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Spatial distribution of Antarctic shrimps (Crustacea: Decapoda) by underwater photography

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Abstract: Three species of shrimps (*Notocrangon antarcticus, Chorismus antarcticus, Nematocarcinus lanceopes*) were investigated in the south-eastern Weddell Sea using of underwater photography. Maximum densities of *c.* 100 specimens per 100 m^2 were found for *N. antarcticus* on the continental shelf (200–600 m) and for *N. lanceopes* on the slope (800–1200 m). Small-scale dispersion patterns and size-frequency distributions were analyzed within dense concentrations. These direct observations indicate that the behaviour of the three species is adapted to different habitats with *Chorismus* distribution correlated with that of sponges and *Notocrangon* with base sediment.

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Key words: density, *Chorismus, Nematocarcinus, Notocrangon,* Weddell Sea

Introduction

In some areas the Antarctic continental shelf is totally covered by a high epifaunal biomass, consisting mostly of sessile suspension feeders (Hedgpeth 1969, Dayton *et al.* 1974, Gutt & Vogel 1988), whereas in other areas the epifaunal biomass is low. The suspension feeders may influence the small-scale structure of the seafloor depending on their size, distribution pattern and shape. Echinoderms may dominate where forms such as bryozoans, sponges or compound ascidians are scarce. Voß (1988) described such faunal assemblages for the same area in the Weddell Sea as used in this study. They have been shown on underwater photographs by various authors (Hempel 1986, Gutt *et al.* 1988, Kirkwood & Burton 1988, Arntz *et al.* 1990, Gutt 1991). Similar communities are known from the Ross Sea (Bullivant 1959, 1961, 1967).

Shrimps, together with other crustaceans such as isopods and amphipods, are a major component of the highly motile benthic fauna on the shelf. In the high Antarctic, while some natant decapods reach maximum size, reptant decapods are not found at all (Yaldwyn 1965, Maxwell 1977, Arntz & Gorny 1991).

Benthic and benthopelagic shrimps have been found in several localities around the Antarctic continent (Calman 1907, Borradaile 1916, Coutière 1917, Bage 1938, Hale 1941, Yaldwyn 1965). *Chorismus antarcticus* and *Notocrangon antarcticus* are the most abundant shelf inhabiting Antarctic shrimps (Kirkwood 1984) and are distributed around the Antarctic continent. *C. antarcticus* also occurs in the Magellan region, but *N. antarcticus* has been recorded north of the Antarctic convergence only once (Zarenkov 1968). *Nematocarcinus lanceopes* is known from deeper waters in the Indian Ocean sector of East Antarctica, off Japan and off South Africa (Bate 1888, Barnard 1950, Kirkwood 1984, Ledoyer 1989). This Antarctic species was shown by Tiefenbacher (1990) to be different from *N. longirostris*, which occurs around South Africa.

In the Weddell Sea *Notocrangon antarcticus* Pfeffer, 1887 (Crangonidae), *Chorismus antarcticus* Pfeffer, 1887 (Hippolytidae) and *Nematocarcinus lanceopes* Bate, 1888 (Nematocarcinidae) are the most common shrimps (Arntz & Gorny 1991). An additional two benthic species, *Lebbeus antarcticus* Hale, 1941 and *Eualus kinzeri* Tiefenbacher, 1990, are known from the Weddell Sea, but are rarely encountered. Estimates of shrimp densities based on trawl catches, however, may be subject to serious methodological errors.

Trawl catches by RV *Polarstern* revealed that *Notocrangon antarcticus* and *Nematocarcinus lanceopes* were most abundant on the shelf and slope of the eastern Weddell Sea, whereas *Chorismus antarcticus* was present at most stations sampled but was less numerous. *Nematocarcinus lanceopes* is considered to be bathybenthic and restricted to latitudes north of 75°S (Voß 1988, Arntz & Gorny 1991). The two other species appear to inhabit mainly the shelf ($\leq$600 m in the Weddell Sea, Carmack & Foster 1977, Picken 1985). Larvae of *C. antarcticus* and *N. antarcticus* were found on the continental shelf in plankton net catches (38 % and 75 % presence respectively), but not at oceanic stations (Boysen-Ennen & Piatkowski 1988). Adult shrimps were present with varying abundances in nearly 90% of all bottom trawl catches taken in the Weddell Sea since 1983 (Voß 1988, Arntz & Gorny 1991).

