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The genus *Sterechinus* (Echinodermata: Echinoidea) on the Weddell Sea shelf and slope (Antarctica): distribution, abundance and biomass*

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Summary. Two species of the echinoid genus *Sterechinus* were documented from 92 trawl stations and 55 photographic stations in the eastern and southern Weddell Sea between 100 and 1200 m water depth. We found two species occuring along the whole shelf and slope, *S. neumayeri* being more abundant above 450 m water depth and *S. antarcticus* dominating the deeper regions. The size-frequency distributions of both species indicate differences in growth, mortality and longevity. First estimates of abundance and biomass of *S. neumayeri* and *S. antarcticus* are 0.085 ind/m^2 & 0.005 gAFDW/m^2 and 0.022 ind/m^2 & 0.005 gAFDW/m^2, respectively.

Introduction

Sterechinus is the only genus of the superorder Echinacea that is present in Antarctic waters (Pawson 1969). On the Weddell Sea shelf and slope, *Sterechinus* is found in almost every trawl sample. According to Voss (1988) it is the most abundant genus of regular echinoids in this area. The various species of this genus are mainly surface deposit feeders, but have been found to graze on algae, sponges and bryozoans too (see review in De Ridder and Lawrence 1982). Due to its motility and feeding mode, *Sterechinus* spp. may have a considerable effect on community structure in the Antarctic benthos.

During the last years a large number of samples has been acquired allowing for an analysis of the distribution and the species composition of the genus. Additionally, first estimates of abundance and biomass were made based on semi-quantitative trawl samples and on photographic surveys.

Methods

Investigation area, sampling and preservation

The investigation area is the eastern and southern shelf and slope of the Weddell Sea that has been studied intensively by several expeditions with *RV Polarstern*. The present study on *Sterechinus* is limited to the area between 100 m and 1200 m water depth. Hydrography and topography of the Weddell Sea have been described by Hellmer and Bersch (1985), Johnson et al. (1981) and others. Trawl samples were taken during the *RV Polarstern* cruises ANT I/2 (1983), ANT II/4 (1984), ANT V/3 (1986), ANT V/4 (1987) and ANT VI (1988) on stations between 178 m and 1176 m water depth. The standard gear was a modified Agassiz trawl with a mouth opening of 3 m by 1 m and a mesh size of 20 × 20 mm in the front parts and 10 × 10 mm in the medium parts and the cod end (Voß 1988). Trawl time and speed depended on ice conditions and bottom topography at the 84 stations sampled, the aim was to trawl for 20–30 min at a speed of 0.5 knots. Additionally, five stations were sampled with a 140 foot bottom trawl (see Ekau 1988), and at three stations a small dredge (100 × 30 cm opening) was applied (see Fig. 1 for location of trawl stations). Macrobenthic specimens were collected from the total catch or from a representative subsample, if the catch was too voluminous, and stored in 4% Formaldehyde solution buffered with Borax ($Na_2B_4O_7$). In autumn 1989, all specimens of *Sterechinus* spp. were transferred to 70% Ethanol.

Underwater still photographs were taken by a camera system consisting of a Hasselblad 500 and an electronic flash, that was lowered from the ship and released by a ground weight (Gutt 1988). One picture covered a bottom area between 0.56 and 1.40 m^2, depending on different setups of the system during different cruises. 2898 pictures of the bottom surface were taken at 55 stations (depth range: 100–1202 m) during the *RV Polarstern* cruises ANT III/3 (1985), ANT VI (1988) and ANT VII (1989), see Fig. 1.

Taxonomy and morphometry

The collected material was of variable condition, from unbroken animals with spines and pedicellaria down to single Aristotle's lanterns without any test. Wherever possible, animals were determined to the species level by means of the position of the ocular plates (exert or insert), the tube feet (with or without spicules) and the globiferous pedicellariae, according to Koehler (1926) and Mortensen (1909, 1920, 1943, 1950). Diameter and height of unbroken tests were measured to the lower 0.1 mm. The lanterns of broken specimens were cleaned from organic matter by a 5% solution of NaOCl. The length of the half-pyramids (jaws) was measured from the oral tip to the outer aboral edge.

