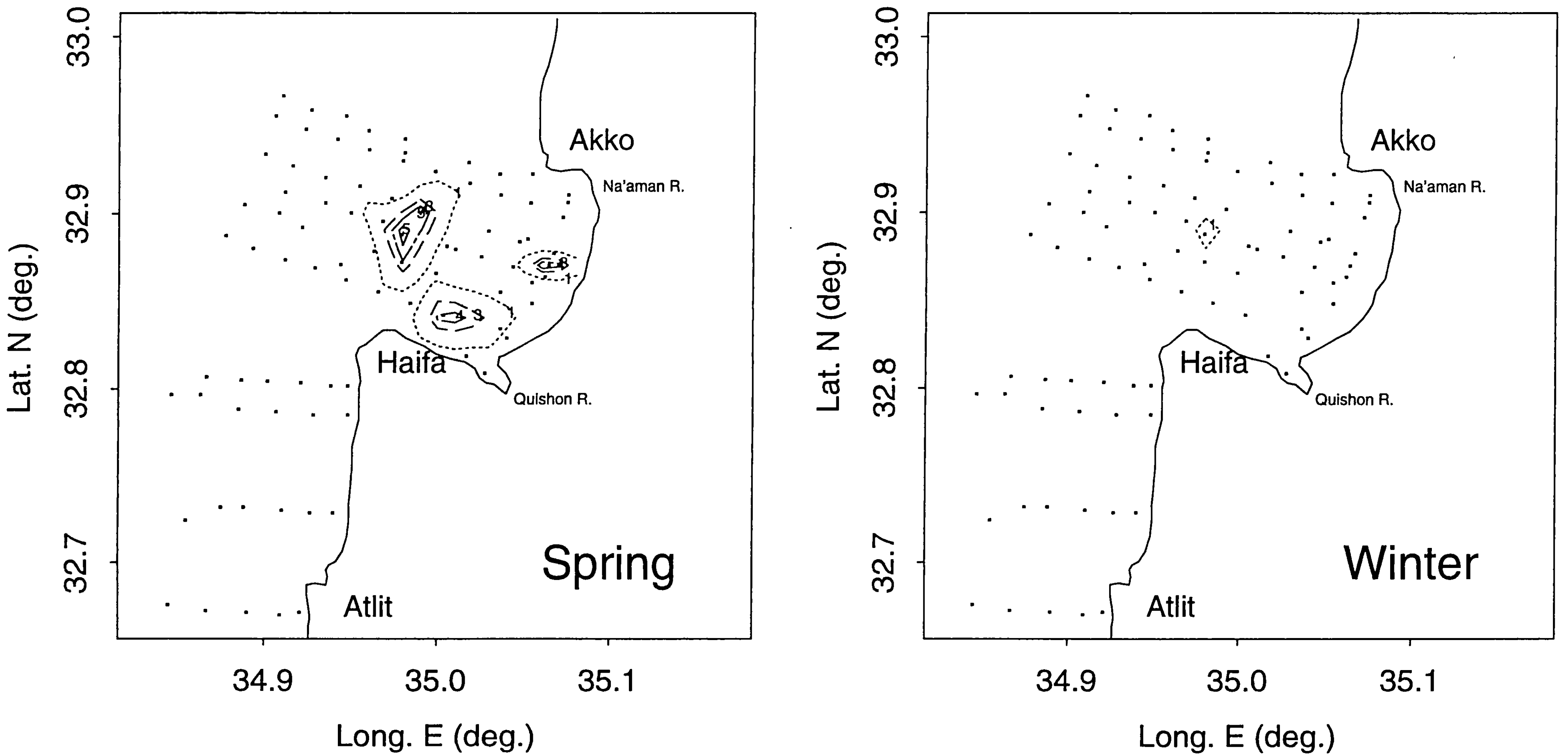
Absolute abundance of Brizalina striatula



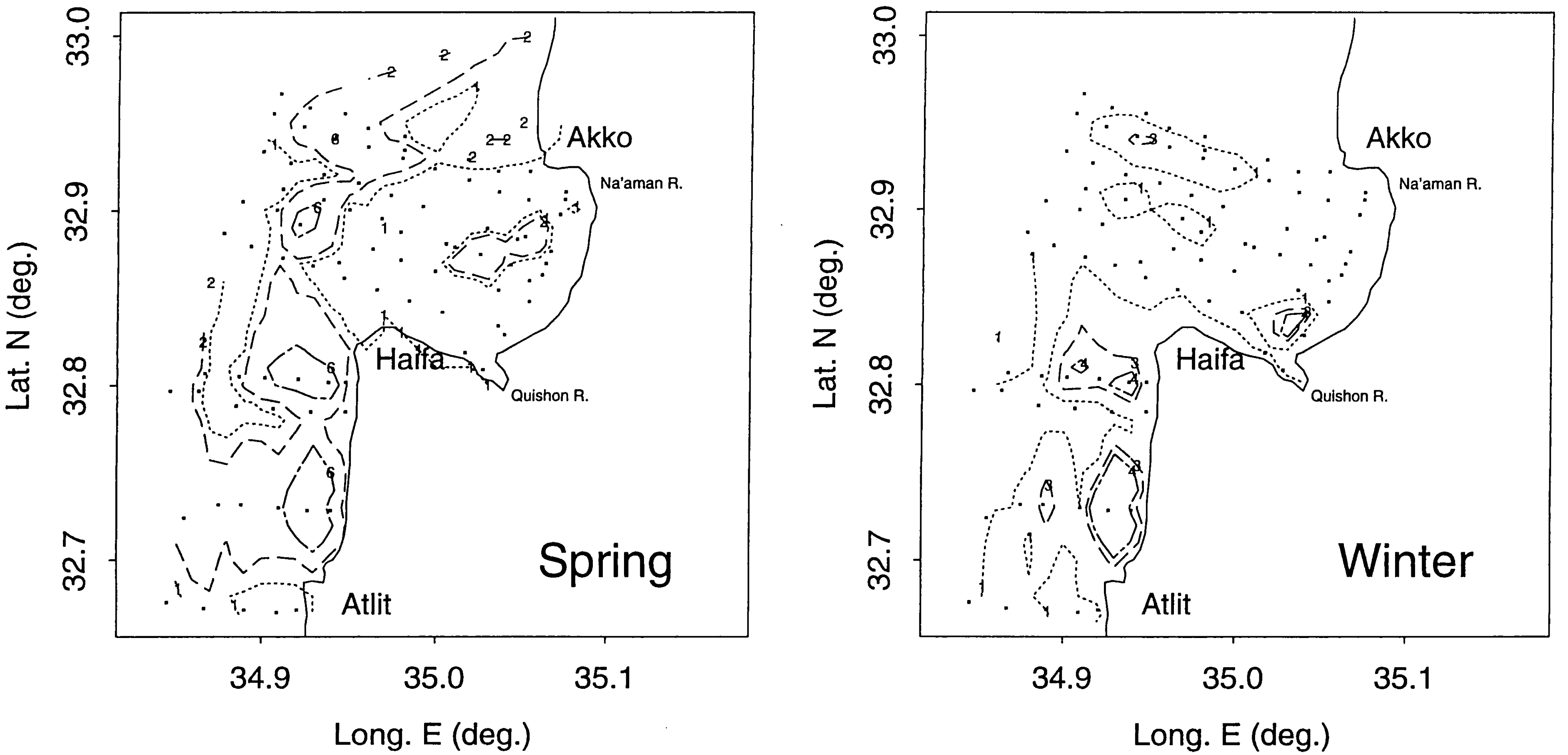
Absolute abundance of Challengerella bradyi



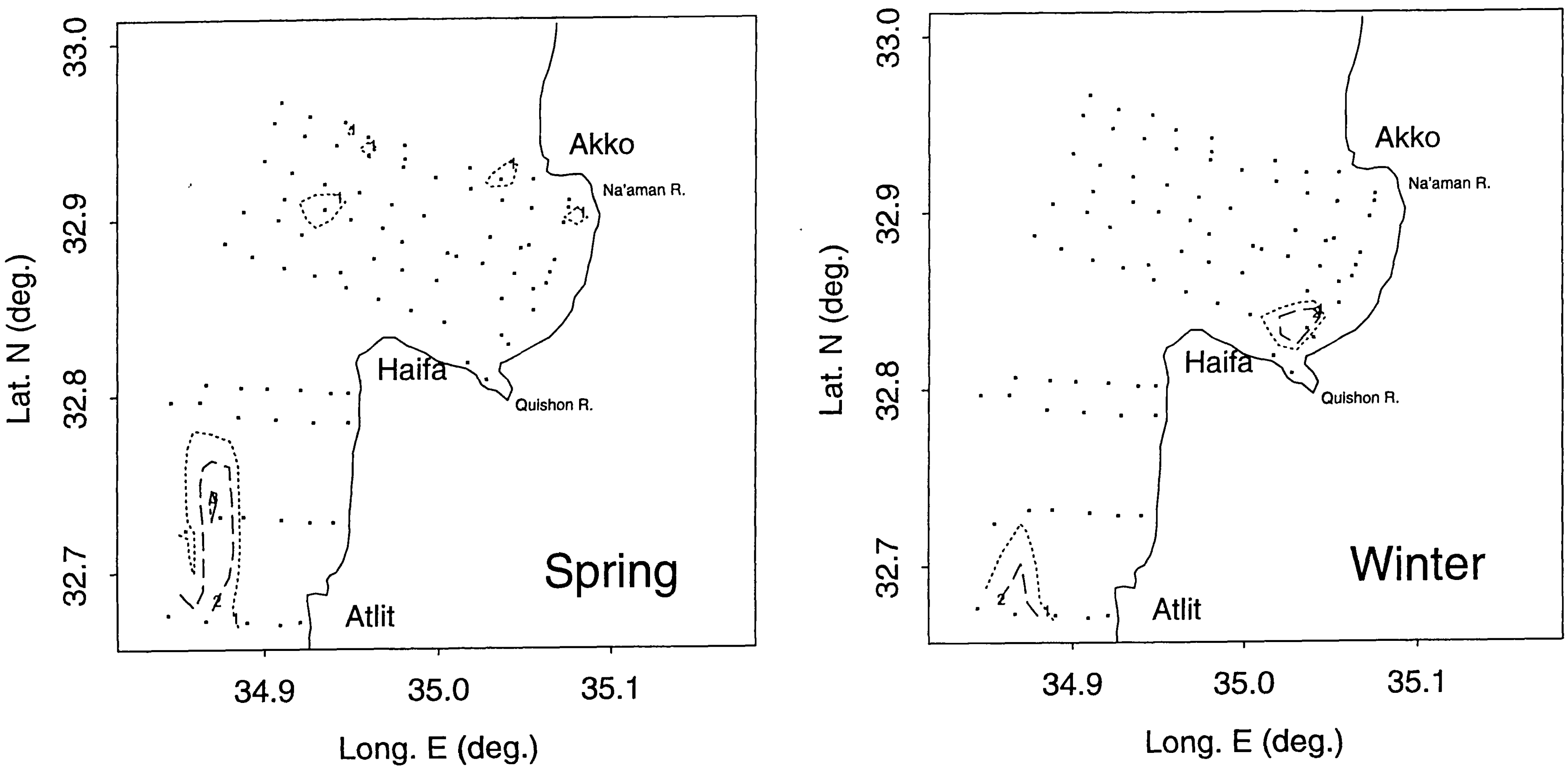
Absolute abundance of Cibicides advenus



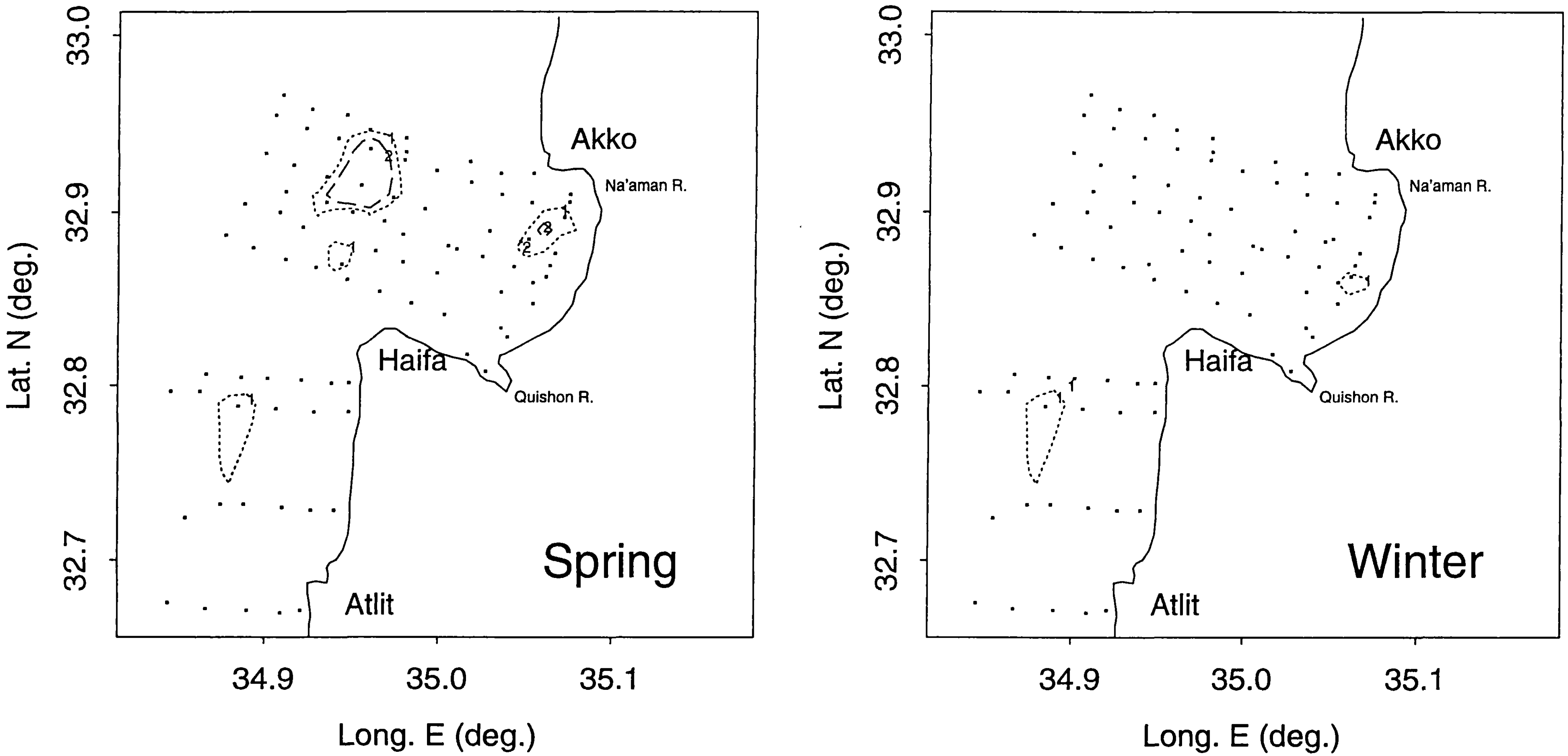
Absolute abundance of Coscinospira hemprichii



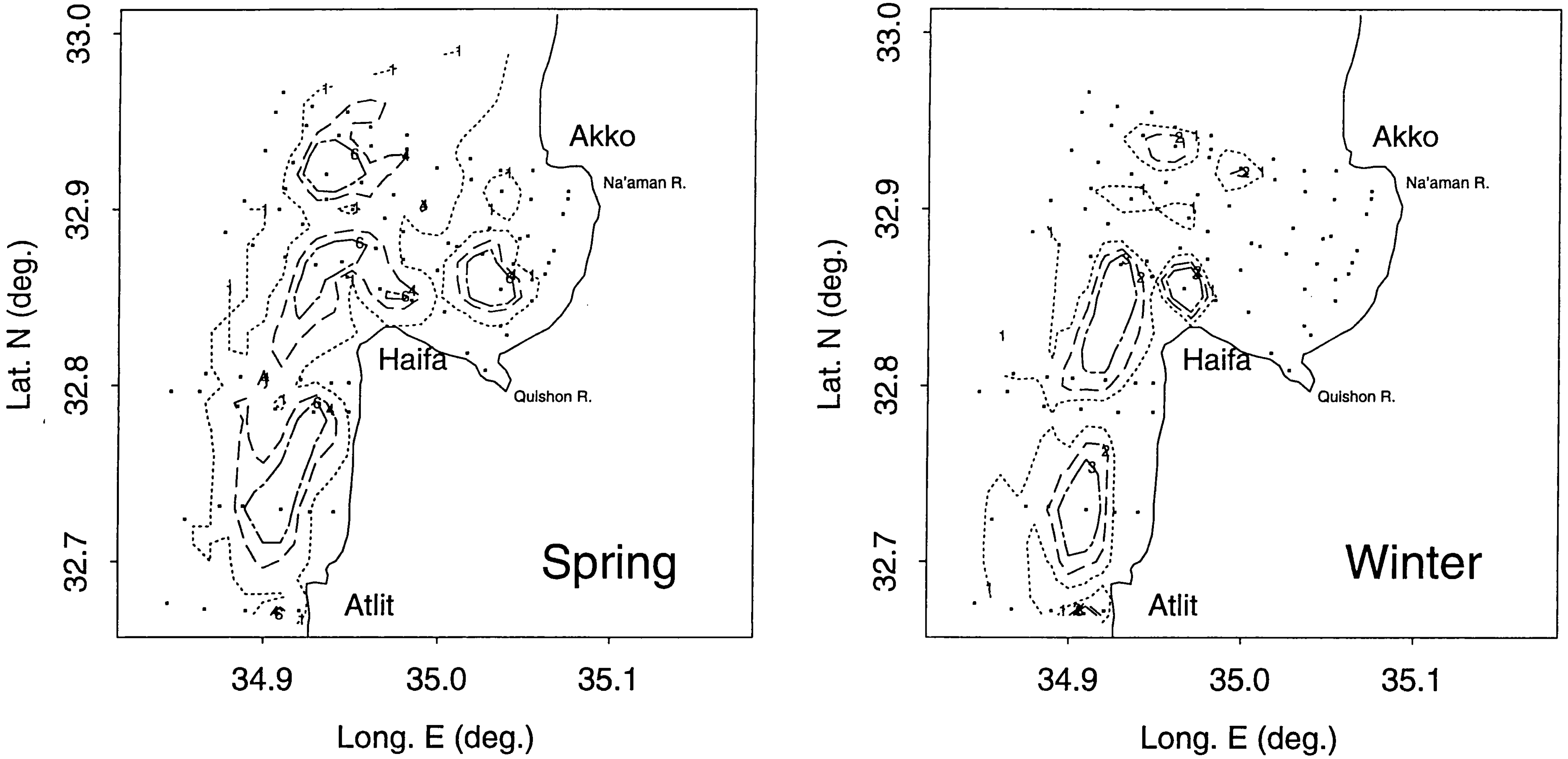
Absolute abundance of Discorbinella berthelotti



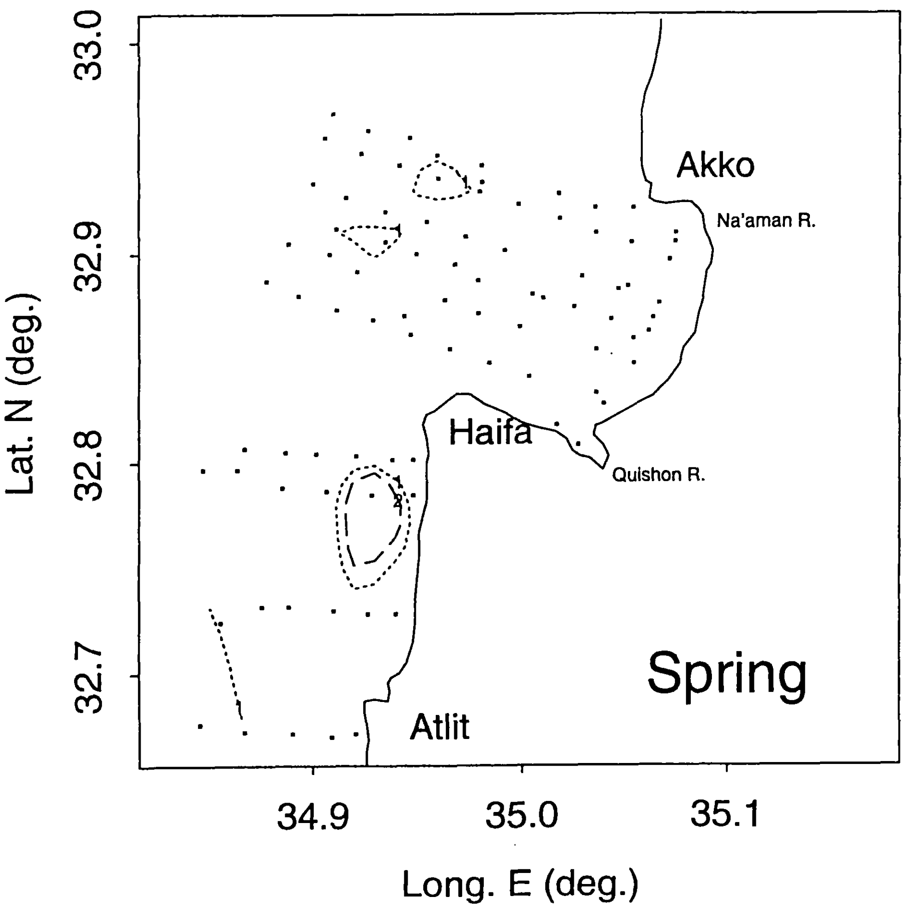
Absolute abundance of Edentostomina cultrata