The objective of this investigation was to estimate absolute densities of shrimps in the Weddell Sea using a direct method, underwater photography, and to compare those values with net density estimates. This method reveals both small-scale dispersion patterns and presence on a larger spatial scale and thus provides insights into the biology of these species which cannot be derived from trawl catches. The fauna with which the three species are associated provides information about their behaviour, and can be used to explain inhomogenities in their pattern of occurrence. The combination of data available from these different sources should improve our knowledge of the role of shrimps in the high Antarctic benthic ecosystem.

Material and methods

The material was collected during the expeditions ANT III, ANT VI and ANT VII with RV *Polarstern* in 1985, 1988 and 1989. For cruise reports and detailed station lists see Hempel (1985), Fütterer (1988), Arntz *et al.* (1990). All stations at which bottom photographs were taken are listed in Table I.

A 70 mm deep-sea camera and strobes pointing vertically downward was triggered by a bottom contact switch. Each photo station of the drifting ship, here defined as "transect", comprised up to 75 colour slides covering from 0.56–1.4 m^2 per frame. The total areas photographed per station are given in Table I. The methodological error in this parameter is estimated to be less than 10%. The length of a complete 70 picture transect was between 200 and 800 m, depending on the drift speed of the ship. The time between single photographs varied between 12 and 25 s. In order to investigate the small-scale distribution pattern at stations with high densities the "measure of patchiness" (Lloyd 1967) was used:

$$m'/m = 1 + V/m^2 - 1/m,$$

where m' denotes the index of mean crowding, m the sample mean and V the sample variance. This term is independent of the mean and therefore appropriate when comparing samples of different abundances (Elliott 1971). Uniform, random or patchy dispersion is indicated by a value <1, not significantly differing from 1, or >1, respectively.

The individual length measurements of the shrimps (to the

Table I. List of stations with shrimps recorded by means of underwater photography with depth, size of observed area, species names, numbers of specimens and densities. Order of stations: from north-east to south-west.

cruise/ station	depth [m]	observed area [m^2]	species	n	density [specimens/ 100m^2]
III/357	141	34.4	*C. antarcticus*	1	≤10
III/358	447	48.0	*N. antarcticus*	1	≤10
			C. antarcticus	1	≤10
VI/512	305	67.2	-	0	
VII/293	831	37.0	*N. lanceopes*	50	135
VII/307	194	38.1	*C. antarcticus*	4	10
VII/294	1125	42.6	*C. antarcticus*	5	12
VII/304	100	39.2	-	0	
VI/503	436	103.6	*N. antarcticus*	6	≤10
			C. antarcticus	2	≤10
VII/305	99	43.1	-	0	
VII/285	630	39.2	*N. antarcticus*	1	≤10
VI/396	529	102.2	*N. antarcticus*	34	33
			C. antarcticus	1	≤10
VI/504	184	36.4	*C. antarcticus*	1	≤10
VII/278A	458	44.2	*N. antarcticus*	5	11
VII/278B	545	41.4	*N. antarcticus*	12	29
VII/274	225	42.0	*C. antarcticus*	1	≤10
VII/275	295	28.6	*C. antarcticus*	3	10
VII/276	112	15.1	*C. antarcticus*	2	13
VII/277	399	29.7	*N. antarcticus*	4	13
VII/280	138	42.6	-	0	
III/336	761	56.8	*N. lanceopes*	9	16
III/271	961	15.4	-	0	
III/330	553	51.2	*N. lanceopes*	1	≤10
III/335	437	48.0	-	0	
III/329	241	38.4	-	0	
III/275	263	32.2	-	0	
III/273	624	30.8	-	0	
III/348	421	52.8	*N. antarcticus*	2	≤10
VII/270	299	41.4	*N. antarcticus*	4	10
III/345	487	54.4	*N. antarcticus*	1	≤10
III/311	244	89.6	*N. antarcticus*	15	17
			C. antarcticus	2	≤10
VII/261	1202	45.9	*N. lanceopes*	8	17