Specimens from several stations were used to establish relations between jaw length and diameter of the test for each species. These relations were used to estimate the diameter of broken animals from the size of the Aristotle's lantern. With other specimens, empirical

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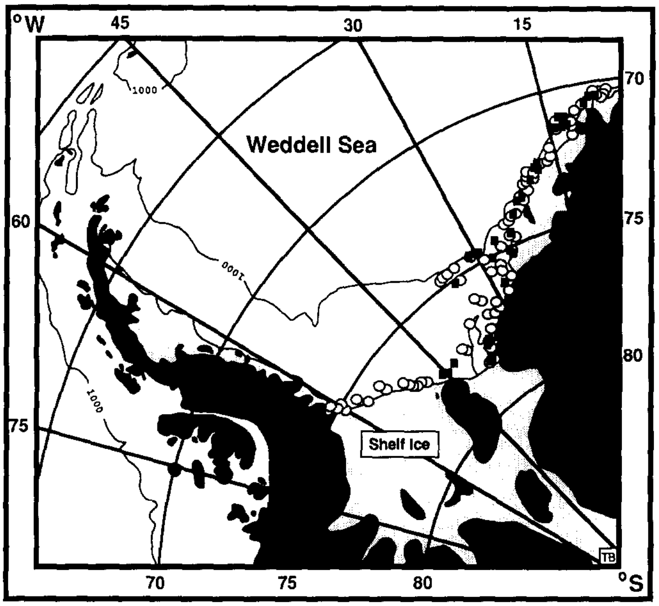

Fig. 1. Distribution of trawl stations (*circles*) and photo stations (*squares*) in the Weddell Sea

relations between test diameter and ash free dry weight (AFDW) of test (including lantern), of gonads and of gut were established.

Specimens observed on the still photographs were counted and measured (if possible), determination to the species was not possible.

Distribution, abundance and biomass

Trawl samples as well as photo samples were not analyzed on a yearly basis due to the low overall number of specimens per year, but pooled to get representative samples of the whole area and to increase precision in the subsequent analysis.

The relative abundance per trawl sample (i.e. % of *Sterechinus* spp.) was used to investigate the distribution of the different species found with respect to depth and sediment parameters.

Abundance of *Sterechinus* spp. was calculated from 42 trawl samples of which the sampling area was estimated (data kindly provided by J. Voß, Kiel, see also Voß 1988), and from the 55 photo stations.

Average weight of *Sterechinus* spp. was estimated from the length-frequency distributions and the length-weight regression. Biomass was estimated by multiplying average weight with average abundance. To compensate for weight losses due to the storage in formaldehyde solution, biomass values were multiplied by a factor of 1.2 (see Brey 1986 and references therein). Abundance and biomass values were calculated for the genus, for both species and for different depth strata. We applied Woolf's G-test to a two-way table based on grouping of data with respect to the common median in order to detect significant differences in abundance between different data sets (see Sachs 1982).

Results

Taxonomy and morphometry

Two species of the genus Sterechinus were found in the investigation area: *Sterechinus neumayeri* and *Sterechinus antarcticus*. These two are clearly separable by the spicules in the tube feet that are not present in *S. neumayeri* and by the valves of the globiferous pedicellariae (see plates in Koehler 1926 and Mortensen 1920). The relation between diameter and height is significantly different between both species ($P < 0.001$), but the distributions overlap (Fig. 2). The regressions of diameter and jaw length (Fig. 3) are significantly different ($P < 0.001$). The relations between weight and diameter are not significantly different between the two species, Fig. 4 shows the regression lines for the pooled data.

