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STRUCTURE OF A SCALLOP *ARGOPECTEN PURPURATUS* (LAMARCK, 1819) DOMINATED SUBTIDAL MACRO-INVERTEBRATE ASSEMBLAGE IN NORTHERN CHILE

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ABSTRACT The structure and biomass of the subtidal, macro-invertebrate assemblage of Tongoy Bay was analyzed from 255 samples taken by divers during the winter and summer periods of 1990 and 1991. The main purpose of the study was to assess the relative importance (in numbers and biomass) of the scallops within the assemblage and to look for functional relationships between scallops and associated species. Of 52 taxa found, the scallop *Argopecten purpuratus* was the dominant species (30% of total biomass) followed by the crab *Cancer polyodon,* the sea stars *Meyenaster gelatinosus* and *Luidia magellanicus* and the predatory snails *Xanthochorus sp.* and *Priene rude*. As shown by a cluster analysis, these 6 species (which present 70% of the biomass) are closely associated, suggesting a functional unit with the scallop as prey and the others as predators. This is confirmed by literature reports on the feeding behavior of the above predators. As the species abundance data conformed to a straight line the log-series model was applied and the diversity index α was calculated based on the numbers of species (=7.5). For comparison with published data from Independence Bay (Peru), located about 2000 km to the north of the study area, the Shannon-Wiener diversity index H′ (=3.6) and the index of species evenness J′ (=0.64) were also calculated. Species richness (58), H′ (4.4) and J′ (0.76) were higher for the macro-invertebrate assemblage of the Peruvian Bay, while th dominant species and their rank order seemed similar, indicating important functional similarities between the two bays. The biomass found in Tongoy Bay (26.4 g m^{-2} wet wt, macrophytes excluded) is low when compared to reports from temperate zones and is also somewhat lower than that reported for the coast of Volta and Congo and West Africa. This low biomass in Tongoy Bay is explained by a heavy clandestine scallop fishery over the past years causing a two- to threefold decrease in scallop biomass and a concomitant biomass decrease of associated species. It is postulated that *Argopecten purpuratus* occupies a central role in the assemblage as a filter feeder that converts planktonic food into available prey biomass, and that is not fully replaceable by other species of the system. Scallops and associated species were found on gravel, sand and soft sand bottoms, but scallops, the sea star *M. gelatinosus* and the snail *P. rude* were more frequent on gravel, and the crab *C. polyodon* and the sea star *L. magellanicus* on soft sand grounds.

KEY WORDS: scallops, community structure, macrobenthos, predation

INTRODUCTION

The scallop *Argopecten purpuratus* is the only commercially important pectinid species in the southeast Pacific upwelling system. It belongs to the *Argopecten* group, that evolved in the subtropical Caribbean/Atlantic region, from where it gave rise to a radiation of species into the Atlantic and Pacific (Waller 1969). Of about 10 recent species of the *Argopecten* group, only two persist in the Pacific: *Argopecten circularis* in Mexico and Ecuador and *Argopecten purpuratus* in Peru and Chile. Like other species of this group *A. purpuratus* is a "bay scallop", that can be found in shallow water from Paita (5°S 81′W) in the north to Bahia Vincente (37°S, 73′W) in the south. Among the most important scallop grounds are those located in Independence Bay (Peru) and Tongoy Bay (Chile), being separated by about 2000 km of coastline (Fig. 1). On the sandy bottoms of both bays, *A. purpuratus* is the dominant macroinvertebrate that has sustained a diving fishery for many decades. At present, fishing is closed in both bays as the resource is considered to be overfished. Clandestine fishing has continued, however, and fisherman report scallop densities as low as $<0.1/m^2$. Several studies have been carried out on the population ecology and dynamics of this scallop in Peru (Wolff and Wolff 1984, Wolff 1985, 1987, Mendo et al. 1987, Yamashiro and Mendo 1988) and Chile (Illanes et al. 1985), and a recently published report gives some additional information on the scallop species assemblage in Independence Bay (Mendo et al. 1987).

The purpose of the present study is to describe the structure of the subtidal, macroinvertebrate assemblage of Tongoy Bay and to gain insight into functional relationships between the scallop and associated species. Specifically, we analyzed species richness, species abundance order, diversity and biomass and determined species associations conducting a cluster analysis. In addition we looked for summer/winter differences in the scallop assemblage structure and for correlations between substrate softness and abundance of scallops and associated species. The present study is of particular interest, as Tongoy Bay is becoming the center for suspended scallop culture in Chile and the structure of the macrobenthos assemblage is therefore most likely to change in the coming years due to the organic enrichment of the bay. The study thus provides the basis to assess future changes and to formulate adequate conservation policies.

MATERIAL AND METHODS

Sampling and Processing

During the winter (July–October 1990) and summer (February–April 1991) periods, samples (132,123 respectively) were taken along transects covering the whole bay area (Fig. 1). Along each transect approx. 10 sample units (distance between sample units approx. 200 m) were taken by a scuba diver who collected all the epibenthic macrofauna > 10 mm within 30 square meters, using a 5.5 m × 5.5 m metal frame that was lowered onto the seafloor from the anchored boat. This sampling unit was considered more

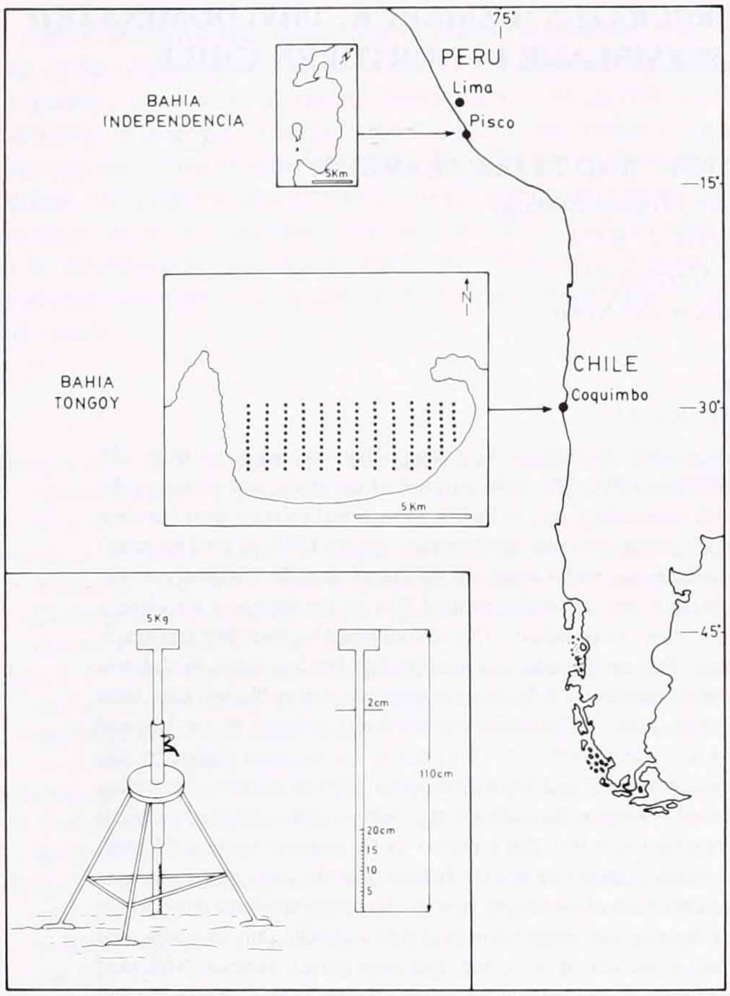

Figure 1. Study site and penetrometer used for the study.

