J. mar. biol. Ass. India, 1976, **18** (1) : 140-148

ALGAE AS A SUBSTRATE FOR FORAMINIFERA IN THE PUERTO DESEADO AREA (PATAGONIA)*

E. BOLTOVSKOY, HAYDEE LENA AND A. ASENSI

Museo Argentino de Ciencias Naturales ' B. Rivadavia ' and Consejo Nacional de Investigaciones Cientificas y Técnicas, Argentina

ABSTRACT

Algae are used by benthonic foraminifera as a substrate. Those algae which due to their morphology provide a better shelter contain more numerous and diverse foraminiferal assemblages. The infralittoral belt is more populated than the mesolittoral. No preference was found among foraminifera with respect to the algae used as a substrate.

OBJECTIVES

THIS study is aimed at determining the relationship between algae as a substrate and foraminifera as their epiphyts.

Previous studies

Foraminiferological papers treating the relationship between algae and foraminifera usually do not identify the algae. These are simply referred to as ' algal bottom ' (Schmidt, 1953), ' seaweed ' and/or ' seagrass ' (Murray, 1970). In some cases only one or two dominant algal genera are identified and cited (Christiansen, 1958 ; Mateu, 1965).

Some exceptions are the calcareous alga *Corallina officinalis* Linnaeus whose foraminiferal inhabitants were described accurately by Hedley *et al.* (1967) and Dommasnes (1969), and *Thalassia testudinum* König, whose foraminiferal dwellers were studied and described in detail by Bock (1968, 1969).

There are also some studies in which comparisons between foraminiferal standing crop of different biotops where made. The authors concluded that the richer populations are usually found on algae (Behm & Grekulinski, 1958 ; Murray, 1970 ; Boltovskoy, 1971).

There are very few studies, however, dedicated to the relationship between algae and foraminifera in which genera and/or species of both algae and foraminifera are identified and in which comparisons between foraminiferal biocoenosis associated with particular algae are made.

To our knowledge only four studies of this type have been recorded in the literature. These are briefly summarized here. The names for both algae and foraminifera, as used by the original authors, are maintained.

* This is Contribution No. 108 of the Puerto Deseado Marine Biological Station.

Blanc-Vernet (1969) investigated foraminiferal fauna in several areas of the Mediterranean Sea. According to her study, epiphytic foraminifera which dwell on vegetation are very numerous. She ascribed the following foraminifera to four types of vegetation : (a) *Posidonia* : *Nubecularia*, *Cibicides*, *Planorbulina*, *Rosalina*, *Iridia*, *Webbinella*. (b) *Cymodocea* : This biotop supports a less 'pure' assemblage, since several representatives of other biotops are often co-mixed. The characteristic epibionts of *Cymodocea* are ; *Elphidium*, *Rotalia*, and rather numerous agglutinated species : *Eggerella scabra* (Williamson), *Trochammina*, *Quinqueloculina irregularis* d'Orbigny, *Qu. agglutinans* d'Orbigny and *Qu. aspera* d' Orbigny). (c) *Halophila* : The most numerous foraminifera are *Peneroplis*, *Sorites*, *Amphistegina madagaskariensis* d'Orbigny ; less numerous are Discorbidae, Miliolidae, *Cibicides*, *Planorbulina*. (d) algae *Jania Haloptera*, *Cystoseira* : Rich assemblage dominated by Miliolidae.

Atkinson (1969) studied the relationship between algae and foraminifera in the littoral zone of Wales. He found that algae contained numerous living foraminifera andhe constructeda Table which shows this association with respect to 15 species of algae and 29 of foraminifera. It is quite clear from this Table that some algae support a more diverse population than others. Atkinson explained this, stating that some algae, due to their morphology, provide a more suitable living environment for foraminifera. He concluded, however, that the data obtained is insufficient and that more observations should be made with respect to this problem.