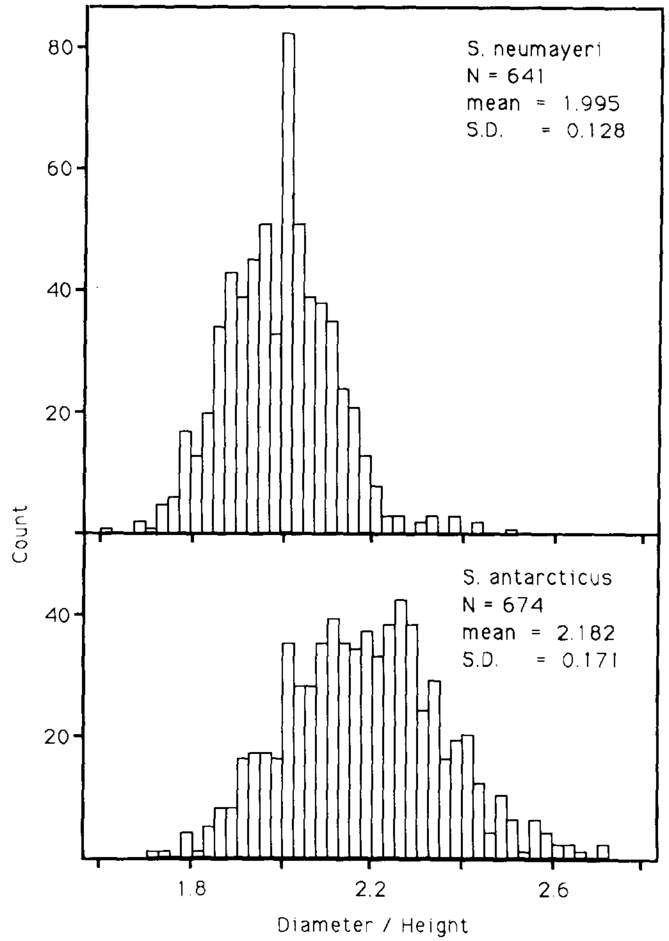

Fig. 2. Relation between diameter and height in *S. neumayeri* and *S. antarcticus*

Distribution

The genus *Sterechinus* was present throughout the whole investigation area, at 70 out of 92 trawl stations (=76%) and at 24 out of the 55 photographic stations (=44%). *S. neumayeri* was found at 50 trawl stations, and *S. antarcticus* at 58 trawl stations. From the trawl stations, depth and qualitative descriptions of the sediment are available. Table 1 shows that the percentage of *S. antarcticus* increases significantly (i.e. the percentage of *S. neumayeri* decreases) with increasing depth, whereas the type of the inorganic sediment and the presence of biogenic sediments have no significant effect. Figure 5 shows the partitioning of abundance and biomass between the two species with

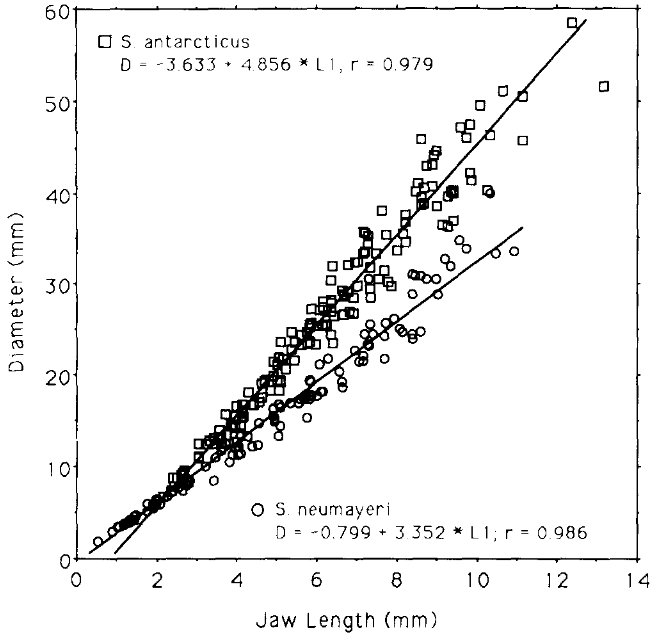

Fig. 3. Regression between diameter and jaw length in *S. neumayeri* and *S. antarcticus*