appropriate than smaller units as it avoids too many zero counts at the low scallop densities in the bay ($<0.1\ m^{-2}$) and as species associations are more likely to be detected. Sampling was restricted to a depth range of 7 to 25 m, where scallops are known to be most abundant. In addition, the diver measured the substrate softness using a "penetrometer", that had been constructed for this purpose. This instrument consists of a tripode and a iron-bolt of 2 cm diameter with a 5 kg weight on top that penetrates the sediment according to its softness (see Fig. 1). The samples were stored in plastic bags and transferred to the laboratory the same day for processing. All scallops were measured and weighted to the nearest 0.1 mm and 0.1 g respectively and the numbers and total weight of all the other species collected were also registered. Macroalgae biomass was roughly estimated on board using a bucket and a hand held balance. These estimates, however, were not included in our biomass per area estimates.

Data Analysis

Species Richness, Diversity and Biomass

Data from the winter and summer samples (255) were pooled and a rank order of species according to their corresponding biomass and numbers was established. As the data fell on a straight line using the natural logarithm of the abundances, the log-series model (Taylor et al. 1976) was applied and the model parameter α (diversity index) was calculated by maximum likelihood using the following equation (Southwood, 1978):

$$ST = \alpha \ln (1 + N/\alpha), \qquad (1)$$

where ST is total number of species and N is the total number of individuals sampled. Contrary to other numerical estimators of diversity (like H', see below) this model also allows for a graphical representation of the relative importance of each species of the assemblage. In addition, and for the purpose of comparison with published data, we calculated the Shannon-Wiener diversity index (H') for the total number of species as well as Species evenness (J'):

$$H' = -\Sigma (n_i/N)^* \log2 (n_i/N) \text{ (Pielou, 1969)} \qquad (2)$$

$$J' = H'/\log2 (S) \text{ (Pielou, 1969)} \qquad (3)$$

where N is the total number of individuals, and n_i is the number of individuals of the i^{th} species; S is the total number of species found. Prior to the above procedure, we plotted the number of species found against the cumulative number of samples taken to see at how many samples the curve reached its maximum, thus verifying that our sample number was adequate for the determination of species richness.

In order to compare the species composition of Tongoy Bay with that reported for Independence Bay (Peru) by Mendo et al. (1987) we used Sørensen's index (Sørensen 1948) given by:

$$CC = 2C/(A + B), \text{ where} \qquad (4)$$

C is the number of species shared in both areas and A and B are the total numbers of species in area A and B respectively

Scallop Dominance and Species Associations in the Winter and Summer Samples

We expressed the dominance of the scallop in the winter and summer samples by the following index "d":

$$d = B_{sc}/B_t \qquad (5)$$

where B_{sc} is the total biomass of the collected scallops and B_t the total biomass of all specimens collected. This index was chosen because of its simplicity and as it is considered not to be influenced by species richness ST (Southwood 1978). For both winter and summer samples, a cluster analysis was performed from a species abundance (biomass) matrix using the program package SYSTAT. Euclidean distances were calculated and the Ward-linkage algorithm was used. A clustering of sample stations was also performed to look for regions of the bay with characteristic species associations. No evidence was found, however, that such areas exist (i.e. sample stations with species belonging to the same species clusters were scattered over the entire bay) which confirmed our initial assumption that the bay can be considered as a discrete habitat for this study. The "scallop clusters" determined from the winter and summer samples were further analyzed with respect to the biomass proportions of the component species and possible trophic relationships. Following Mendo et al. (1987) a simple "predation index" was calculated:

$$Pb/Sb \qquad (6)$$

where Pb and Sb are the total predator and scallop biomasses respectively.

Frequency of Occurrence of Scallops and Linked Species According to Substrate Type

Sample stations were classified according to substrate softness using the penetration depth of the penetrometer. The following categories were established: soft sand (penetration depth, p.d.: 12–16 cm) sand (p.d.: 7–11 cm) and hard sand or gravel (p.d.: 2–6 cm). Samples taken from the so classified sample stations then were analyzed separately for the frequency of occurrence of scallops and associated species.

RESULTS

Species Richness, Diversity and Biomass

At about 60 samples (= 24% of all samples taken, 1800 m^2) the total number of species found in the study was reached (Fig. 2). The species rank order and their corresponding abundances (biomass and numbers) can be seen in Fig. 3. The species names are given in Table 1. Except for the scallop (first point), the (Ln) biomass data (upper line) fit a straight line well (r = 0.9923). A similar line is produced when (Ln) numbers are substituted for (Ln) biomass as a measure of abundance. These data also fit a straight line (r = 0.9956), except for the first three species, whose points were therefore omitted for the calculation. Fig. 3 also contains the values calculated for the diversity index of the log-series model α, the Shannon-Wiener index H′ and the index of species evenness ′J. Average macrobenthic biomass in Tongoy Bay (area sampled = 7650 m^2) was estimated as 26.4 g m^{-2} wet wt (macrophyte biomass not included).

Scallop Dominance and Species Associations

Scallop dominance was similar between summer and winter (d = 0.27 and 0.33 respectively). As seen in Fig. 4, scallop biomass and the biomasses of the crab *Cancer polyodon* and the sea stars *Meyenaster gelatinosus* and *Luidia magellanicus* was considerably higher in the summer samples. The gastropods *Priene rude* and *Xanthochorus sp.* had higher biomasses in winter and summer