Lee *et al.* (1969) studied material collected near Long Island (USA). They stated that foraminifera were most numerous in epiphytic communities of *Enteromorpha* in early summer, and later they spread to *Zostera*, *Zanichellia*, *Ulva*, *Polysiphonia* and *Ceramium*. As for specific preference, the authors found that *Protelphidium tisburyense* (Butcher) is more frequent than *Quinqueloculina* spp. on *Enteromorpha*, whereas *Ammonia beccarii* (Linne) and *Elphidium* spp. show little substrate preference. In addition they stated that decaying *Enteromorpha* had the greatest standing crop of foraminifera but a low specific diversity index (0.581). Indices for *Zostera*, *Zanichellia*, *Polysiphonia*, *Fucus*, *Ulva* and *Codium* were respectivey 0.82, 0.99, 0.86, 0.70, 0.77 and 0.196. They compiled several Tables showing different types of relationship between foraminifera species and algae genera.

Furssenko & Furssenko (1970) studied the foraminiferal fauna of the Busse Lagoon (Sakhalin Island) and, like Lee *et al.*, concluded that different foraminifera have different preference with respect to the algae on which they live. They published a Table which shows which foraminifera (15 species) were encountered on which algae (9 genera). In this Table all the algae were cited by their generic names only. However, in the text some algae are cited by specific names.

Area of study

The samples were collected from the Puerto Deseado creek and the area between this creek and Cabo Blanco, located 90 km to the north. Puerto Deseado is located on the Patagonian shore of South America at latitude 47°45′S and longitude 65°55′W. A brief description of this area was given earlier by Boltovskoy (1963). This creek is characterized by a very large tidal range with an amplitude of up to 6 m. The temperature of the water ranges between 3.8°C (recorded in August; winter in the southern hemisphere) and 14.5°C (recorded in February ; summer in the southern hemisphere). The salinity is between 32.5‰ and 34.0‰. Fig. 1 shows a map of the Puerto Deseado Creek and its surroundings including all the geographical names used in this paper.

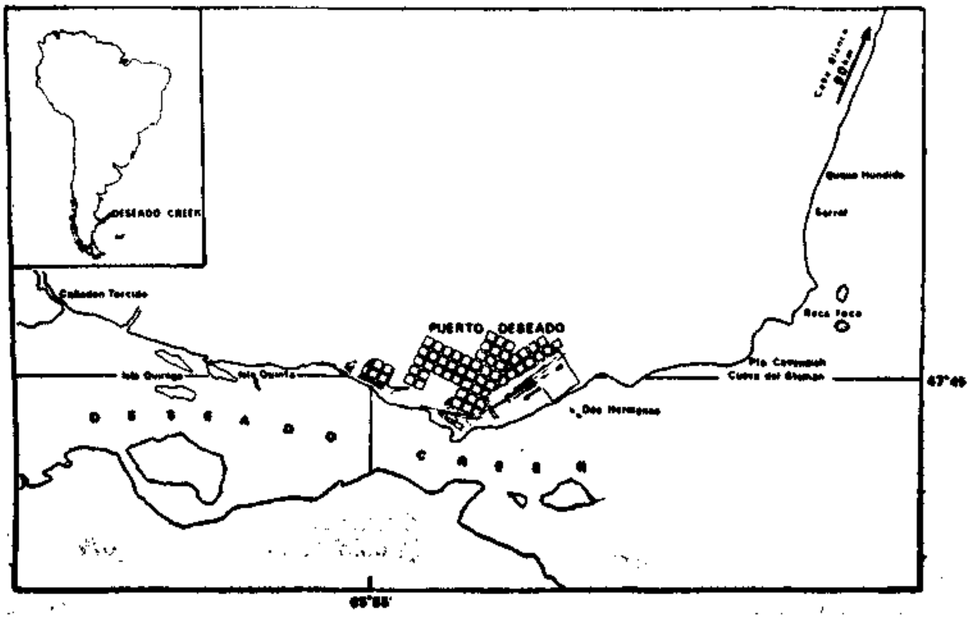

Fig. 1. Map showing localities mentioned in this paper.

