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THE ECHINODERMATA OF THE  
ESTUARINE REGION OF THE RIVERS  
RHINE, MEUSE, AND SCHELDT, WITH  
A LIST OF SPECIES OCCURRING IN  
THE COASTAL WATERS OF  
THE NETHERLANDS

W. J. WOLFF

(Communication no. 67 of the Hydrobiologisch Instituut,  
afdeling Delta-Onderzoek, Yerseke, The Netherlands)

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E. J. BRILL, LEIDEN

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WITH A LIST OF SPECIES OCCURRING IN THE  
COASTAL WATERS OF THE NETHERLANDS

by

W.J. WOLFF

(Division Delta-Research, Hydrobiological Institute, Yerseke, The Netherlands)\*

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I. INTRODUCTION

In the near future several of the estuaries in the southwestern part of The Netherlands will be cut off from the sea and changed into fresh-water lakes, thus creating conditions under which echinoderms cannot live. During research work on other subjects, the Division Delta-Research of the Hydrological Institute collected many data on the

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occurrence of echinoderms in this region and it seems useful to publish these findings, because it will soon be impossible to study this group in our area. In addition, many new data on the echinoderms of The Netherlands have been obtained since the publication of ENGEL'S (1932) paper and we therefore also give a list of the Dutch species of echinoderms.

## II. ACKNOWLEDGEMENTS

Mrs. C.H. Borghouts-Biersteker, Dr. C. den Hartog, Dr. K.F. Vaas, and Mr. W.J.M. Vader permitted me to use their observations on the occurrence of echinoderms in our area. Messrs. P. de Koeijer, W.J.L. Rober, C. de Rooij, and especially A.J.J. Sandee and L. de Wolf helped greatly in the work of collecting and sorting the samples. Mr. J. Nieuwenhuize determined the grain-size distributions mentioned in this paper.

Mr. D. Eisma (Netherlands Institute for Sea Research, Den Helder) extended hospitality on board the vessels employed by him for mineralogical studies in the southern part of the North Sea, and permitted me to study the organisms that occurred in his grab samples. Prof. H. Engel and Dr. W. Vervoort made it possible for me to study the echinoderm collection of the Zoölogisch Museum in Amsterdam and the Rijksmuseum van Natuurlijke Historie in Leiden, respectively. Mrs. I. Seeger-Wolf read the English manuscript.

## III. BRIEF DESCRIPTION OF THE AREA INVESTIGATED

The area in which our investigations were made comprises the estuaries of the rivers Rhine, Meuse, and Scheldt (Fig. 1). DEN HARTOG (1961, 1963) and PEELLEN (1967) have given an excellent survey of the hydrography of this area, to which the reader is referred. We shall only give isohalines of 10‰, 15‰, and 16.5‰ Cl' of PEELLEN'S map of the hydrographical situation during mean river discharge before any of the Delta works were completed. Near the mouth of the Nieuwe Waterweg the situation is certainly more complicated than indicated by PEELLEN.

Almost the whole area shown on the map is covered by loose sediments. In the estuaries themselves there are muddy and sandy sediments with median grain-sizes ranging from 50  $\mu$  to 300  $\mu$  (coarse silt to medium sand). In the North Sea the median grain-size gradually increases in a seaward direction to about 500  $\mu$  (coarse sand). Only where the tidal currents attack the shore and dunes do not sufficiently protect the low-lying country, dikes were built of various materials, *e.g.*, wood, bricks, basalt, Vilmordian limestone, and concrete. To-

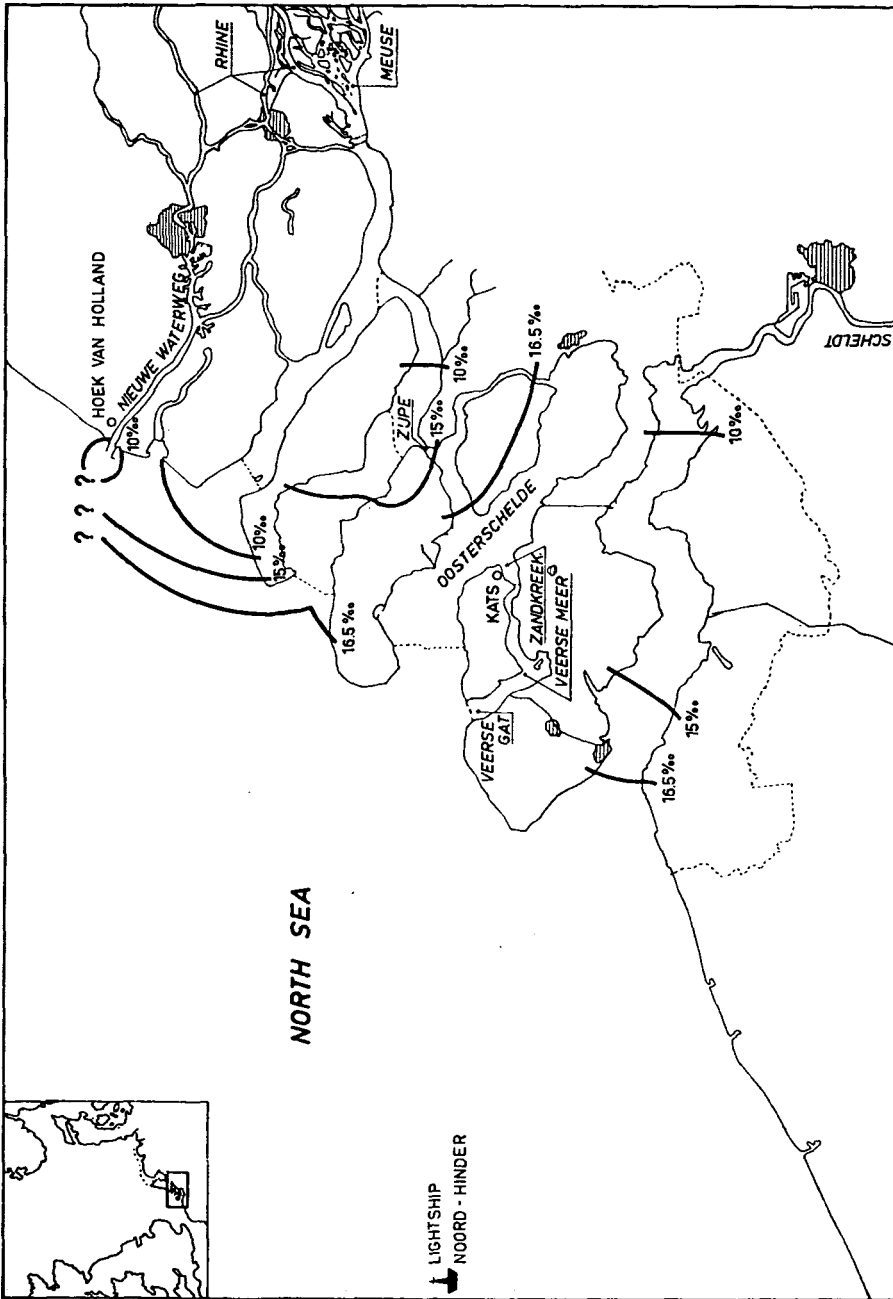


Fig.1. Map of the Delta area. Lines represent the mean positions of the isohalines of 10, 15, and 16.5‰ Cl'.

gether with harbour moles, oyster basins, and wrecks, these form the only firm substrates available in the area.