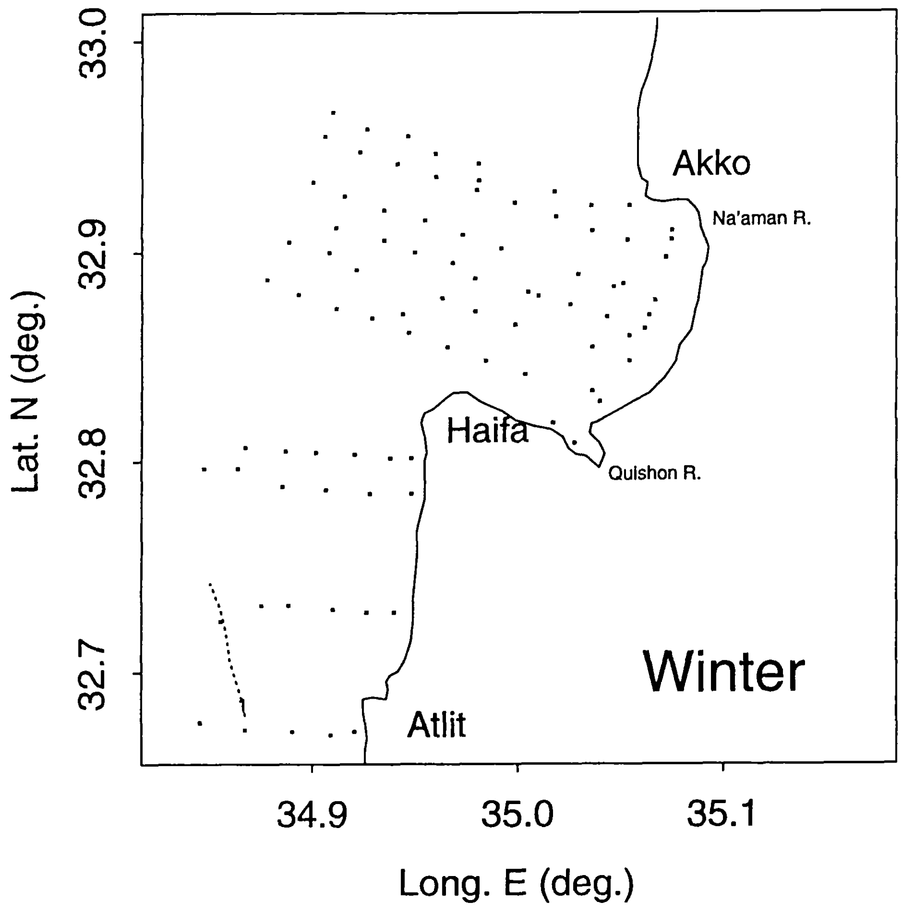


Absolute abundance of Elphidium advenum

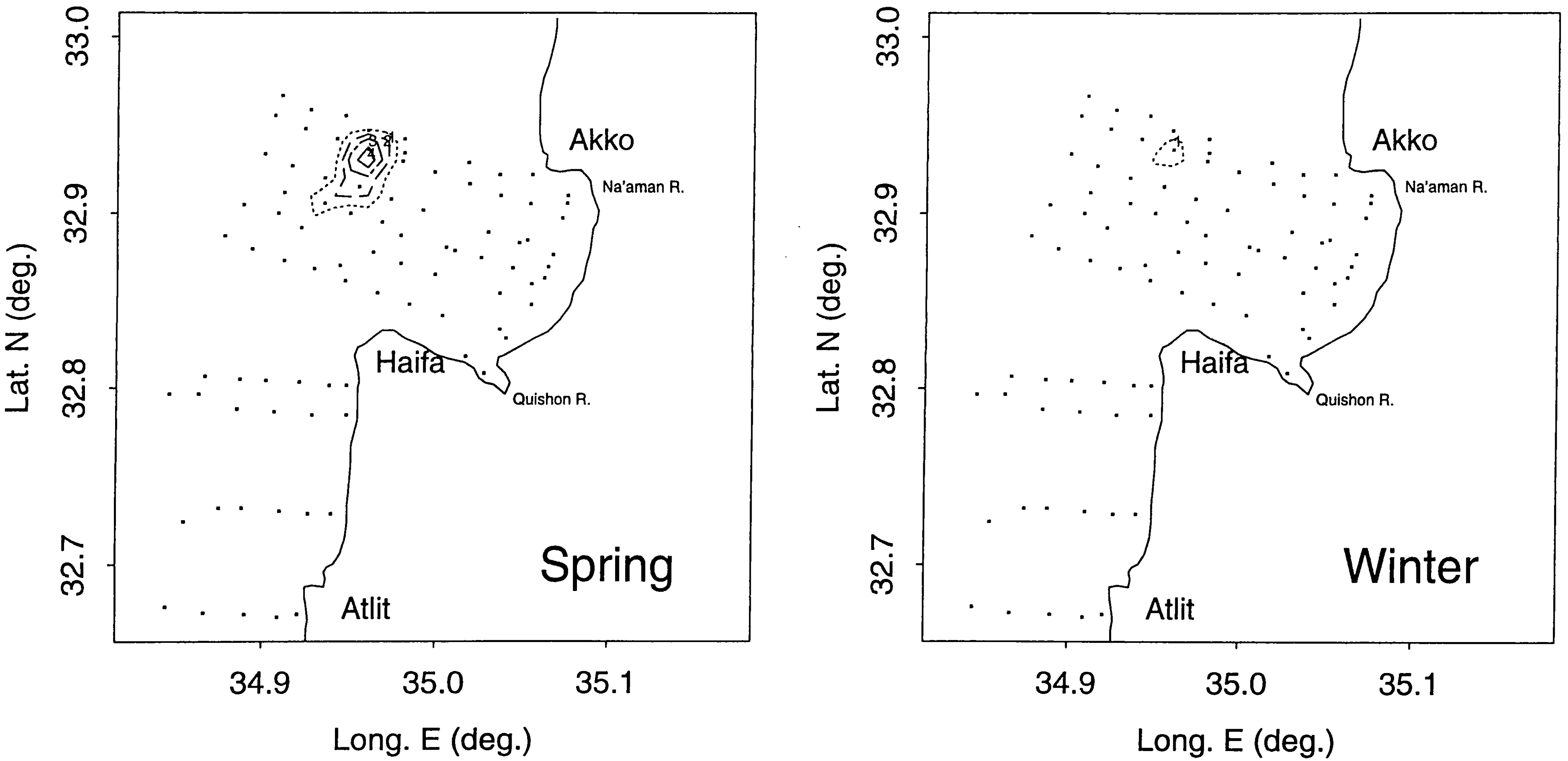


Absolute abundance of Elphidium crispum

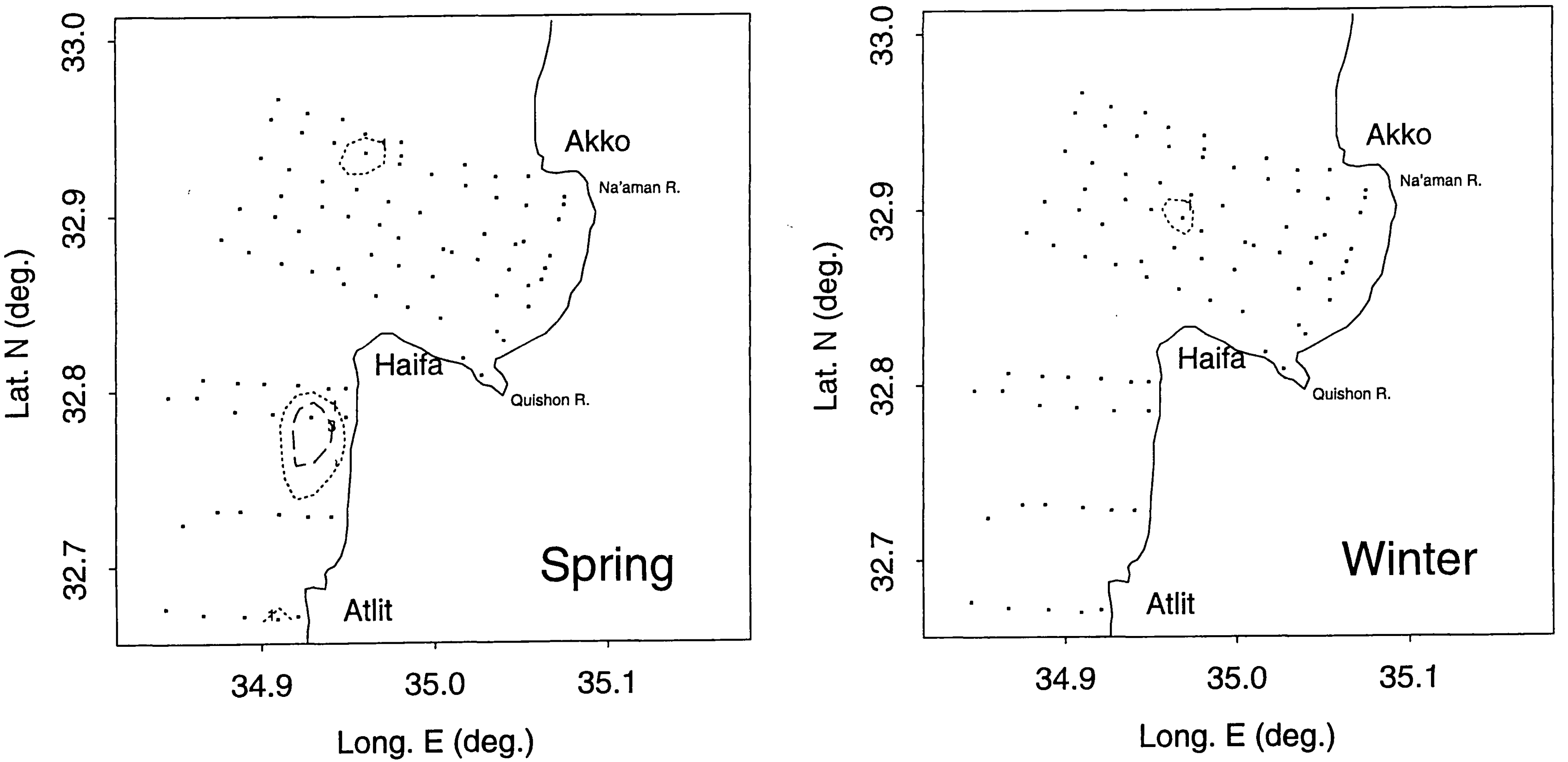




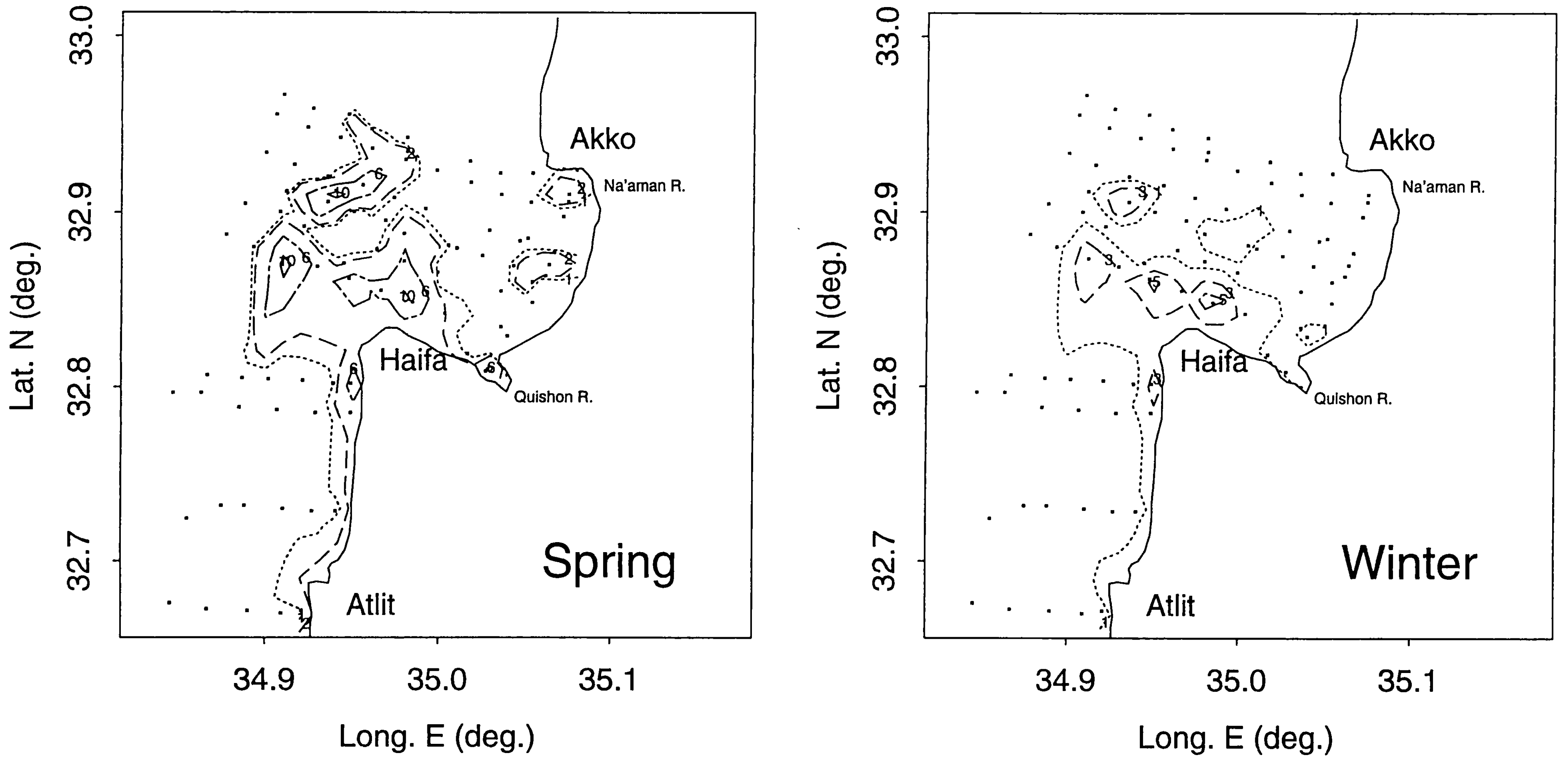
Absolute abundance of Elphidium depressulum



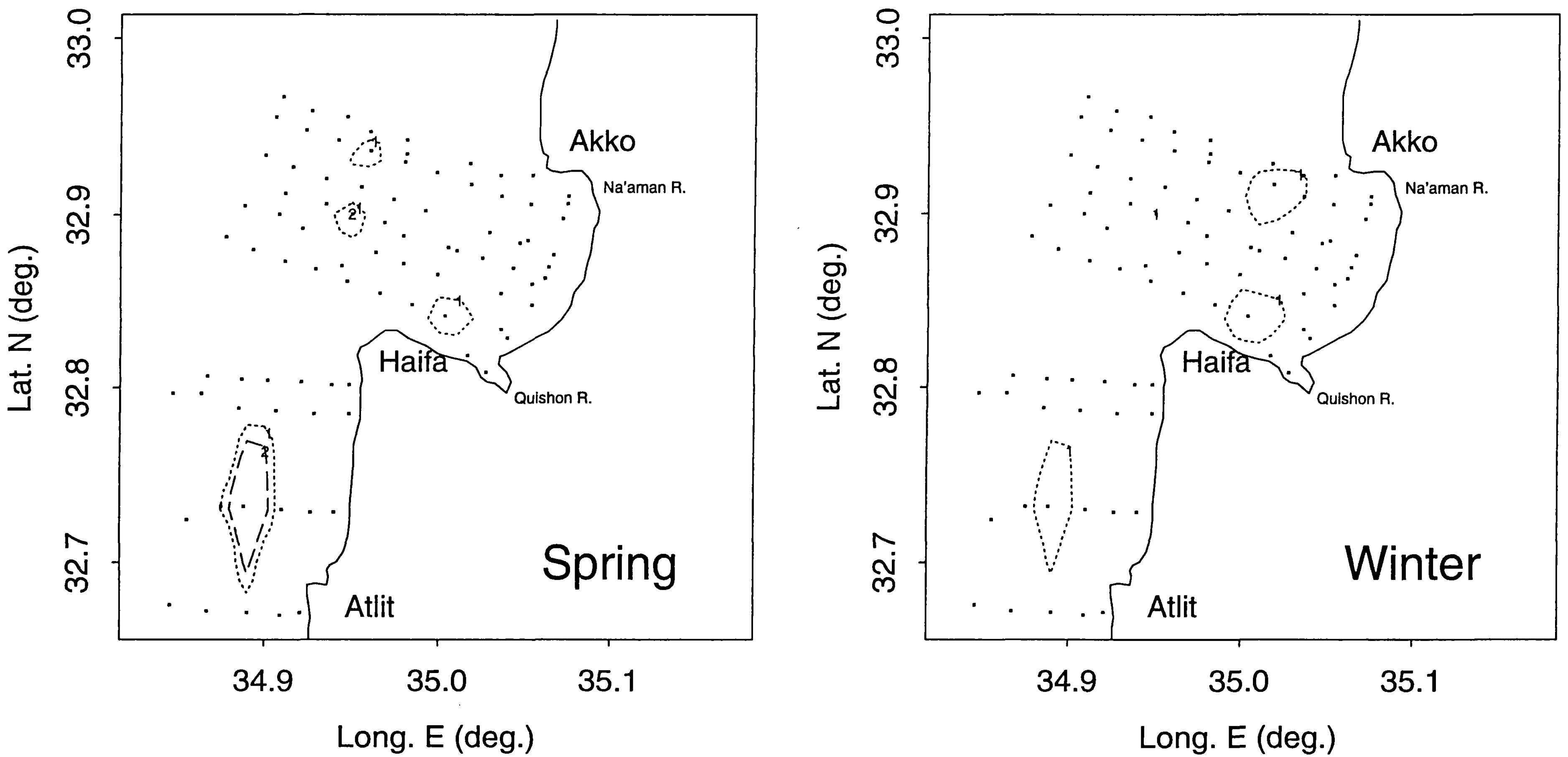
Absolute abundance of Elphidium jenseni



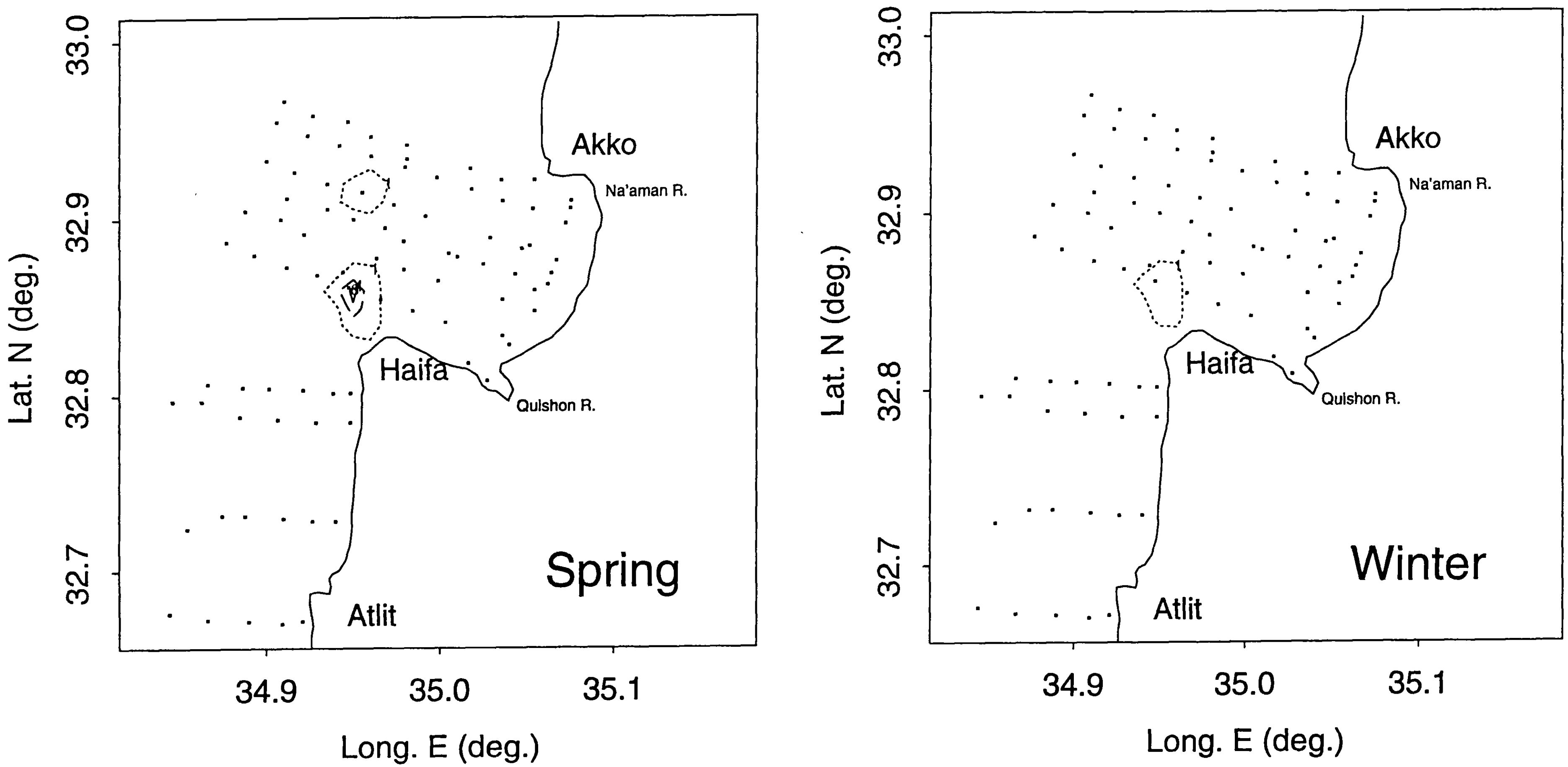
Absolute abundance of Elphidium striatopunctatum



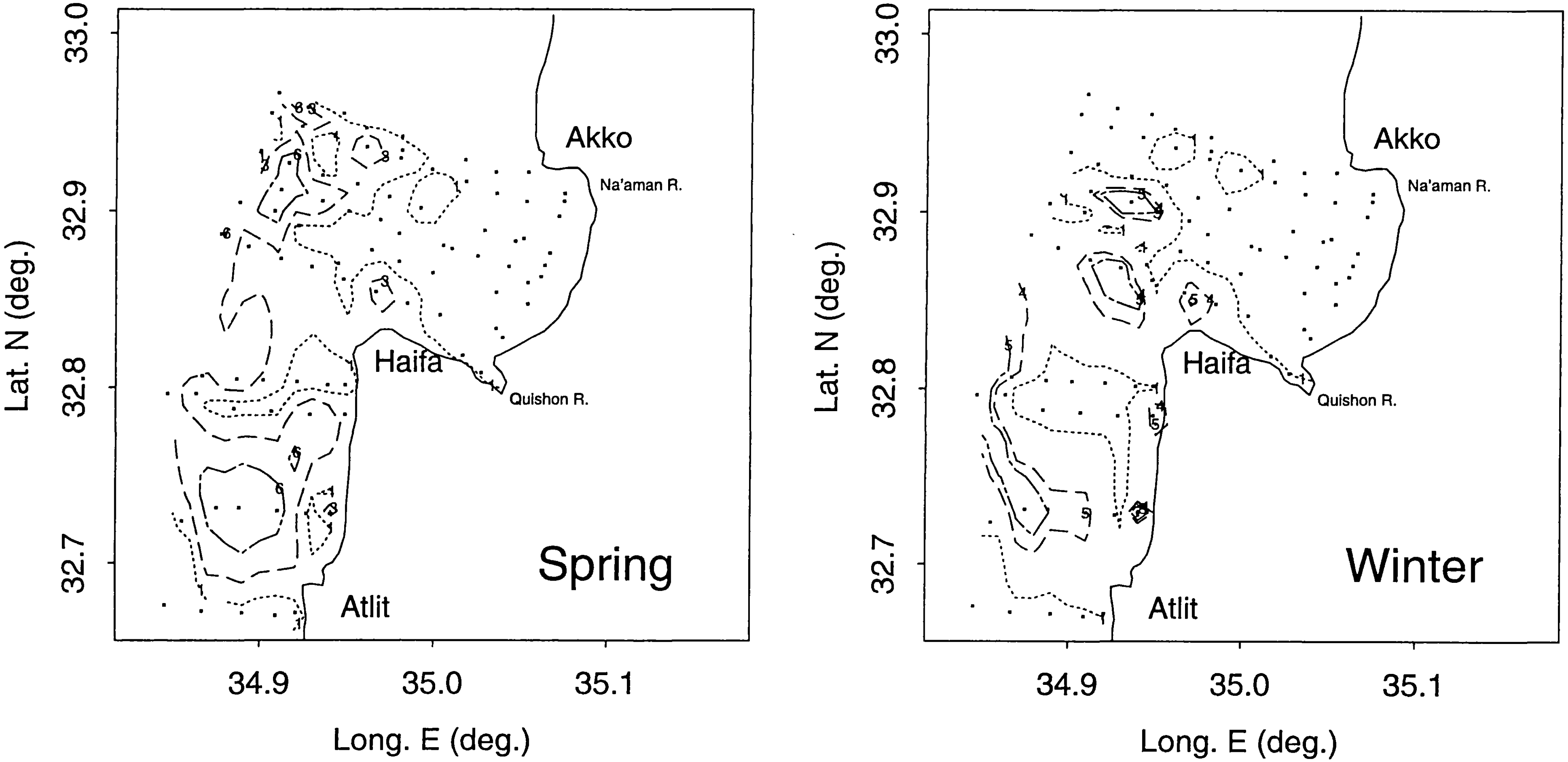
Absolute abundance of Hauerina diversa



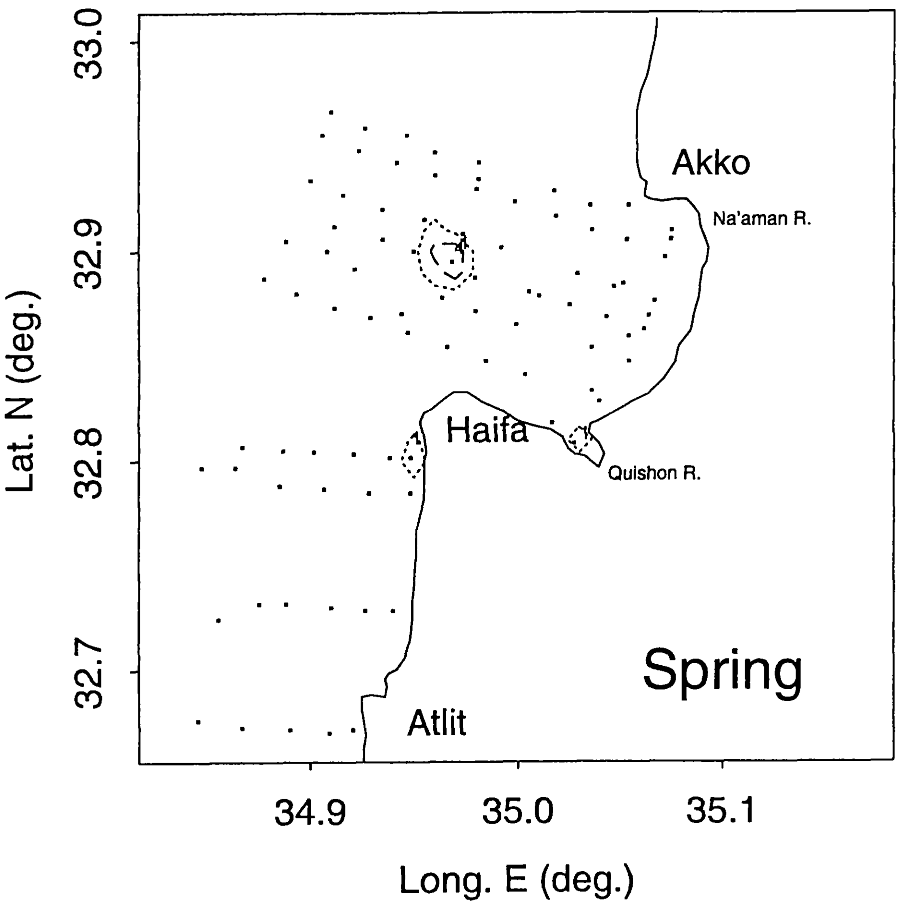
Absolute abundance of Haynesina depressula