The foraminiferal fauna of the area has been studied by Boltovskoy (1963) and Boltovskoy & Lena (1966, 1970). In total 130 species were found; *Elphidium macellum* (Fichtel & Moll) strongly predominates. The following species were found in fewer quantities: *Buccella peruviana* (d'Orbigny), *s.l.*, *Miliammina fusca* (Brady), *Miliolinella subrotunda* (Montagu), *Nonion depressulum* (Walker & Jacob), *Quinqueloculina seminulum* (Linné), *Rotalia beccarii* (Linné), *Buliminella elegantissima* (d'Orbigny), *Cibicides aknerianus* (d'Orbigny) and *Oolina melo* d'Orbigny. They are arranged approximately in the order of their abundance. The remaining 120 species occurred rarely or very rarely. Several foraminifera were ascribed to *nomenclatura aperta*.

Pappenfuss (1964) compiled a Catalogue of Antarctic and Subantarctic benthic marine algae in which all the algae found by us were enumerated. Kühnemann (1971) published a Catalogue of algae of Puerto Deseado including some ecological data.

Material and Method

One hundred and seventy-eight algal samples were hand collected from the sea floor during the period covering February 1969 through February 1971. The weight of each sample was approximately 0.5 kg.

The following 26 kinds of algae were found by the authors and used in this study. We especially use a term 'kind' but not species, because in several cases not one undetermined species was found but several mixed together. It was very difficult to separate them and not go lose their epibionts, so they are listed here as spp.

Adenocystis utricularis (Bory) Skottsberg
Ballia callitricha (C. Agardh) Kützing
Bostrychia vaga J. D. Hooker & Harvey
Ceramium rubrum (Hudson) C. Agardh
Chaetangium fastigiatum (Bory) Agardh
Chondria macrocarpa Harvey
Cladophora spp.
Codium fragile (Suringar) Hariot
Corallina officinalis Linnaeus
Desmarestia ligulata (Lightfoot) Lamouroux
Dictyota sp. A
Dictyota sp. B
Enteromorpha spp.
Gigartine skottsbergii Setchell *et* Gardner
Grateloupia spp.
Griffithsia antarctica J. D. Hooker *et* Harvey
Hymenena laciniata (J. H. Hooker *et* Harvey) Kylin
Iridaea laminarioides Bory
Leathesia difformis (Linnaeus) J. E. Areschoug
Macrocystis pyrifera (Linnaeus) C. Agardh
Porphyra spp.
Pseudophycodrys phyllophora (J. Agardh) Skottsberg
Rhodymenia spp.
Schizoseris laciniata (Kützing) Kylin
Ulva rigida (C. Agardh) Thuret
Monostroma sp.

Great care was taken not to lose epiphytic fauna encountered on the algal samples during collection. After collecting the samples were vigorously shaken and washed in a pail of sea water from the same place. Shaking them served to remove all the epiphytic foraminifera from their substrate. The water from the pail was then filtered through a sieve with average mesh size of 63 microns. The material retained by the sieve (sand grains, foraminiferal tests and other epibionts) was immediately fixed in a 5 to 10% solution of neutralized formalin.

Later, in the laboratory, it was processed with rose Bengal, washed thoroughly again to remove the excess dye, dried, floated several times in carbon tetrachloride, and then examined under the binocular microscope. Rose Bengal stains the protoplasm but not the shells; thus it was possible to distinguish living specimens which contained protoplasm at the time of collection from dead ones, which do not. All the living specimens, stained by the Rose Bengal, were picked out, mounted on slides, identified and counted.

Although an attempt was made to always collect the same quantity of algae, (0.5 kg of moist weight) at each station, and the number of living foraminiferal specimens obtained were thoroughly counted, this study cannot be considered quantitative. It is essentially a qualitative study with only some approximation to the quantitative result.