Water temperatures in the Oosterschelde (Eastern Scheldt) vary between 2–3°C in winter and about 20°C in summer and in the North Sea at the lightship Noord-Hinder between 4.5°C in winter and 17.4°C in summer.

The fairly strong tidal currents (up to 5 km/hr) in the area result in good vertical mixing of the waters; therefore, temperatures and salinities at the surface and at the bottom do not differ greatly. Maximal depths encountered are less than 60 m.

#### IV. MATERIAL AND METHODS

The material studied belongs to a large number of qualitative and quantitative samples taken all over the estuarine region of the rivers Rhine, Meuse, and Scheldt.

Qualitative samples were collected at almost every place where a firm substrate occurred in the littoral zone and also at several other littoral and sublittoral places.

Quantitative samples were collected by means of a 0.1 m<sup>2</sup> Van Veen grab used east of a line connecting the most westerly outcrops of the islands; the total number of samples amounted to about 1400. West of this line, 105 samples were taken with a 0.2 m<sup>2</sup> Van Veen grab along four straight lines at roughly right angles to the coast. East of the former line, the samples were taken in a density such that there is at least one sample for each square centimeter of water on the map, scale 1 : 1,000,000. We have also included the data obtained by fishing with a small shrimp-trawl, the net having a mesh-width of 0.8–1.5 cm. About 2000 hauls, each lasting 15 minutes and covering a stretch 1500 to 2000 m long and 3 m wide, were carried out between 1959 and 1967.

All quantitative grab samples were passed through a sieve with 1 mm-wide meshes after which they were carefully sorted by hand. The institute collection is preserved in the Zoological Museum of the University, Amsterdam.

#### V. SYSTEMATIC LIST OF THE SPECIES OCCURRING IN THE AREA INVESTIGATED

##### 1. *Astropecten irregularis* (Pennant, 1777) (Fig. 4)

*Astropecten irregularis*—Engel, 1932: 10, fig. 1.

The only specimens of this species ever captured in this area have already been mentioned by ENGEL (*l.c.*), and originated from the Zandkreek near Kats and from the Oosterschelde (perhaps the same locali-

ty). They were all found in 1902. This case probably concerns a temporary colonization of a basically unsuitable area. The species is also never caught by fishing boats in this area, although it is regularly washed ashore on the beach at Hoek van Holland (Hook of Holland), where it probably lives very close to the shore. The absence of *A. irregularis* from the Delta region can probably be explained by its temperature requirements. URSIN (1960) has shown that the species does not occur in places where the lowest winter temperature falls below 3° C, and in the estuaries of the Delta area the temperature in winter indeed frequently falls below 2° C (KORRINGA, 1941).

## 2. *Solaster papposus* (Linnaeus, 1767) (Fig. 4)

*Solaster papposus*—Engel, 1932: 17, fig. 5.

This species has been found twice in the Oosterschelde, the first time at an unknown locality, the second near St. Maartensdijk, also in 1902 (ENGEL, *l.c.*). Since this species is at least rare off the Dutch coast, its arrival there will probably never be explained. It certainly occurs only accidentally in the Dutch area. Because this species has no pelagic larvae (MORTENSEN, 1927), its absence from the Delta region is probably due to difficulties in accessibility, because it occurs on the English side of the Southern Bight of the North Sea (URSIN, *l.c.*). According to its temperature and salinity requirements, it certainly could occur in the Delta area.

## 3. *Asterias rubens* Linnaeus 1758 (Fig. 2)

*Asterias rubens*—Engel, 1932: 21, fig. 9.

*Asterias rubens* is by far the most common species in the Delta area. It is often a real pest in the oyster and mussel beds. Of all Dutch echinoderms it is certainly the species with the largest ecological range.

It occurs on almost all kinds of substrate except soft muds. Especially on breakwaters and stone-covered dikes it can be quite abundant between young mussels (*Mytilus edulis*), often with several specimens per square metre. Our grab samples from the North Sea, together covering 21 m<sup>2</sup>, contained only four small specimens, thus constituting an average density of 0.19 specimens per square metre, a high figure as compared to the values calculated by URSIN (1960) for offshore areas. It is nevertheless true that *A. rubens*, as indicated by URSIN (*l.c.*), is much commoner in coastal waters than offshore. Although we found