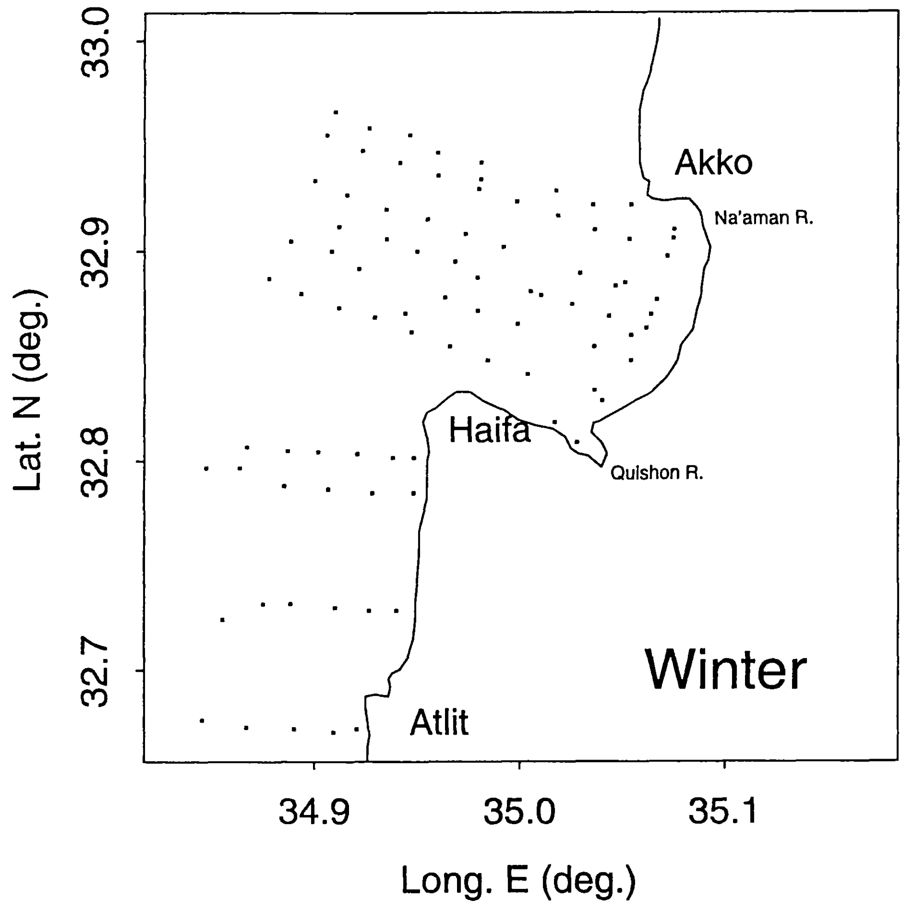


Absolute abundance of Lachlanella variolata

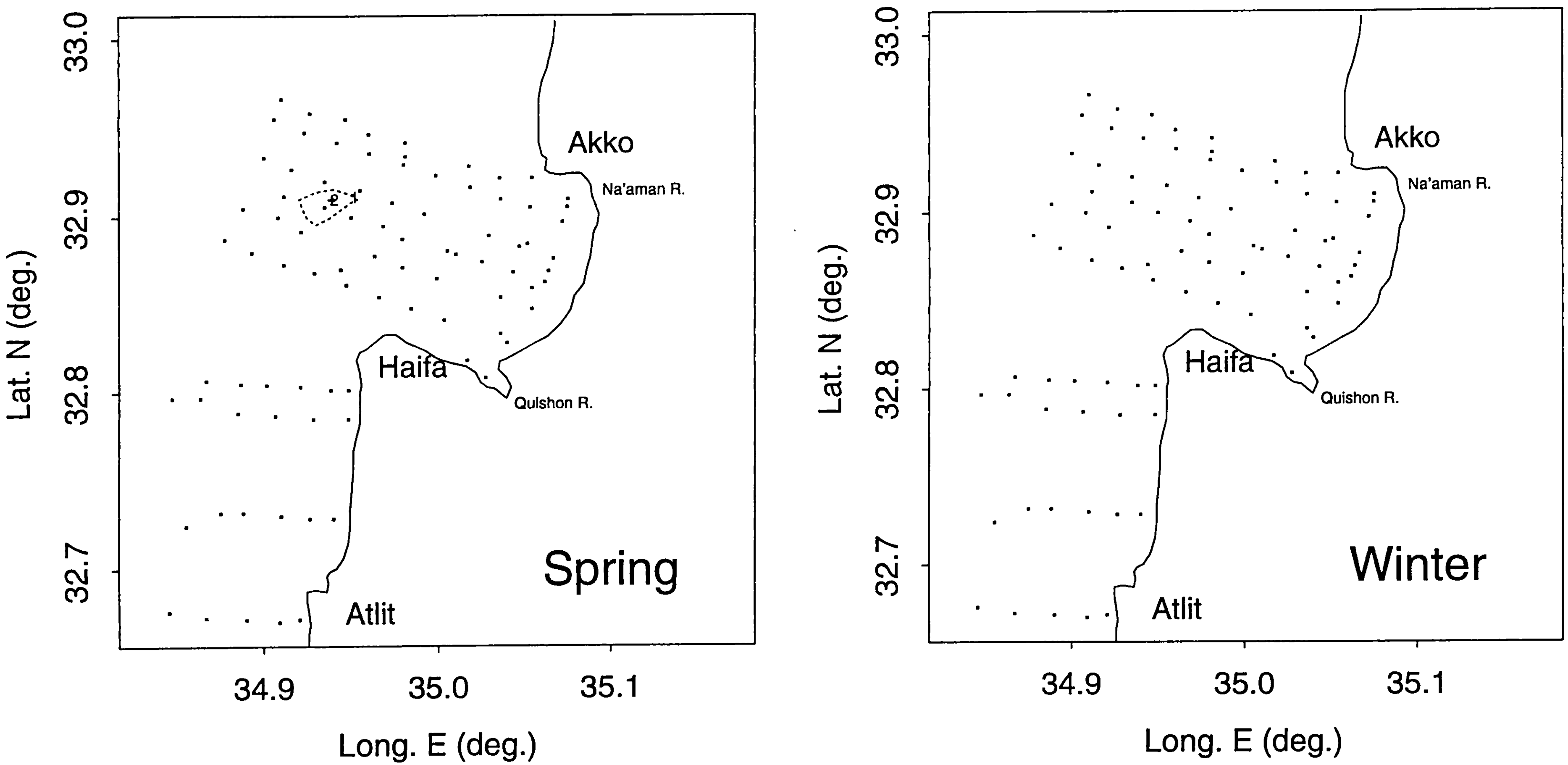


Absolute abundance of Lobatula lobatula

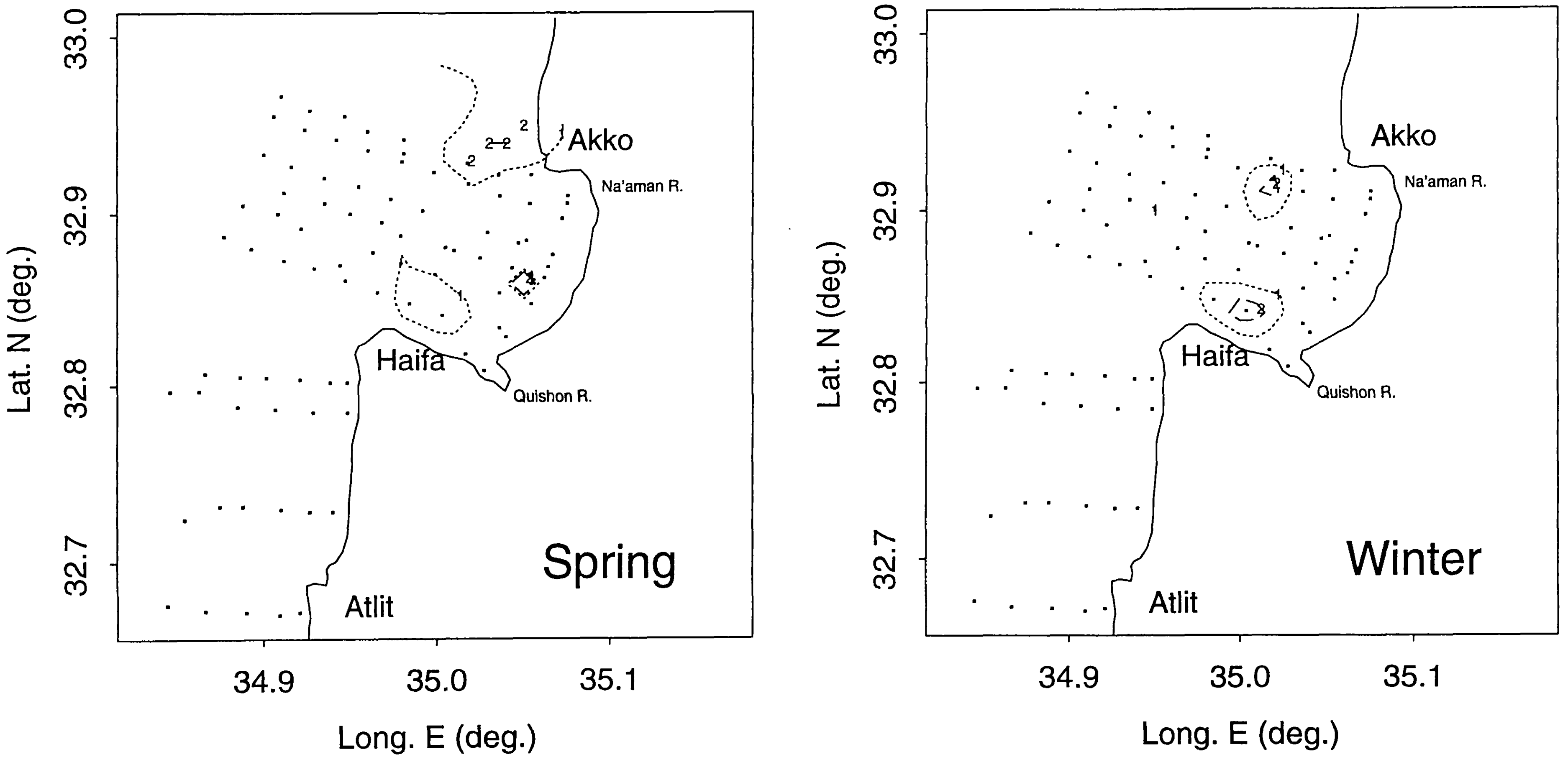




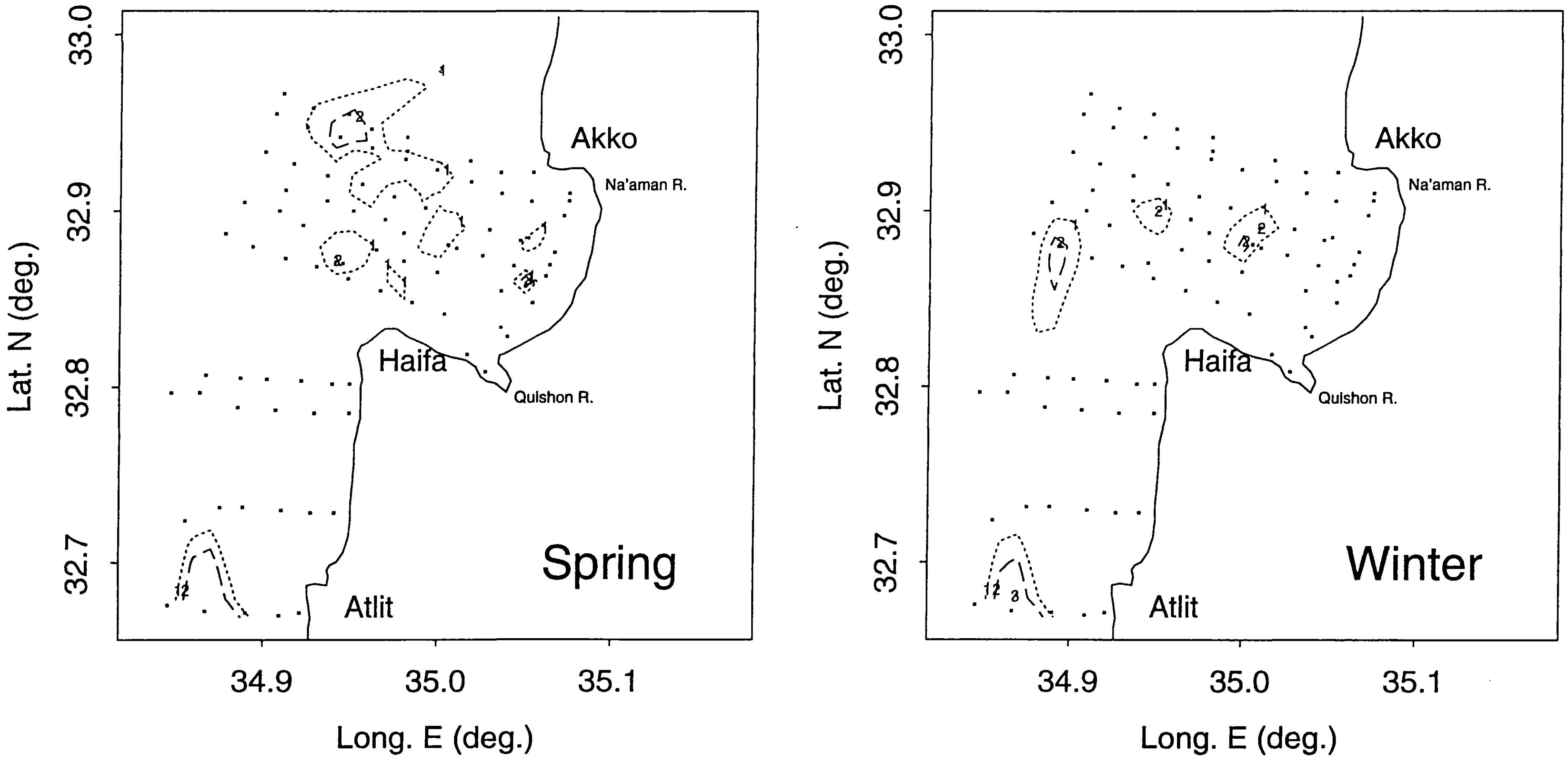
Absolute abundance of Massilina secans



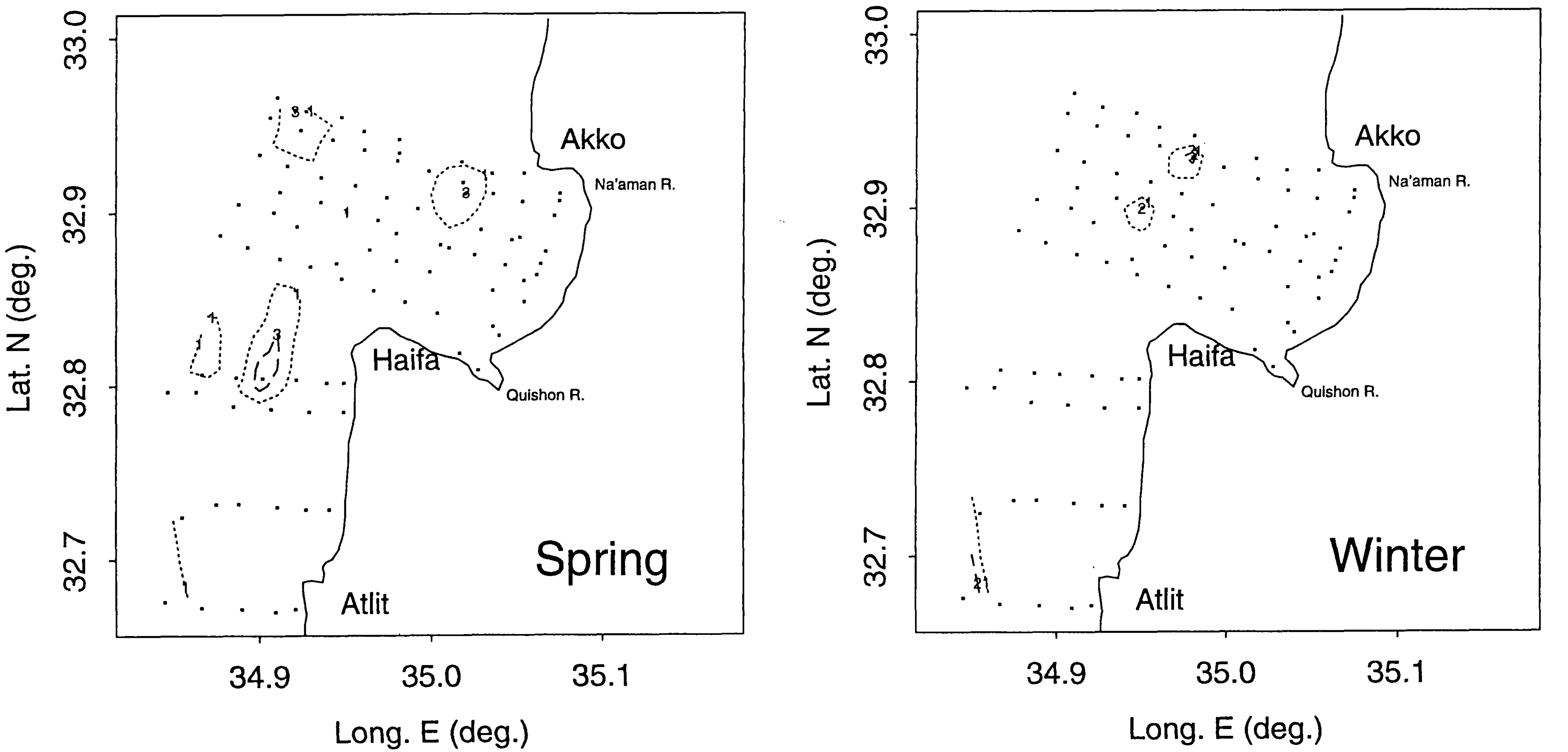
Absolute abundance of Miliolinella dilatata



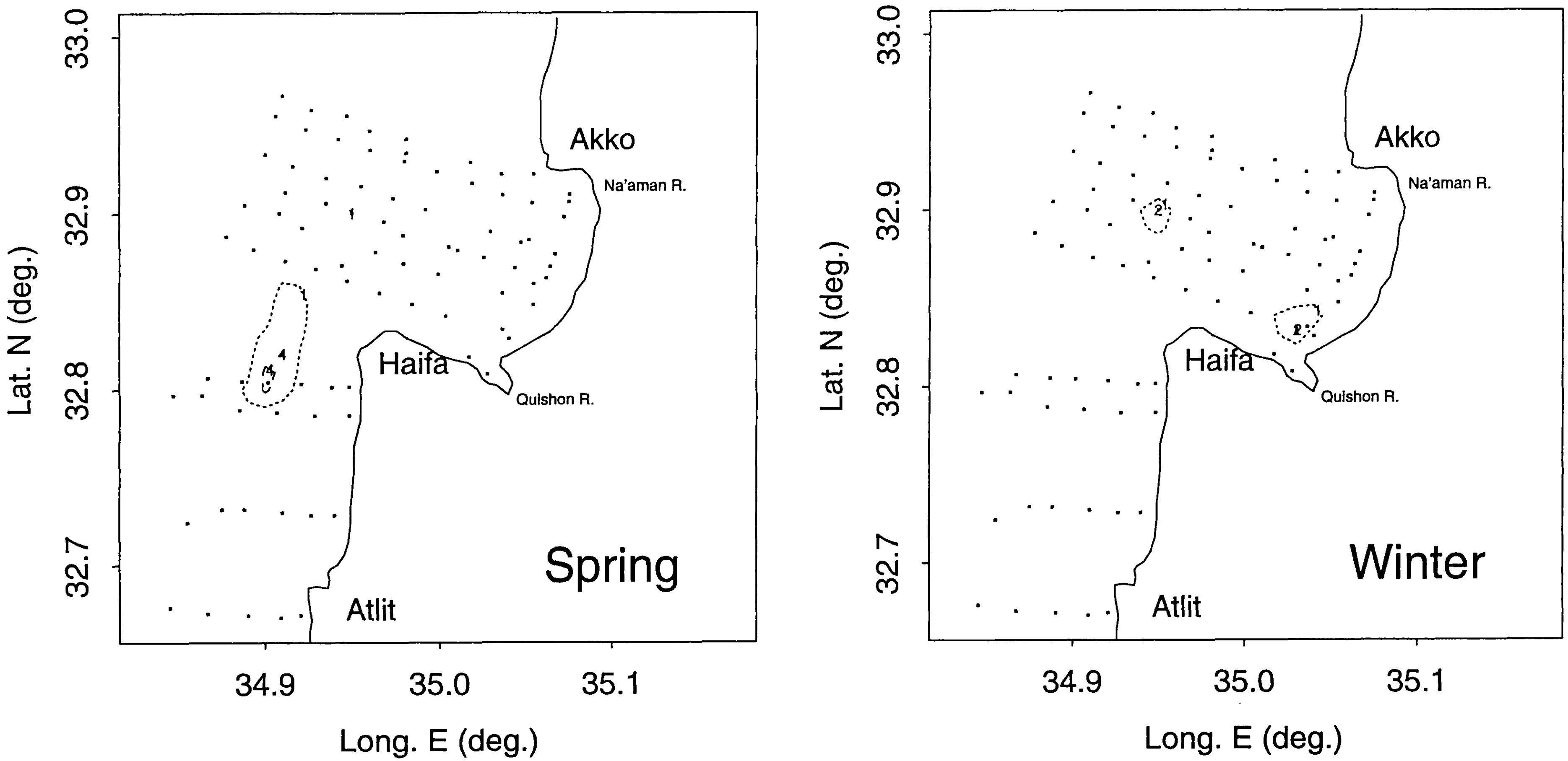
Absolute abundance of Miliolinella labiosa



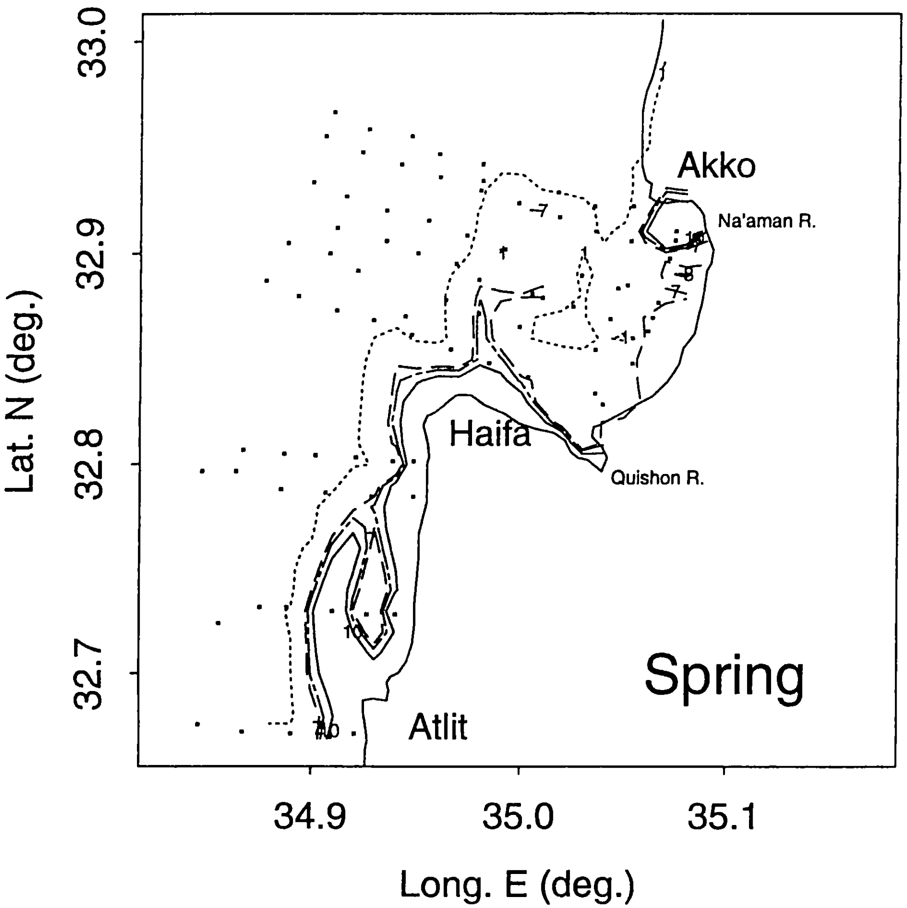
Absolute abundance of Neoconorbina terquemi

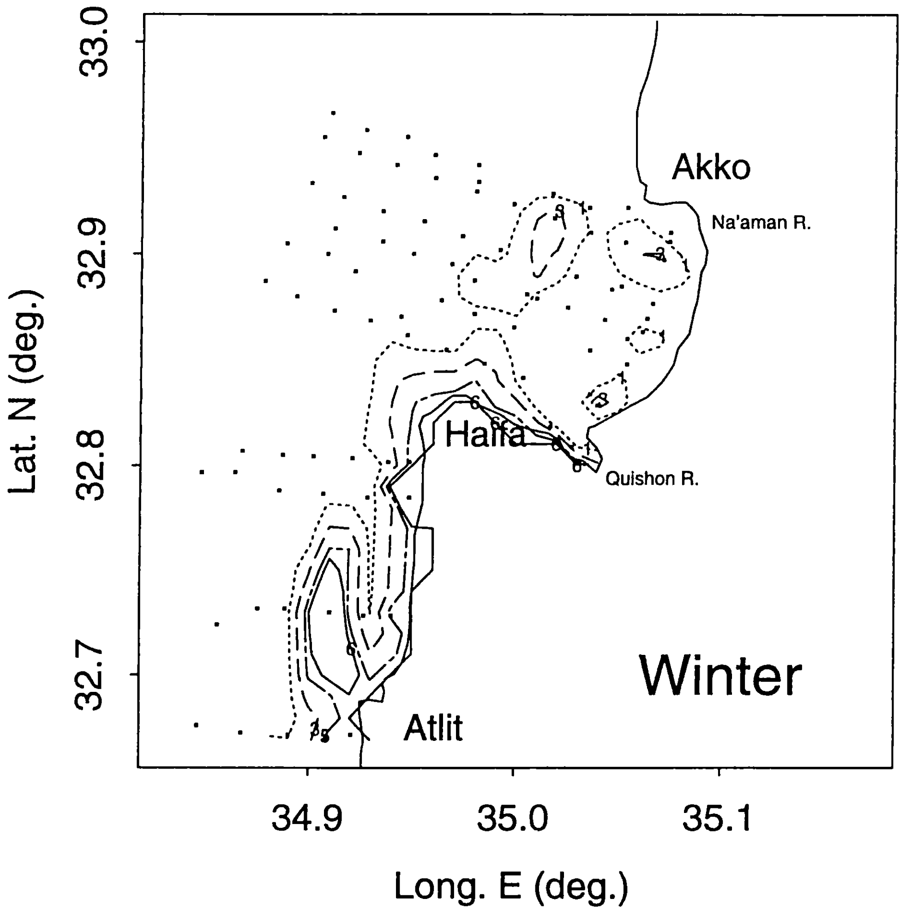


Absolute abundance of Nonionella sp

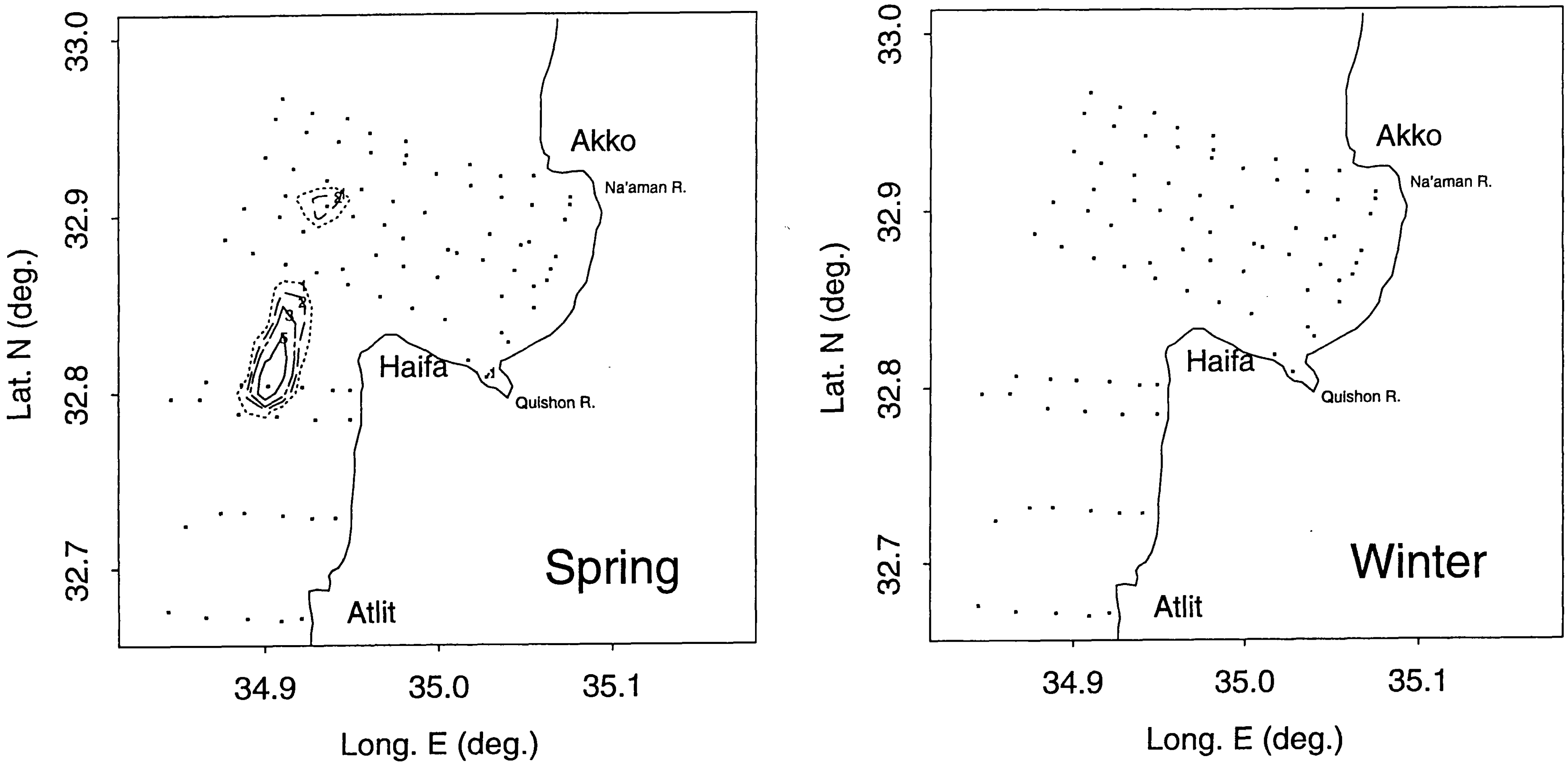


Absolute abundance of Nonionella turgida

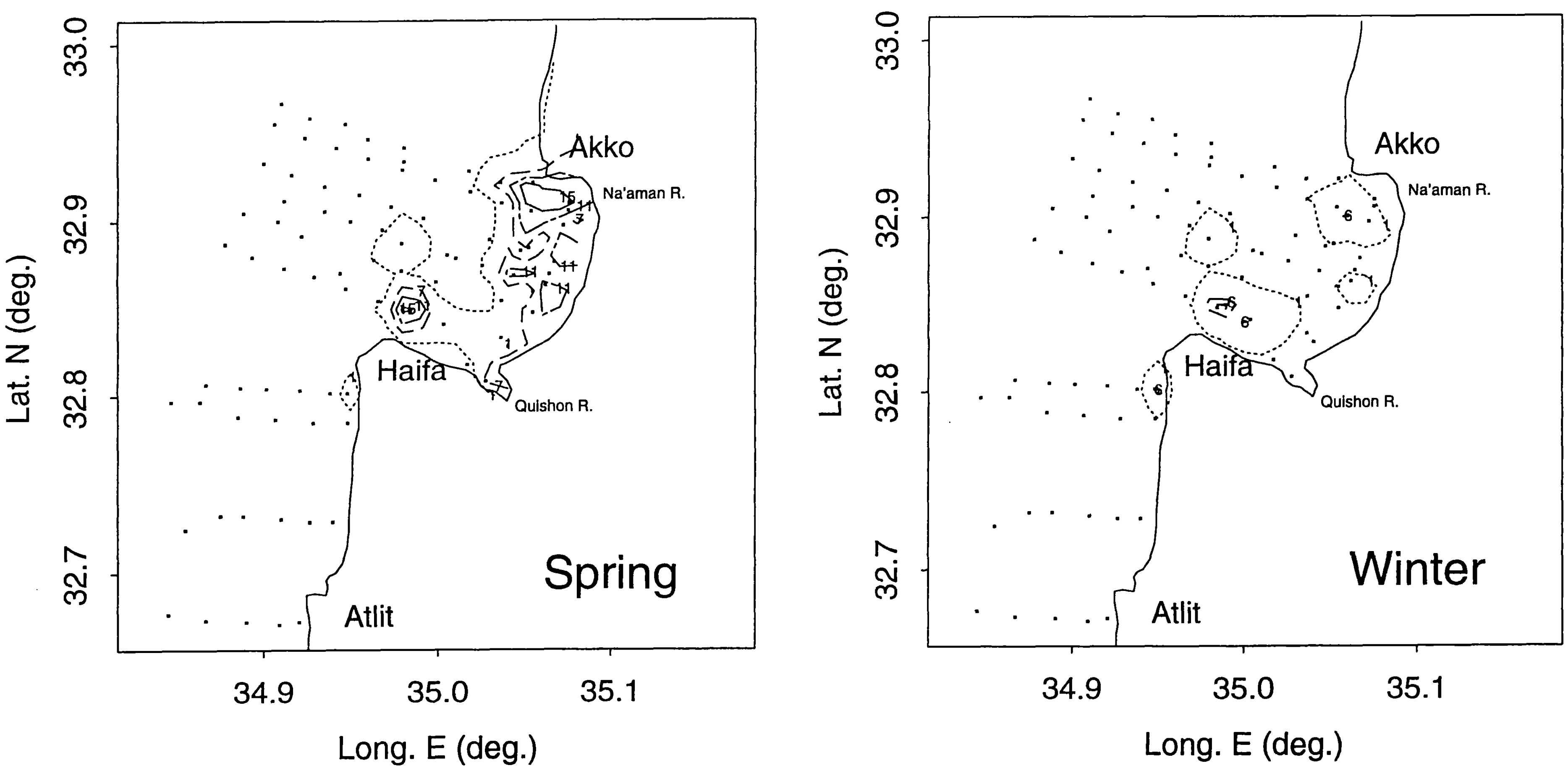




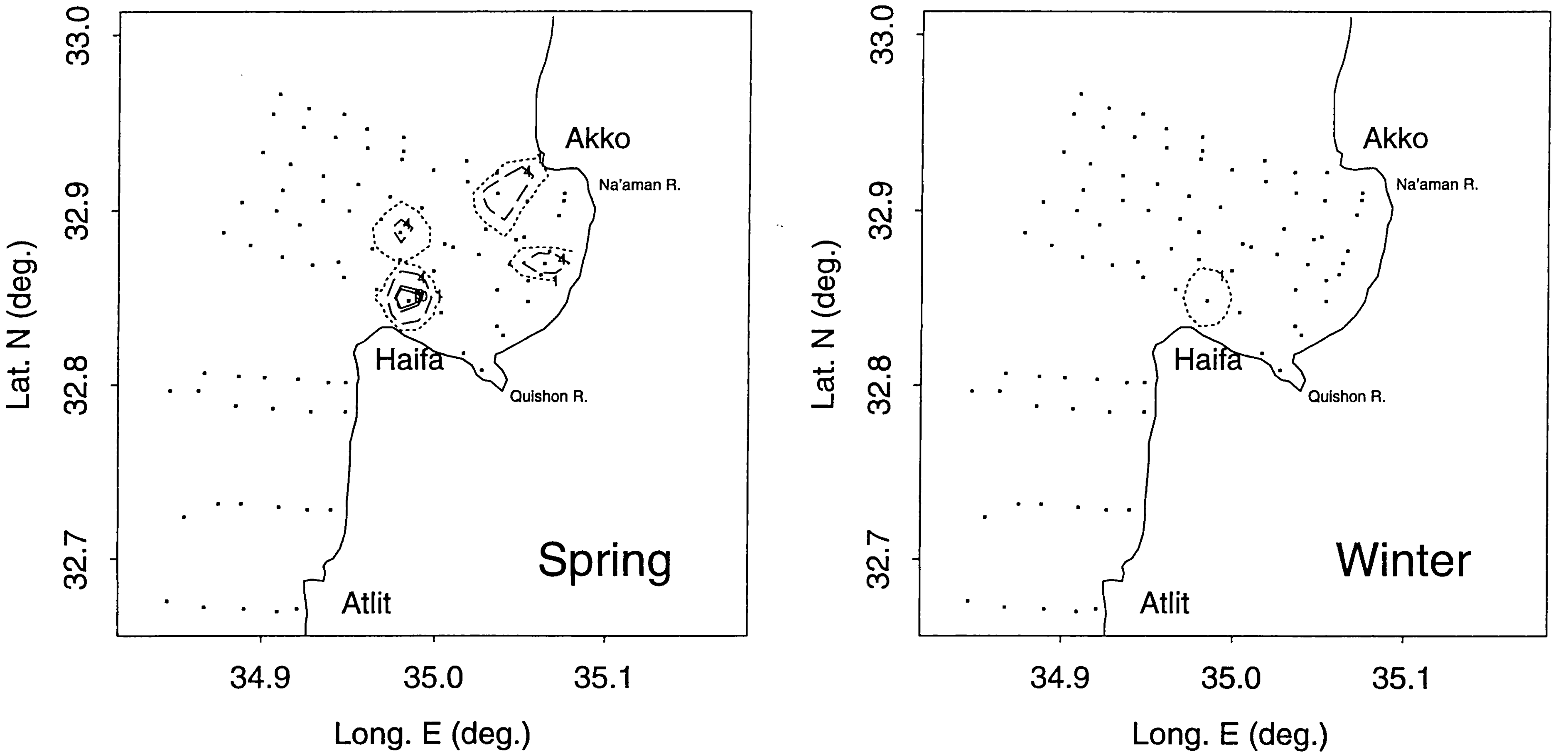
Absolute abundance of Pararotalia spinigera