Numerous Tables and graphs were prepared on the basis of the data obtained. To save space we have only included the two most illustrative figs. 2 and 3.

Results and Discussions

Fig. 2 shows the average number of foraminiferal species found on 0.5 kg of moist weight of algae studied at different places. Table 1 is based on this data ; it shows the average number of foraminiferal species encountered on the five most populated and the five less populated algae. The algae are arranged in the order of decreasing diversity of foraminiferal assemblages.

TABLE 1. *Average number of foraminiferal species found on 0.5 kg (humid weight) of some selected algae*

Qualitatively most populated algae :	
Corallina officinalis	24
Bostrychia vaga	21
Dictyota sp. B	20
Criffithsia antarctica	18
Pseudophycodrys phyllophora	17.3
Qualitatively less populated algae :	
Enteromorpha spp.	10
Cladophora spp.	8.5
Macrocystis pyrifera	7
Grateloupia spp.	4
Desmarestia ligulata	3.3

The algae cited in Table 1 have the following characteristics with regards to their capacity to retain sediments.

TABLE 2. *Characteristics of algae as a substrate for sediments*

Corallina officinalis : Very rigid, dense branching plants.
Bostrychia vaga : Forms a very entangled mat a few cm thick.
Dyctyota sp. B : Flat frons, with surface not totally smooth.
Griffithsia antarctica : Dense branching plants.
Pseudophycodrys phyllophora : Foliaceous frons, with nervations capable of retaining sediments.
Enteromorpha spp. : Cylindrical thallus with irregularities on their surface.
Cladophora sp. :Brancing tuft with very thin filaments.
Macrocystis pyrifera : Wrinkled frons with slime. They float on the surface.
Grateloupia spp. : Flexible and smooth frons.
Desmarestia ligulata : Frons with smooth surface and without slime, with excretion products probably toxic.

Examination of figure 2 and Tables 1 and 2 reveals that (a) on the average those algae which are capable of retaining sediments better (provide best shelter) are the most populated. This is specially true of *Corallina officinalis*. (b) Another factor of importance is the location of the algae. Those which are typical of the infralittoral belt, on the average, are more populated than the algae living in the mesolittoral belt. *Porphyra* sp., for example, despite its high qualities as a shelter, has qualitatively poor assemblage (this alga has foliaceous frons with smooth surface), because this alga lives in the upper mesolittoral belt which at low tide usually is uncovered by water. Naturally this creates unfavorable life conditions for epiphytic foraminifera. (c) *Desmarestia ligulata* has the poorest foraminiferal assemblage. It is well known that this alga has sulphuric acid. If it dies, pH decreases and this destroys not only a plant, but all the epiphyts too, certainly foraminifera also. It can be supposed that even when alive, *Desmarestia ligulata* has excretion toxic for foraminifera, which explains why this alga is so poorly populated.