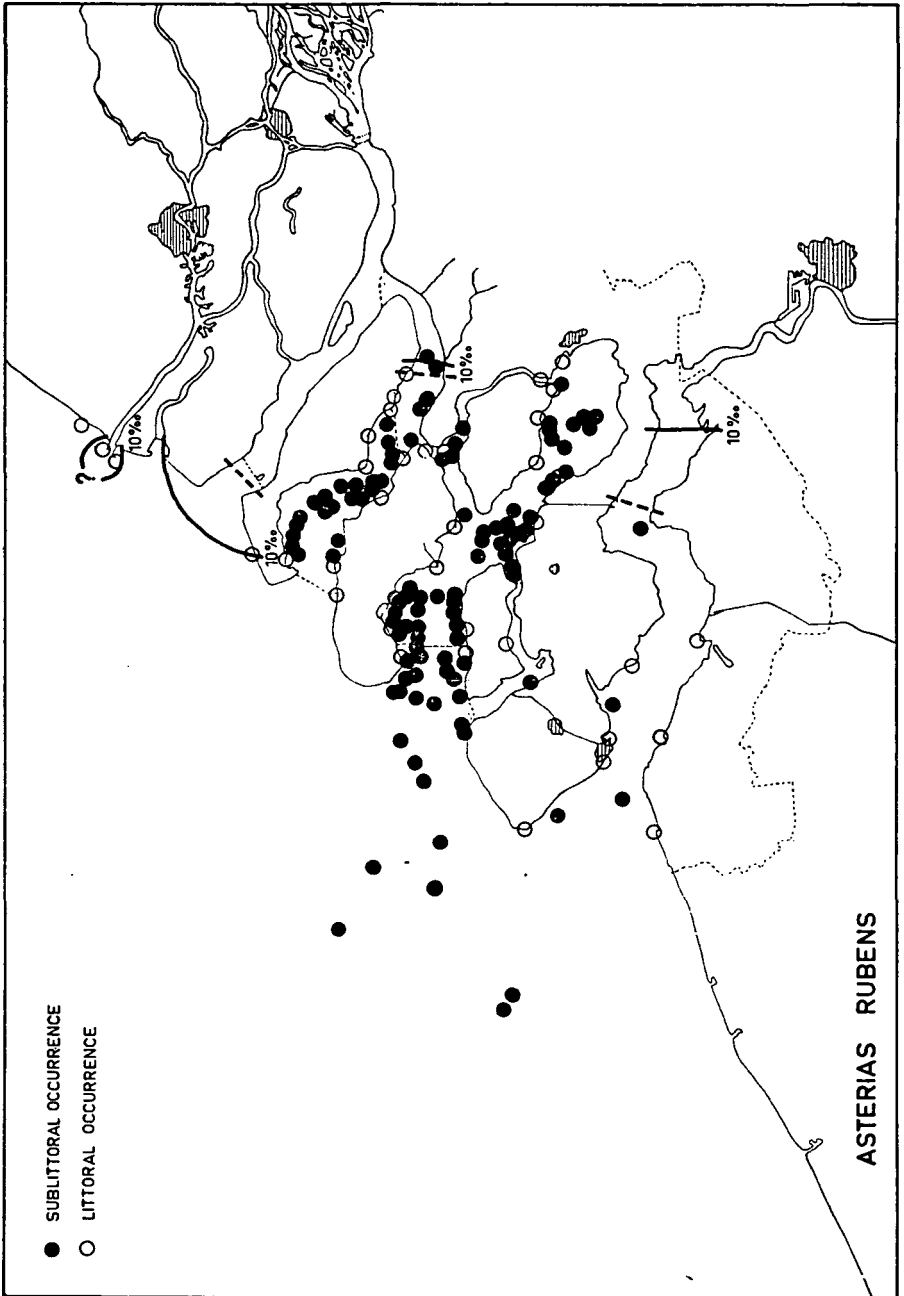


Fig.2. Distribution of *Asterias rubens*. The dashed line represents the boundary of the occurrence of mussels (*Mytilus edulis*).

*A. rubens* in the North Sea, it is not clear to me how it manages to live there on a substratum of shifting coarse sands.

Its vertical range is relatively large in our area; from the lower part of the tidal zone down to 48 m, the deepest place sampled. It is a remarkable fact that it still occurs in the littoral zone at its furthest inland localities where there are fairly strong influences of brackish water. Many species, e.g., the sea-urchin *Echinocardium cordatum* and the amphipod *Haustorius arenarius* (VADER, 1965), live near the North Sea both in the littoral and the sublittoral zones, whereas in more brackish environments they submerge to the sublittoral zone. This phenomenon is connected with a descent of euryhaline littoral species to lower levels in more brackish environments, e.g., the polychaete *Nereis diversicolor* (DEN HARTOG, 1961). As has already been noted, *Asterias rubens* does not perform a similar descent. From Fig. 2 it is evident that *A. rubens* reaches the 10‰ Cl' isohaline, which is also the boundary of its principal food *Mytilus edulis*. Therefore, it is difficult to say much about its salinity requirements. In the Veerse Meer, the lake formed by the damming up of the Zandkreek and the Veerse Gat, *Asterias rubens* occurred up to 1966, living in low numbers at salinities of about 13‰ Cl', albeit only in the vicinity of the locks to the Oosterschelde. However, according to KOWALSKI (1955), *A. rubens* is still found at a salinity of about 4.5‰ Cl' in the Baltic. The species continues to reproduce at a salinity of about 8‰ Cl'. Therefore, we may conclude that its distribution in the Delta area is probably limited by the occurrence of its principal food species *Mytilus edulis*.

#### 4. *Ophiothrix fragilis* (Abildgaard, 1789) (Fig. 3)

*Ophiothrix fragilis*—Engel, 1932: 30, fig. 13.

*Ophiothrix fragilis* is a common species in the Delta area. Its distribution is restricted, however, by the scarce occurrence of suitable substrates. It may be found wherever running water of high salinity keeps firm substrates free of silt and mud. According to observations of SCUBA divers (personal communication of Mr. H.A. van Vlimmeren), sometimes thousands of individuals can be seen here, filtering the plankton from the strong tidal currents in their peculiar manner (VEVERS, 1956; FONTAINE, 1965). The species is found on stones, in sponges, between the egg capsules of *Buccinum undatum*, between hydroids, on large molluscs, etc. On the basis of our observations we fully agree with URSIN's description of *O. fragilis* as "a decidedly current-dependent (rheophile) animal". Its absence in the samples from the Southern Bight of the North Sea, which has fairly strong tidal currents, as re-

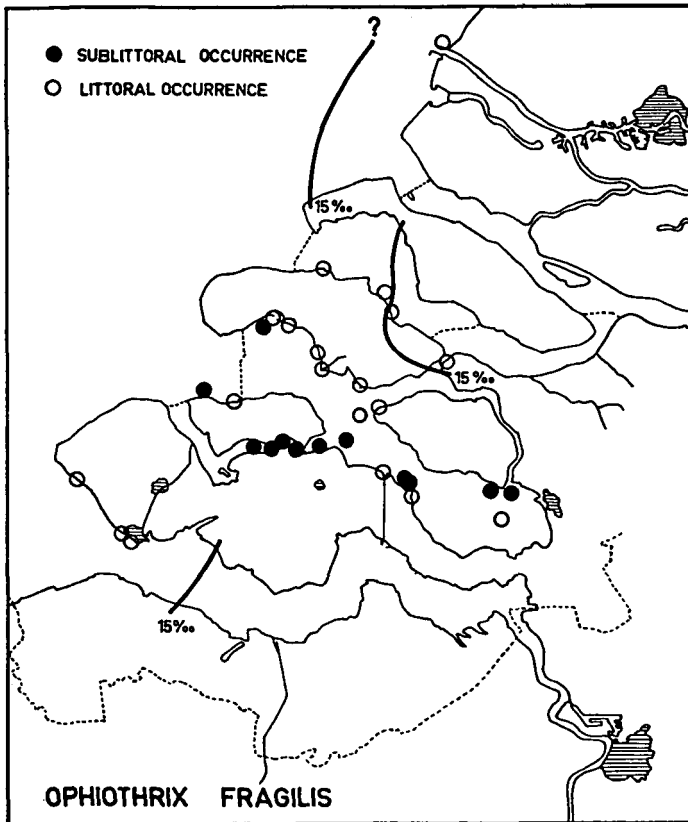


Fig.3. Distribution of *Ophiothrix fragilis*.

corded by URSIN (*l.c.*), may probably be explained by lack of suitable substrates.