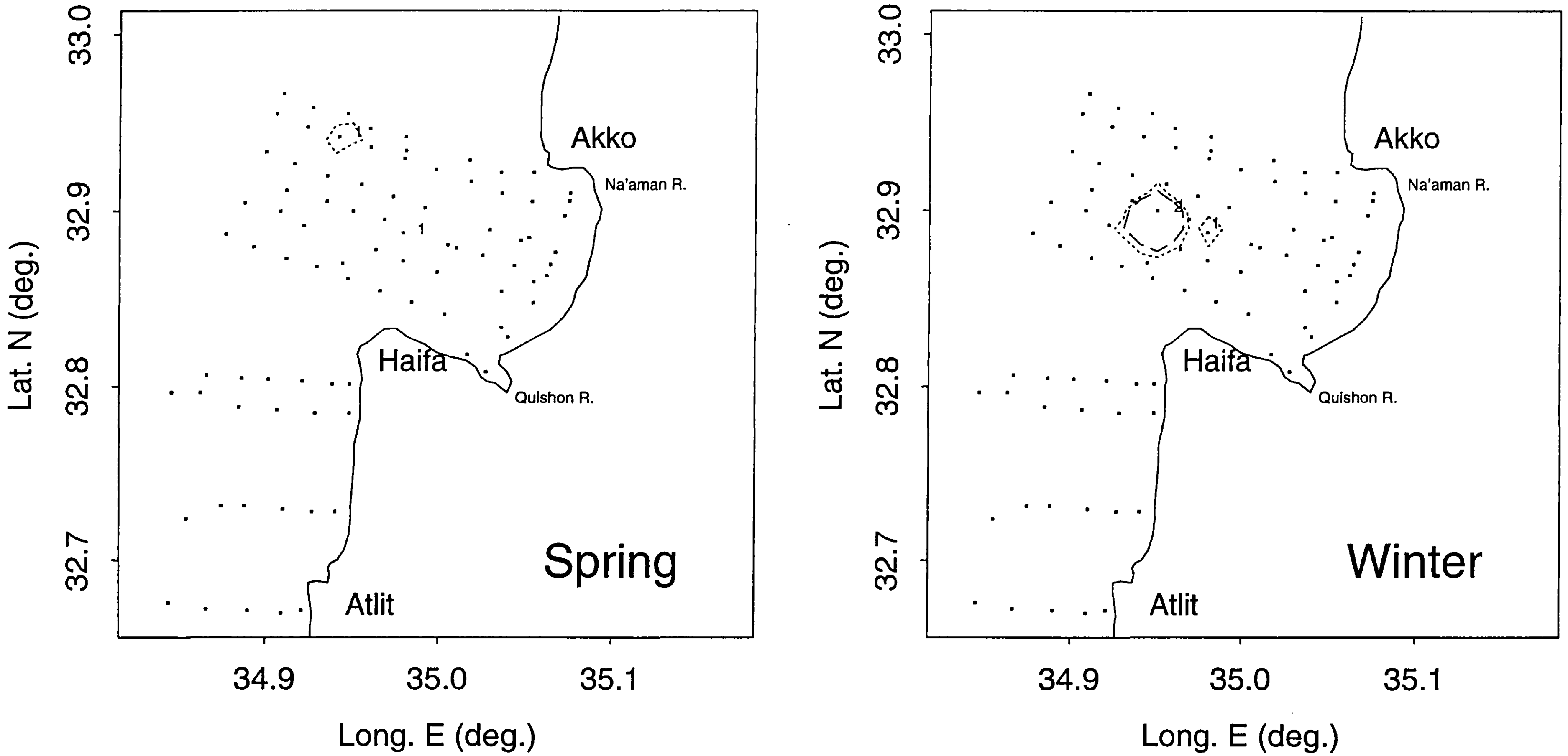
Absolute abundance of Parrina bradyi



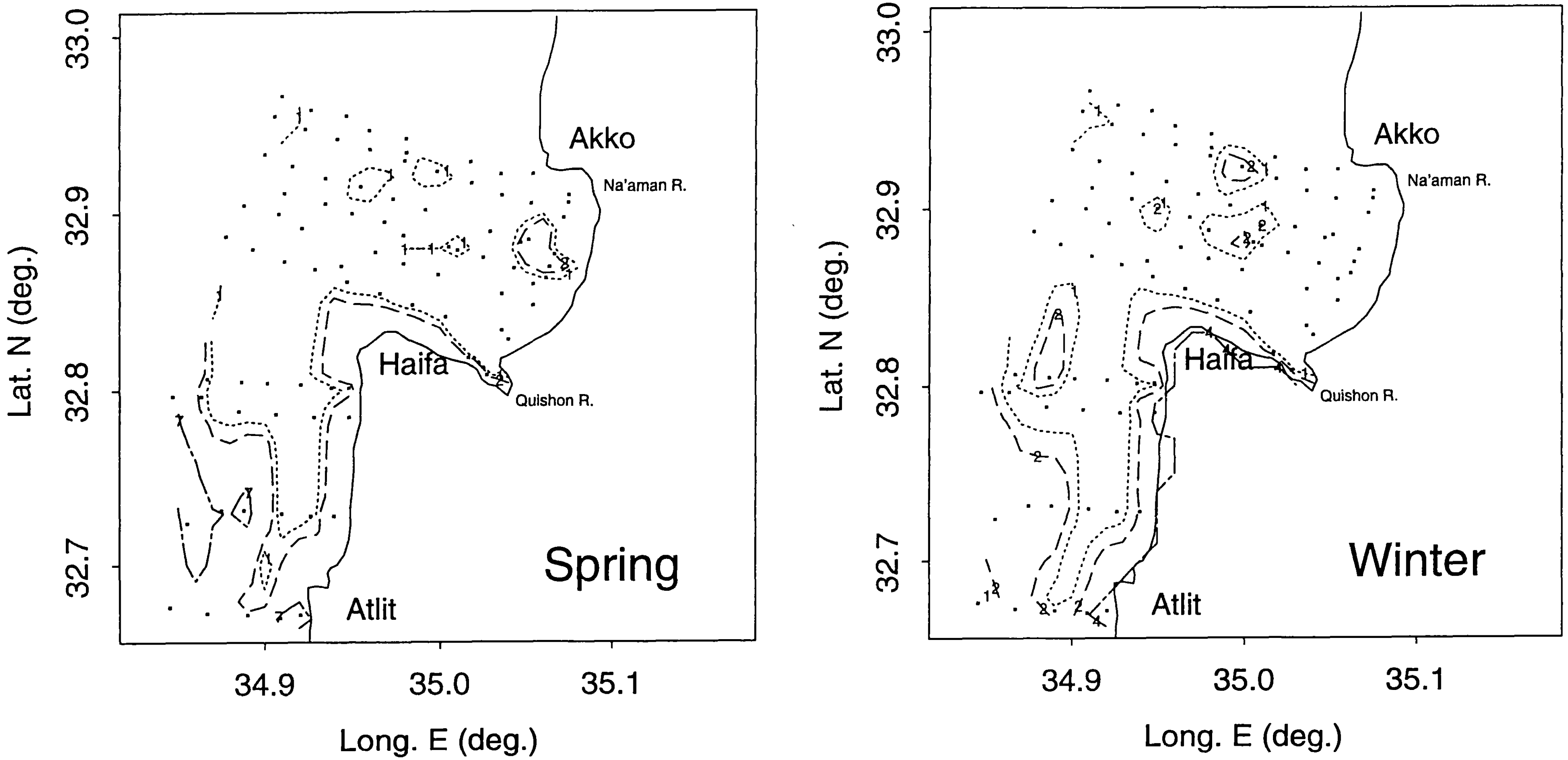
Absolute abundance of Peneroplis pertusus



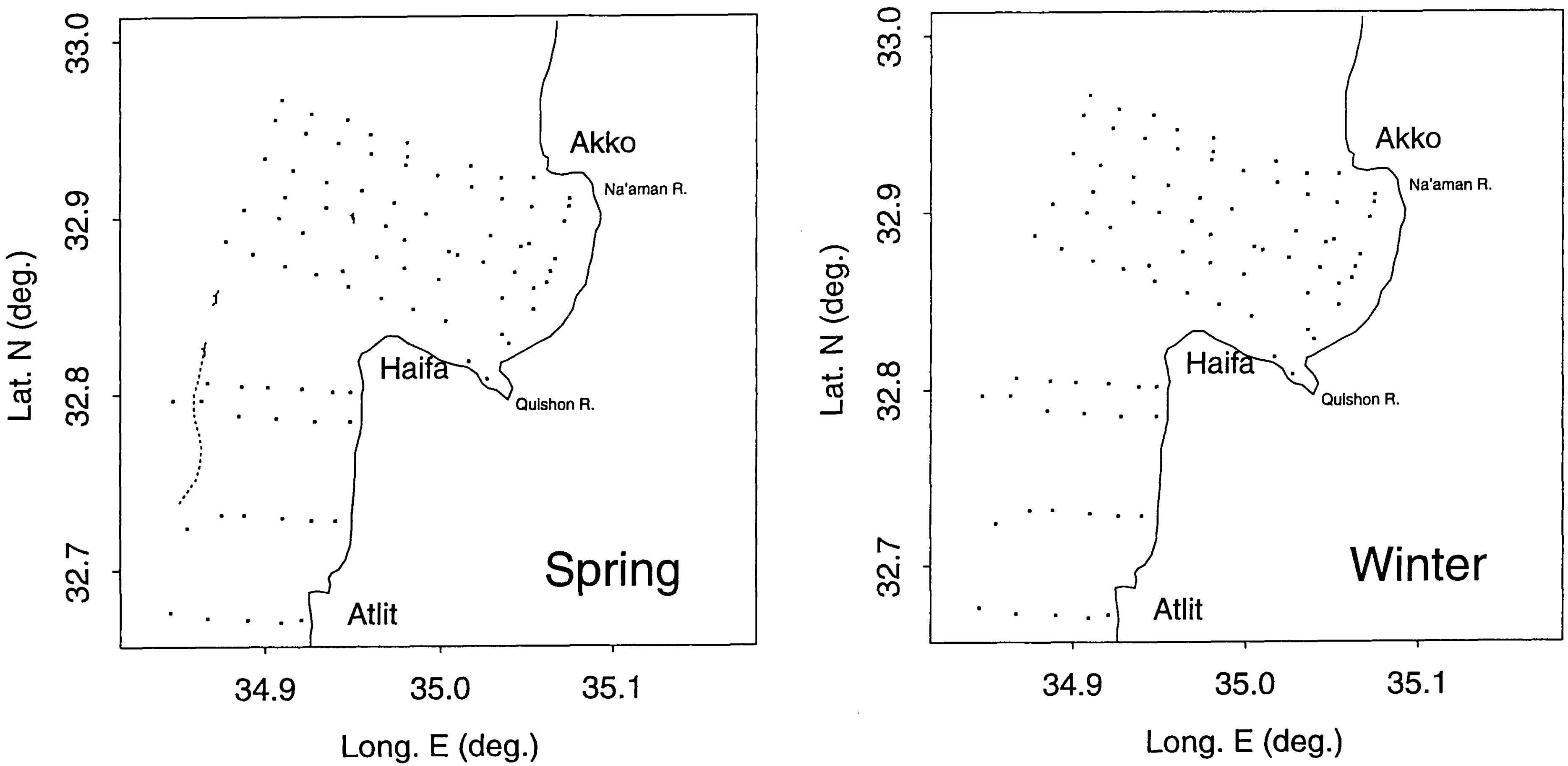
Absolute abundance of Peneroplis planatus



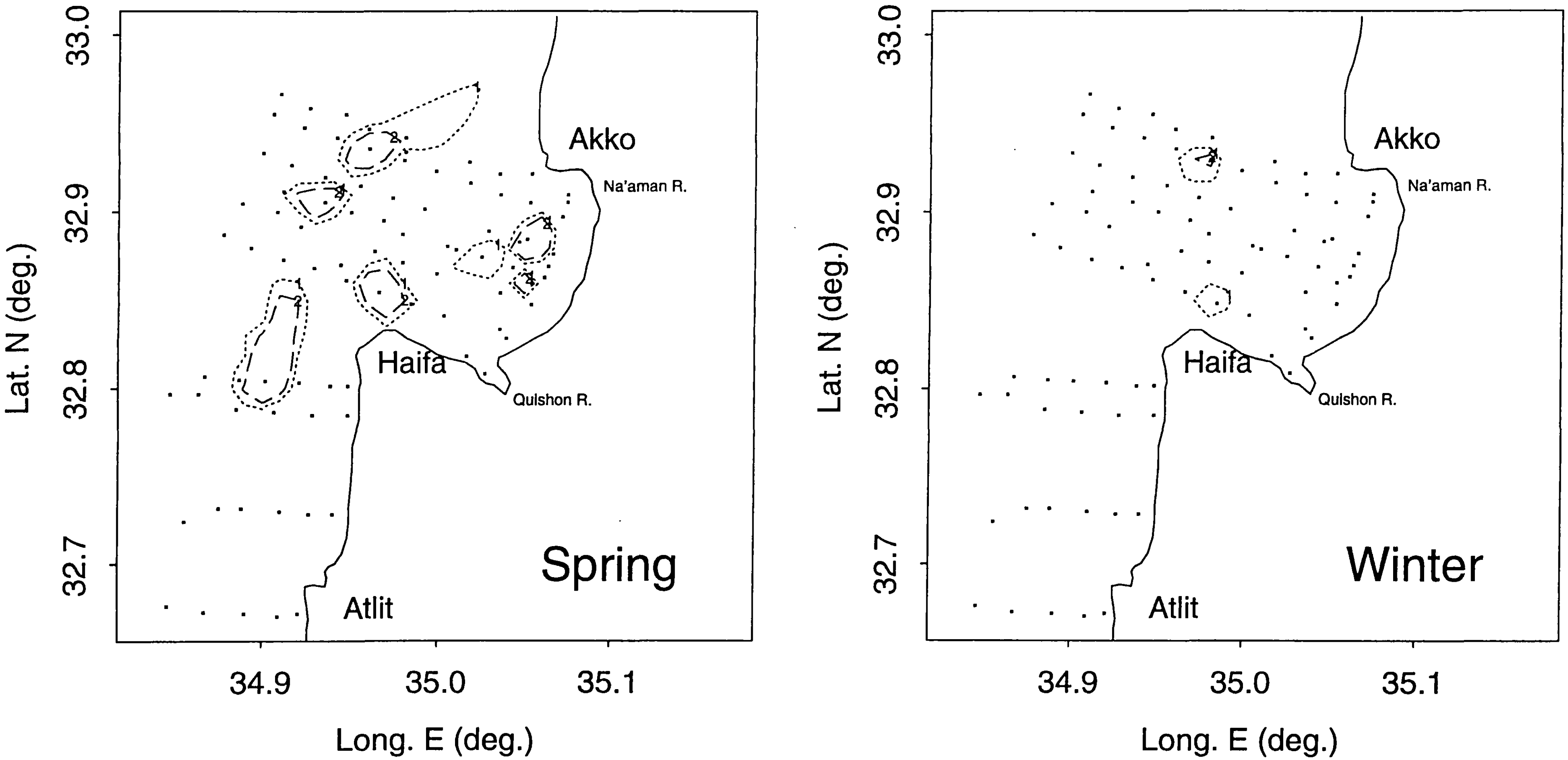
Absolute abundance of Planorbulinella larvata



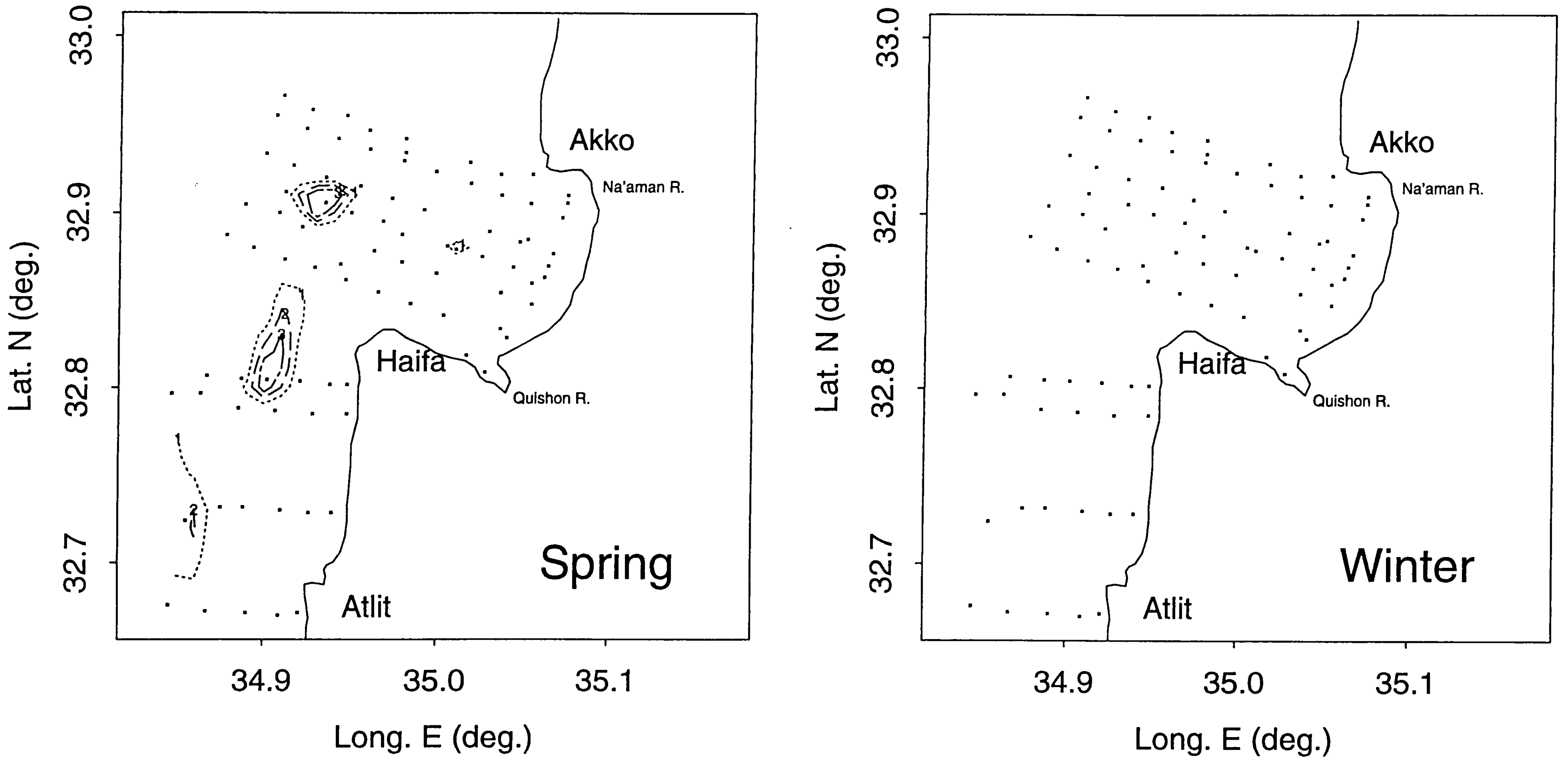
Absolute abundance of Porosononion subgranosus



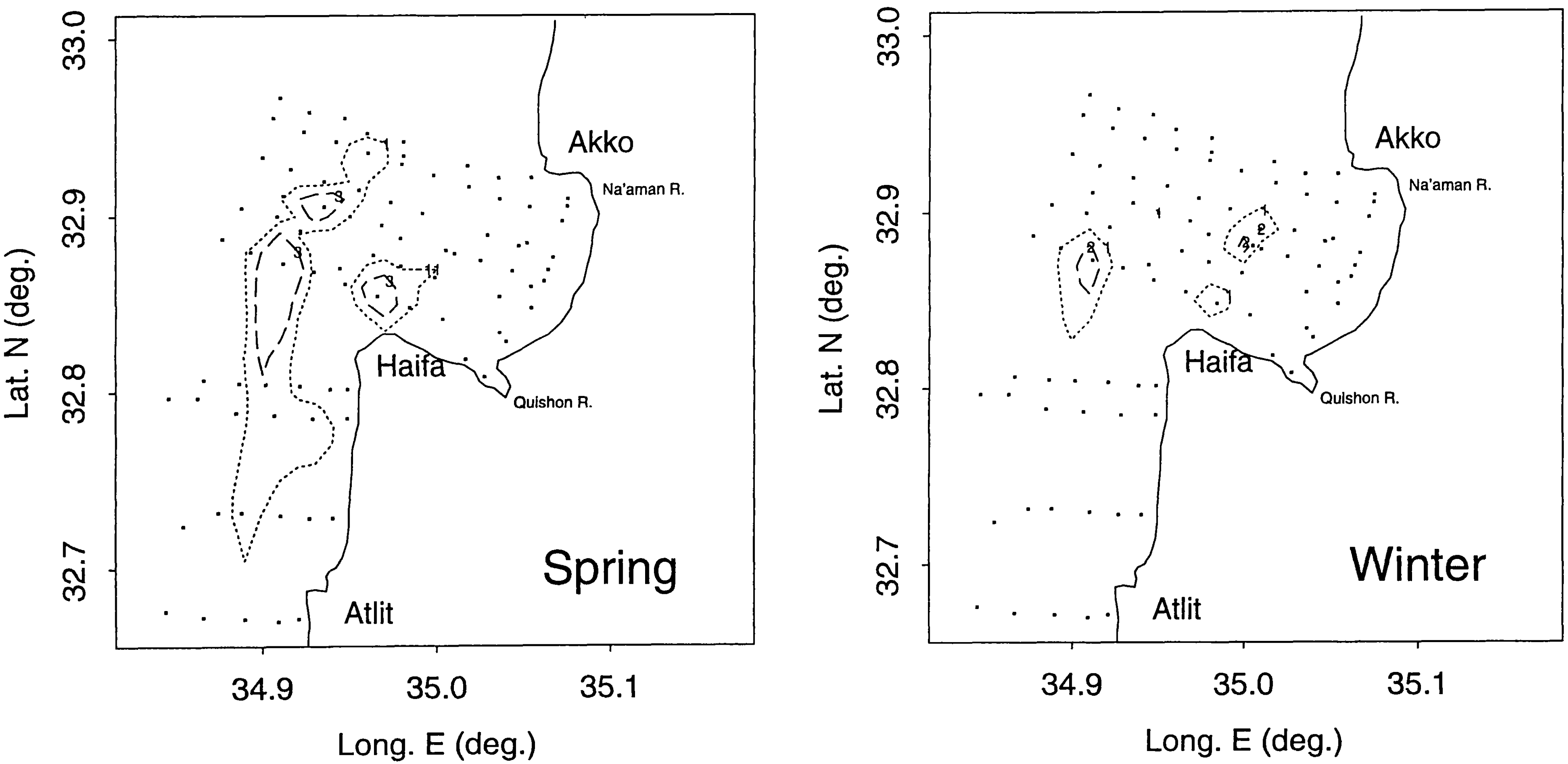
Absolute abundance of Pyrgo elongata



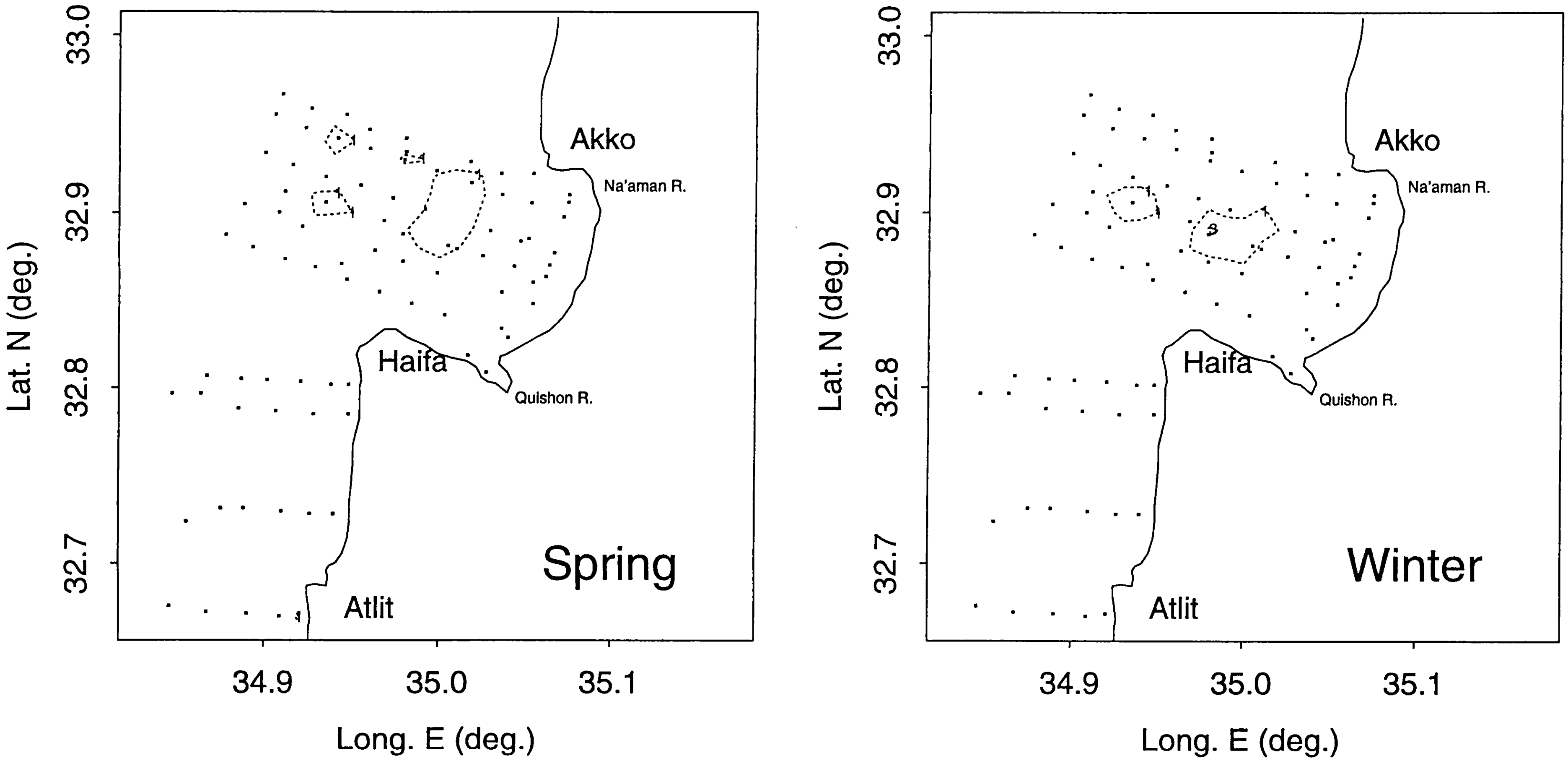
Absolute abundance of Pseudotriculina oblonga