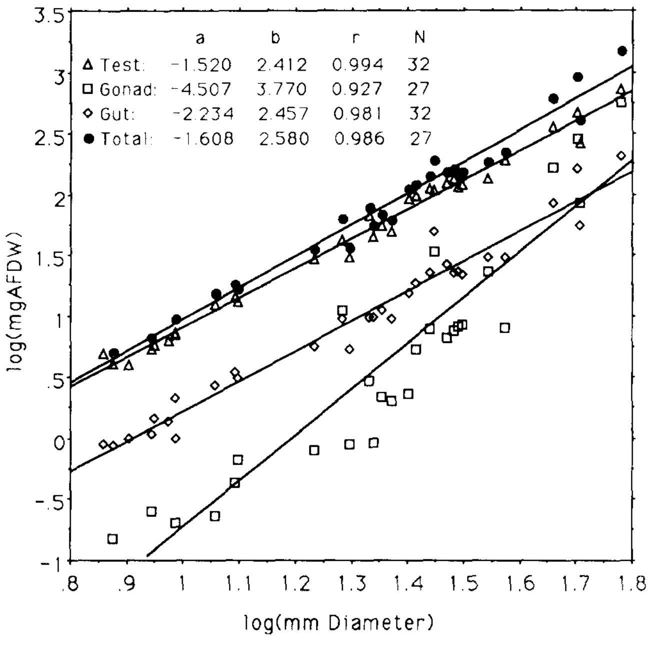

Fig. 4. Weight-Diameter regressions for *Sterechinus* spp

depth. *S. neumayeri* dominates the shallower regions above 450 m water depth but lives down to 850 m water depth. *S. antarcticus* occurs along the whole depth gradient (100–1200 m), but dominates the deeper regions. *S. neumayeri* is not present at many of the deeper stations on the continental slope and in the Filchner depression, whereas *S. antarcticus* is not present at many of the shallower stations along the eastern shelf.

Table 1. Distribution of the two *Sterechinus* species in relation to depth and sediment parameters. Sperman rank correlation coefficient matrix. % *S. ant.*: Percentage of *S. antarcticus* per sample (% *S. neumayeri* = 100 – % *S. ant.*). Sed. inorg.: 0: silt, 1: silt/sand, 2: sand 3: gravel. Sed. org.: 0: no, 1: sponge needle felt or dead bryozoans

	Depth	Sed. inorg.	Sed. org.
% *S. ant.*	0.692***	–0.264	–0.235
Depth	1	–0.516**	–0.398*
Sed. inorg.	-	1	0.538**

$^*P<0.01$; $^{**}P<0.001$; $^{***}P<0.0001$

Abundance and biomass

From the trawl samples a total of 1394 specimens of *S. neumayeri* and 1113 specimens of *S. antarcticus* was counted and measured. On the photographs 309 specimens were detected, 217 of these could be measured. Figure 6 shows the corresponding size-frequency distributions.

Mean abundance of *Sterechinus* spp. is estimated to be 0.053 ind/m^2 (trawl samples) and 0.105 ind/m^2 (photo samples), respectively (see Table 2). Estimates from trawl and photo samples are not significantly different ($P>0.10$), neither for the whole depth range nor within the two depth strata 100–450 m and 450–1200 m water depth (Table 2). Also between depth strata abundances are not significantly different (Table 2). Average biomass is estimated to 0.006 gAFDW/m^2 (trawl samples) and to 0.031 gAFDW/m^2 (photo samples). Table 3 shows estimates of abundance and biomass per species and per depth stratum based on the trawl samples. With respect to the total depth range, abundances of *S. neumayeri* and *S. antarcticus* are not significantly different (0.043 vs 0.011 ind/m^2), and biomasses are equal (0.002 gAFDW/m^2). Within the range 100–450 m abundance of *S. neumayeri* (0.061 ind/m^2) is significantly higher than abundance of *S. antarcticus* (0.006 ind/m^2). Below 450 m *S. neumayeri* shows a significantly lower abundance than *S. antarcticus*, <0.001 ind/m^2 vs 0.024 ind/m^2. The relation between the biomass values of both species is similar to abundance: 0.004 gAFDW/m^2 vs 0.001 gAFDW/m^2 above 450 m, and <0.001 gAFDW/m^2 vs 0.005 gAFDW/m^2 below 450 m water depth. Within species, the abundance of *S. neumayeri* is significantly higher above 450 m than below 450 m, whereas no depth related significant differences could be detected in *S. antarcticus*.