Table I. continued

cruise/ station	depth [m]	observed area [m^2]	species	n	density [specimens/ 100m^2]
VII/250	813	40.9	*N. lanceopes*	4	10
VII/246	626	10.1	-	0	
III/288	604	22.4	*N. antarcticus*	9	40
VII/245	508	29.7	-	0	
VII/260	705	43.1	-	0	
VI/384	526	105.0	*N. antarcticus*	4	≤10
VII/259	580	42.6	-	0	
III/289	346	22.2	*N. antarcticus*	11	50
			C. antarcticus	9	40
VII/256	390	27.4	*N. antarcticus*	20	73
VI/354	567	11.0	-	0	
VI/471	222	100.8	-	0	
III/310	380	91.0	*C. antarcticus*	2	≤10
III/290	401	32.2			
			N. antarcticus	4	12
III/309	839	86.8	*N. lanceopes*	1	≤10
VI/372	572	61.0	*N. antarcticus*	7	11
III/292	1093	43.4	*N. lanceopes*	5	12
VI/378	834	107.8	*N. antarcticus*	3	≤10
VI/368	1119	62.0	-	0	
VI/374	1129	67.0	-	0	
VI/380	1194	96.6	-	0	
III/307	1174	74.2	-	0	
VI/366	1185	22.0	-	0	
VI/376	1243	84.0	-	0	
III/303	446	91.0	*N. antarcticus*	18	20
III/302	253	88.2	*N. antarcticus*	33	37
III/301	242	92.4	-	0	
Σ					
58 stations (total)			shrimps	343	
20 stations with			*N. antarcticus*	194	
8 stations with			*N. lanceopes*	115	
13 stations with			*C. antarcticus*	34	
23 stations (without shrimps)			-	0	

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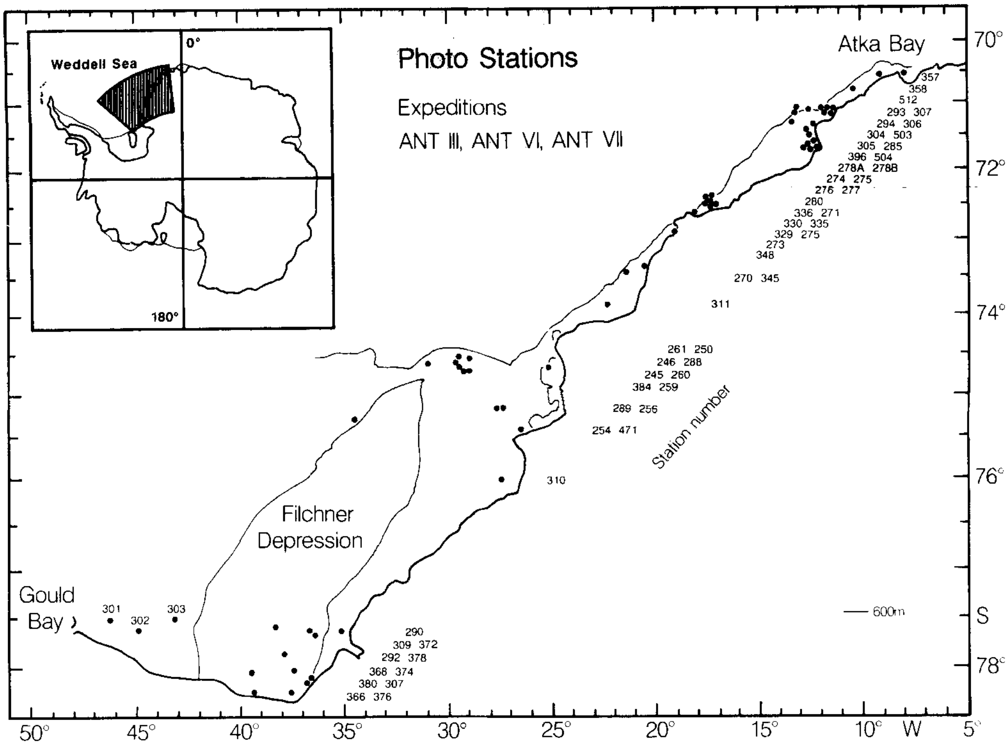

Fig. 1. Station map.

nearest mm) taken from the photographs refer to the distance from the anterior tip of the rostrum to the posterior dorsal edge of the telson (total length). Only photographs of entire specimens without a ventrally flexed tail were used. Even in small specimens the three species could be clearly separated.