The vertical range of *O. fragilis* is from about the MLWS-level to a depth of 44 m. In our area greater depths scarcely occur. *O. fragilis* was found in the Delta area at minimal salinities of about 15‰ Cl'. ENGEL (1932) recorded the species from a place with a minimal salinity of about 9.5‰ Cl'. According to ENGEL (1936) and VOLKER (1942), the mean salinity at that place amounted to 12–13‰ Cl'. Moreover, the specimens found were juveniles and had probably settled there in a period of still higher salinity. Since it is not known exactly when the observation was made, it is not possible to infer anything about the salinity before the observation. It is not justified, however, to assume that *O. fragilis* was able to live there at a salinity of 9.5‰ Cl'. When, in the winter of 1966, due to various causes the salinity in the Oosterschelde

dropped to about 10‰ Cl', *O. fragilis* disappeared. In the following summer, when normal salinities were restored, *O. fragilis* came back.

URSIN (*l.c.*), quoting ENGEL's records, is somewhat puzzled by his observation, but, as shown above, it can be explained satisfactorily.

Concerning the 3° C isotherm, forming the shoreward limit of *O. fragilis*, we may remark that the species is quite common in parts of the Dutch Wadden Sea and, also as mentioned above, in the estuaries of the Delta area, where the temperature often falls below 3° C. However, in the severe winter 1962-'63, when the temperature in the estuaries fell below 0° C, it was affected very seriously, so it is not completely impervious to low temperatures.

#### 5. *Amphipholis squamata* (Delle Chiaje, 1828) (Fig. 4)

*Amphipholis squamata*—Engel, 1932: 34, fig. 16.

*Amphipholis squamata* is one of the rarer species in the Delta area. In the eight years of collecting for the institute, it was never seen. Nevertheless, there are several records of this species from the Delta area; all these, however, were made before the severe winters of 1956 and especially of 1963. *A. squamata* being a viviparous species, it seems quite probable that the whole population was destroyed and that the species awaits a new introduction. The large imports of oysters and mussels from other areas will certainly favour this, as will *A. squamata*'s mode of hermaphroditism. The species has been observed in the following localities: Westkapelle (ENGEL, 1932); Yerseke (collection Zoological Museum, Amsterdam); Gorishoek, Tholen (SWENNEN, 1956). We have discarded an observation of a very juvenile specimen by LUCAS (1957) from the island of Schouwen in the summer of 1956.

The small number of observations does not permit extensive remarks on its ecology. *A. squamata* has only been found in the littoral zone and at high salinities (16–17‰ Cl'). Since in winter the temperature in the estuaries of the Delta area repeatedly falls below 3° C, this species must have a fairly low temperature limit.

#### 6. *Ophiura texturata* Lamarck, 1816 (Fig. 5)

*Ophiura texturata*—Engel, 1932: 37, fig. 12b.

*Ophiura texturata*, together with *Ophiothrix fragilis*, is the most common ophiurid of the estuaries of the Delta area. It can be found in many places with a mean salinity above about 15‰ Cl'. In the Oosterschelde the species is most common in the western part, where adult specimens

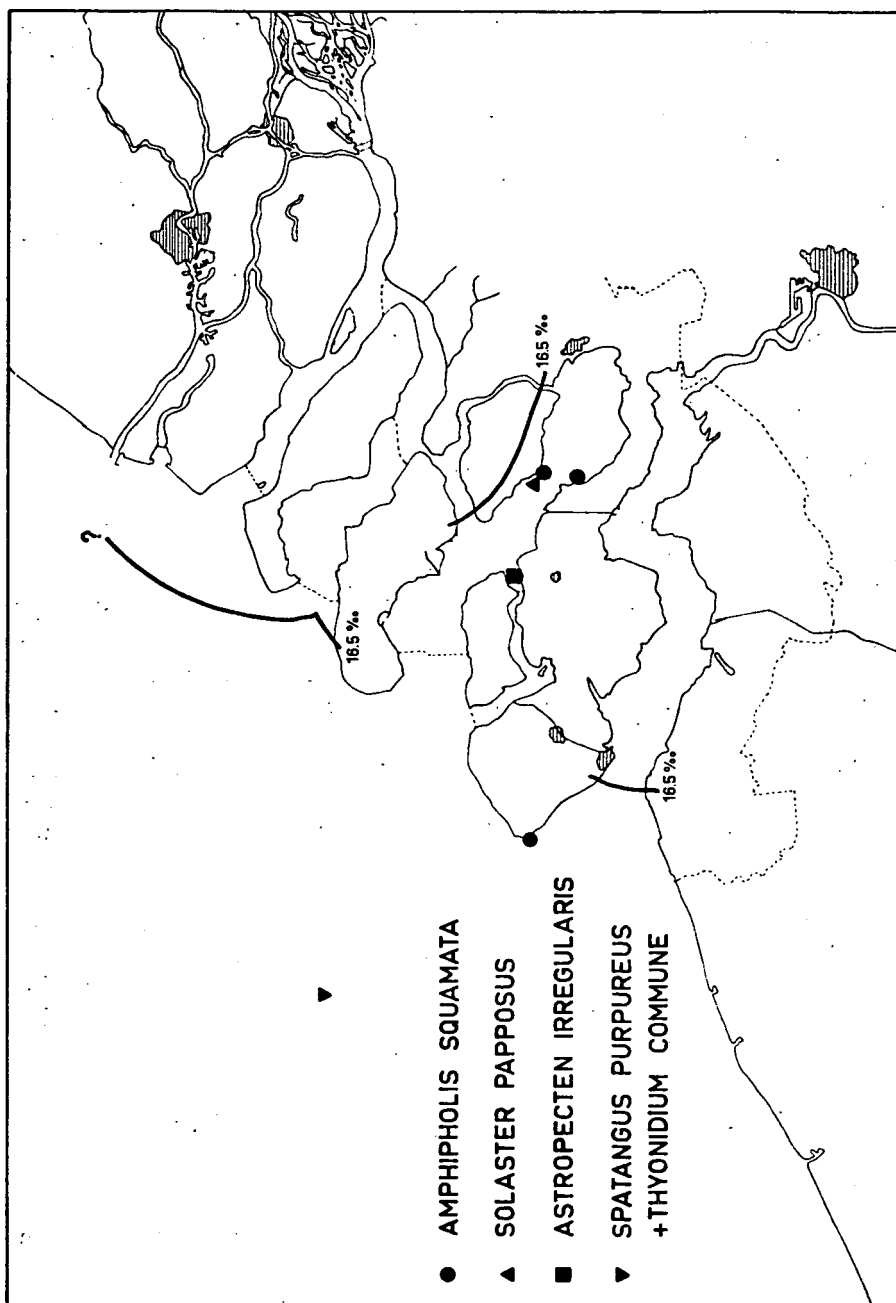


Fig.4. Distribution of *Amphipholis squamata*, *Solaster papposus*, *Astropecten irregularis*, *Spatangus purpureus*, and *Thyonidium commune*.