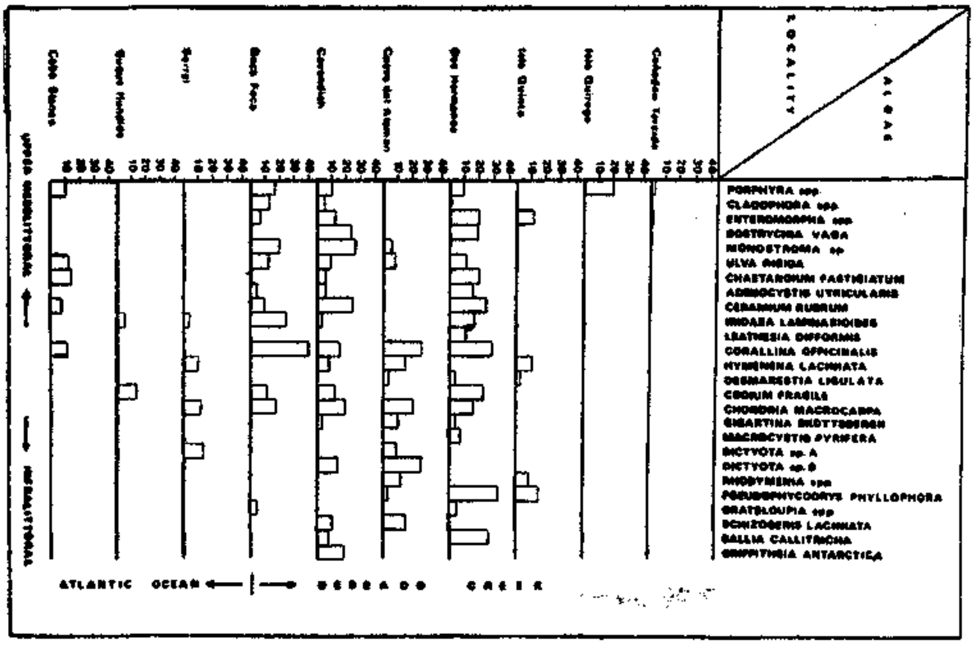

Fig. 2. Average number of foraminiferal species found on 0.5 kg of moist weight of different algae.

As for the qualitative characteristic of the foraminiferal assemblages found on algae, it can be summarized by saying the following. The total number of foraminiferal species associated with algae in the Puerto Deseado is 53. It does not mean that other species (from the 130 found in Puerto Deseado) do not live on algae. It means that being very rare they were not found in the present study. As a general trend the most common species were found associated with a large number of algal species. *Elphidium macellum*, which is known as the most abundant species in the area under consideration, was found on all 26 algae examined. Other species which are also abundant or very common in the Deseado Creek area and which were found on numerous algae are as follows (number of algal species on which each foraminiferal species was found is in parenthesis): *Miliolinella subrotunda* (Montagu) (24), *Bolivina compacta* Sidebottom (23), *B. pseudoplicata* Heron-Allen & Earland (23), *Cibicides aknerianus* (d'Orbigny) (23), *Cornuspira involvens* (Reuss) (20), *Miliammina fusca* (Brady) (20).

However, this general rule that occurrence on algae corresponds to occurrence in the whole area has some exceptions, namely: (*a*) Unicameral calcareous species belonging to the genera *Lagena*, *Oolina*, *Fissurina* and *Parafissurina* are much more numerous on the sea bottom than on algae. The relative small quantity of these genera found on algae is probably explained by the fact that their fixation by the protoplasm extruding from the aperture is not sufficiently strong to keep a shell which should resist shaking of the algae and movements of water. (*b*) On the other hand such as *Spirillina vivipara* Ehrenberg, *Patellina corrugata* Williamson and some other flat and small species are considerably much more abundant on the algae than in the area in general, which is explained obviously by their shape especially favourable for epiphytic life. (*c*) *Dahlgrenia* and *Allogromia*, two agglutinated genera, are rare among algal epiphytic dwellers, probably because they need for the construction of their test anorganic particles which are easily found on the bottom, but not on the algae.

It should be emphasized that no preference was found to exist among foraminifera with respect to the studied algae.

Fig. 3 shows the maximum number of specimens of the most abundant species, *Elphidium macellum*, found on different algae (0.5 kg of wet weight) at three most studied places, namely Dos Hermanas, Cavendish and Roca Foca. Table 3 is based on these data; it shows the maximum number of specimens of *Elphidium macellum* found on five quantitatively most populated algae.

TABLE 3. *Maximum number of* Elphidium macellum *found on* 0.5 kg *(moist weight) of five quantitatively most populated algae*

Corallina officinalis	24,000	specimens
Schizos ris laciniata	20,000	„
Chondria macrocarpa	3,750	„
Pseudophycodrys phyllophora	3,500	„
Enteromorpha spp.	2,000	„

From an examination of fig. 3 and Table 3 we can see that quantitative abundance shows the same tendency as the qualitative one, namely, *Corallina officinalis* is the most populated, the infralittoral belt has on the average higher abundance than the mesolittoral and an extremely small number of *Elphidium macellum* was found on *Desmarestia ligulata*. In addition following observations which prove the importance of the algal morphology should be mentioned: *Monostroma* sp. has more lobulated margin than *Ulva rigida* and consequently more numerous population of *Elphidium macellum*. *Iridea laminarioides*, *Macrocystis pyrifera*, *Gigartina* are characterized by their large and smooth frons and the number of foraminiferal specimens found on these algae is very low. Another interesting observation is a very poor population encountered on *Chaetangium fastigiatum* which is probably explained, by some unknown substance excreted by this alga which gives it a very particular smell.