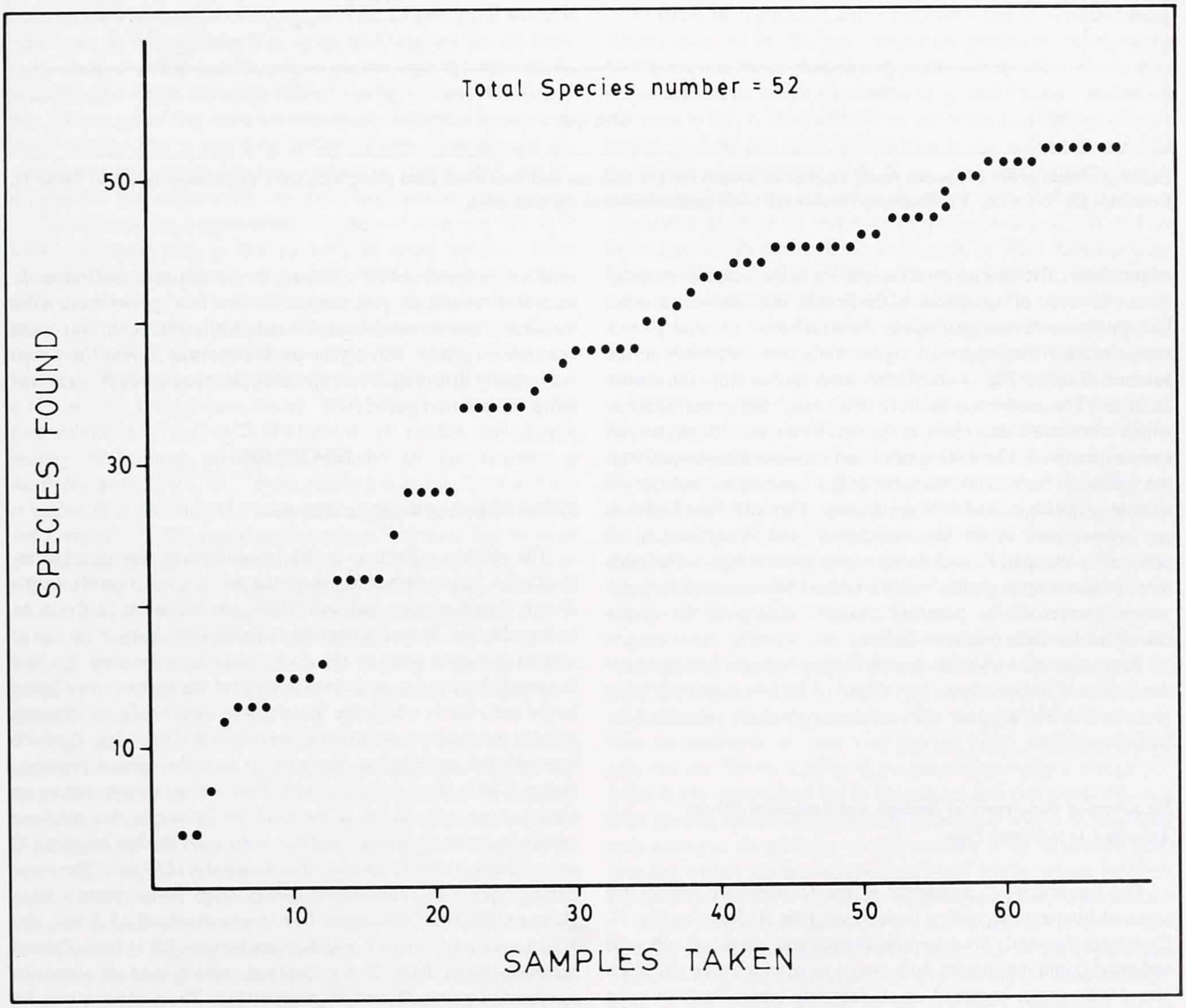

Figure 2. Number of samples taken versus cumulative species number (total number of samples taken was 255).

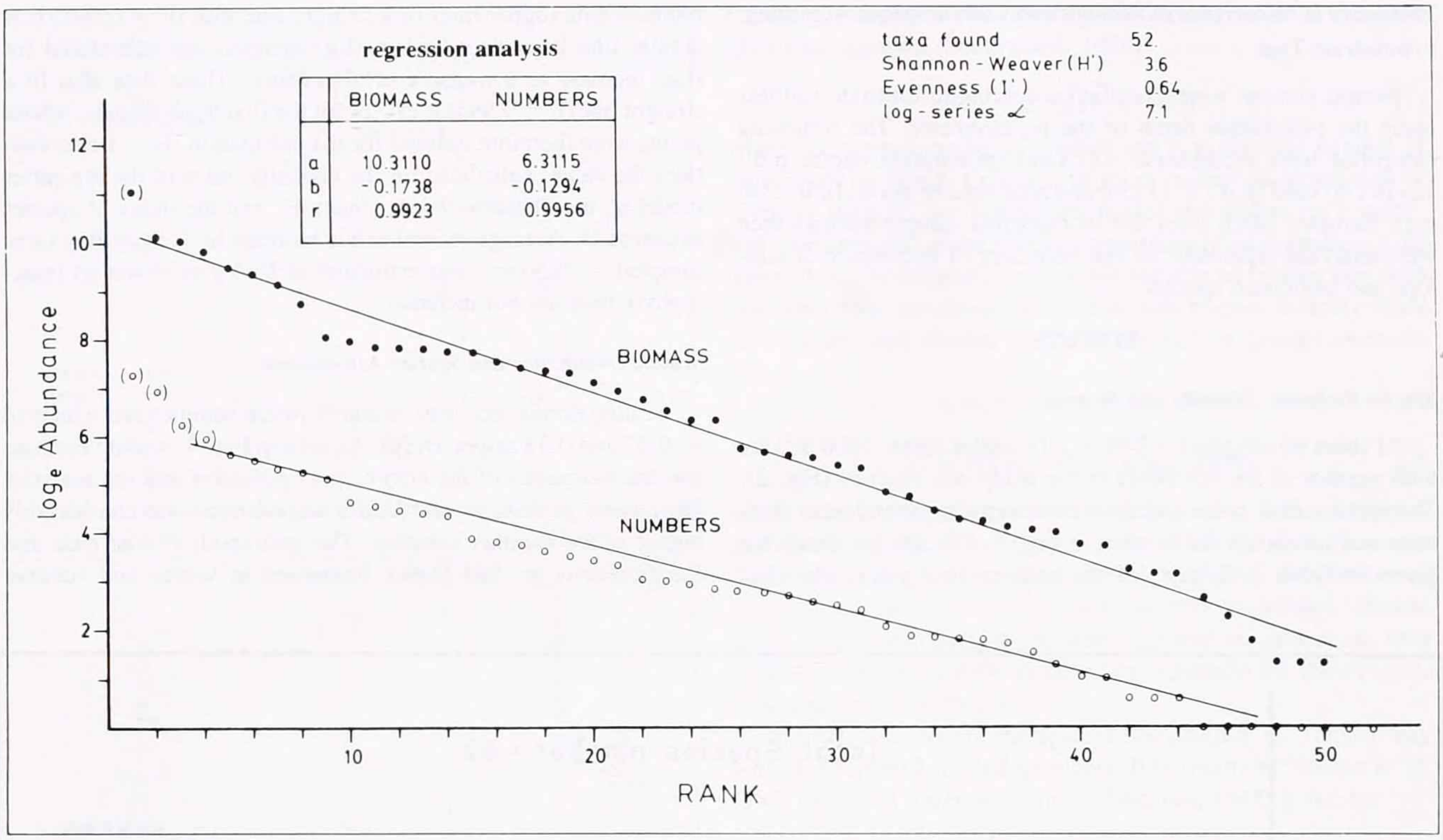

Figure 3. Rank order of species found (log-series model) for the biomass and numerical data along with their regressions (see also Table 1); Estimates for Evenness (I'), Shannon-Weaver (H') and species richness are also given.

respectively. The frequency of occurrence in the samples remained similar for most of the species of the first 20 in biomass rank order Exceptions were the gastropods *Xanthochorus sp.* and *Priene rude,* because they appeared significantly less frequently in the summer samples. Fig. 5 shows the dendrograms from the cluster analysis. The analysis was done with only the major species, which contributed about 90% to the total biomass in the winter and summer samples. The three species that are closest associated with the scallop in both clusters are the crab *C. polyodon,* and the sea stars *M. gelatinosus* and *L. magellanicus*. The snail *Xanthochorus sp.* follows next in the summer cluster, and is replaced in its position by the snail *P. rude* in the winter cluster. Fig. 6 illustrates these relationships together with the relative biomasses of the component species of the "scallop clusters" and gives the values calculated for their predation indices.