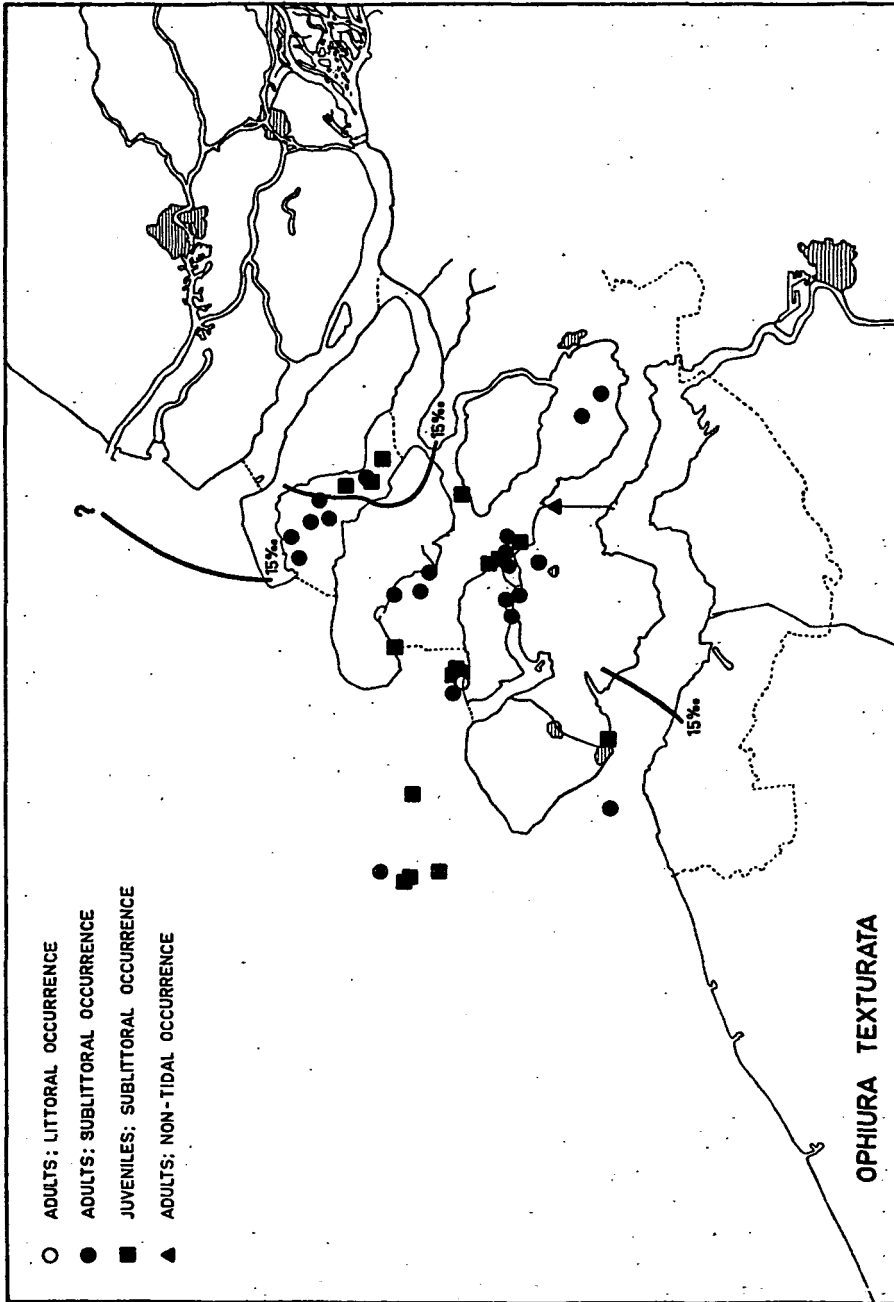


Fig.5. Distribution of *Ophiura texturata*.

are often caught. More to the east, juveniles are still fairly common but adults are only found after a series of warm summers and temperate winters. It therefore seems that this species normally lives at the entrances of the estuaries but that it may be able to colonize waters further inland in favourable years. The low winter temperatures and temporary influxes of brackish water probably impede permanent occurrence. KRISTENSEN (1957) recorded for the Dutch Wadden Sea that *O. texturata* is able to colonize parts of this area in some years, but that its occurrence there too is not permanent. It must therefore be concluded that *O. texturata* does not inhabit the shallowest coastal waters of the North Sea. URSIN's records (*l.c.*) of its occurrence in the German and Danish Wadden Sea probably also concern cases of a temporary nature or were made at the entrances of the tidal inlets. On the other hand, we too failed to find *O. texturata* far offshore, where it is replaced by *O. albida* and *O. affinis*. URSIN (*l.c.*) also did not find it in large numbers offshore. Therefore, we prefer to conclude that *O. texturata* is a coastal form. Its occurrence in coastal areas is facilitated by its fairly large salinity range (11 to 17‰ Cl') and by its tolerance to high temperatures (URSIN, *l.c.*). Of the three species of *Ophiura* occurring in the coastal waters of The Netherlands, *O. texturata* is undoubtedly the one that occurs nearest to the coast. This is obvious from our maps and also from fact that *O. texturata* is washed ashore regularly. *O. albida* and *O. affinis*, to the contrary, are never washed ashore (personal observations).

Although its extension far inshore may be explained by *O. texturata*'s wide ecological range with respect to temperature and salinity as compared to the other species, it is difficult to explain its decrease in the offshore direction. This could be due to competition with *O. albida*, which is less tolerant of high temperatures and therefore cannot approach so close to the coast. If we consider the maps of URSIN (*l.c.*), the hypothesis of competition between *O. texturata* and *O. albida* seems even more probable. *O. albida* occurs mainly in the central North Sea on all grades of sediment, but with fairly constant low bottom-temperatures, whereas *O. texturata* lives especially in the coastal waters of the North Sea, also on all grades of sediment, but with high summer temperatures of the water.

We observed *O. texturata* on sediments with a median grain-size ranging from 100 to 220  $\mu$ . Its vertical range as found by us is from about low tide level to 32 m.