Discussion

Distribution

Our results confirm the circum-Antarctic distribution of *S. neumayeri* as well as *S. antarcticus* (Pawson 1969). In contrast to Mortensen (1943) and Pawson (1969), who assume *S. neumayeri* to occur only above 700 m water depth, we found *S. neumayeri* down to 850 m. *S. dentifer*, that may be widespread in deeper Antarctic waters (Pawson 1969), was not found at all. Either this species is

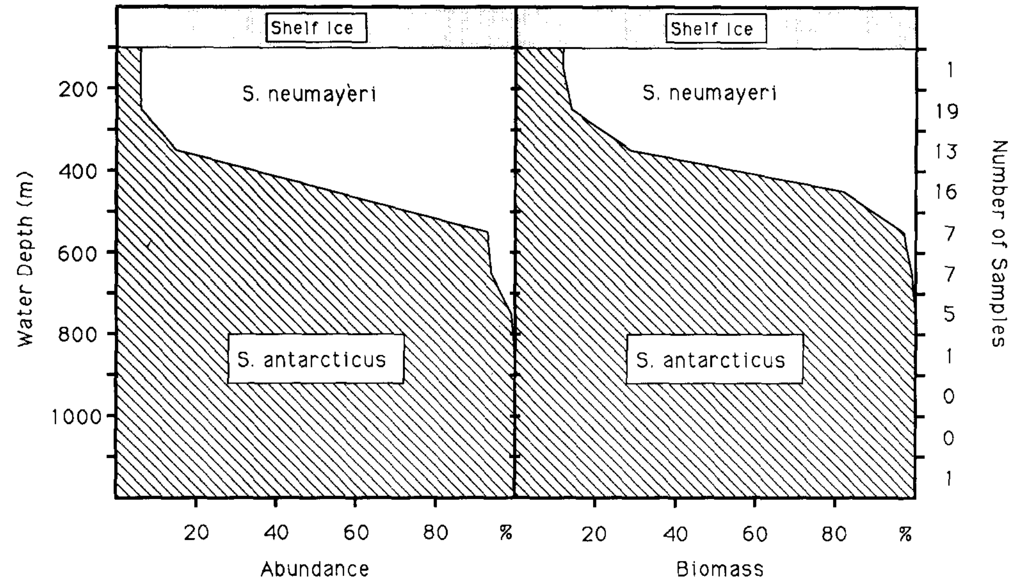

Fig. 5. Depth distribution of *S. neumayeri* and *S. antarcticus* abundance and biomass between 100 m and 1200 m water depth based on 70 trawl samples. (Sum of both species = 100% at each depth)