Results

A total of 343 shrimps were photographically recorded on 36 out of a total of 58 stations, which covered an area of 3026 m^2 of sea floor (Table I, Fig. 1). The average density per station was 135 individuals (all three species) per 100 m^2. The densest concentration on one photograph was five *Nematocarcinus lanceopes*, constituting nine per m^2. *Notocrangon antarcticus* was shown to be more or less uniformly distributed from Atka Bay to Gould Bay, whilst *Chorismus antarcticus* was more abundant, and *N. lanceopes* only occurred north of 75°S. The depth distribution of the three species is given in Fig. 2 which shows that the highest densities were found between 200 and 600 m for *N. antarcticus*, between 100 and 350 m for *C. antarcticus* and between 800 and 1200 m for *N. lanceopes*. The latter depth denotes the lower limit of the investigations.

Small-scale dispersion for *Notocrangon antarcticus* and *Nematocarcinus lanceopes* was determined at five stations with more than 20 specimens per station (Table I, Figs. 3 & 4). The calculated values for the measure of patchiness do not significantly differ from 1 (Chi-Square test; $P \leq 0.05$, one-sided). This indicates random dispersion within all stations except for station 396 where a factor of 1.92 denotes a patchy dispersion of *N. antarcticus*. No tendency for an increase or decrease in density was observed along the transects. The absence of shrimps at the end of station 302 was probably the result of perturbation by the gear, indicated by clouds of suspension on the photographs.

Size frequencies show (Figs. 5 & 6) that total lengths of *Notocrangon antarcticus* at the shallowest station (302) were significantly smaller than those at stations 256 and 396. The sizes at the two latter stations did not differ significantly although at station 256 there were two peaks in the length-frequency distribution whereas there was only one mode at the deeper station 396 (Kruskal Wallis test, comparison of two independent samples according to Nemenyi; $P \leq 0.05$, two-sided; Sachs 1984). The specimens of *N. lanceopes* at the shallower station 293 (831 m) were significantly smaller than those from the deeper station 294 (1125 m) (Mann Whitney test, $P \leq 0.05$, two-sided).

The photographs suggested that each of the three species has a distinct spatial niche. *Chorismus antarcticus* was always observed living epizoically on sponges, mainly at the sides of the sponges facing downwards. *Notocrangon antarcticus* was often found digging itself ventrally into the sediment, but was never covered dorsally by the substrate and left a characteristic fusiform, keeled mark, several millimeters deep in the mud. It was mostly found at stations with poor epifaunal coverage. *Nematocarcinus lanceopes* was photographed either stalking or standing on its legs, which are comparatively longer than those of the other species. Thus the body was always positioned several millimeters above the substratum. The fauna at these deeper slope stations was generally poorer than in most shelf areas. Two *N. antarcticus* and two *N. lanceopes* were photographed