Juvenile specimens were sometimes encountered living on the beach. Its occurrence in the tidal zone is also recorded by URSIN (*l.c.*). It seems useful to conclude with a few comments on the identification of very juvenile *Ophiura*'s. Our identification of juvenile specimens was

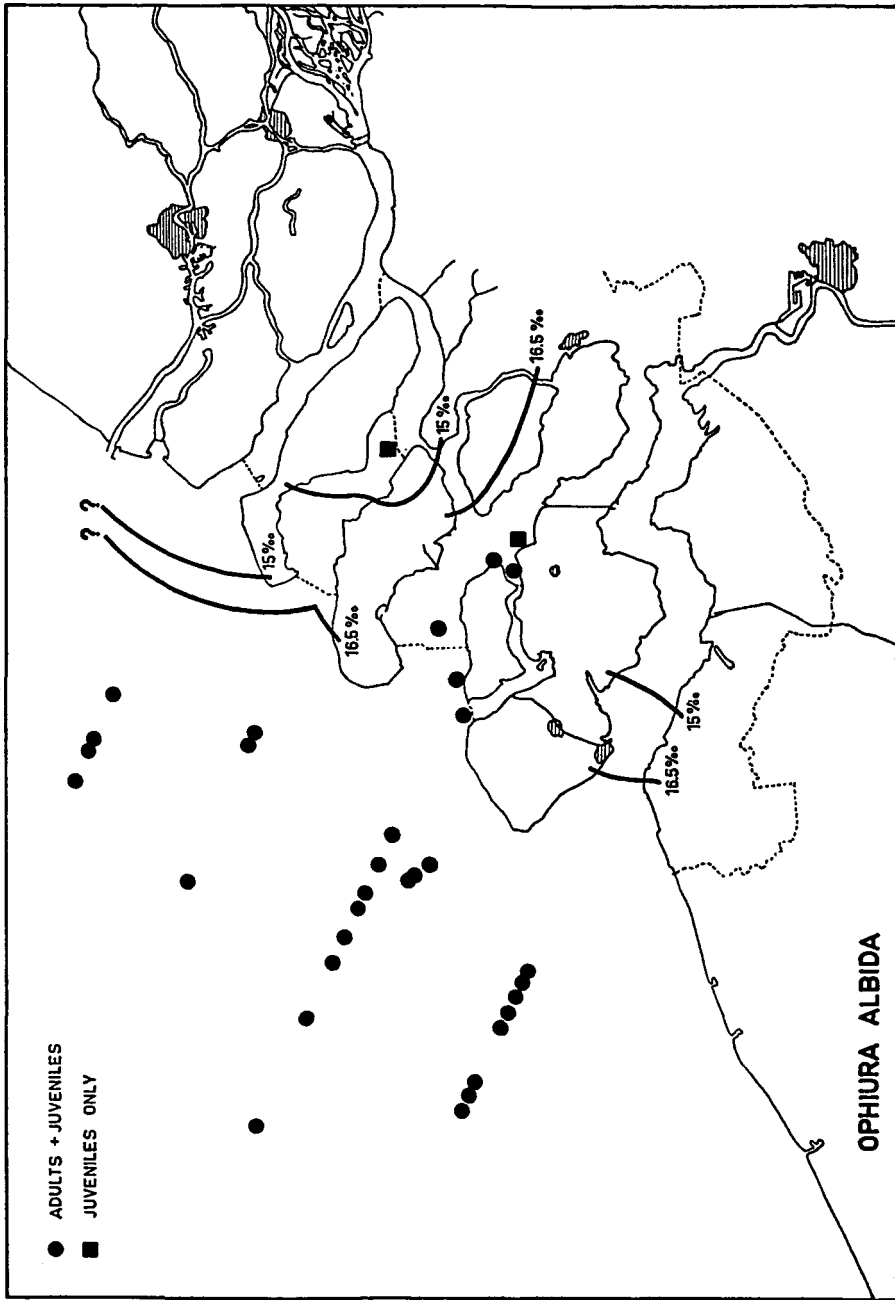


Fig.6. Distribution of *Ophiura albida*.

based on the following characters and on the assumption that juveniles were found only of those species of which adults were met with in our area.

When the diameter of the disk is about 1 mm, the number of arm-segments is 9 to 10 for *O. affinis*, but only 6 to 8 for *O. texturata* and *O. albida* of comparable size. Moreover, the disk of *O. affinis* is perfectly circular, contrary to the other two species which have a disk with notches above the bases of the arms.

The dorsal armplates of these small specimens are triangular and widely separated in *O. texturata* and *O. albida* (cf. URSIN, 1960), but more or less quadrangular and adjoining in the proximal segments of *O. affinis*. In these stages we were not able to separate *O. texturata* and *O. albida*.

Slightly larger *O. albida* could be identified properly using the very characteristic first dorsal armplate, which becomes heart-shaped at a fairly early stage. The number of papillae on the outer armcomb is still low in this stage (4-7), and much smaller than in *O. texturata* of comparable size. The latter species reaches during its development fairly soon a number of papillae on the outer armcomb exceeding 10-12, thus undoubtedly proving its identity, as adult *O. albida* has only about 12 papillae.

*O. texturata* of the same size is moreover characterized by the concave distal edge of the first ventral armplate and in later stages of course by the very conspicuous pores between the central arm plates.

### 7. *Ophiura albida* Forbes, 1839 (Fig. 6)

*Ophiura albida*—Engel, 1932: 39, fig. 12c.

*Ophiura albida* is decidedly less common in the Delta area proper than *O. texturata*, unlike its occurrence offshore where *O. texturata* seems to be the rarer species. In the Delta area adult specimens occur only in the large tidal channels, but are never found above a depth of 8.5 m. Juveniles were found further inland, but their minimal depth still amounted to 6.5 m, unlike the juveniles of *O. texturata* which even occur between the tidemarks. The fact that *O. texturata* is regularly washed ashore, whereas this has never been observed for *O. albida*, also points to an occurrence of *O. albida* in deeper water. URSIN (*l.c.*) also states that it does not occur in very shallow coastal waters. He put forward the hypothesis that *O. albida* is unable to stand the rapid changes of salinity and temperature occurring in a tidal coastal area. Our data support this hypothesis. The occurrence of *O. albida* offshore in the southern part of the North Sea, together with the absence of *O. texturata*