For comparison with the data of Tongoy bay, the species abundance data of Independence Bay (Peru) of Mendo et al. (1987) are given in Table 1 together with community indices calculated for both bays.

Frequency of Occurrence of Scallops and Associated Species According to Substrate Type

The frequency of occurrence of the 15 dominant species (in terms of biomass) according to substrate type is shown in Fig. 7. Except for the snail *Oliva peruana* (which was absent on soft sand and gravel) and the mussel *Aulacomya ater* (which was absent on gravel) all species occurred on all substrate types. Scallops were found most frequently on gravel (66.7%) but also appeared on sand and soft sand (40%). Among the predators *C. polyodon, L. magellanicus* and *M. gelatinosus,* the first two species were more frequently encountered on soft sand, while the latter was more common on gravel. Among the predatory snails *Xanthochorus sp.* was equally distributed over all substrate types while *P. rude* was more common on gravel.

DISCUSSION

Species Richness, Diversity and Biomass

The species collection in the present study was directed towards the larger epibenthic macrofauna > 1 cm (visible to the diver). Small species and individuals are therefore likely to be undercollected. Indirect sampling methods with drags or the use of smaller sampling units by the diver would have avoided this bias but would have led to an undercollection of the sparsely distributed larger individuals which are important scallop predators. Species number did not increase after 60 samples (1800 m^2) (Fig. 2) which demonstrates an adequate sampling to describe species richness. Parker (1963) gives a similar curve from a shell dredge survey on sand bottoms (11–36 m) in the Gulf of California that shows a steady increase of species number with each dredge sample (20 m^2) yielding over 140 species after 9 samples (180 m^2). The same author reproduces cumulative curves from boreal waters from Holme (1953) for Whitesand bay (water depth of 16.5 m), England, and from Petersen and Boysen-Jensen (1911) from Thisted bredning (water depth 27 m), Denmark, which level off at species numbers of about 35 and 15 respectively. These reports suggest that the species richness (52) found in Tongoy Bay for the depth range 7–26 m lies between boreal and tropical waters. Mendo et al. (1987) hand-collected macrofauna in Independence Bay (Peru) as we did, and their results seem comparable to ours (they, however, sampled only 1 square meter at each of their 180 sample stations and do not report on the biomass of most of the species). They found a slightly higher species richness (58 taxa), despite the fact that only three years before their study (1982/83), a strong El NINO event had caused drastic changes in the macrofaunal species assemblage, i.e. mortalities of many species, immigration of others and an enormous scallop (*A. purpuratus*) proliferation (Wolff 1987, Arntz et al. 1988).

Species diversity (log-series α, H′) and evenness (J′) are also higher than in Tongoy Bay and Sørensen's similarity index of 0.51 (Table 1) indicates higher structural differences between the two habitats than when only judged by the species richness. These differences are most likely to be due to the more tropical position of Independence Bay and to Panamanian species that are absent in Tongoy Bay. The species registered in both bays and their rank order show notable similarities, however: both habitats share 8 of the first 20 species in numeric rank order and 6 of those species of Independence Bay are also among the first 20 species in biomass rank order in Tongoy Bay. Among these 20 species are the predatory snails *P. rude* and *Xanthochorus sp.* and the sea star *L. magallanicus* which form part of the "scallop cluster" of Tongoy bay. This suggests that there are important similarities in the functional relationships between the scallop (which is numerically the second and third most important species in Tongoy Bay and Independence Bay respectively) and associated species in both bays.

The average macroinvertebrate biomass of 26 g wet wt* m^{-2} found in Tongoy Bay is low for subtidal sandy bottoms, when compared to temperate zones. A comparison with the literature is difficult because of the heterogeneity of sampling techniques used and the incompatibility of units. We shall try to compare assuming that 1 g Carbon represents about 19 g wet weight (Mills and Fournier, 1979). Sanders (1956) report 4.8 g C m^{-2} (about 91.2 g wet wt) for Long Island Sound, USA, Wolff & Wolff (1977) give values of 10 g C m^{-2} (190 g wet wt) for the Gravelingen estuary, Netherlands, and the macrobenthic biomass recorded in the Baltic Sea (1.7 g C m^{-2} corresponding to about 32.3 g wet wt) is higher than our biomass values in Tongoy bay. Sparck (1951) and Longhurst (1959) report similar values, however, for the coast of Volta and Congo and West Africa (30–40 g wet wt m^{-2} and 6.73–74.23 g wet wt m^{-2}) and Buchanan (1958) gives values of 28–120 g wet wt m^{-2} for the coast of Ghana. Despite these similar values the question arises why the macroinvertebrate biomass in Tongoy bay is so low, considering that the bay is strongly influenced by a nearby upwelling center and regarded as highly productive (Alarcon 1975, Acuna et al. 1989).

Food does not seem to be a limiting factor for the filter feeding macrobenthos as the bay is known to have supported scallop densities of >30 ind. m^{-2} (500 g wet wt) in past years. In Independence Bay (Peru) the El Niño event 1982/83 produced densities of >500 ind./m^{-2} and biomasses of 5000–6000 g m^{-2} (Arntz et al. 1985) while primary production had not increased. This enormous scallop proliferation coincided with heavy mortalities of most of the scallop predators (Wolff 1987), which suggests that predation is important in keeping scallop densities low. This seemed confirmed by the post El Nino increase of predator biomass paralleled by a simultaneous reduction of scallop biomass (Mendo et al. 1988). However, while this mechanism could explain that predator and scallop biomass are interdependent, it would not explain the low total macro-invertebrate biomass found in Tongoy. The answer may lie in a heavy clandestine scallop fishery that has intensified over the past years due to the high demand for seed scallops for the suspended cultures (Wolff and Alarcon, personal observations) leaving an average scallop population, that is 2–3 times reduced compared with previous "average" years (CIS,U. del Norte 1975, Viviani 1979). This is also confirmed by a low average scallop size found in the present study (59.1 mm) compared with the late seventies (85 mm reported by SERPLAC, 1978).

Scallop Dominance and Species Associations

Despite its low abundance (compared to past years), *A. purpuratus* is still the dominant macroinvertebrate (representing about 30% of the total biomass) which seems indicative of the above-mentioned interdependence of total epibenthic macroinvertebrate biomass with scallop abundance. The almost constant predation index (around 1.3) between the summer and winter samples (by significantly higher total macro-invertebrate biomass in summer) is a further indication of this.

In terms of biomass, *Cancer polyodon* and *Meyenaster gelatinosus* seem to be the most important predators (representing 17.8% and 16.7% of the other species), followed by *Luidia magellanicus* and the snails *Xanthochorus sp.* and *Priene rude* (which represent 9.5%, 8.5% and 4.5% of the remaining species respectively). It is notable that the 6 species of the scallop cluster represent 70% of the biomass of the 52 species found in the bay which corroborates their trophic relations. As cited by Parker (1963), a dominance of about 10 invertebrate species was also reported by Buchanan (1958) for the Gold Coast area of West Africa and by Longhurst (1957, 1958) off Sierra Leone to the north, while in the tropical Gulf of California such a dominance did not exist.