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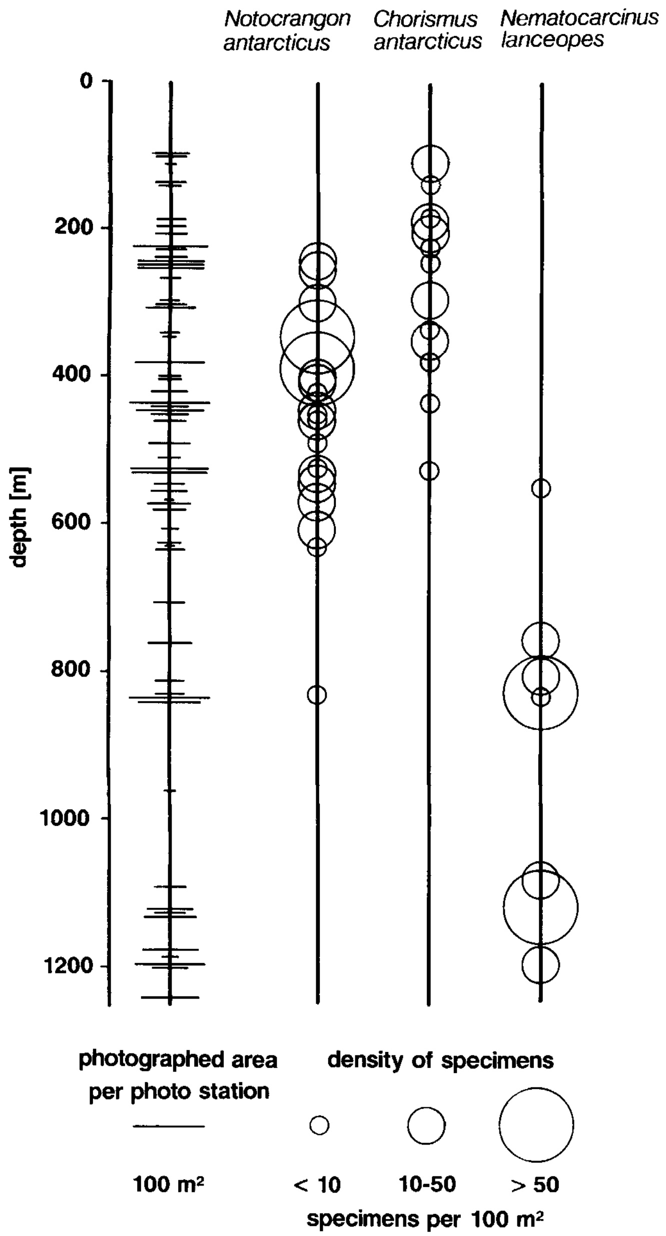

Fig. 2. *Notocrangon antarcticus, Chorismus antarcticus, Nematocarcinus lanceopes.* Depth distribution of abundances in the south-eastern Weddell Sea, investigated by means of underwater photography. Left column: horizontal bars indicate the underwater photo stations in the total area of investigation according to depth; widths of horizontal bars refer to the size of the photographed area. Three right columns: Abundances of the three shrimp species in the total area of investigation according to depth.