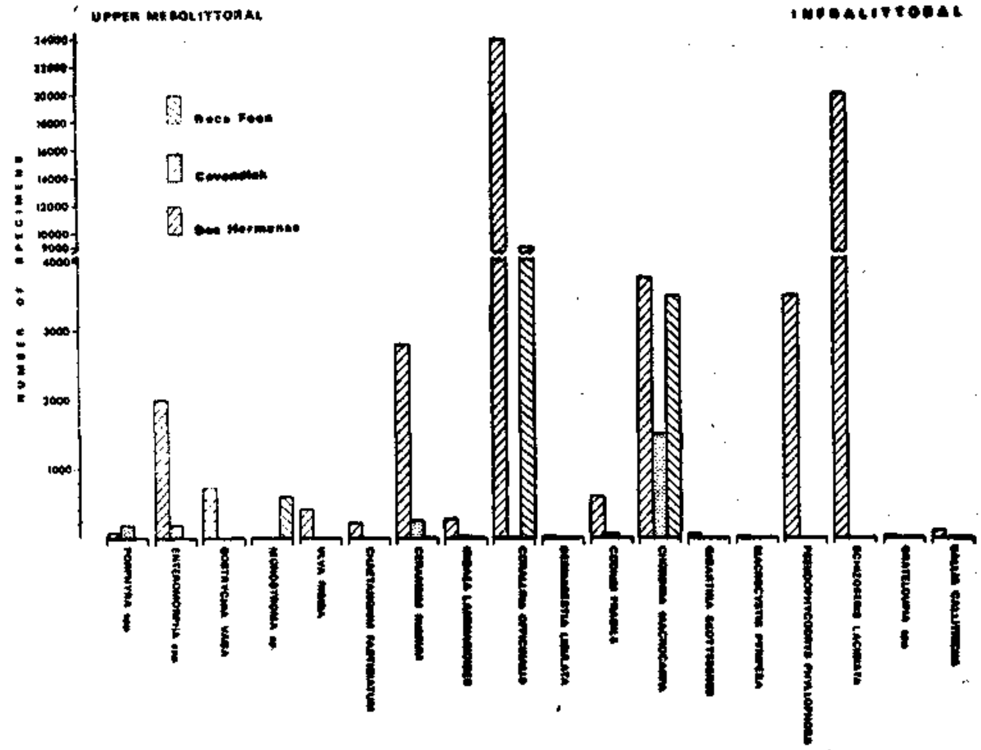

Fig. 3. Maximum number of specimens of the most abundant species—*Elphidium macellum* found on different algae (0.5 kg of moist weight).

Conclusions

We can summarize the results obtained by stating the following :

1. Benthonic foraminifera, at least in the area under consideration, use algae only as a substrate and do not show preference with respect to some particular alga.

2. The number of foraminiferal species and specimens found on algae depends primarily on the characteristic of the latter. Those algae which provide a better shelter should have the most numerous and diverse foraminiferal assemblage.

3. Another factor which plays a role is the location of algae. The algae typical of the infralittoral belt are on the average more populated than those from the mesolittoral belt.

4. Foraminifera avoid some algae probably due to the toxic substance excreted by the latter.

5. Unicameral flash-shaped calcareous foraminifera are rare as epiphytic species, whereas unicameral or multicameral flat species are, on the contrary, very often.