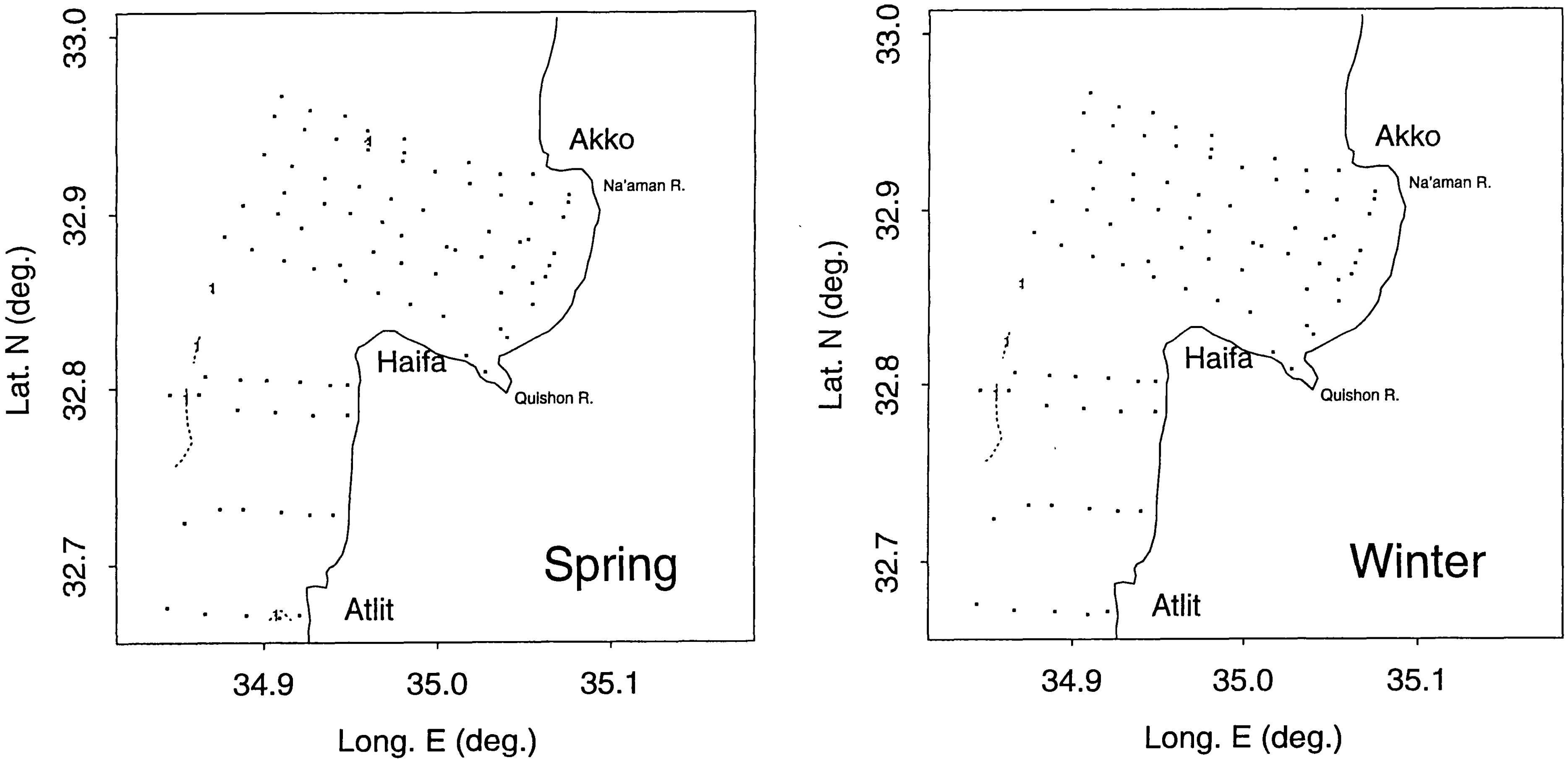
Absolute abundance of Pseudotriloculina rotunda



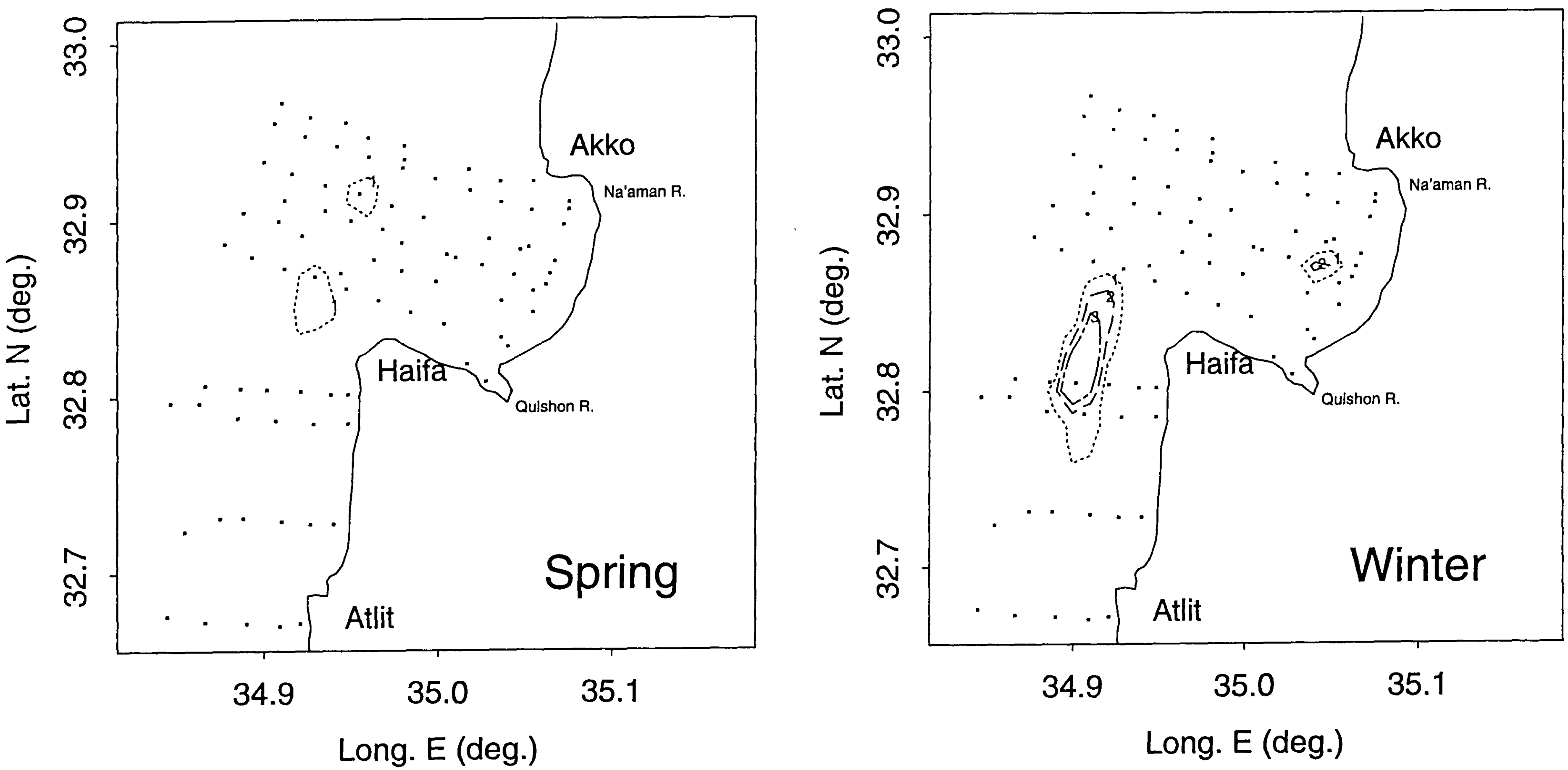
Absolute abundance of Pseudotriloculina laevigata



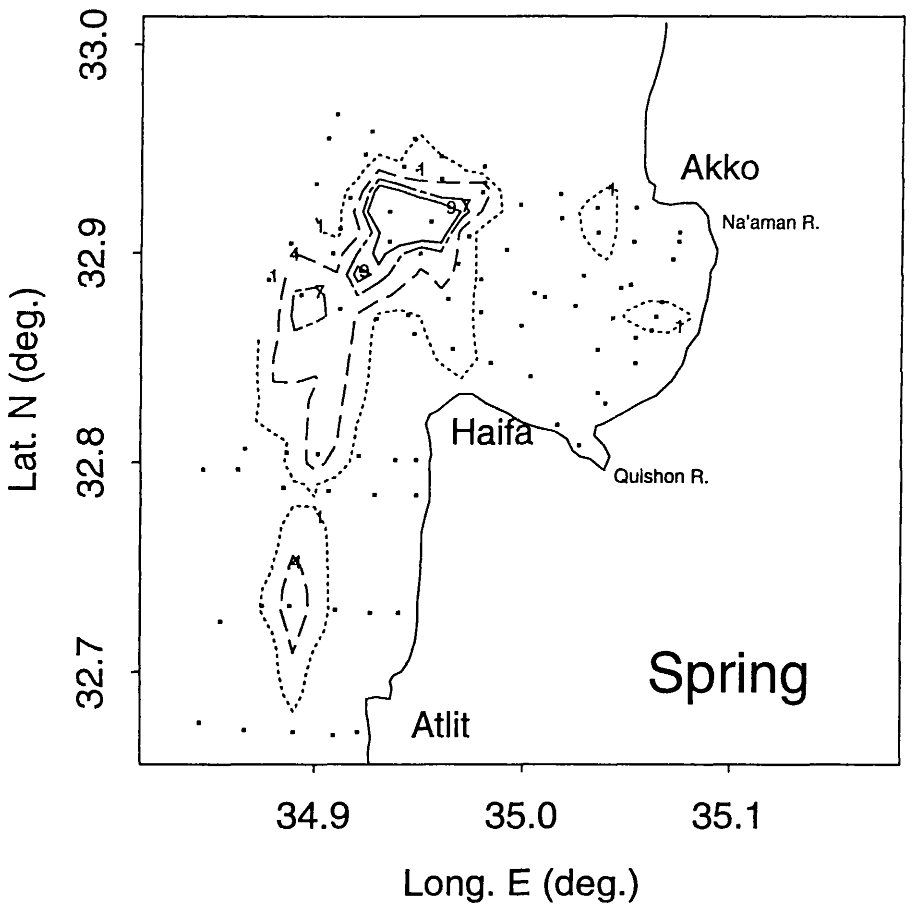
Absolute abundance of Pseudopyrgo milletti

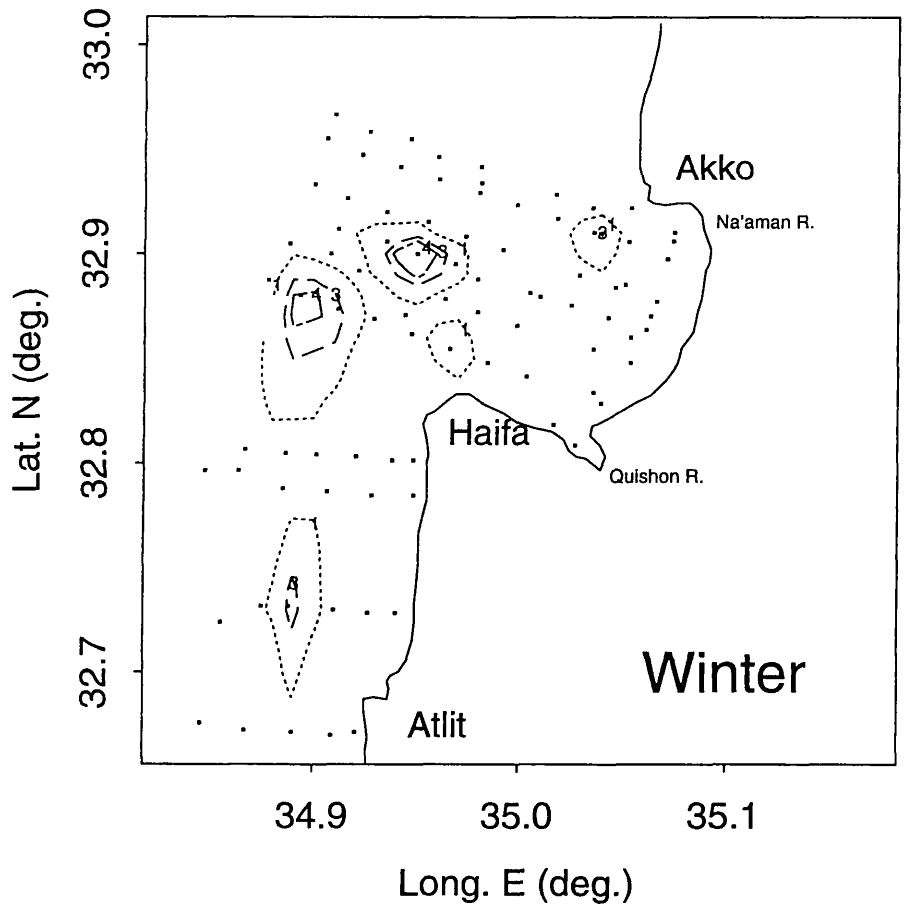


Absolute abundance of Pyrgo anomala

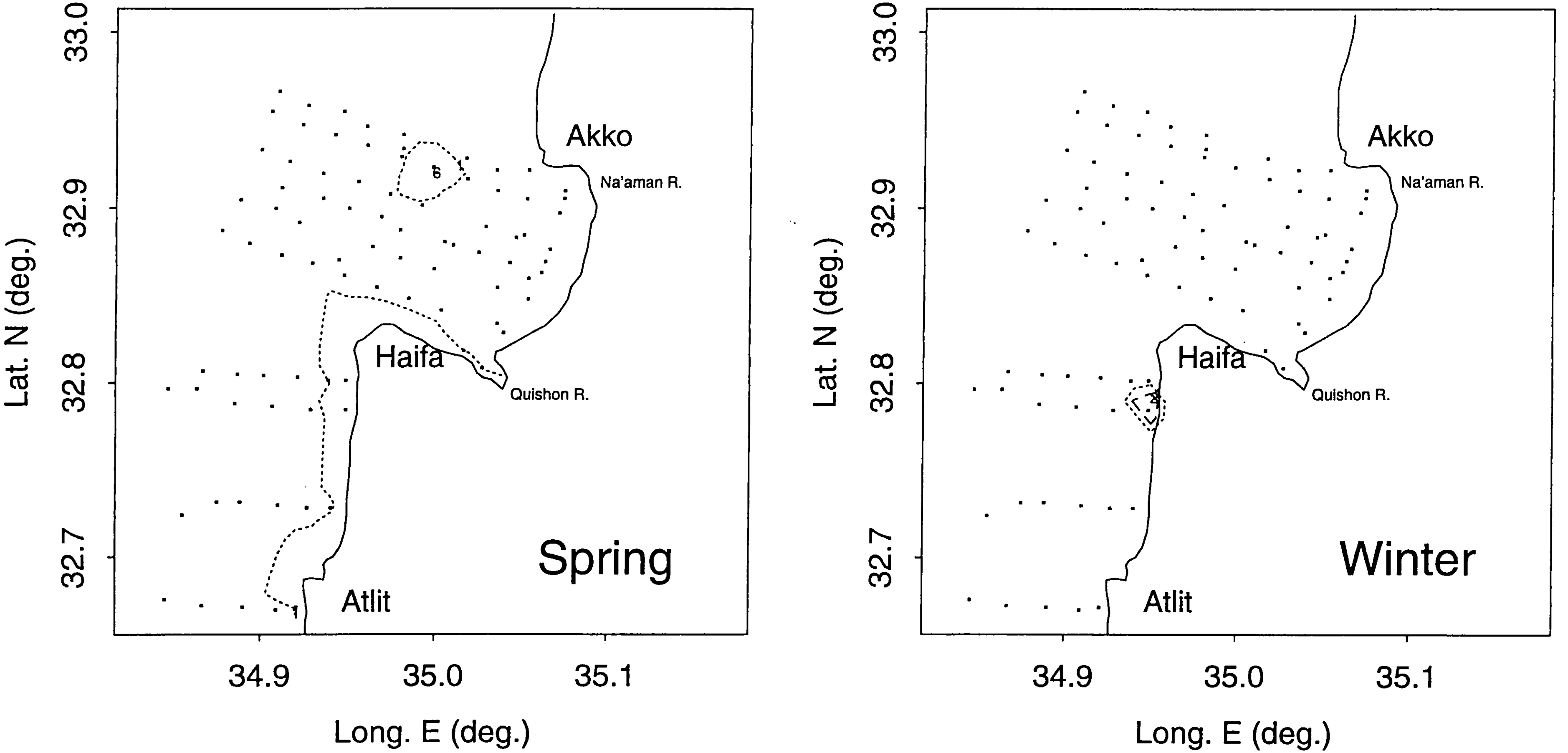


Absolute abundance of Quinquelocuina pseudobuciana

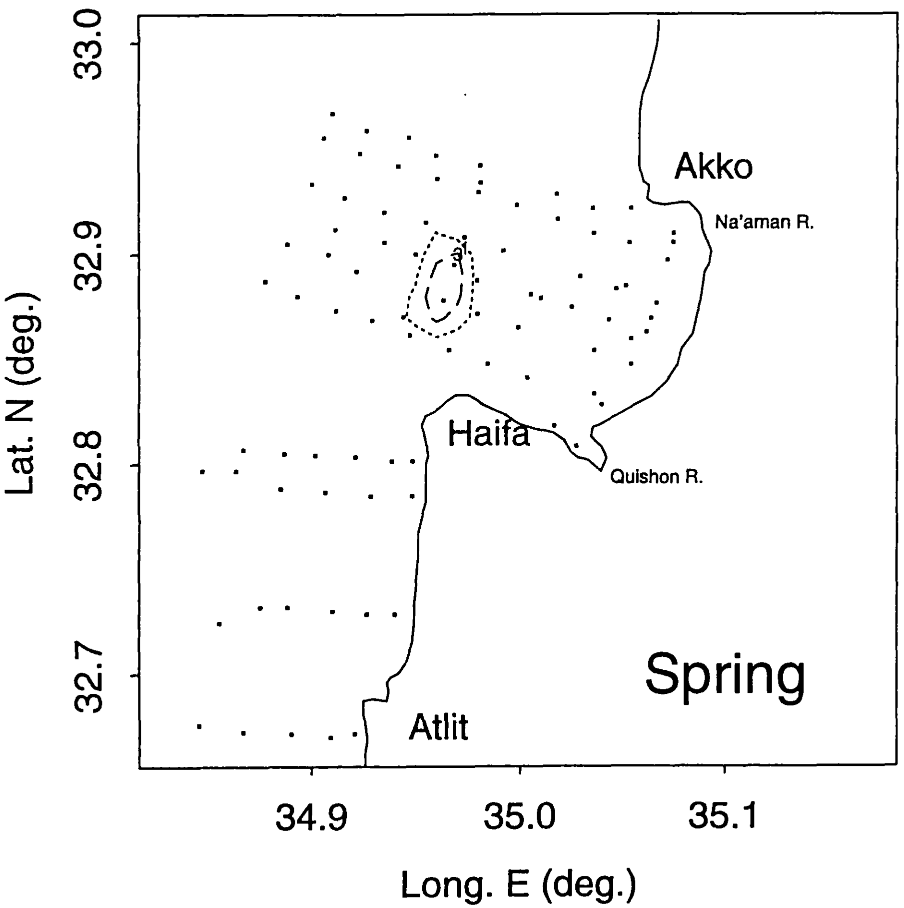


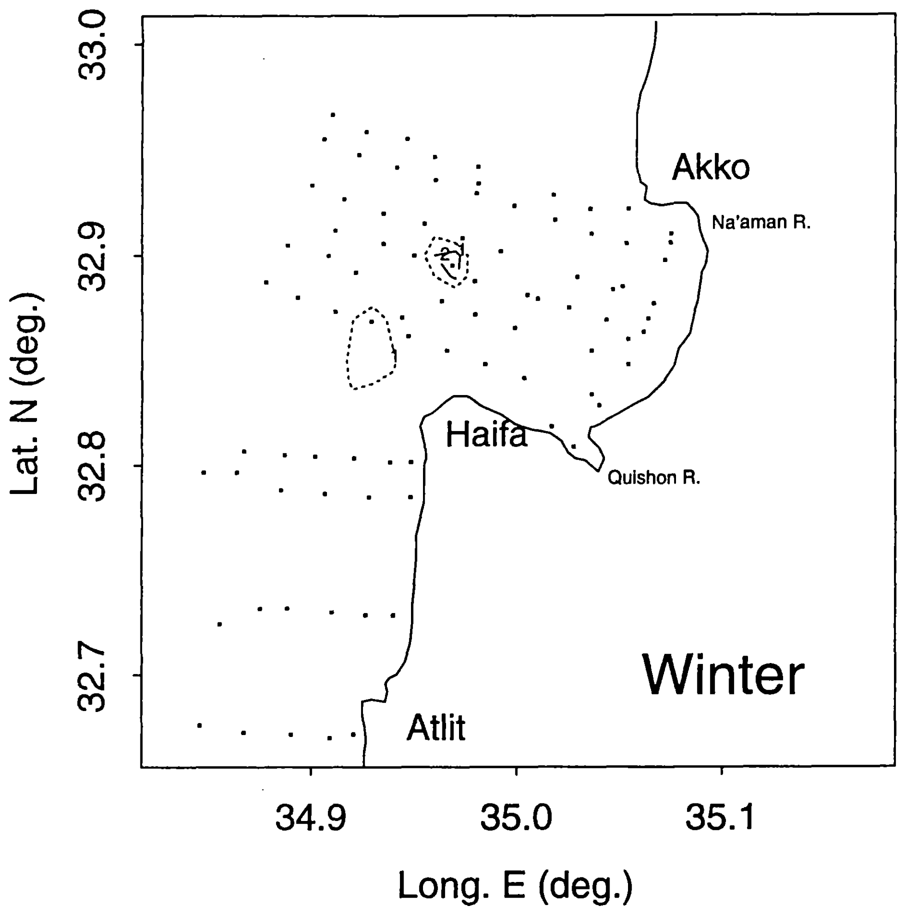


Absolute abundance of Quinqueloculina disparilis

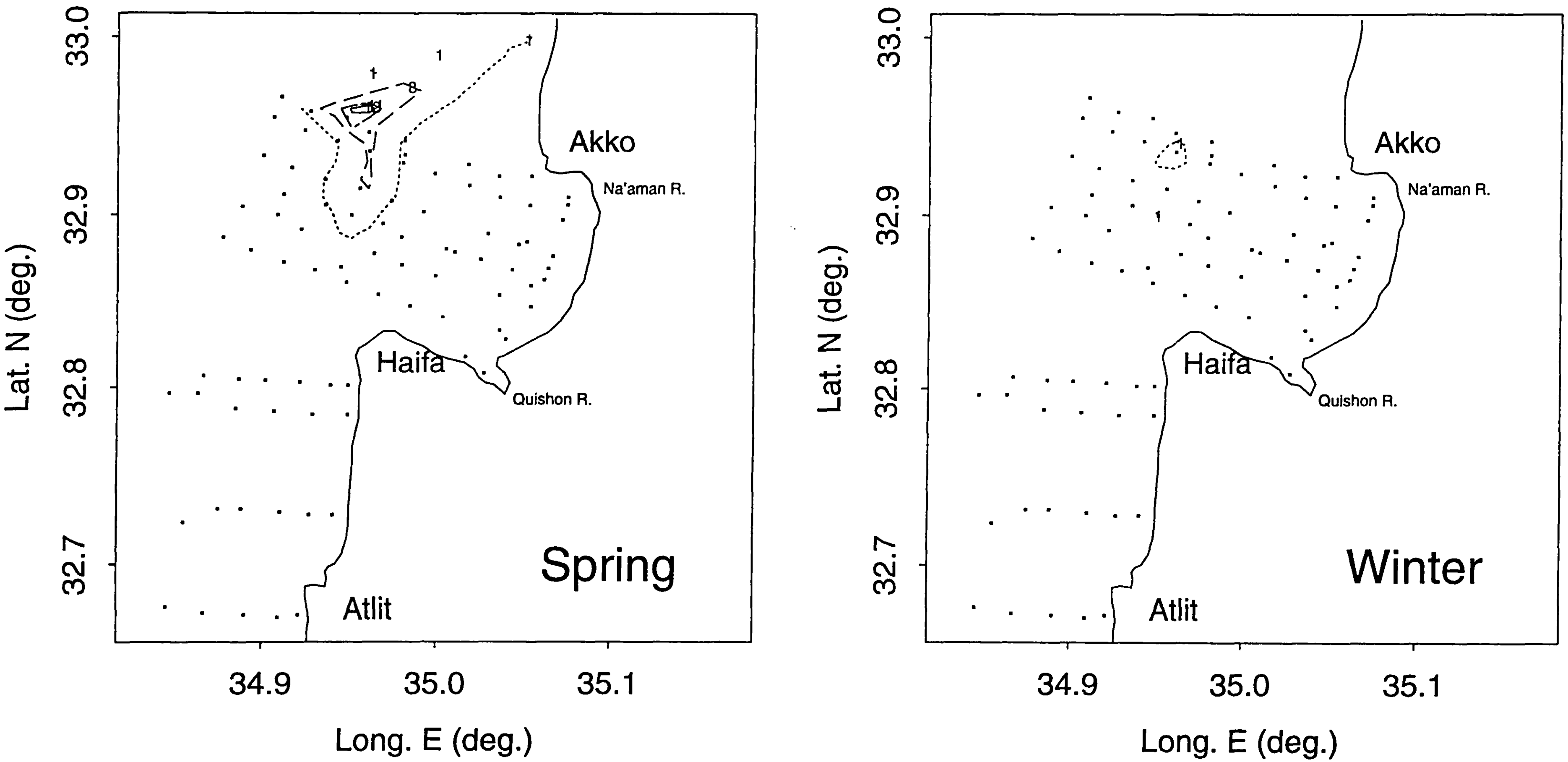


Absolute abundance of Quinqueloculina jugosa

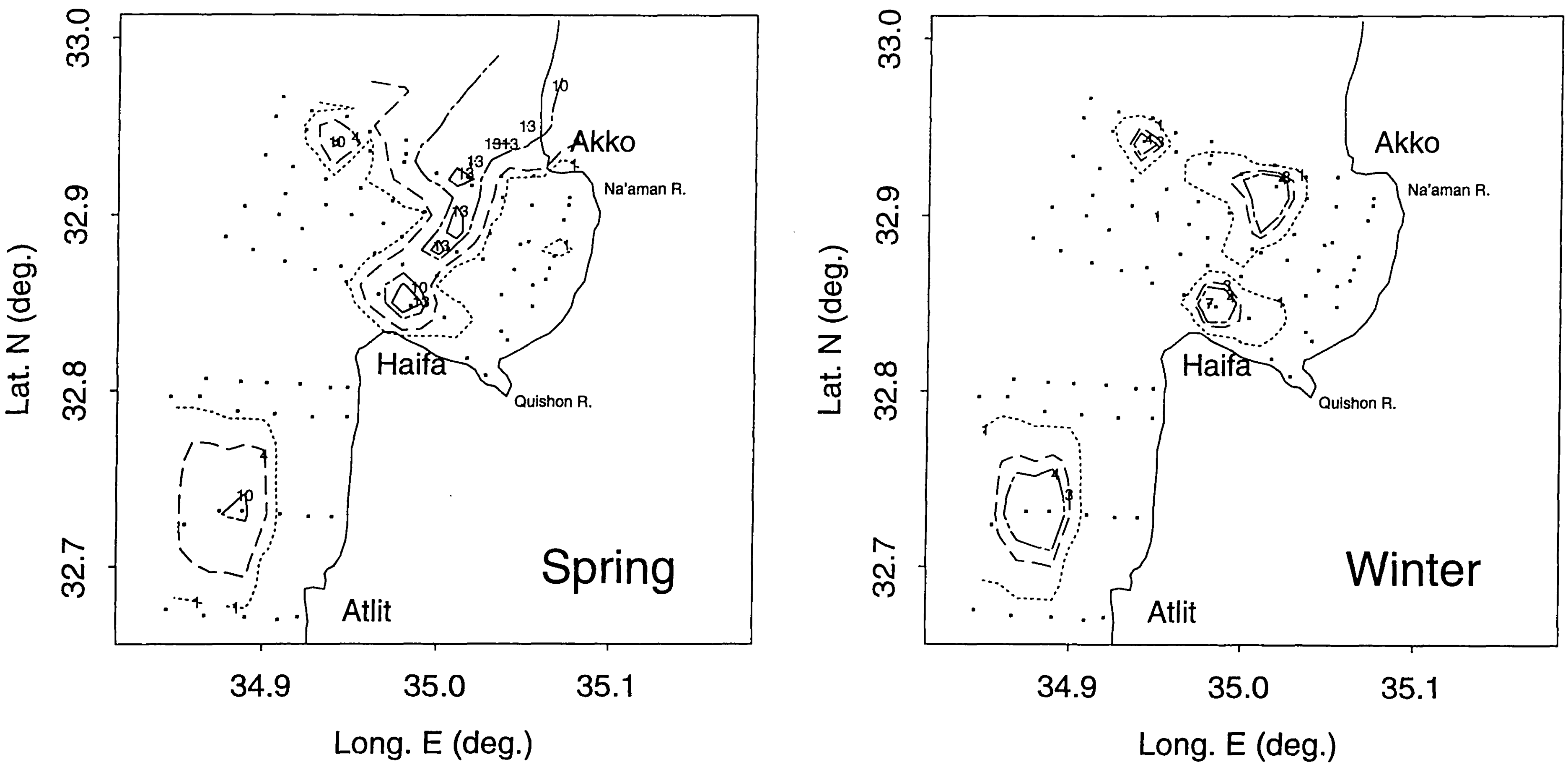




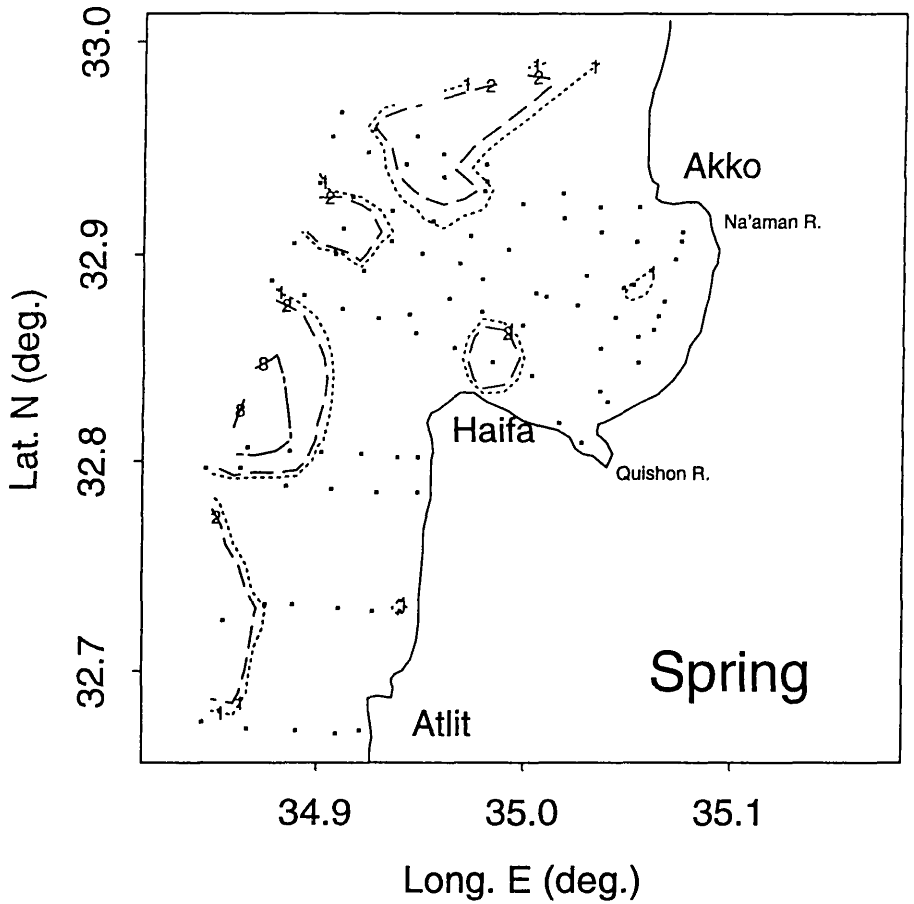
Absolute abundance of Quinquelocuina laevigata