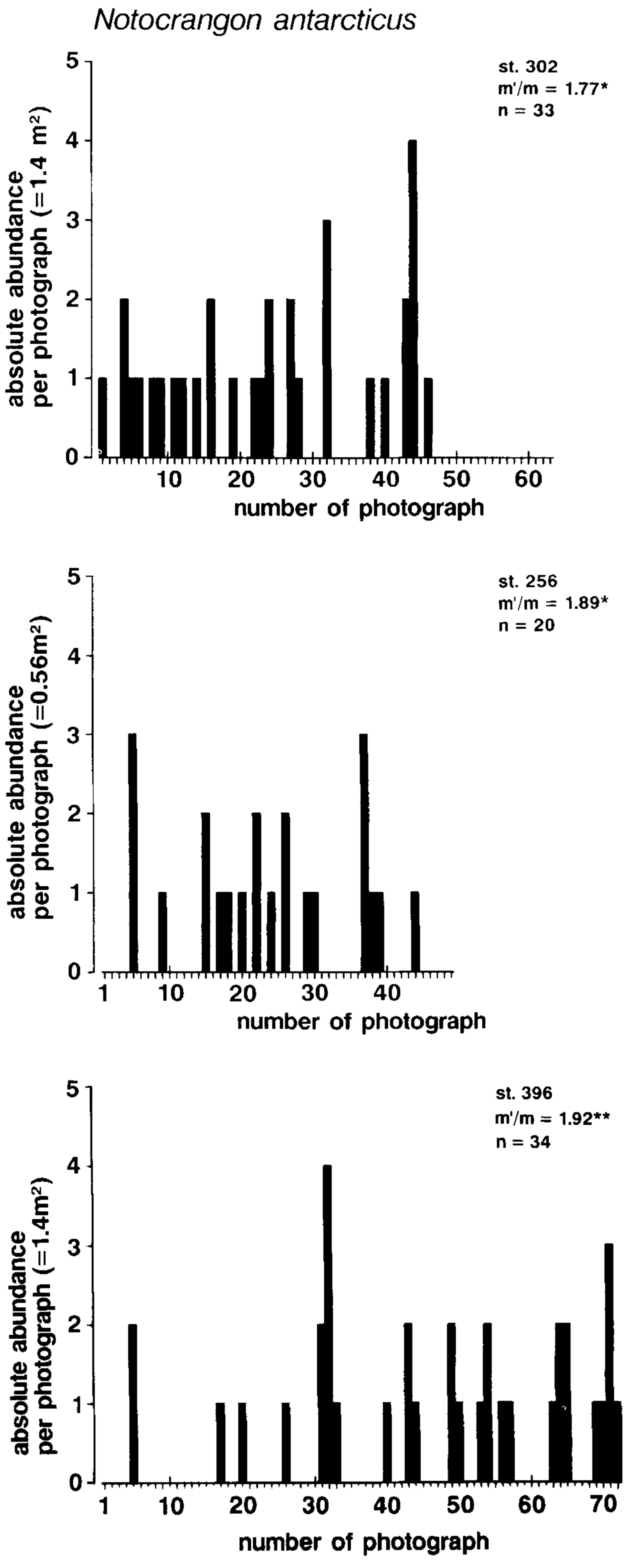

Fig. 3. *Notocrangon antarcticus.* Small-scale dispersion pattern at stations 302, 256, 396. Values in parenthesis (st. 302) refer to the transect from picture no. 1 to no. 46. * denotes a value for the measure of patchiness not significantly different from 1 (= random dispersion), ** denotes a value significantly higher than 1 (= patchy dispersion).

while escaping. This sudden and intense swimming behaviour by reaction propulsion was indicated by a cloud of suspension.

Discussion

The abundance of species is one major feature of the role of

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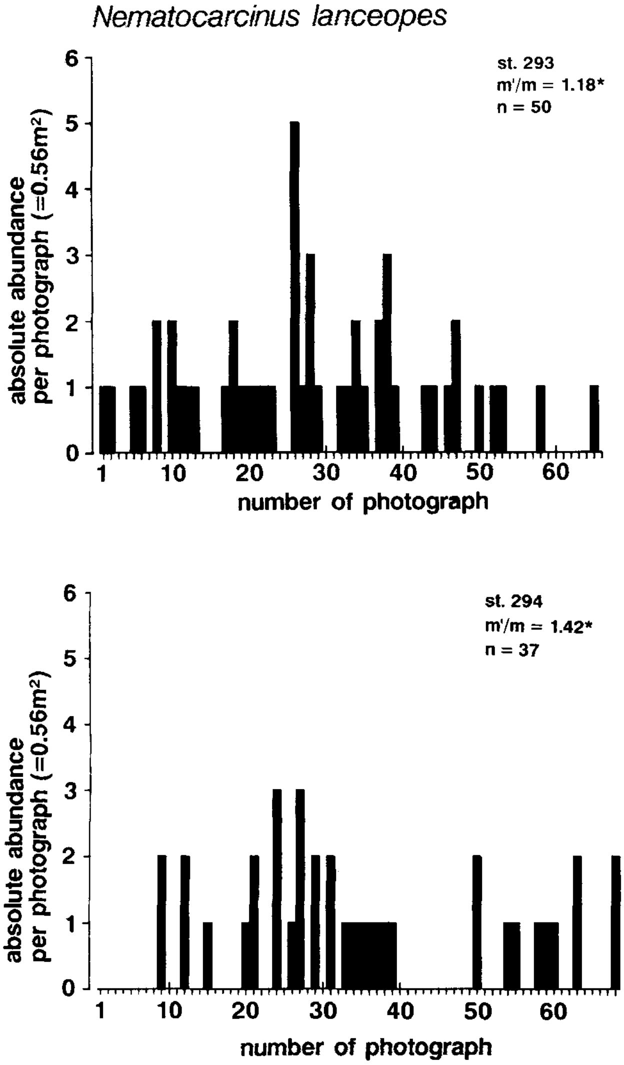

Fig. 4. *Nematocarcinus lanceopes*. Small-scale dispersion pattern at stations 293, 294. * denotes a value for the measure of patchiness not significantly different from 1 (= random dispersion).