C. polyodon is known as a voracious predatory omnivore that is able to detect dense patches of prey, to aggregate quickly around these and to feed at high rates (Wolff and Cerda 1992). DiSalvo et al. (1984) reported that 1000 scallops (*Argopecten purpuratus*) of 30 mm shell length in an open cage were consumed in less than three days by this crab. *Meyenaster gelatinosus* is also known as an omnivorous predator and eats sea urchins, bivalves, other sea stars and crabs (Vasquez, per. com). Mendo et al. (1987) consider the sea star *Luidia magellanicus* and the snails *Xanthochorus sp.* and *Priene rude* as important predators of *A. purpuratus* in Peru, which is also coincident with our data through the position of these species in the scallop cluster. The muricid snail *Crassilabrum crassilabrum,* although not as abundant as the other predators and not identified as part of the "scallop cluster" might also prey on *A. purpuratus*.

Evidently, the above predators also feed on other species besides the scallop or on each other (known for *C. polyodon* and *M. gelatinosus*), but the scallop *A. purpuratus* occupies a central position in this assemblage for its abundance and functional role as a filter feeding species that converts planktonic food into available prey biomass. In addition, *A. purpuratus* is an extremely fast-growing, highly productive species (Wolff 1987), whose mobility allows its population biomass to be distributed over wide areas.

As the recruitment success of *A. purpuratus* is known to vary significantly between years (Wolff 1988), one would expect total macro-invertebrate biomass also to vary. At high scallop densities most of the energy leading to the predators supposedly travel through a short 3-step food chain (similar to the pelagic food chain

TABLE 1.

(a) Species abundance data from Tongoy Bay (this study) and from Independence Bay (Mendo et al. 1987); (b) community indices calculated from these data.

a.

Tongoy Bay				Independence Bay	
Species	Taxonomic group	Biomass (g)	Number	Species	Number
1. Argopecten purpuratus	Mollusca	61,712	1397	1 Diopatra sp.	80
2. Cancer polyodon	Crustacea	25,144	96	2. Massarius gayi	74
3. Meyenaster gelatinosus	Echinodermata	23,370	80	3 Argopecten purpuratus	60
4 Aulacomya ater	Mollusca	18,645	21	4. Ophiactix kroyeri	48
5. Xanthochorus sp.	Mollusca	13,249	263	5. Crucibulum spp.	40
6. Luidia magellanicus	Echinodermata	11,977	46	6. Pagurus spp.	34
7. Tegula sp.	Mollusca	9,573	1,085	7. Tegula atra	31
8. Priene rude	Mollusca	6,367	371	8. Eurypanopeus transversus	31
9. Turritella cingulata	Mollusca	3,132	516	9. Mitrella sp.	28
10. Crucibulum quiriquimae	Mollusca	2,971	87	10. Trophon sp.	25
11. Crassilabrum crassilabrum	Mollusca	2,609	100	11. Espongiarios	25
12. Raja sp.	Chondrichtys	2,431	31	12. Xanthochorus buxea	22
13. Arbacia dufresmii	Echinodermata	2,271	28	13. Priene rude	20
14. Pagurus sp.	Crustacea	2,270	190	14. Luidia bellonae	19
15. Anthozoa	Cnidaria	2,559	203	15. Synalpheus sp.	19
16. Hepatus chilensis	Crustacea	1,922	16	16. Arbacia spatuligera	18
17. Cancer coronatus	Crustacea	1,733	15	17. Bursa ventricosa	17
18. Oliva peruana	Mollusca	1,599	204	18. Polynices otis	17
19. Thais chocolata	Mollusca	1,531	10	19. Majidae	17
20. Calyptrea trochiformis	Mollusca	1,248	17	20. Crepipatella dilatata	16
21. Ovalipes trimaculatus	Crustacea	1,055	5	21. Actinias	15
22. Diopatra sp.	Polychaeta	888	1,636	22. Hepatus chiliensis	11
23. Tagelus dombeii	Mollusca	703	35	23. Poliqueto 2	10
24. Nucella calcarlongus	Mollusca	633	105	24. Poliqueto 1	10
25. Semele solida	Mollusca	631	13	25. Fissurella spp.	10
26. Paraxanthus barbiger	Crustacea	330	7	26. Oliva peruviana	9
27. Gari solida	Mollusca	287	2	27. Malaguas	8
28. Decapoda indet.	Crustacea	270	2	28. Aulaconya ater	8
29. Homalaspis plana	Crustacea	259	1	29. Thais chocolata	8
30. Murcia gaudichaudi	Crustacea	220	3	30. Senele solida	6
31. Pseudochorystes sicarius	Crustacea	218	7	31. Asterina chilensis	5
32. Squilla mantis	Crustacea	124	2	32. Poliplacoforos (chitones)	5
33. Ovalipes catharis	Crustacea	117	1	33. Cancer porteri	5
34. Crepipatella dilatata	Mollusca	84	8	34. Ascidia	4
35. Grapsidae	Crustacea	71	67	35. Calyptraea trochifornis	4
36. Octopus vulgaris	Mollusca	71	1	36. Cynatium sp.	4
37. Crepipatella sp.	Mollusca	62	18	37. Tertrapigus niger	3
38. Venus antigu	Mollusca	56	1	38. Balanus sp.	3
39. Nassarius sp.	Mollusca	55	245	39. Cancer setosus	3
40. Plumnoides perlatus	Crustacea	44	78	40. Tegula tridentata	2
41. Taliepus dentatus	Crustacea	42	2	41. Cancellaria sp.	2
42. Pisoides edwarsi	Crustacea	25	2	42. Petrolisthes spp.	2
43. Perymytilus purpuratus	Mollusca	23	2	43. Heliaster helianthus	2
44. Porifera	Porifera	23	2	44. Hyatella solida	2
45. Chiton cummingsii	Mollusca	14	44	45. Calliostroma fonkii	2
46. Nudibranchia	Mollusca	10	1	46. Cancer edwardsii	2
47. Fissurella sp.	Mollusca	6	14	47. Cardita sp.	2
48. Loxechinus albus	Echinodermata	4	7	48. Platyxanthus orbignyi	1
49. Eurypodius longirostris	Crustacea	4	1	49. Glycyneris ovata	1
50. Alpheus sp.	Crustacea	4	22	50. Sipunculidae	1
51. Tetrapigus niger	Echinodermata	1	4	51. Pilumnoides perlatus	1
52. Cancer edwarsii	Crustacea	1	2	52. Huevos de cefalopodos	1
				53. Pinnixa spp.	1
				54. Sinum cymba	1
				55. Caenocentrotus gibbosus	1
				56. Discinisca lamellosa	1

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TABLE 1.

continued

Tongoy Bay				Independence Bay	
Species	**Taxonomic group**	**Biomass (g)**	**Number**	**Species**	**Number**
				57. Nitra sp.	1
				58. Crassilabrum crassilabrum	1
Total (area: 7650 m^2)		202,648	7,116	Total (area: 180 m^2)	799

b.