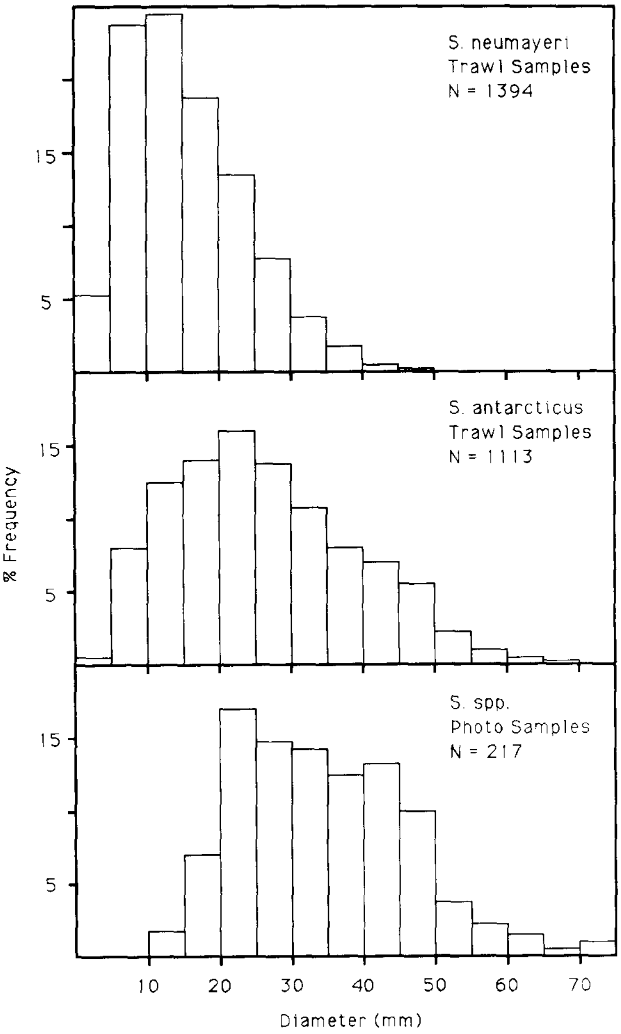

Fig. 6. Size-Frequency distributions of *S. neumayeri*, *S. antarcticus*, and *Sterechinus* spp. in trawl and photographic samples

restricted to areas below 1200 m water depth or it is limited to the Indian Ocean sector of the Antarctic Ocean, where it was found exclusively up to now.

Our data on sediment structure are not sufficient to identify those parameters which determine the depth distribution of the two species found (Table 1). Up to now, only water depth seems to be of importance.

Abundance and biomass estimates

The validity of quantitative estimates depends on two parameters, precision (i.e. low variability) and accuracy (i.e. low bias).

The missing of a significant difference between abundance estimates of trawl and photo samples most likely depends on the low level of precision in both data sets, i.e. an unsufficient number of samples in relation to the large variation of abundance values encountered. Especially the photo samples include a large number of zero counts, which decrease the precision of the estimate of average abundance (see Eleftheriou and Holme 1984). Obviously, the average sampling area per photo station (47.6 m^2) was to small with respect to the abundance of *Sterechinus* spp.

The accuracy of an estimate of abundance and biomass mainly depends on two parameters, size specific gear efficiency (i.e. gear selection) and overall gear efficiency. In slow-moving epibenthic animals such as regular sea urchins gear selection depends on the relation between mesh size and animal size only, i.e. below a certain limit size specific gear efficiency decreases with decreasing animal size. The size-frequency distributions (Fig. 6) indicate that this is the case in the trawl samples as well as in the photo samples.

With respect to the trawl samples, the smaller animals are caught more frequently in *S. neumayeri* than in *S. antarcticus* (Fig. 6). This difference may be due to the

Table 2. Mean abundance N (ind/m^2), mean ind. weight W (mgAFDW) and mean biomass B (gAFDW/m^2) estimates of *Sterechinus* spp. from trawl and photo samples. Test on significant differences of abundance estimates between gears and depth strata by the G-test. NS: Number of samples, P: Level of significance

	Trawl samples			Photo samples	
Depth (m)	NS	N ± 95% CL	*P*	N ± 95%CL	NS
100–1200	42	0.053 ± 0.046	> 0.10	0.105 ± 0.097	55
100–450	29	0.067 ± 0.067	> 0.10	0.179 ± 0.319	28
P		> 0.10		> 0.10	
> 450–1200	13	0.024 ± 0.021	> 0.10	0.064 ± 0.137	27

	W	B[a]	W	B[a]
100–1200	101.1	0.006	241.17	0.031
100–450	59.63	0.005	285.95	0.061
> 450–1200	164.96	0.005	177.97	0.014

[a] Biomass values are corrected for weight loss due to preservation by multiplying with the factor 1.2

Table 3. Mean abundance N (ind/m^2 ± 95% CL), mean ind. weight W (mgAFDW) and mean biomass B (gAFDW/m^2) estimates per species and depth range from trawl samples. Test on significant differences of abundance estimates between species and depth strata by the G-test. NS: Number of samples, P: Level of significance

		S. neumayeri		*S. antarcticus*
Depth (m)	NS	N ± 95% CL	*P*	N ± 95% CL
100–1200	42	0.043 ± 0.045	> 0.100	0.011 ± 0.007
100–450	29	0.061 ± 0.064	< 0.010	0.006 ± 0.004
P		< 0.001		> 0.100
> 450–1200	13	< 0.001 ± 0.001	< 0.001	0.024 ± 0.021