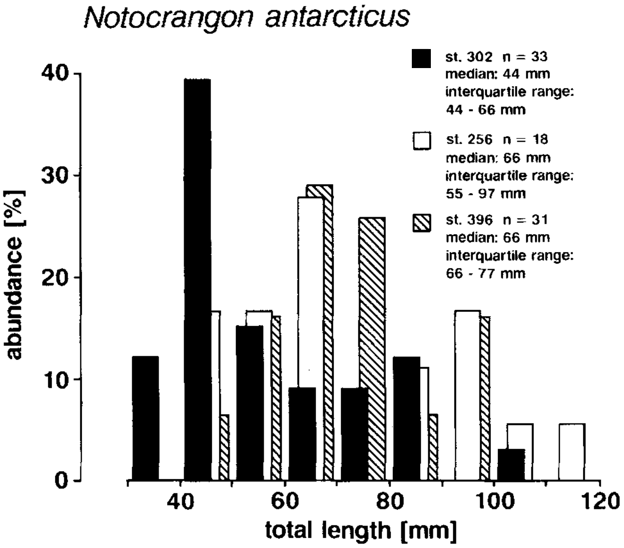

Fig. 5. *Notocrangon antarcticus*. Size-frequency distribution (total length) at stations 302, 256, 396.

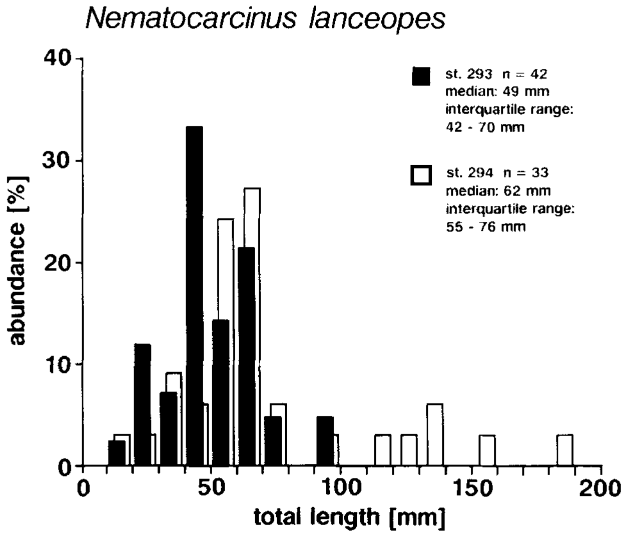

Fig. 6. *Nematocarcinus lanceopes*. Size-frequency distribution (total Length) at stations 293, 294.

organisms in an ecosystem (Odum 1980). In fisheries biology, trawling replaces direct observations, and standard catches are taken to represent a relative measure for the standing stock. In some areas of the eastern Weddell Sea, for example, ≥ 20 kg shrimps per 30 min trawling were caught by a commercial bottom trawl (Arntz & Gorny 1991).

Underwater photography provides density estimates of certain taxa with a low methodological error, but such estimates are considered conservative because of avoidance effects. In this study only four specimens out of a total of 343 were photographed while escaping suggesting avoidance was minimal. Another reason for underestimating real densities could be that shrimps may sometimes swim above the bottom so that they are not fully recorded by the photographic method.

The highest shrimp abundance, five specimens of *Nematocarcinus lanceopes*, was observed on one photograph (0.56 m^2). Several sequences of such small-scale patches were recorded at stations where shrimps were common in general but in many cases no shrimps were found at adjacent stations. This was also true for *Notocrangon antarcticus*, and indicates that the two species aggregate in patches which cover a greater area than the photographic observation (= 100 m^2, = 500 m transect length). It is not known, if these concentrations represent single stocks as assumed for the brown shrimp (*Crangon crangon*) along the German coast in the North Sea (Tiews 1969, Tiews & Schumacher 1981).

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Table II. Comparison of mean and maximum densities of shrimps obtained by different gears. This study: underwater photography; Arntz & Gorny (in press): bottom trawl; Voß (1988): Agassiz trawl. The densities refer to the sampled area sizes (by order of magnitude) and to one square meter for comparison.