	Tongoy Bay (Chile)	Independence Bay (Peru)
Species richness, ST	52	58
Log-series diversity, α	7,1	14,4
Shannon-Wiener, H'	3,6	4,4
Evenness, J'	0,64	0,76
Similarity (Sørensen), CC	0,51	0,51

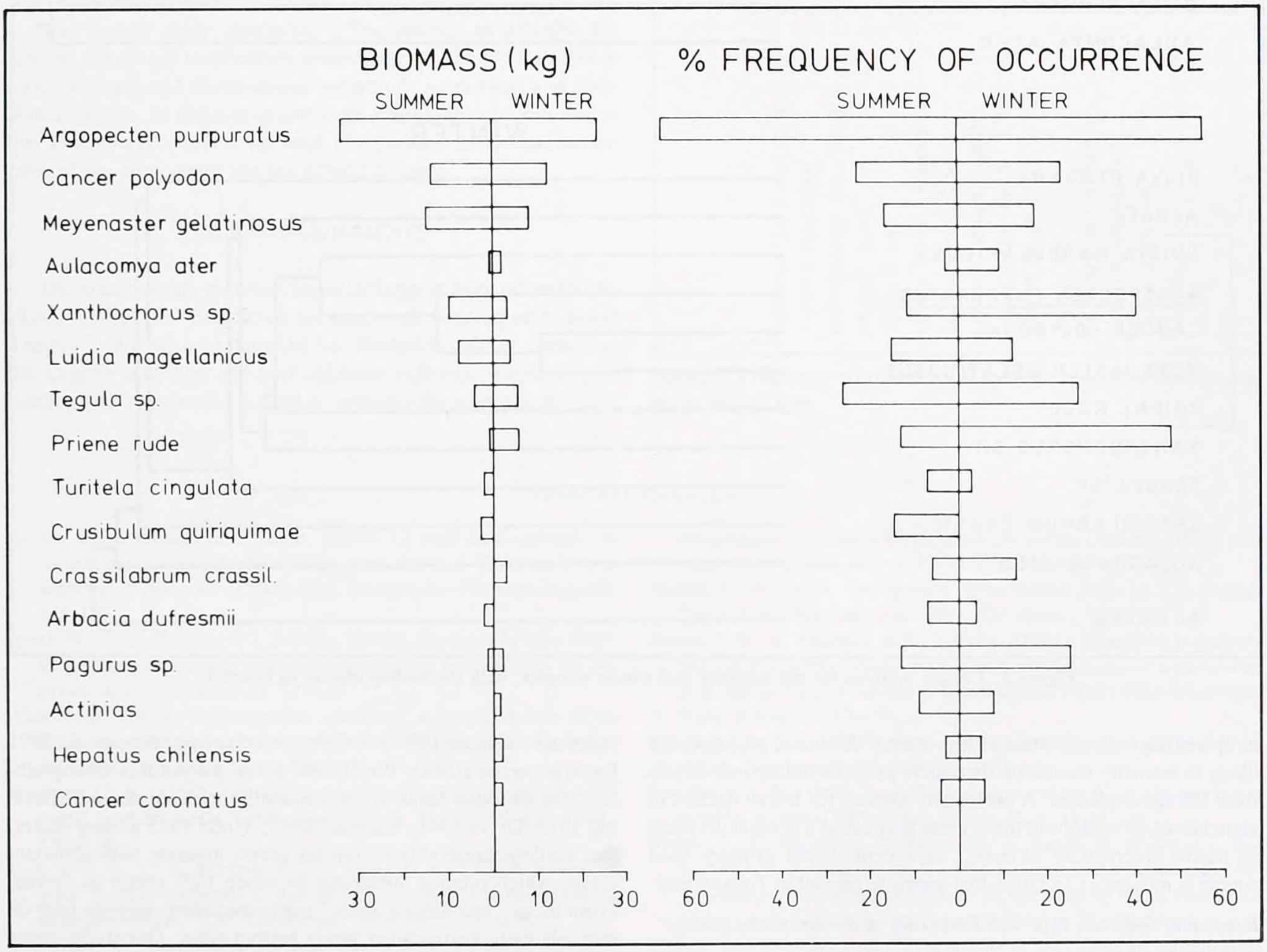

Figure 4. Biomass and frequency of occurrence of the 16 most important species (representing >90% of total epibenthic biomass) in the winter and summer samples.

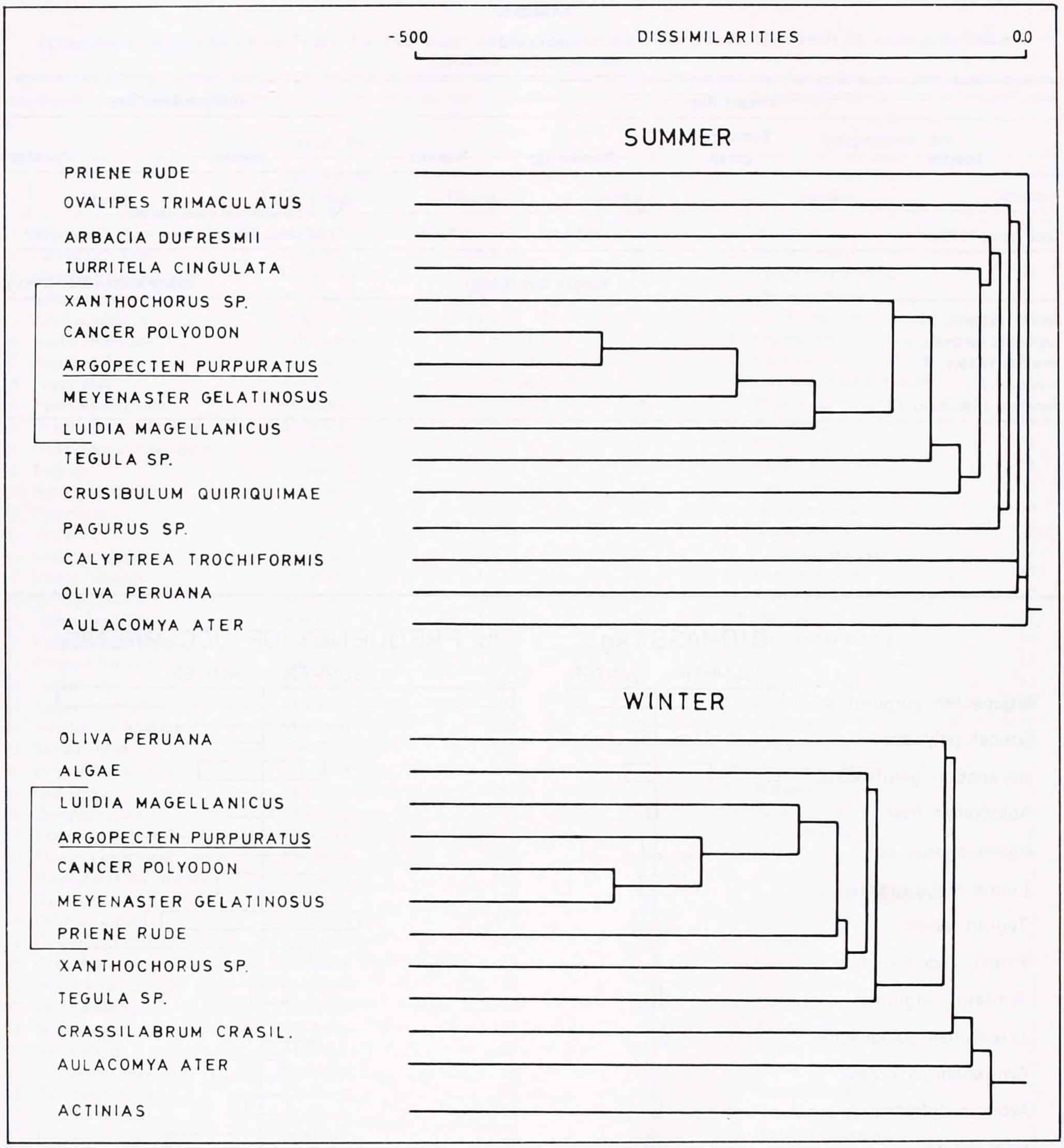

Figure 5. Cluster analysis for the summer and winter samples, with the scallop cluster in brackets.