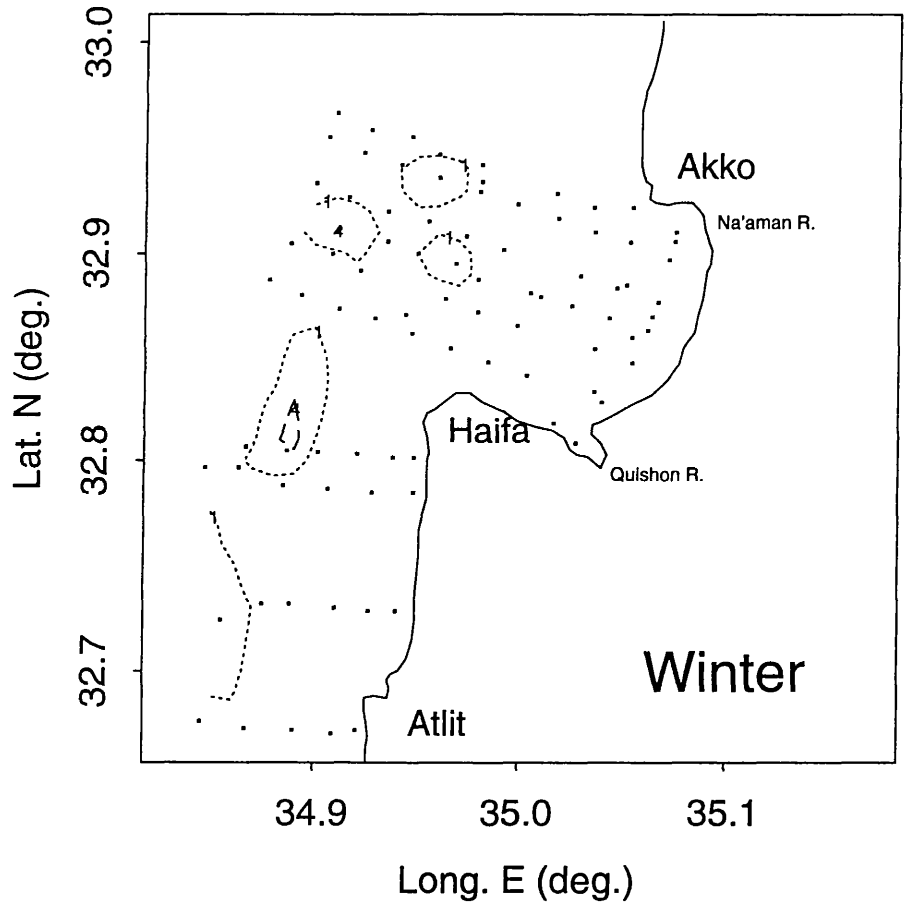


Absolute abundance of Quinqueloculina seminula

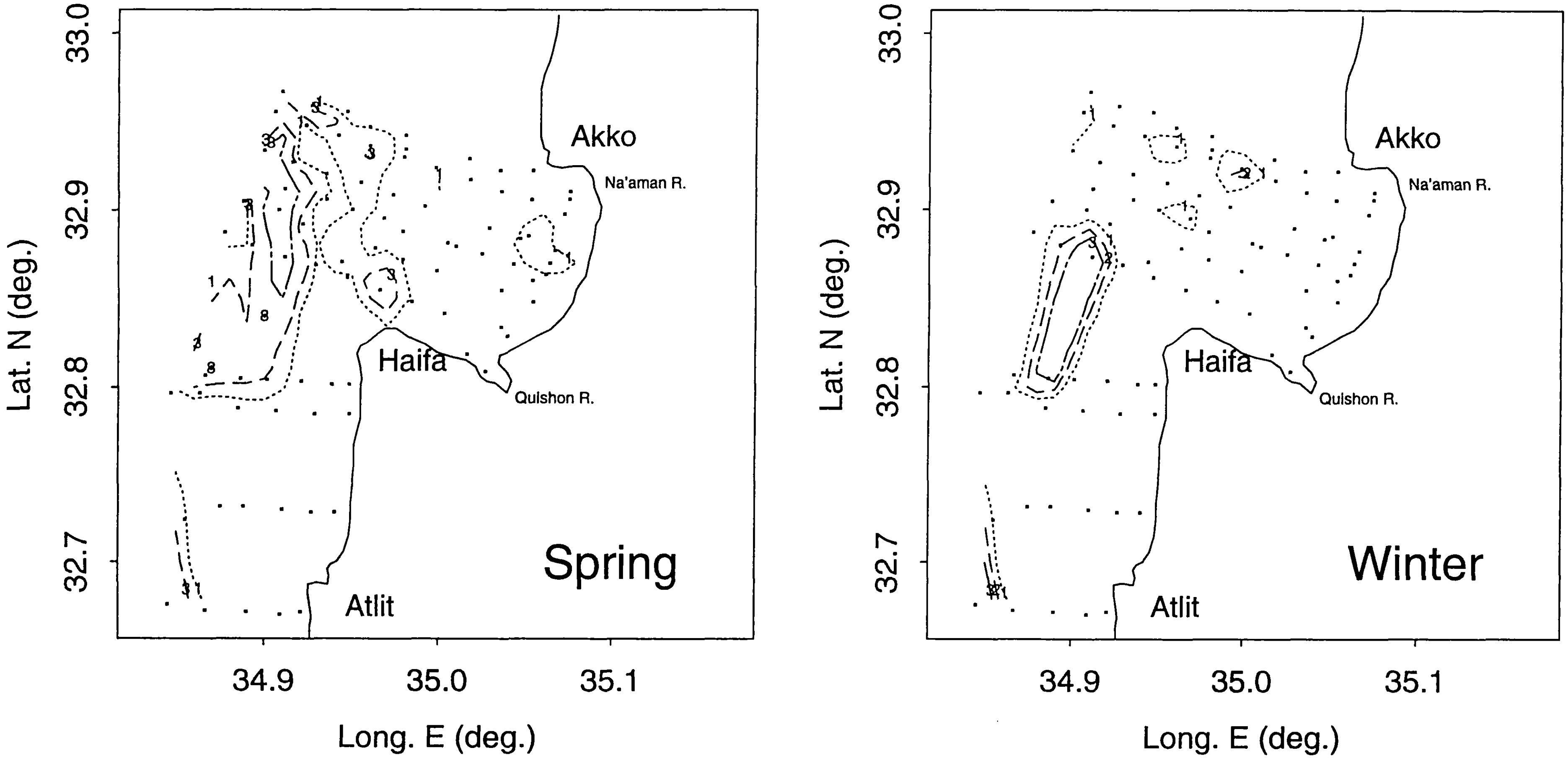


Absolute abundance of Quinqueloculina stelligera

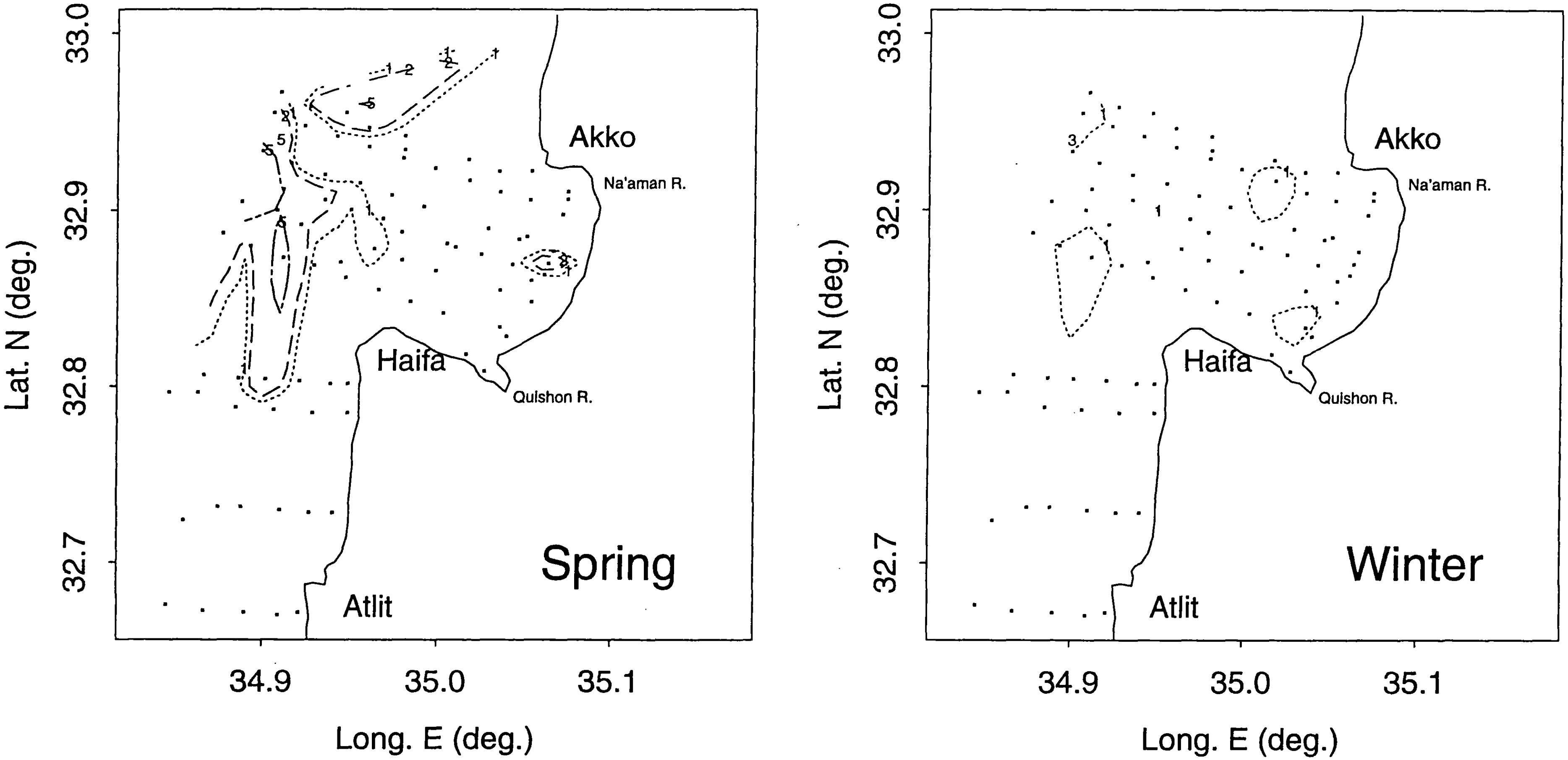




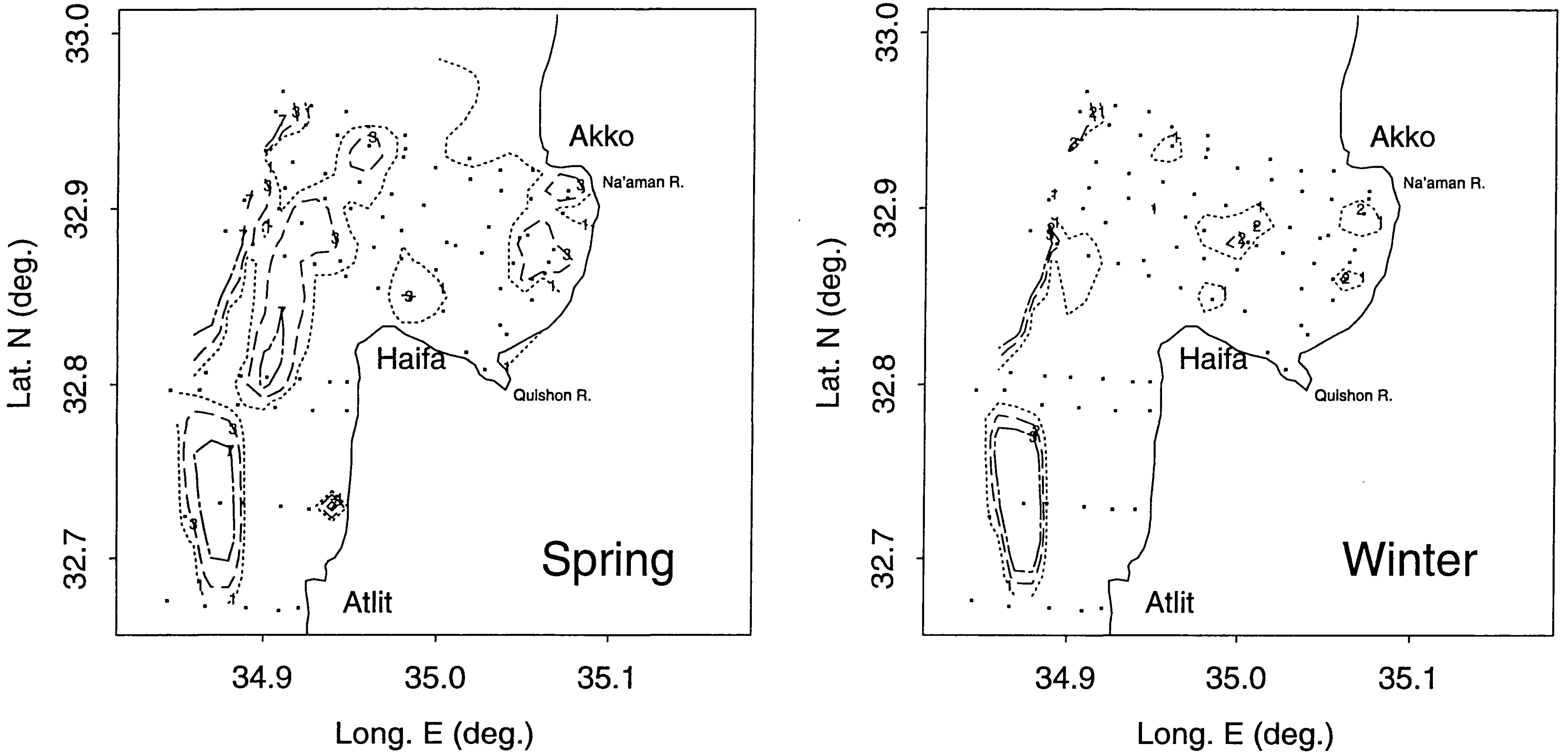
Absolute abundance of Reussella spinulosa



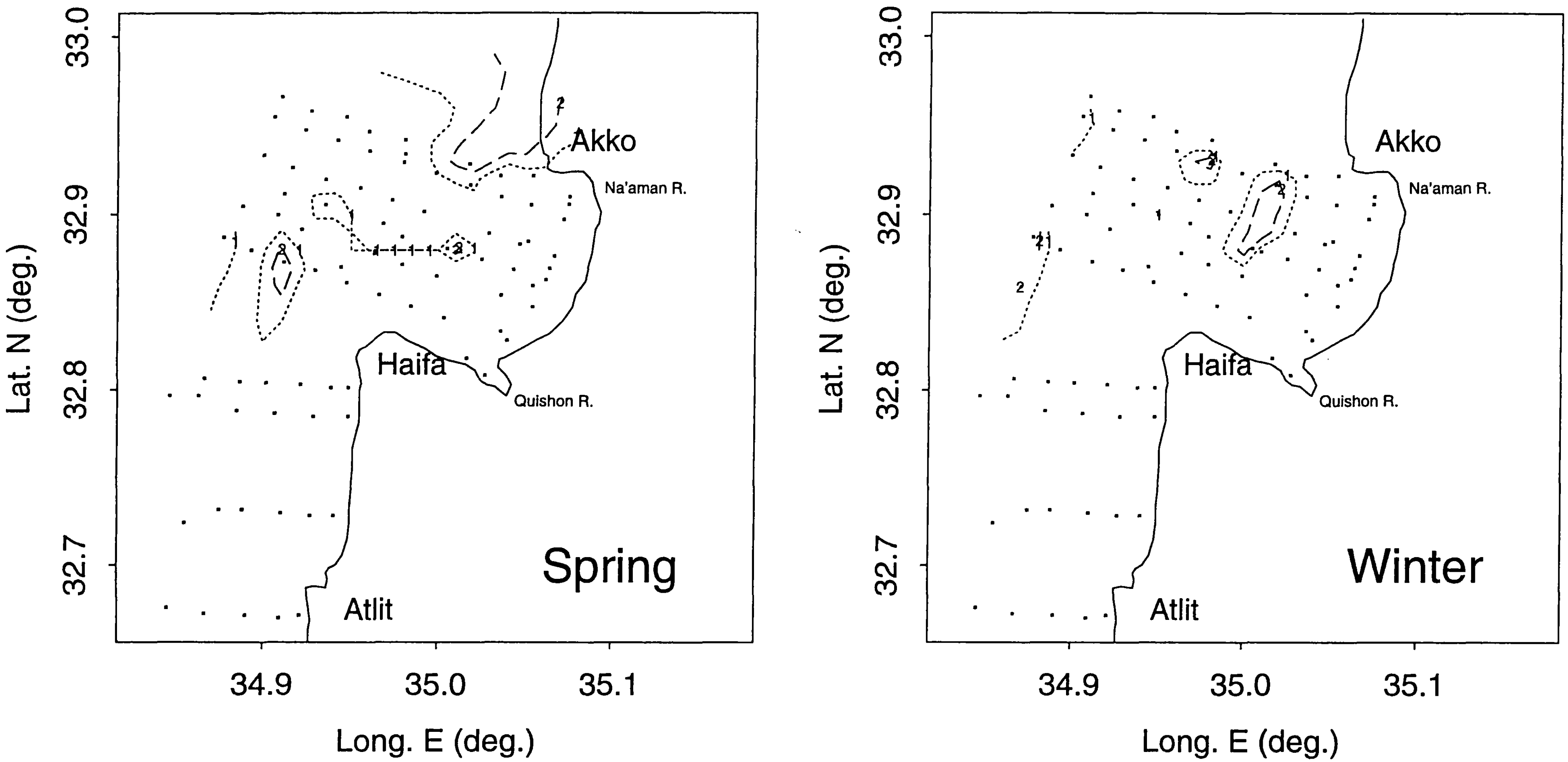
Absolute abundance of Rosalina bradyi



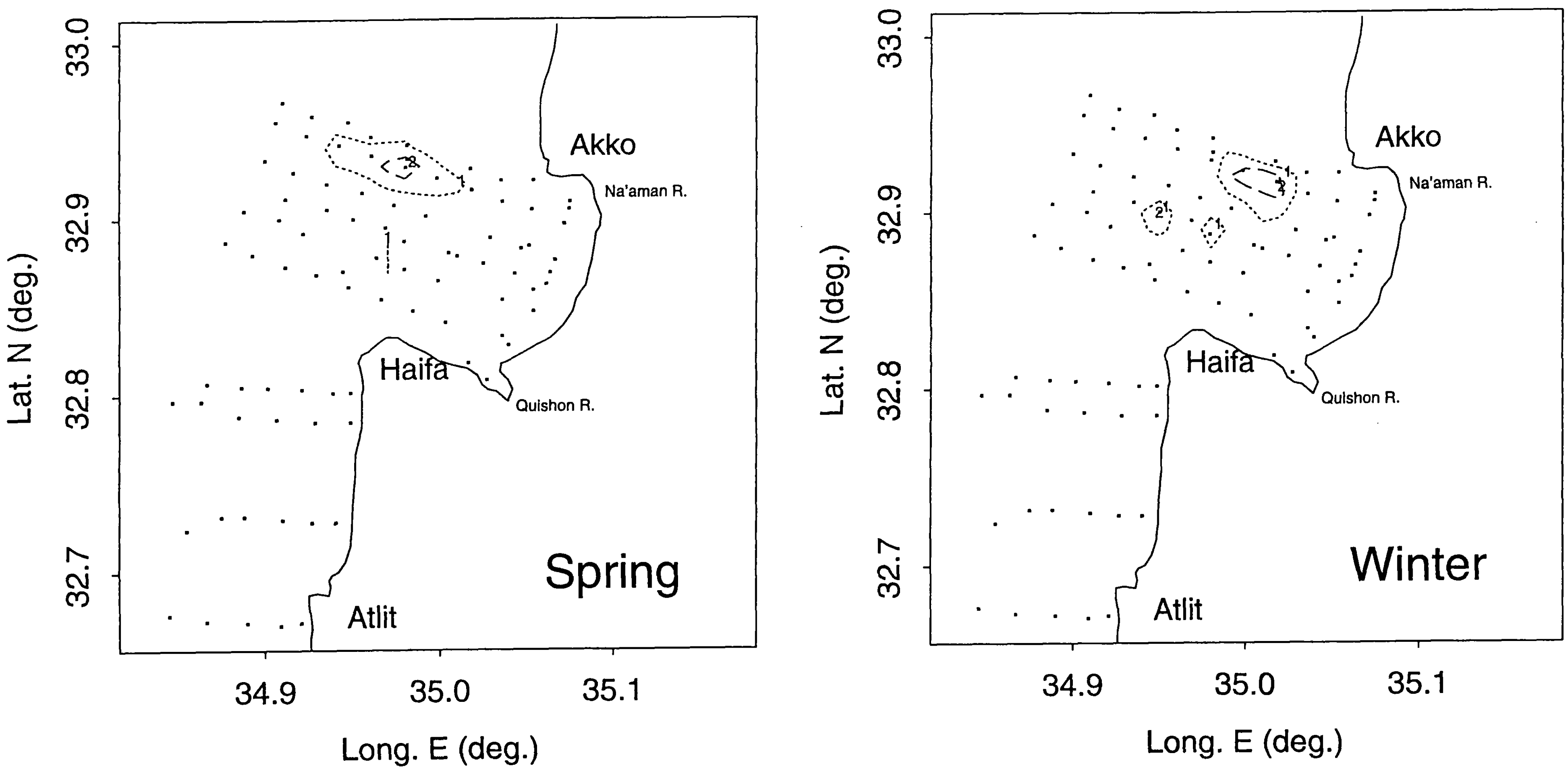
Absolute abundance of Rosalina globularis



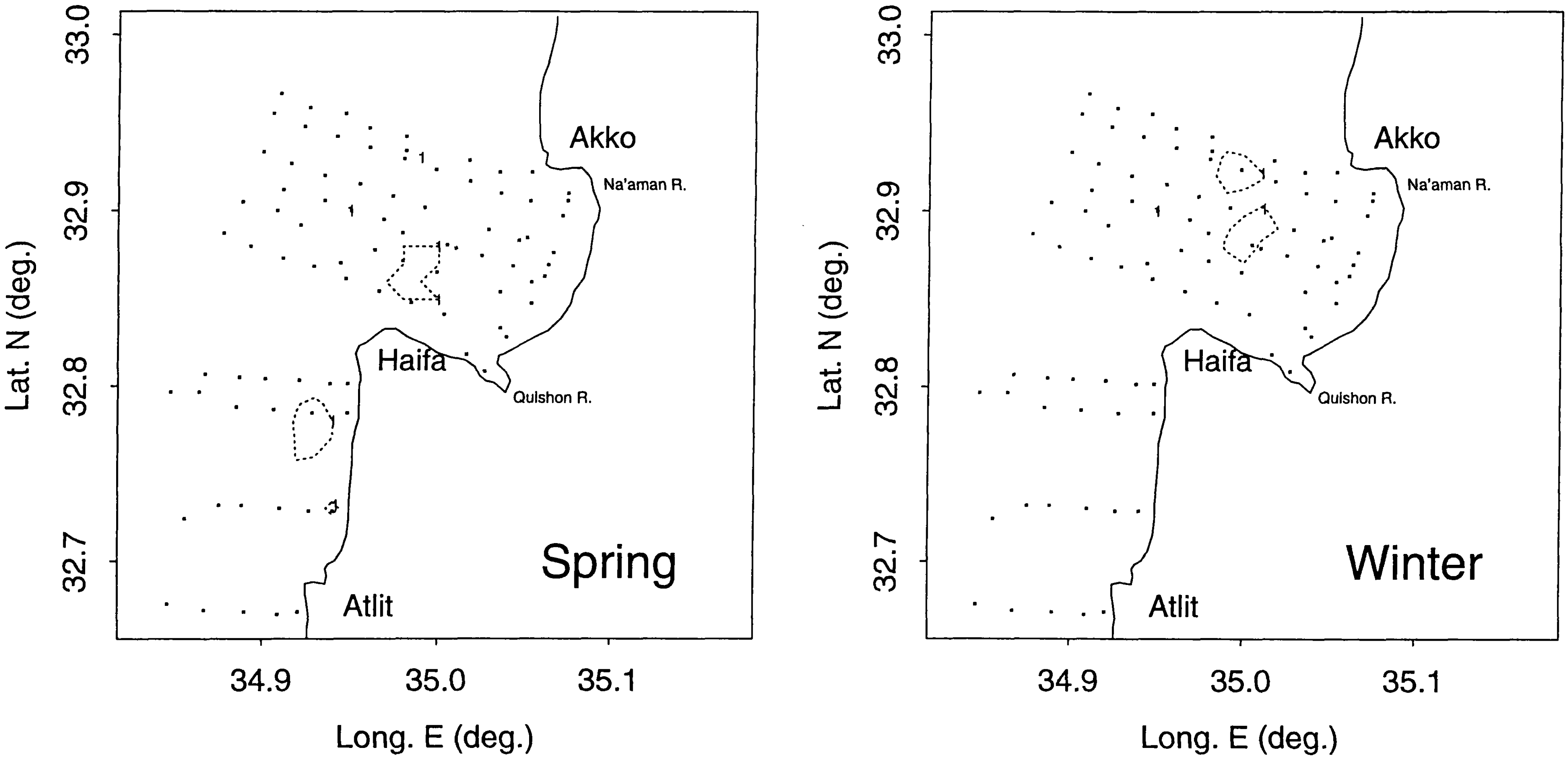
Absolute abundance of Rosalina macropora