6. Agglutinated foraminifera as dwellers on the algae are few. Of course we do not exclude the possibility of some other type of relationship between epiphytic foraminifera and algae, although we did not observe any in the area of Puerto Deseado.

References

Atkinson, K. 1969. The association of living foraminifera with algae from the littoral zone, south Cardigan Bay, Wales. *Journ. Nat. Hist.*, **3** : 517-542.

Behm, H. J. and E. F. Grekulinski 1958. The ecology of foraminifera of Main and Richmond creeks, Staten Island, New York. *Staten Island Inst. Art. Sci., Proc.*, **2** : 51-66.

Blanc-Vernet, Laura 1969. Contribution a l'étude des foraminifères de Mediterranée. *St. Mar. Endoume, Rec. Trav., Fasc.*, **64** : 1-315.

Bock, W. D. 1968. Two new species of foraminifera from the Florida Keys. *Cushman Found. Foram. Res., Contr.*, **19** : 27-29.

———. 1969. *Thalassia testudinium*, a habitat and means of dispersal for shallow water benthonic foraminifera. *Gulf Coast Assoc. Geof. Soc., Trans.*, **19** : 337-340.

Boltovskoy, E. 1963. The littoral foraminiferal biocoenoses of Puerto Deseado (Patagonia Argentina). *Cushman Found. Foram. Res., Contr.*, **14** : 58-70.

———. 1971. Relationship between benthonic foraminiferal fauna and the substrate in the littoral zone. *Journ. Mar. Geol. (Japan)*, **7** : 26-30.

———, and Lena, Haydée 1966. Unrecorded foraminifera from the littoral of Puerto Deseado. *Cushman Found. Foram. Res., Contr.*, **17** : 144-149.

———. 1970. Additional note on unrecorded foraminifera from littoral of Puerto Deseado (Patagonia, Argentina). *Cushman Found. Foram. Res., Contr.*, **21** : 148-155.

Christiansen, B. 1958. The foraminiferal fauna in the Dröbak Sound in the Oslo Fjord (Norway). *Nytt Mag. Zool.*, **6** : 5-34.

Dommasnes, A. 1969. On the fauna of Corallina officinalis L. in western Norway. *Sarsia*, **38** : 71-86.

Furssenko, A. V. and K. B. Furesenko 1970. O forminiferakh laguny Busse i uslovijakh ikh sushchestvovanija. *Acad. Nauk SSSR, Sibirskoe Otd., Inst. Geol. Geofis., Trudy*, **71** : 114-134, (in Russia).

Hedley, R. H., C. M. Hurdle and I. D. J. Burdett 1967. The marine fauna of New Zealand : inter idal foraminifera of the Corallina officinalis Zone. *New Zealand Dep. Sci. Ind. Res. Bull.*, **180** : 1-88.

Kühnemann, O. 1971. Vegetación marina de la ría de Puerto Deseado. *Univ. Tucumán, Op. Lilloana*, **17** : 1-125.

Lee, J. J., W. A. Muller, R. J. Stone, M. E. McEnery and W. Zucker 1969. Standing crop of foraminifera in sublittoral epiphytic communities of a Long Island salt marsh. *Marine Biology*, **4** : 44-61.

Mateu, G. 1965. Datos pera el estudio de los foraminiferos alguicolas del litoral de Blanes (Gerona). *Publ. Inst. Biol. Aplic.*, **39** : 129-135.

Murray, J. W. 1970. The foraminiferida of the Persian Gulf. 6. Living forms in the Abu Dhabi region. *Journ. Nat. Hist.*, **4** : 55-67.

Pappenfuss, G. F. 1964. Catalogue and bibliography of Antarctic and Sub-Antarctic benthic marine algae. *Amer. Geophys. Un., Antarct. Res. Ser.*, **1** : 1-76.

Schmidt, H. 1953. Ökologische Beobachtungen an den Foraminiferen des Golfes von Neapel. *Paläont. Zeitschr.*, **27** : 123-128.