in upwelling regions) while at low scallop densities, predators are likely to intensify the use of alternative prey, including individuals from the same species. A prolonged absence (or heavy decline in abundance) of scallops in these areas may cause a general decrease in macro-invertebrate biomass, as a central and primary food source is missing, a situation that seems to prevail in Tongoy Bay.

Relation of Substrate Type with Frequency of Occurrence of Scallop and Associated Species

The ubiquity of scallops on different bottom types has been reported previously in the literature (Olsen 1955 for *Notovola meridionalis;* Ciocco 1983 for *Chlamys tehuelcha;* Roe et al. 1971 for *Argopecten gibbus;* Wolff 1985 for *A. purpuratus* among others). On the other hand, it has frequently been pointed out (Belding 1919, Dryer 1941, Marshall 1947, Wolff 1985 among others) that scallops preferably recruit on gravel grounds with abundant algae, which provide substrates to which they attach as larvae. From these ''recruitment areas'' many specimens migrate later on into relatively unstructured sandy bottom areas. Our study seems to confirm this as the frequency of occurrence of scallops was almost 70% on gravel (where algal biomass was also higher, Fig. 7) compared to only about 40% on sand and soft sand grounds.

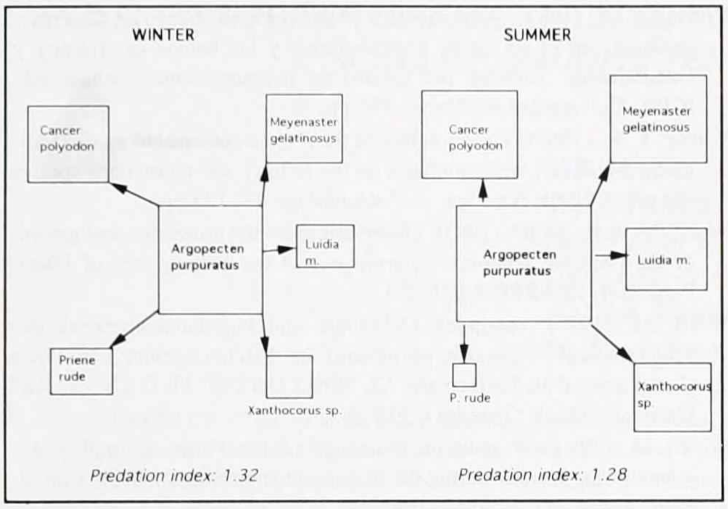

Figure 6. Diagrammatic representation of the biomass proportions and possible trophic interactions within the "scallop cluster" (box size is proportional to biomass).

The higher frequency of occurrence of *M. gelatinosus* on gravel and of *L. magellanicus* and *C. polyodon* on soft sand (Fig. 7) might be indicative for a certain competitive partition of the habitat between the former and the latter two species. The snails *Xanthochorus sp.* and *Priene rude* seem to be as ubiquitus as the scallop with no marked preference for a substrate type.

The present study represents a first attempt to describe the scallop dominated invertebrate assemblage in Tongoy Bay and to look for functional relationships between *A. purpuratus* and associated species. In order to quantify the trophic interactions within this assemblage, studies on food composition and consumption rates of the component species should follow.

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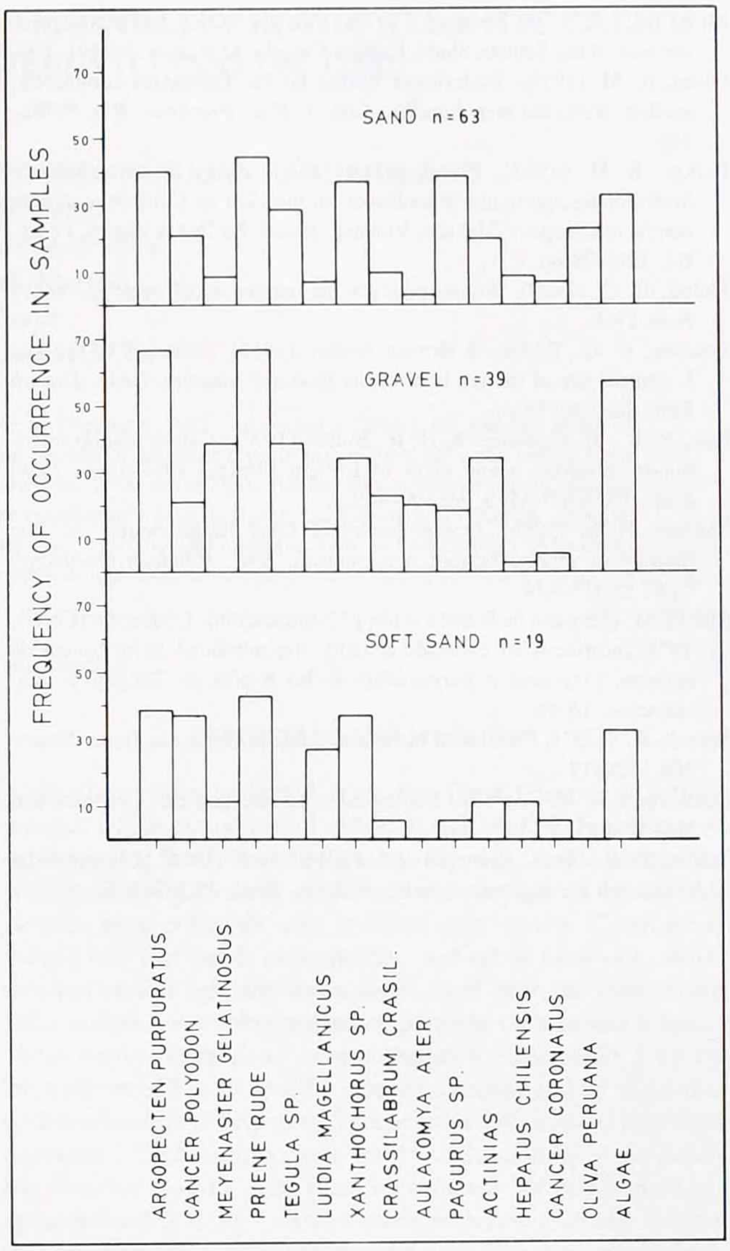

Figure 7. Frequency of occurrence of the most important taxa according to bottom type.