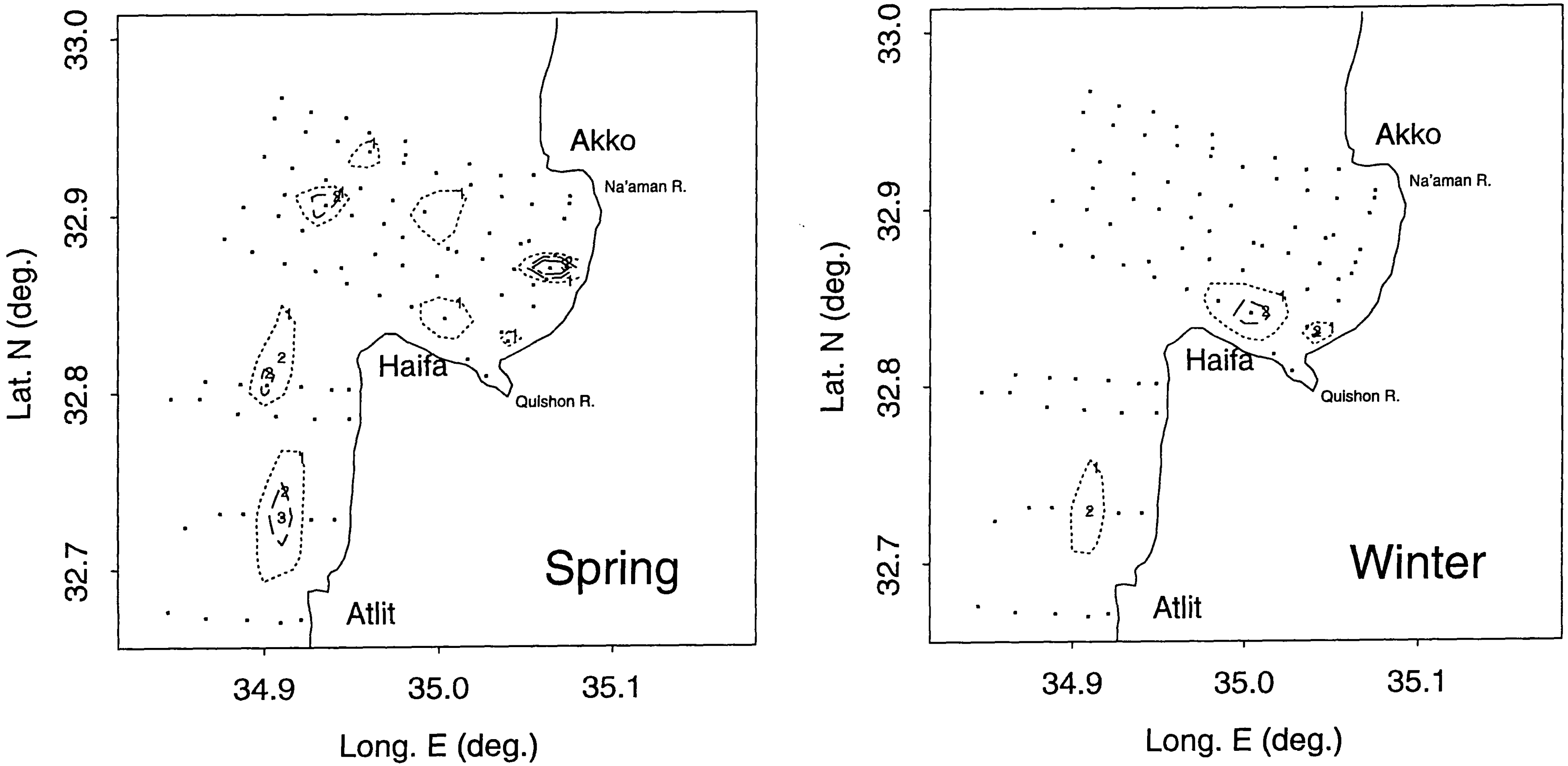
Absolute abundance of Rosalina pellucida



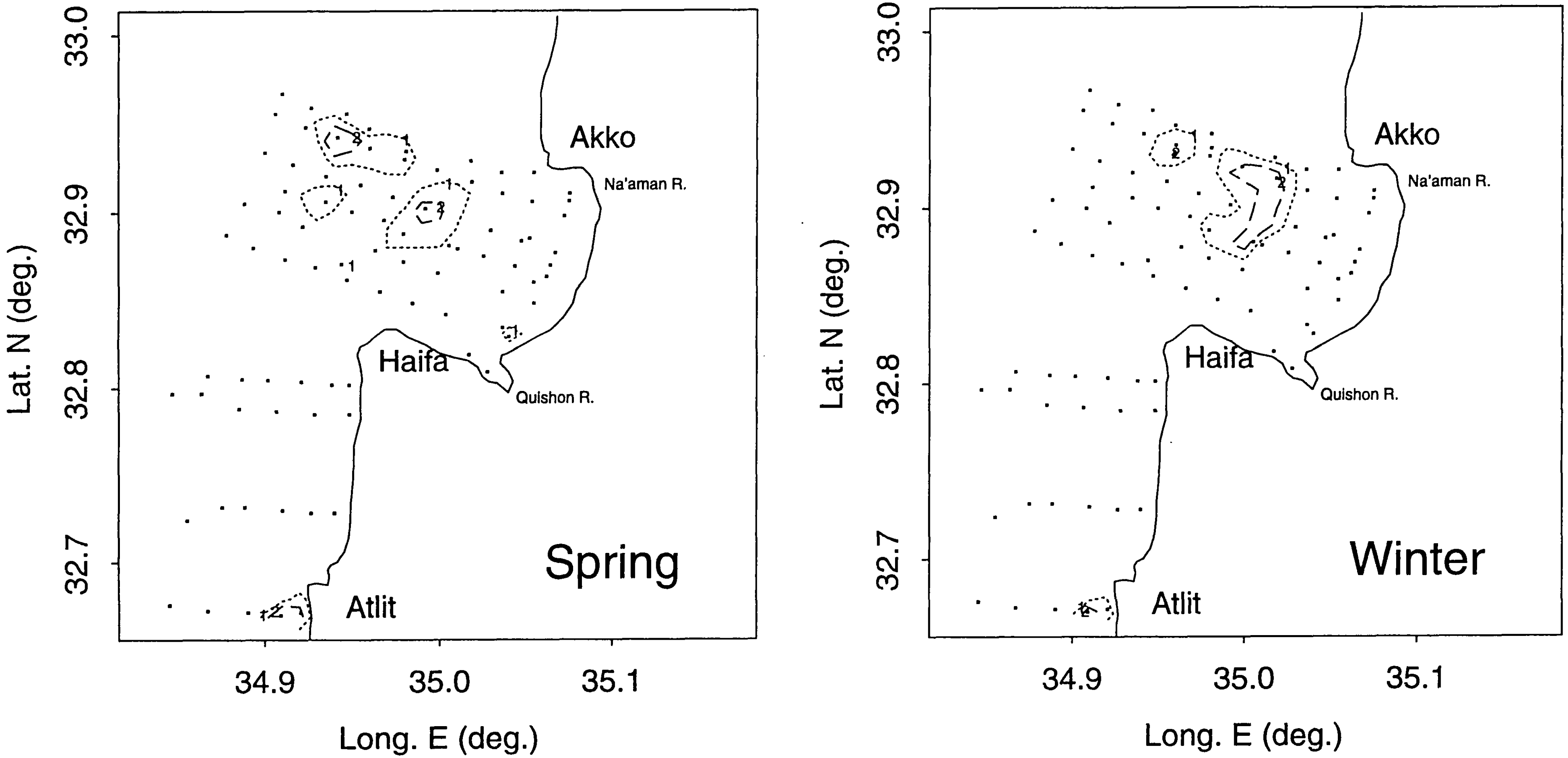
Absolute abundance of Sigmoilinita costata



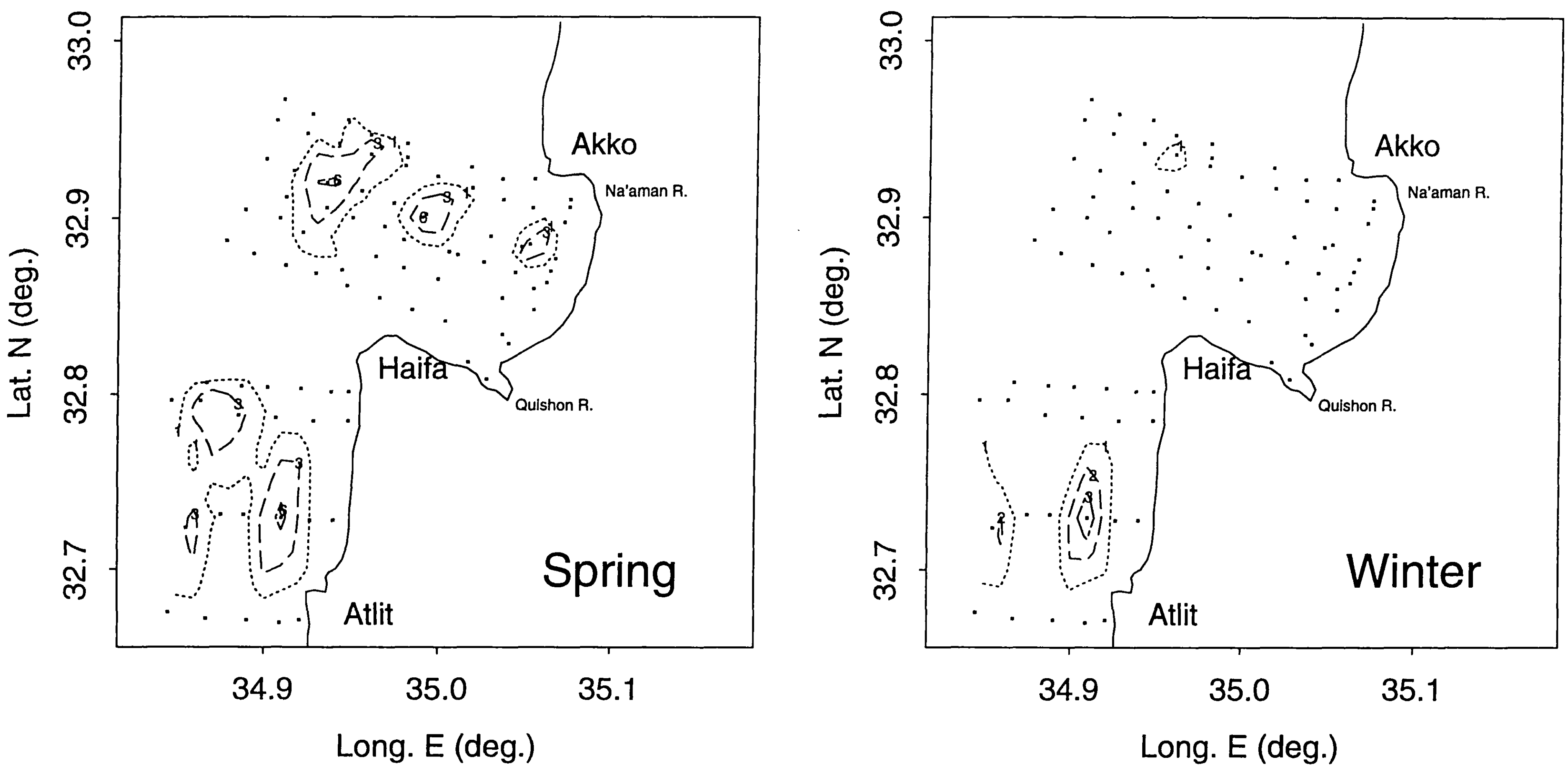
Absolute abundance of Siphonaperta aspera



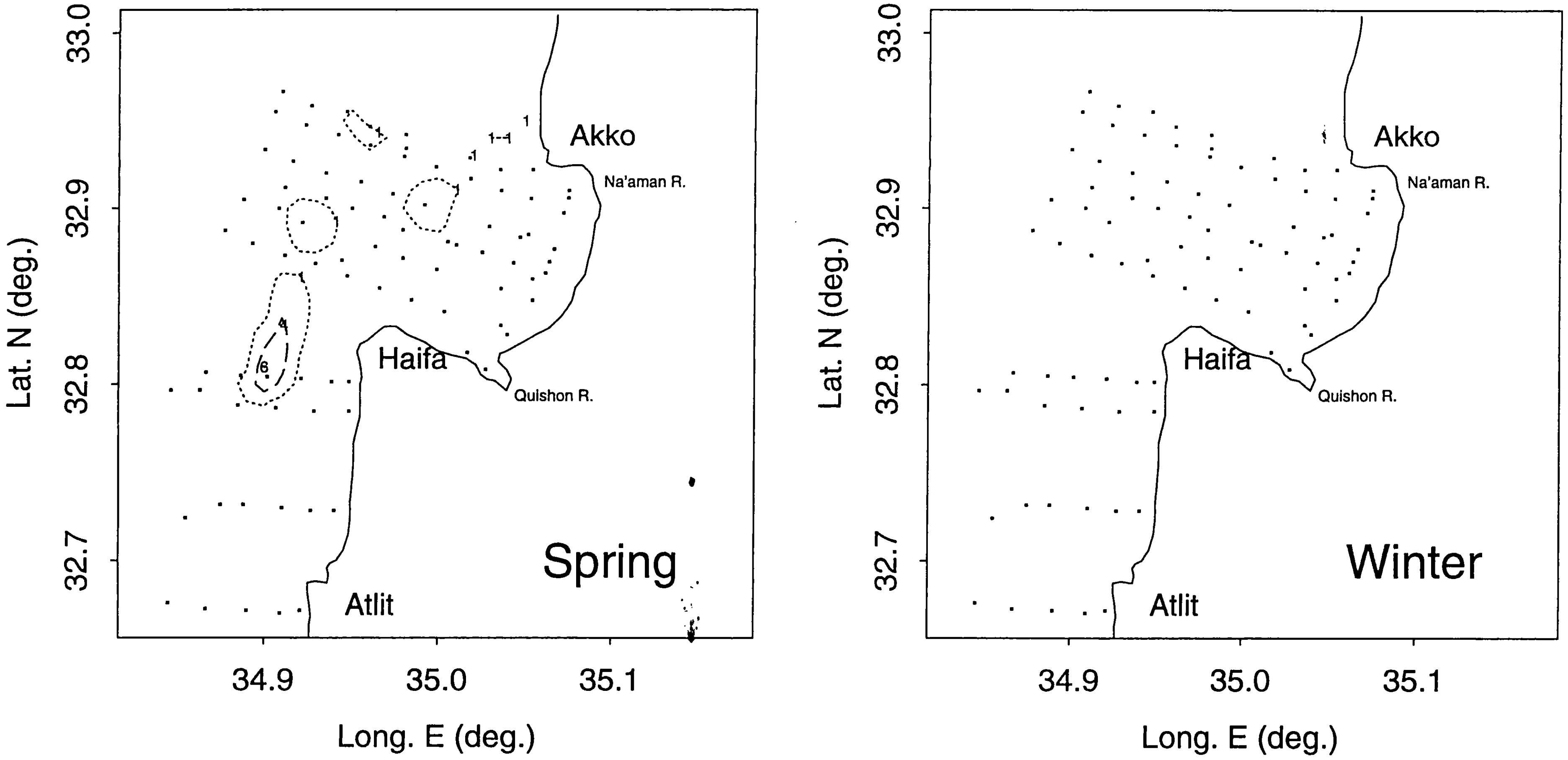
Absolute abundance of Spiroloculina antillarum



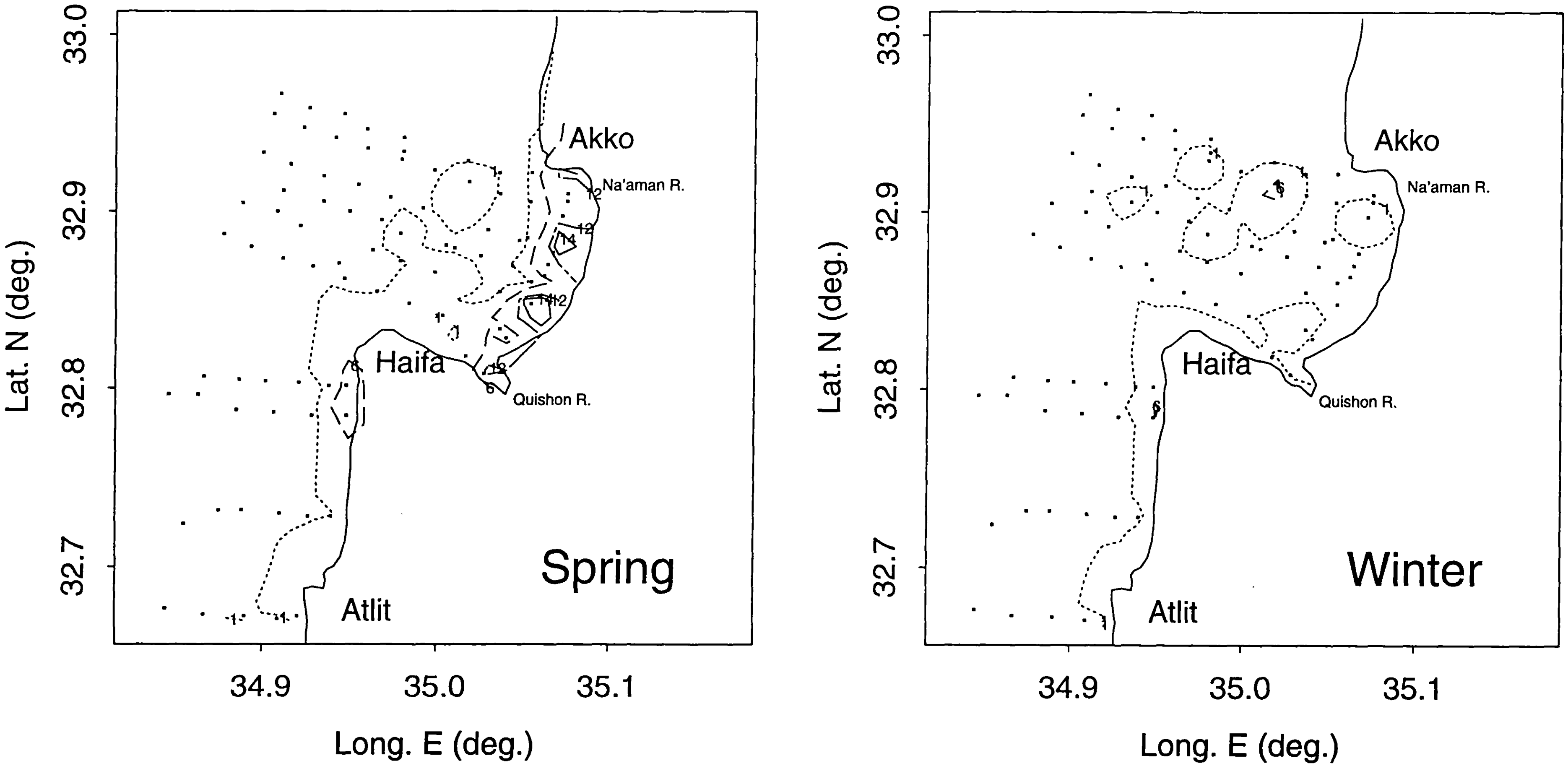
Absolute abundance of Spiroloculina depressa



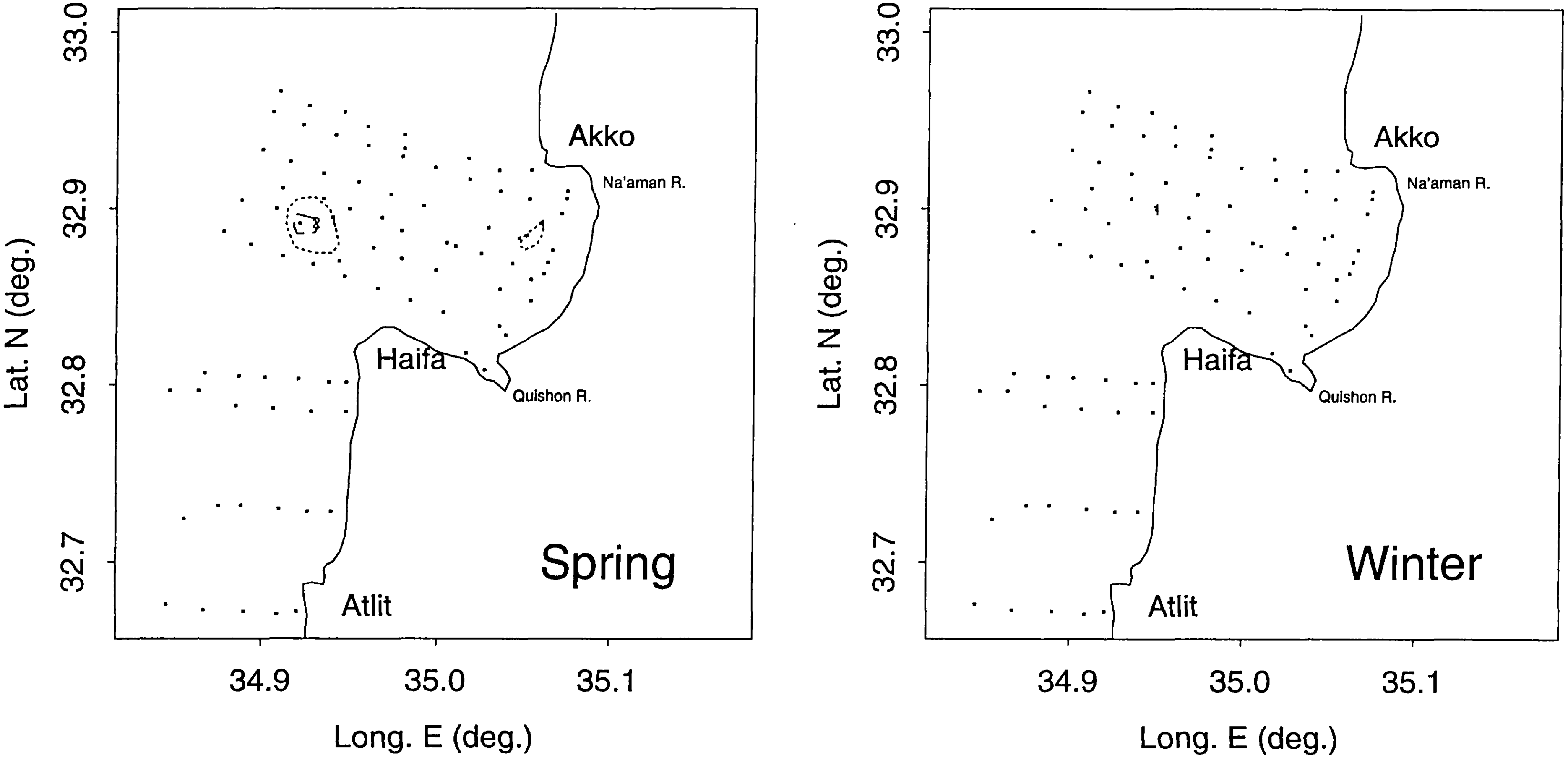
Absolute abundance of Spiroloculina dilatata



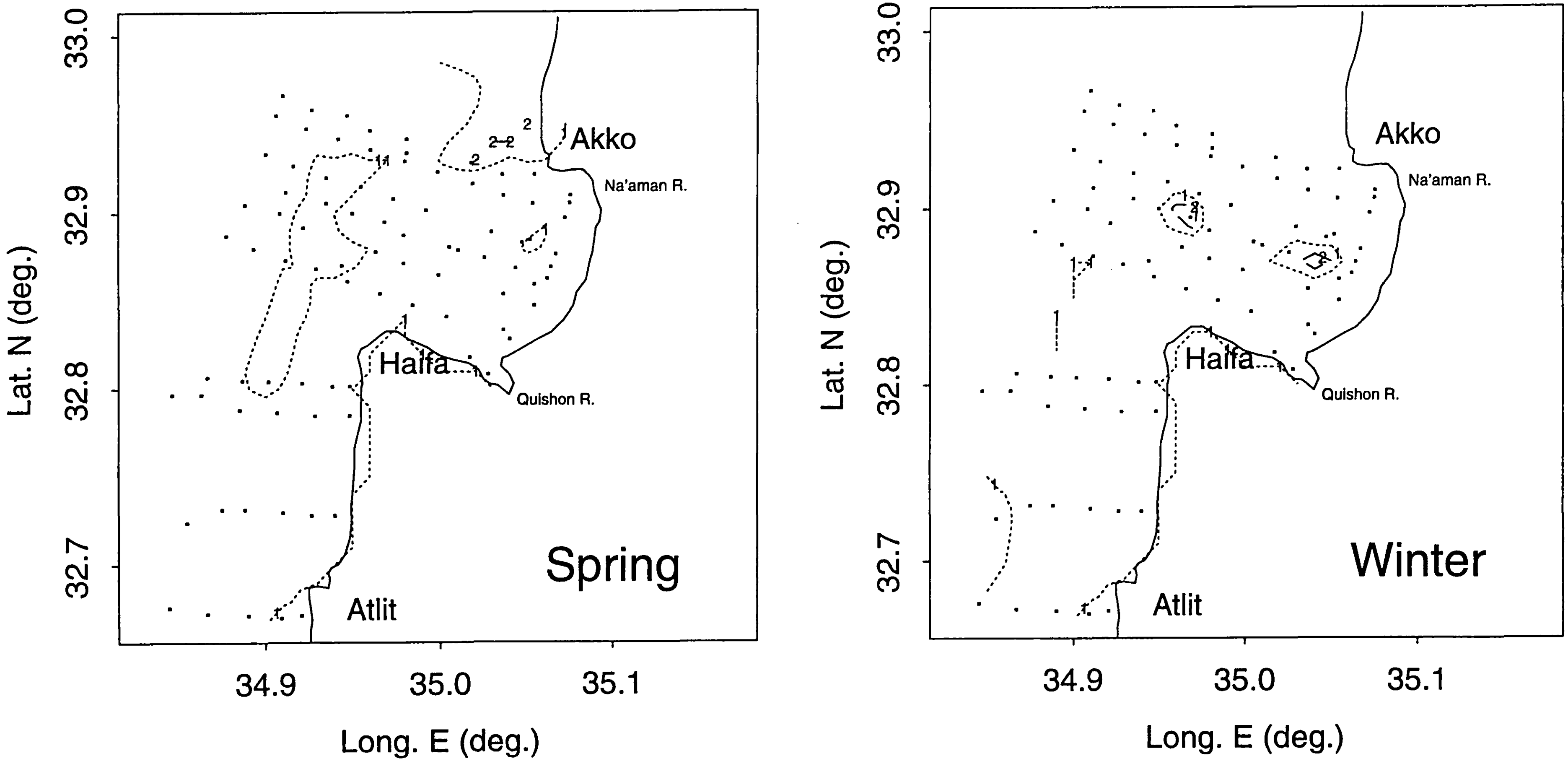
Absolute abundance of Sproloculina excavata