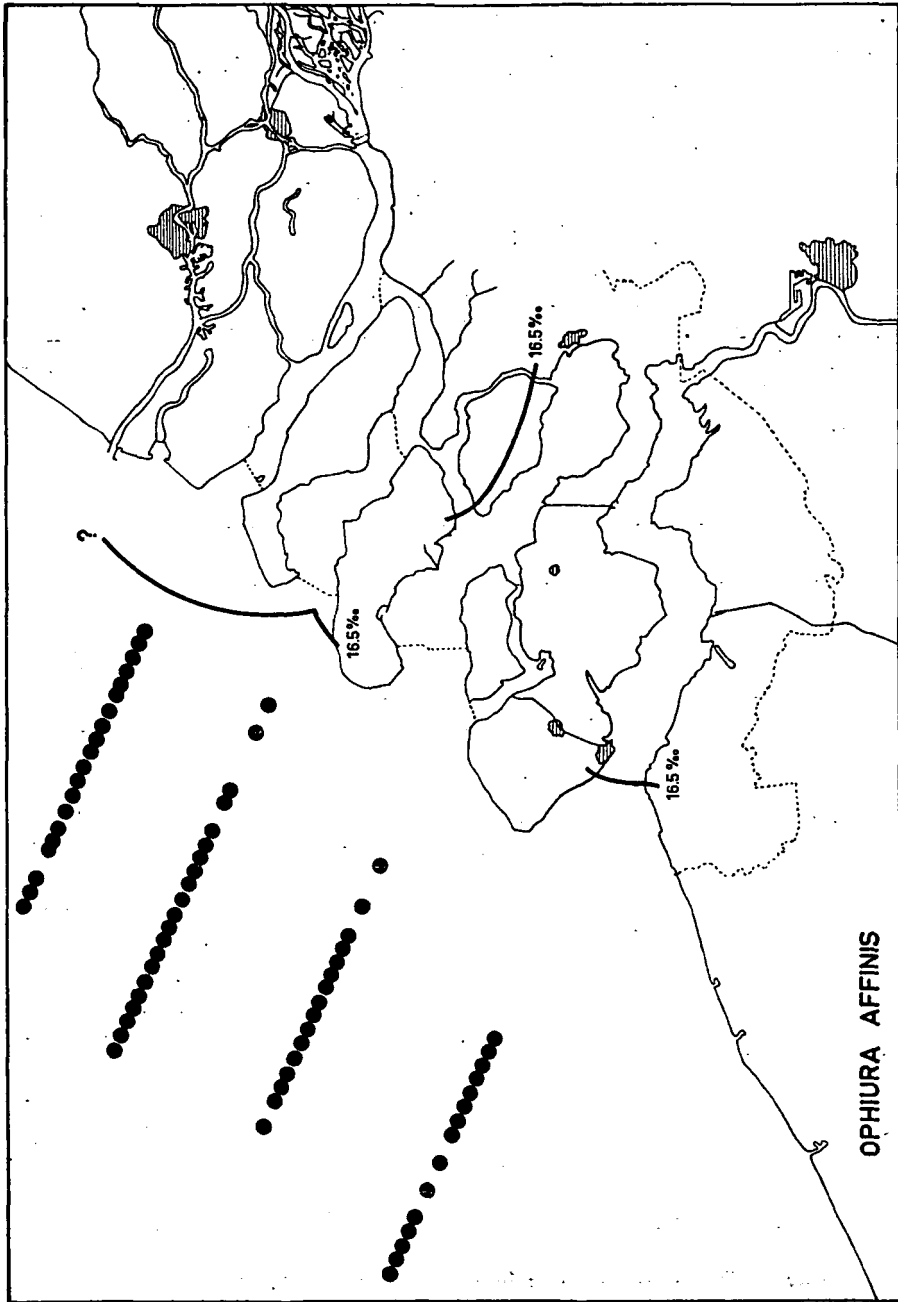


Fig.7. Distribution of *Ophiura affinis*.

offshore, might be explained by the presence of some kind of competition between these species. On the other hand, with increasing distance from the shore *O. albida* is gradually replaced by *O. affinis*. This may be a result of the increasing coarseness of the bottom sediments in an offshore direction.

The vertical range for adults of *O. albida* is from 8.5 m to 34 m, few deeper places having been sampled. Adults were not observed at salinities below 16.5‰ Cl', although young individuals seem to occur at slightly lower values.

ENGEL (1936) records 14.1‰ Cl' as the lowest value at which *O. albida* was observed. BRATTSTRÖM (1941), however, records the occurrence of *O. albida* in mean salinities of about 11‰ Cl', but in the area investigated by this author rapid changes of salinity do not occur.

*O. albida* was found on various sediments with median grain-sizes ranging from 100  $\mu$  to 430  $\mu$ .

### 8. *Ophiura affinis* Lütken, 1859 (Fig. 7)

*Ophiura affinis*—Mortensen, 1927: 244, fig. 84 (part), fig. 132.

*Ophiura affinis* is mentioned here for the first time from Dutch coastal waters. It appeared to be quite common at a distance of 10 to 15 km offshore, living there together with *O. albida*, *Echinocardium cordatum*, and especially *Echinocyamus pusillus*. Only SÜSSBACH & BRECKNER (1911) found it near the Dutch coast (53°11'N, 4°19' E), but this find went unnoticed in The Netherlands.

*O. affinis* was found from a depth of 14 m to the deepest places sampled in the North Sea (36 m). Its occurrence seems to be connected with relatively coarse sediments, since the median grain-sizes of the samples containing the species vary between 210  $\mu$  and 530  $\mu$ . It is also possible that *O. affinis* is unable to support brackish water, because all our localities have a mean salinity above about 17‰ Cl'. Apparently this is also the case for the localities mapped by URSIN (*l.c.*).

The question arises whether *O. affinis* has consistently been overlooked in the Dutch coastal waters or whether we carried out our sampling during a period of high densities, URSIN (*l.c.*) having recorded strongly fluctuating densities for this species. Further sampling in the same area may provide an answer to this question.

### 9. *Psammechinus miliaris* (Gmelin, 1778) (Fig. 8)

*Psammechinus miliaris*—Engel, 1932: 46, fig. 17 no. 1, fig. 18.

In some years *Psammechinus miliaris* is a very common species in the

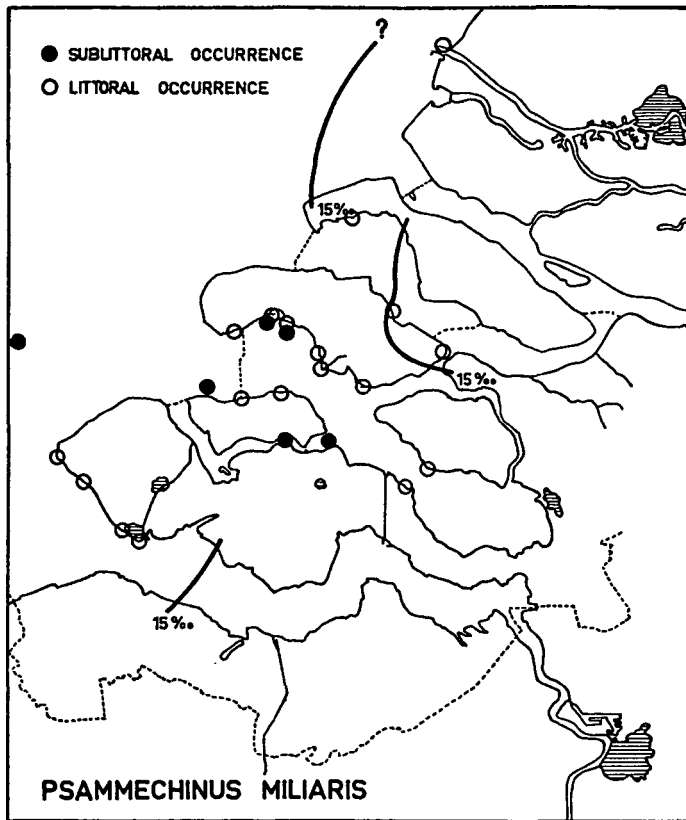


Fig.8. Distribution of *Psammechinus miliaris*.

Delta area. Its numbers fluctuate strongly; it may be absent for a couple of years and then again be present in large numbers wherever conditions are suitable. It was very common in the period from 1949 to 1951 and again in 1958–1962. The severe winter in 1963 apparently destroyed almost the entire population of this species, and since then it has not been observed again in substantial numbers.