LITERATURE CITED

Acuna, E., J. Moraga & E. Uribe. (1989). La zona de Coquimbo: Un sistema neritico de surgencia de alta productividad. Comision Permanente del Pacifico Sur (CPPS), Rev. Pacífico Sur (Número Especial): 145–147.

Arntz, W. E., E. Valdivia & J. Zeballos. (1988). Impact of El Nino 1982–83 on the commercially exploited invertebrates (mariscos) of the Peruvian shore. Meeresforsch. 32:1–23.

Alarcon, E. (1975). Oceanographic conditions in coastal waters of the Coquimbo zone. Proceed. Int. Symp. Coastal Upwelling, Universidad del Norte, Coquimbo, Chile: 149–151.

Buchanan, J. B. (1958). The bottom fauna communities across the continental shelf off Accra, Ghana (Gold Coast). *Proc. Zool. Soc. Lond.*, 130:1–56.

Ciocco, N. F., C. A. Borzone & D. E Ruzzante. (1983). Observaciones sobre el comportamiento de fijación de *Chlamys tehuelchus* en bancos naturales. Mems. Asoc. Latinoamer. Acuicult., 5:271–275.

CIS (Centro de Investigaciones Submarinas, Universidad del Norte) 1975. Informe sobre el recurso ostion (*Argopecten purpuratus*) en las bahías de Tongoy y Guanaqueros, Provincia de Coquimbo. 17 pp.

DiSalvo, L. H., E. Alarcon, E. Martinez & E. Uribe. (1984). Progress in mass culture of *Chlamys* (*Argopecten*) *purpurata* Lamarck (1819) with notes on its natural history. *Rev. Chil. Hist. Nat.* 57:35–45.

Holme, N. E. (1953). The biomass of the bottom fauna in The English Channel off Plymouth. *Jour. Mar. Bio. Assoc., U.K.*, 32:1–49.

Illanes, J. E., S. Akaboshi & E. T. Uribe. (1985). Efectos de la temperatura en la reproducción del ostión del Norte *Argopecten purpuratus* en la Bahía de Tongoy durante el fenómeno EL NINO 1982–83. *Invest. Pesq.* (Chile) 32:167–173.

Longhurst, A. R. (1957). Density of marine benthic communities of West Africa. *Nature*, 179:542–543.

Longhurst, A. R. (1958). An ecological survey of the West African marine benthos. Colonial Office (Br.) *Fishery Publ.* 11:102 pp.

Mendo, J., V. Valdivieso, C. Yamashiro, E. Jurado, O. Moron & J. Rubio. (1987). Evaluación de la población de concha de abanico (*Argopecten purpuratus*) en la Bahía de Independencia, Pisco, Perú 17 de Enero - 4 de Febrero de 1987. Imarpe Informe No. 91:64 pp.

Mendo, J., V. Valdivieso & C. Yamashiro. (1988). Cambios en densidad, numero y biomasa del la Poblacion de Concha de Abanico (*Argopecten purpuratus*) en la Bahia Independencia (Pisco, Peru) durante 1984–87. Bol. Inst. Mar Peru-Callao, Vol. extraordinario, 382 pp.

Mills, E. L. & R. O. Fournier. (1979). Fish production and marine ecosystems of the Scotian Shelf, Eastern Canada. *Mar. Biol.* 54:101–108.

Olsen, A. M. (1955). Underwater studies on the Tasmanian commercial scallop, *Notovola meridionalis*. *Aust. J. Mar. Freshwat. Res.* 6:392–409.

Parker, R. H. (1963). Zoogeography and ecology of some macroinvertebrates, particularly mollusks, in the Gulf of California and the continental slope of Mexico. Vidensk. Medd. fra Dansk naturh. Foren. Bd. 126:178 pp.

Pielou, E. C. (1969). An introduction to mathematical ecology. Wiley New York.

Petersen, C. G., P. Joh. & Boysen Jensen. (1911). Valuation of the sea. I. Animal life of the sea bottom, its food and quantity. *Repts. Danish Biol. Stat.* 20: 81 pp.

Roe, R. B., Jr. Cummins & H. R. Bullis. (1971). Calico scallop distribution, abundance and yield of Eastern Florida, 1967–1968. *Fish. Bull.*, NOAA7NMFS, 69:399–409.

Sanders, H. L. (1956), Oceanography of Long Island Sound. X. The biology of marine bottom communities. *Bull. Bingham Oceanogr. Coll.* 15:345–414.

SERPLAC (Servicio de Planificación y Coordinación), Coquimbo (Chile), 1978. Informe sobre el estado actual y disponibilidad de los bancos de ostiones (*Argopecten purpuratus*) de las bahías de Tongoy y Guanaqueros. 16 pp.

Sparck, R. (1951). Density of bottom animals in the ocean floor. *Nature* 168:112–113.

Southwood, T. R. E. (1978) Ecological methods. 2nd Ed. Chapman and Hall/Wiley.

Taylor, L. R., R. A. Kempton & I. P. Wolwood. (1976). Diversity statistics and the log-series model. *J. Anim. Ecol.* 45:337–365.

Viviani, C. A. (1987). Exploración y prospección del banco de Chorros y Ostiones, en el sector de Choros Bajos y las bahías de Tongoy y Guanaqueros. Informe del Centro de investigaciones Submarinas (CIS), Universidad del Norte. 172 pp.

Waller, T. R. (1969). The evolution of the *Argopecten gibbus* stock (Mollusca: Bivalvia), with emphasis on the tertiary and quartenary species of eastern North America. *J. Paleontology* 43: 125 pp.

Wolff, M. & R. Wolff. (1983). Observations on the utilization and growth of the pectinid *Argopecten purpuratus* in the fishing area of Pisco, Perú. Bol. IMARPE 7:197–235.

Wolff, M. (1985). Fischerei, Oekologie und Populationsdynamik der Pilgermuschel *Argopeten purpuratus* im Fischereigebiet von Pisco (Perú) unter dem Einfluss des EL NINO 1982/83. Ph.D Thesis, Kiel University (Kiel, Germany): 113 pp.

Wolff, M. (1987). Population dynamics of the Peruvian scallop *Argopecten purpuratus* during the El Nino phenomenon of 1983. *Can. J. Fish. Aquat. Sci.* 44:1684–1691.

Wolff, M. (1988). Spawning and recruitment in the Peruvian scallop *Argopecten purpuratus*. *Mar. Ecol. Prog. Ser.* 42:213–217.

Wolff, M. & G. Cerda. 1992. Feeding ecology of the crab *Cancer polyodon* in La Herradura Bay, northern Chile. I. Feeding chronology, food intake, and gross growth and ecological efficiency. *Mar. Ecol. Prog. Ser.* 89:213–219.

Wolff, W. J. & L. de Wolff. (1977). Biomass and production of zoobenthos in the Gravelingen Estuary. The Netherlands. *Estuar. cstl. mar. Sci.* 5:1–24.

Yamashiro, C. & J. Mendo. (1988). Crecimiento de la Concha de Abanico (*Argopecten purpuratus*) en la Bahia Independencia, Pisco, Peru. Bol. Inst. Mar Peru-Callao, Vol. extraordinario, 382 pp.