	W	B[a]	W	B[a]
100–1200	47.58	0.002	168.30	0.002
100–450	48.13	0.004	176.55	0.001
> 450–1200	34.81	< 0.001	166.59	0.005

[a] Biomass values are corrected for weight loss due to preservation by multiplying with the factor 1.2

clogging of the net (sponges, sponge debris, bryozoans etc.) that occured more frequently at the shallower stations (above 450 m), where *S. neumayeri* dominates. The different shape of both species, *S. neumayeri* is more round, whereas *S. antarcticus* is more flat (Fig. 2) may have an additional effect. The higher average abundance value of the photo samples (0.105 ind/m^2) compared to the trawl samples (0.053 ind/m^2) indicates that the latter underestimate natural densities due to a lower overall gear efficiency. Eleftheriou and Holme (1984) discuss the catch efficiency of trawls and dredges in detail. They conclude that the efficiency of trawls may be below 10% in certain cases, especially on uneven ground.

The accuracy of photographic sampling depends on the ability of the observer to detect a specimen on a picture. Figure 6 shows that size specific efficiency decreases towards the smaller animals. This may be due to the fact that smaller specimens often are hidden in the dense epibenthic assemblages of sponges, bryozoans and hydrozoans. Additionally, many specimens at the shallower stations were covered partially or completely with pieces of sponges, dead shells, parts of tests of *Sterechinus* or other unidentifiable matter on the aboral side. Dayton et al. (1970) observed this phenomenon in *S. neumayeri* at McMurdo and described it as a protection against the predatory anemone *Urticinopsis antarcticus*: "... it (*S. neumayeri*) released its camouflage and made its escape, leaving the anemone with the shell debris." *U. antarcticus* is known to be circum-Antarctic distributed in shallow waters, but has not been found in the Weddell Sea up to now (K. Riemann-Zürneck, AWI, personal communication). However, this hiding behaviour may also be a camouflage against predators that locate their prey visually, e.g. demersal fish. This assumption is strengthened by the observation that many of the dead tests of *Sterechinus* spp. which lay at the bottom show a big hole on the aboral side, indicating the existence of a predator that attacks the sea urchins from above.

Due to the limitations of our data (low accuracy of trawl data, size specific gear efficiency as well as low precision in both gears), our estimates of abundance and biomass should be taken with care. All values are minimum estimates, especially those which depend on trawl samples only. However, if we assume that we have sampled the same population with both gears, we can correct the estimates based on trawl samples with respect to the more accurate photo estimates, i.e. by the factor $\text{abundance}_{photo}/\text{abundance}_{trawl}$ (0.105/0.053, Table 2). Due to this correction, abundance and biomass of *S. neumayeri* and *S. antarcticus* (in brackets) are estimated to 0.121 ind/m^2 & 0.007 gAFDW/m^2 (0.012 ind/m^2 & 0.003 gAFDW/m^2) above 450 m, <0.001 ind/m^2 & <0.001 gAFDW/m^2 (0.048 ind/m^2 & 0.010 gAFDW/m^2) below 450 m, and 0.085 ind/m^2 & 0.005 gAFDW/m^2 (0.022 ind/m^2 & 0.005 gAFDW/m^2) between 100 and 1200 m water depth.

Growth, mortality and longevity

Up to now, no information is available on these aspects of the life history of the two species of *Sterechinus*. However, the comparison of the size-frequency distributions (Fig. 6) indicates distinct differences in growth, mortality and longevity of these closely related species. The clear difference in maximum diameter, 66 mm in *S. antarcticus* and 45 mm in *S. neumayeri*, may be related to slower growth and/or longer lifespan in *S. antarcticus* (see e.g. Pauly 1980). The difference in the slopes of the right descending arms of the size-frequency plots may indicate a higher mortality rate as well as higher productivity (see Allen 1971) in *S. neumayeri* than in *S. antarcticus*. Future investigations on the population dynamics of both species will answer these questions.

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