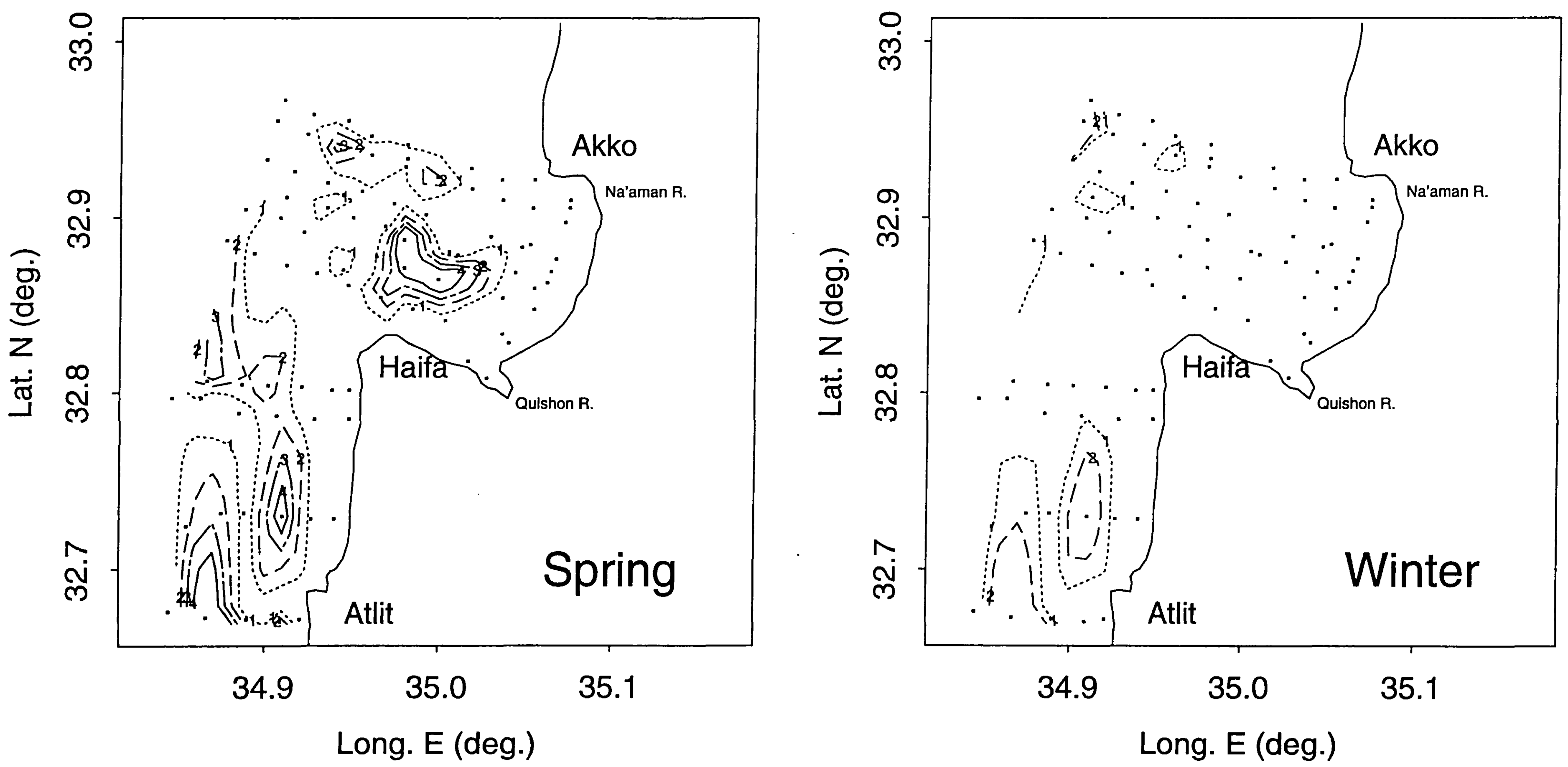
Absolute abundance of Sorites orbiculus



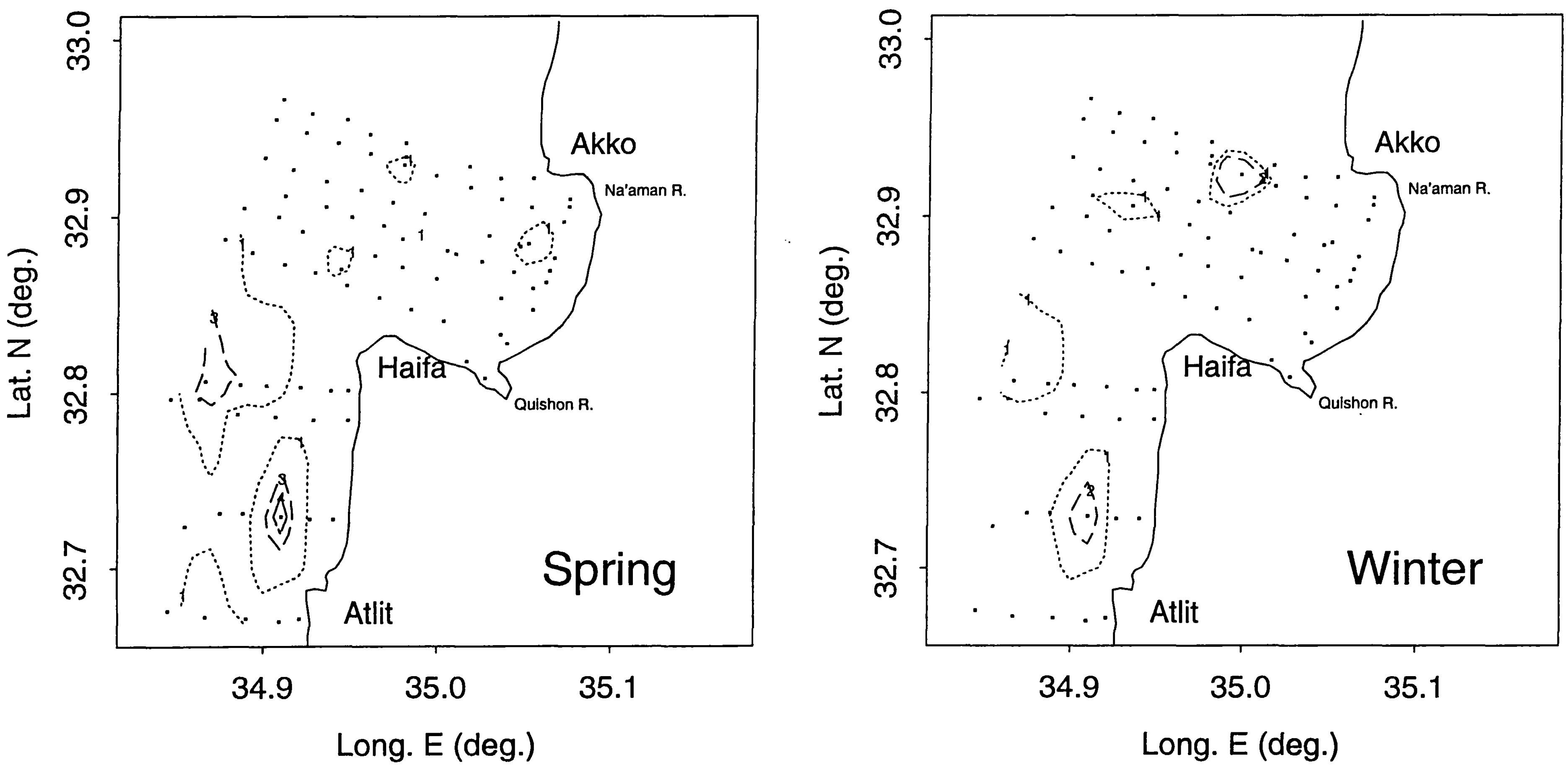
Absolute abundance of Textularia agglutinans



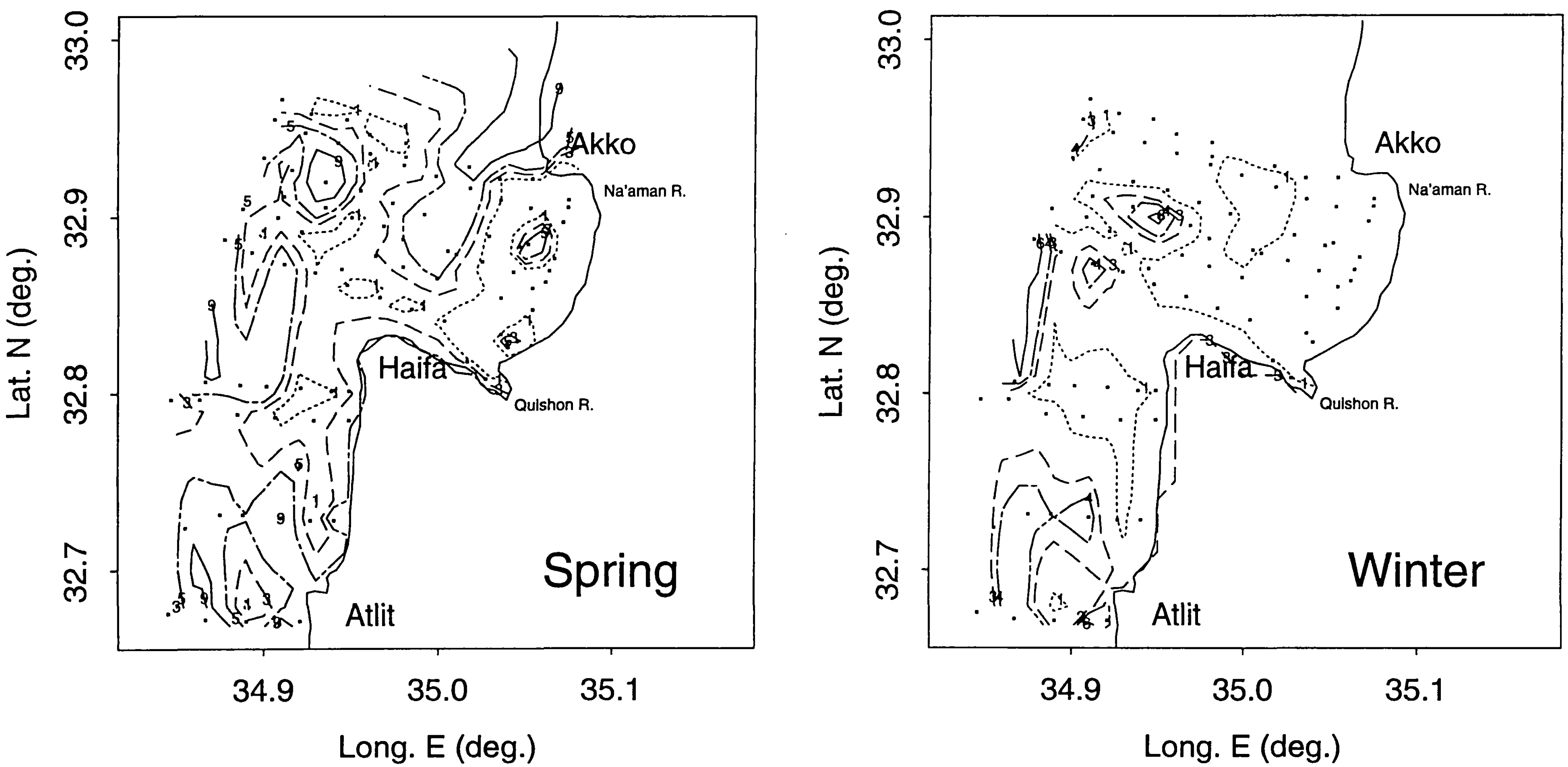
Absolute abundance of Textularia bocki



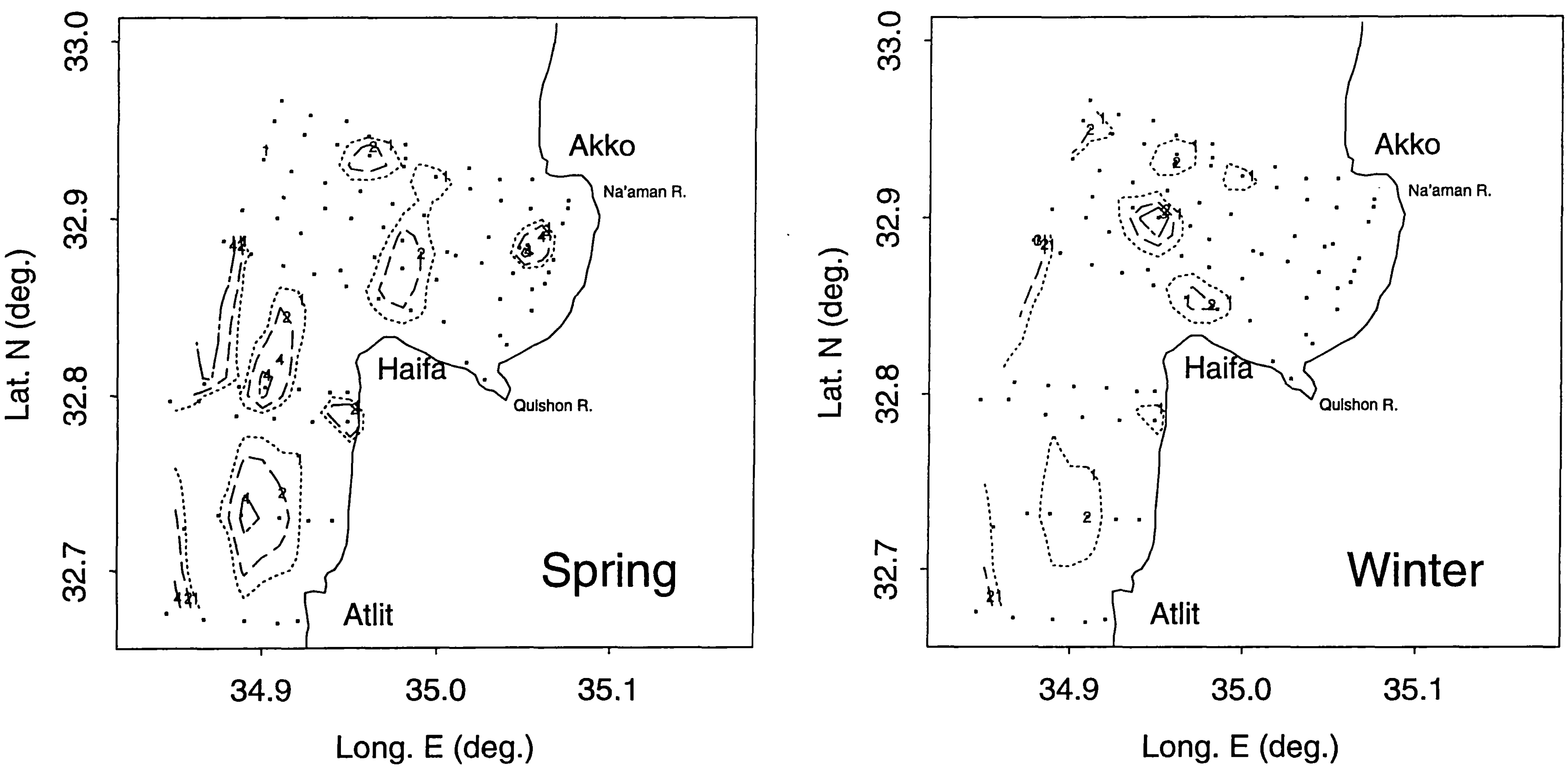
Absolute abundance of Triloculina affinis



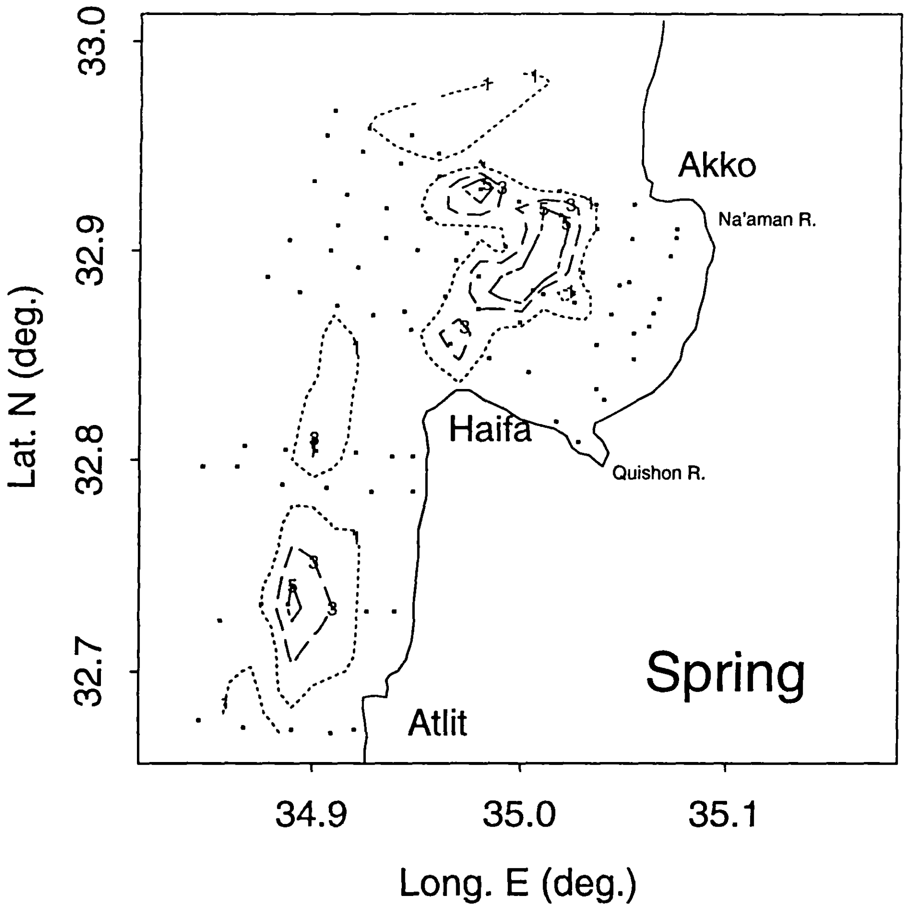
Absolute abundance of Triloculina assymmetrica

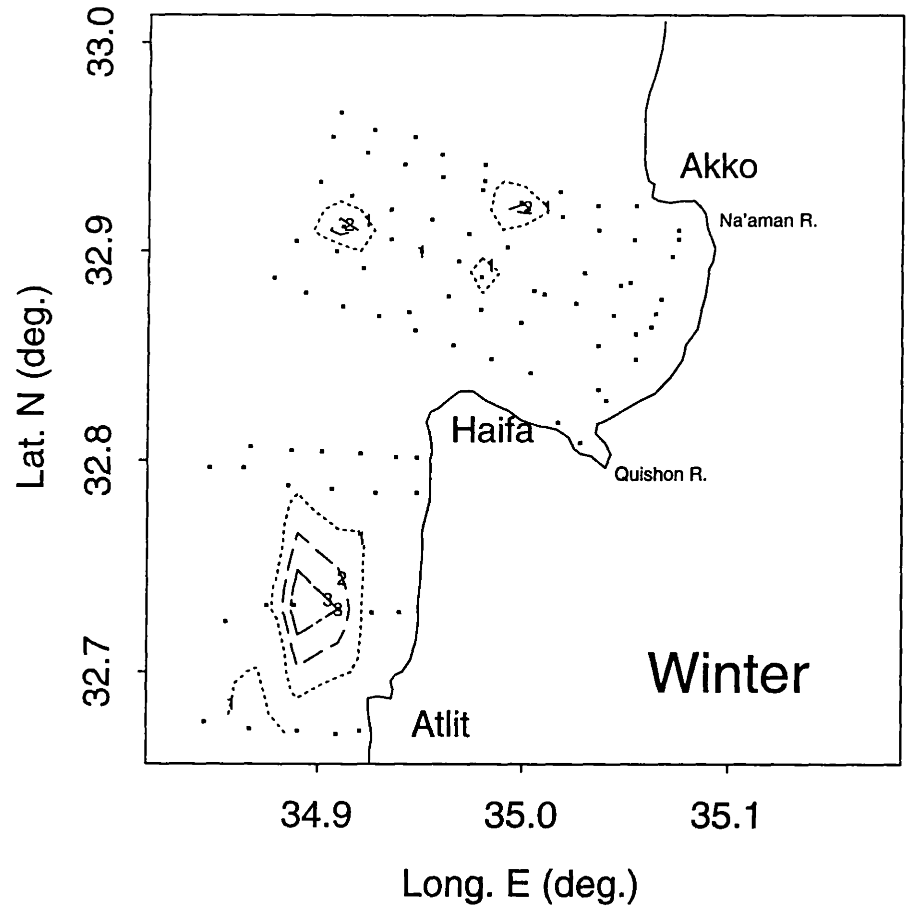


Absolute abundance of Triloculina marioni

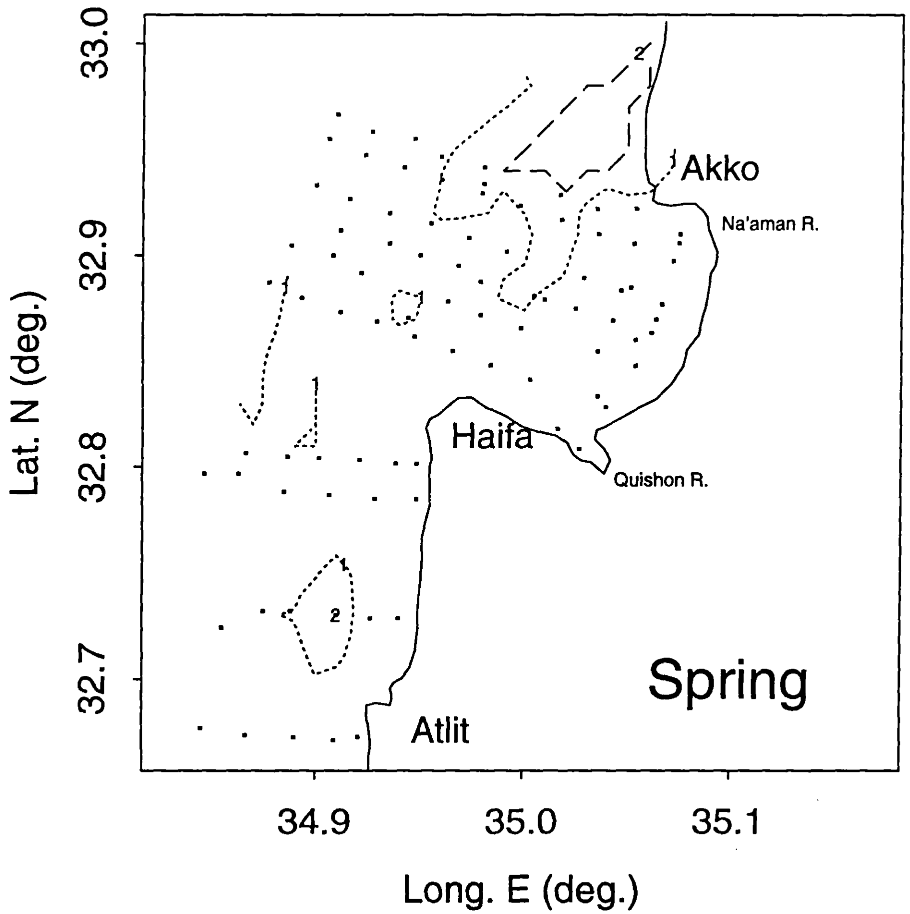


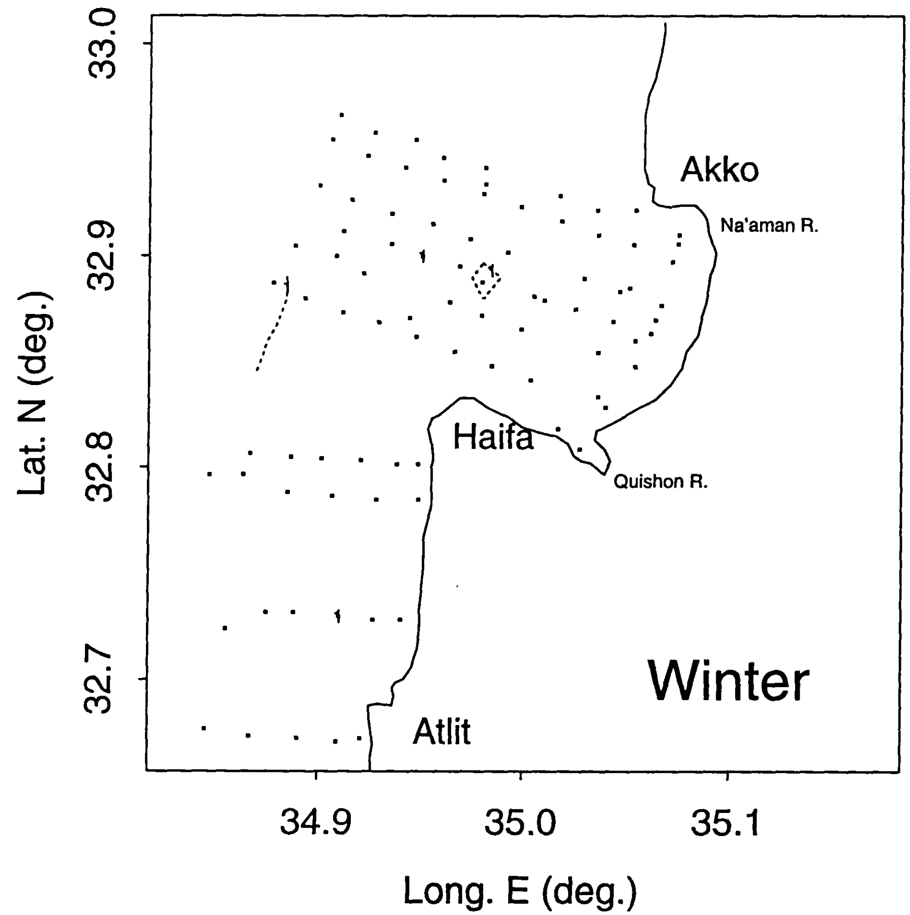
Absolute abundance of Triloculina plicata



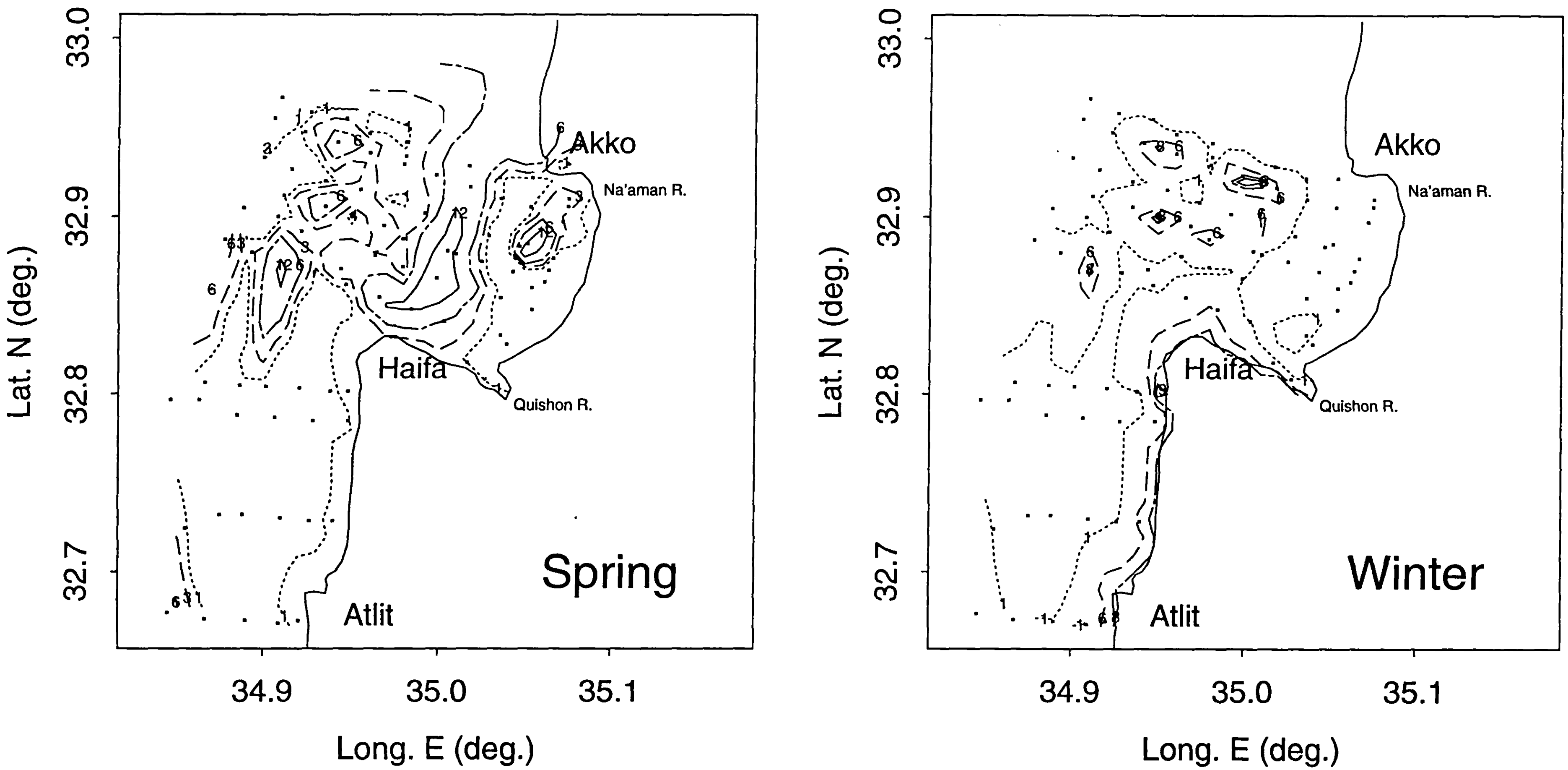


Absolute abundance of Triloculina schreiberiana





Absolute abundance of Triloculina serulata



Absolute abundance of Vertebralina striata