	N. antarcticus	*N. lanceopes*	*C. antarcticus*
This study mean density (total study area) n/1000 m²| n/m²	64 | 0.064	38 | 0.038	11 | 0.011
This study maximum density per station n/100m² | n/m2	73 | 0.73	135 | 1.35	40 | 0.40
This study maximum density per frame |n/m²	| 2.9	|8.9	| 3.6
Arntz & Gorny (in press) mean density (total study area) n/100 000m² | n/m²	1200 | 0.012	2000 | 0.020	300 | 0.003
Arntz & Gorny (in press) maximum density per trawl catch n/10 000m² | n/m²	330 | 0.33	350 | 0.035	80 | 0.008
Voß (1988) mean density (total study area)* n/10 000m² | n/m²	110 | 0.011	**	20 | 0.002
Voß (1988) maximum density per trawl catch n/1000m² | n/m²	<100 | <0.1	36 | 0.004	≥0.01 | ≥10

* only that part of the study area is considered which is also covered by this study
** *N. lanceopes* was found only at one station (see below)

Stock assessment of the brown shrimp along the coast of the Netherlands with traditional trawl gear resulted in average densities of 1000 specimen per 1000 m² and maximum values up to at least one order of magnitude higher (Boddeke 1978). Extensive biomass estimates by underwater photography between 1977 and 1985 off West Greenland (Kanneworff 1986) yielded average densities of *Pandalus borealis* between 50 and 100 specimens per 100 m² on the basis of 100 to 800 m² observed area per station. Maximum values were about 300 specimens per 100 m². Bergström *et al.* (1987) observed average densities of 33 pandalid shrimps (*Pandalus borealis*) per 100 m² in a west Swedish fjord by means of underwater video.

Cautious density estimates for the south-eastern Weddell Sea, based on bottom and Agassiz trawl catches as well as the present results, are combined in Table II. At a few stations of the expedition ANT VII different gears were used even at the same station. The estimates based on photographs are higher than those calculated from the trawl catches. This may be due to a low catchability by the trawls or an effect of the different sample sizes. The highest maximum values were obtained by the photographic method because they refer to the smallest areas. A trawl catch integrates patches of different sizes as well as areas with a poor shrimp fauna which results in lower maximum values for larger total areas.

When comparing distributions the size of the sampling area must be considered. Voß (1988) found shrimps at almost all and Arntz & Gorny (1991) at 87.5 % of the sampled stations during the cruises ANT I, II, and ANT III, VI, and VII respectively with RV *Polarstern*. One conclusion would be that shrimps are ubiquitously present in the Weddell Sea (≤ 1200 m depth) in areas of *c.* 2000 m² (Agassiz trawl). However, at a scale of 10–100 m² areas frequency is only 64 % and ≤ 10 % if a scale of *c.* 1 m² is considered.

Depth zonation in the Weddell Sea of *Notocrangon antarcticus* and *Chorismus antarcticus* was first described by Voß (1988). Our abundance values confirm a preference for depths ≤ 400 m by *C. antarcticus* and for 200–600 m by *N. antarcticus*, which corresponds to the observations of Kirkwood (1984). During ANT I and ANT II *N. antarcticus* was found at all trawl stations in the Filchner Depression (≥ 700 m depth); however, it was not recorded in this area by underwater photography, which might be due to the scale-dependent effect discussed above.

The size-frequency distributions for *Nematocarcinus lanceopes* and *Notocrangon antarcticus* on our photographs generally revealed the same modes as material from the trawl catches. However, the size ranges of both species was skewed towards smaller sizes on the photographs. The shallowest depth for this species registered by the camera was 553 m, 42 m less than by the trawl. The size distributions on the photographs also show a larger share of the smaller size classes in shallower waters for both species despite the fact that the stations cover different depth ranges, i.e. *N. lanceopes* (on the slope) and *N. antarcticus* (on the shelf). The small number of photographed specimens mainly of *N. antarcticus* is probably due to the poorly known early life history.

Compared with the 249 demersal fishes observed on the same photographs (Ekau & Gutt 1991), shrimps can be cautiously considered to be more abundant than fish on the Weddell Sea shelf and upper slope. They do, however, not exceed the fish biomass if an average individual shrimp weight of 5g and an average minimum fish weight of 10g is considered.

The biotic environment is one important factor determining the aggregations and occurrence of shrimps. *Chorismus antarcticus* appears to require sponges, or similar structures, as a substratum. *Notocrangon antarcticus* seems to prefer a substratum which is not covered by concentrations of epifauna, possibly due to its digging behaviour. Voß (1988) also showed these positive and negative correlations between shrimp species and sponges, from trawl catches. However, the existence of a few localities with high concentrations of both species cannot be exclusively explained by the presence or absence of sponges. Additional dynamic processes probably also play a role, as is the case for *Nematocarcinus lanceopes*.

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