In the Zijpe, *P. miliaris* approached the 15‰ Cl' isohaline. ENGEL (1936) records a minimal salinity of 14.8‰ Cl' at which *P. miliaris* was observed. (The salinity of 15‰ mentioned in his 1932 paper should apparently be expressed in ‰ Cl'). Nevertheless, URSIN (*l.c.*) records a minimal salinity of 11‰ Cl' reached by *P. miliaris* in the Lille Bælt. As DEN HARTOG (1964) pointed out, however, there is a striking difference between the salinity tolerance of a species in the Baltic area and in an estuary. In the latter the minimal value endured by a species usually

lies at a much higher level, as seems to be the case for *P. miliaris*. *P. miliaris* can be quite common in the tidal zone, but it may also be found at lower levels down to a depth of 8 m. We did not find it at greater depths, but this was probably due to our methods of collecting, since MORTENSEN (1927) records it from a maximum depth of 100 m.

#### 10. *Echinocyamus pusillus* (O. F. Müller, 1776) (Fig. 9)

*Echinocyamus pusillus*—Engel, 1932: 52, fig. 19.

*Echinocyamus pusillus* is washed ashore in fairly large numbers, but always only as empty tests. At a distance of 10 to 15 km offshore, however, it lives, together with *Ophiura affinis*, in large numbers in water of fairly high salinity (above 17‰ Cl').

All observations are from relatively coarse sands with a medium grain-size ranging from 210  $\mu$  to 460  $\mu$ . The depth of the sampling locations lies between 18 m and 34 m.

Since the same conditions are also found in the estuaries, it is not quite clear why this species is absent from the Delta area. From URSIN (*l.c.*) we conclude that it has a fairly large ecological range, occurring on sandy as well as on muddy deposits, tolerating a minimal temperature of 0° C and a minimal salinity of about 11‰ Cl'. We suppose, however, that the species is normally restricted to coarse sands and gravelly sediments, but that in some years the larvae for some unknown reason may also settle on less suitable substrates, *viz.*, muddy sands. This would explain the unusual extension of the species in the North Sea in 1951–52 (URSIN, *l.c.*).

#### 11. *Spatangus purpureus* (O.F. Müller, 1776) (Fig. 4)

*Spatangus purpureus*—Engel, 1932: 54, fig. 20.

We obtained only one specimen of *Spatangus purpureus*, about 30 km offshore, but of course no conclusions can be drawn from this single case. It is an interesting phenomenon that this species, which according to many earlier authors was fairly common along the coast of the Netherlands (ENGEL, *l.c.*), is at present rare in Dutch coastal waters. No reason for this decrease is known.

#### 12. *Echinocardium cordatum* (Pennant, 1777) (Fig. 10)

*Echinocardium cordatum*—Engel, 1932: 56, fig. 21.

*Echinocardium cordatum* is a common species both in the euhaline part of the estuaries and in the Southern Bight of the North Sea. In the sandy parts of the large tidal channels it can be obtained very easily.

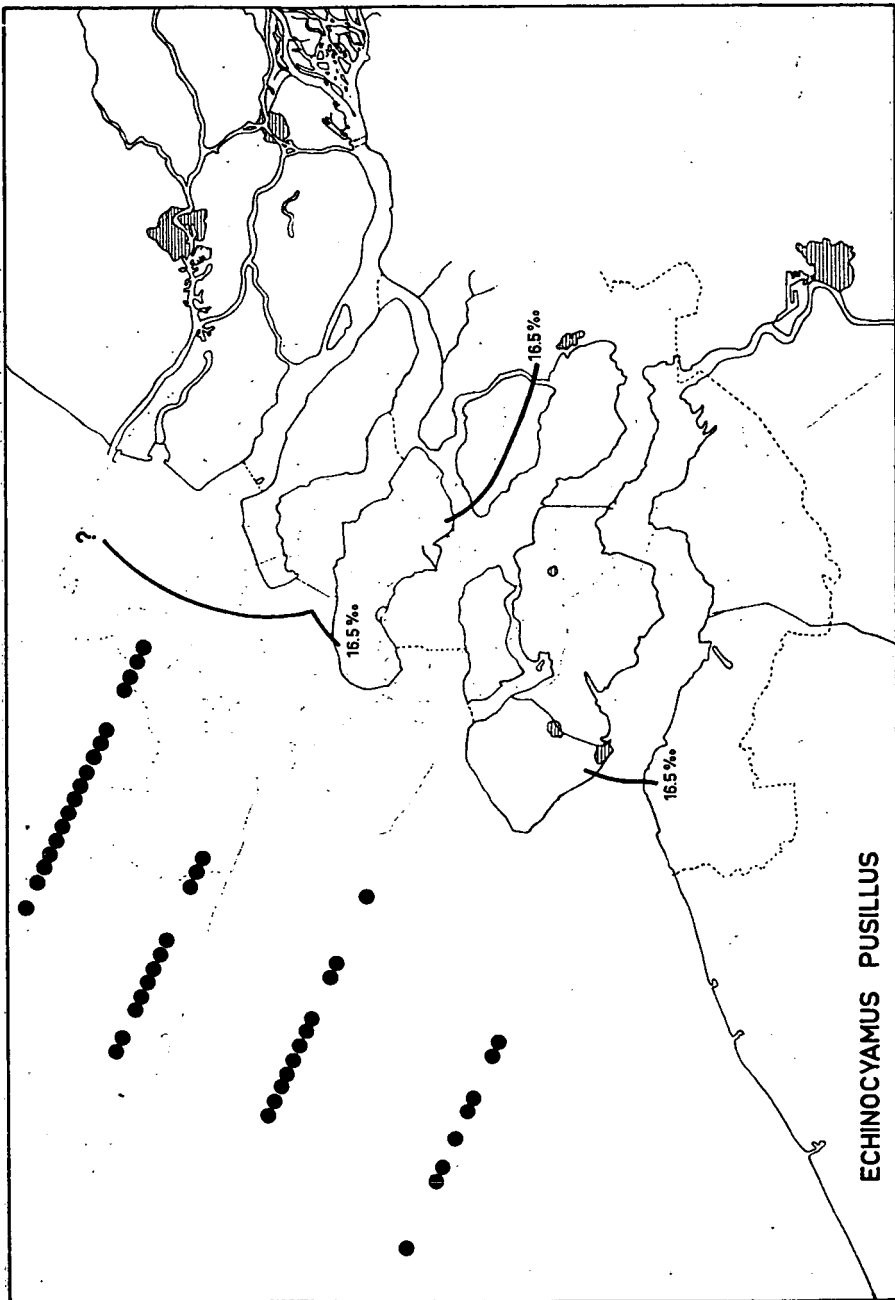


Fig.9. Distribution of *Echinocyamus pusillus*.

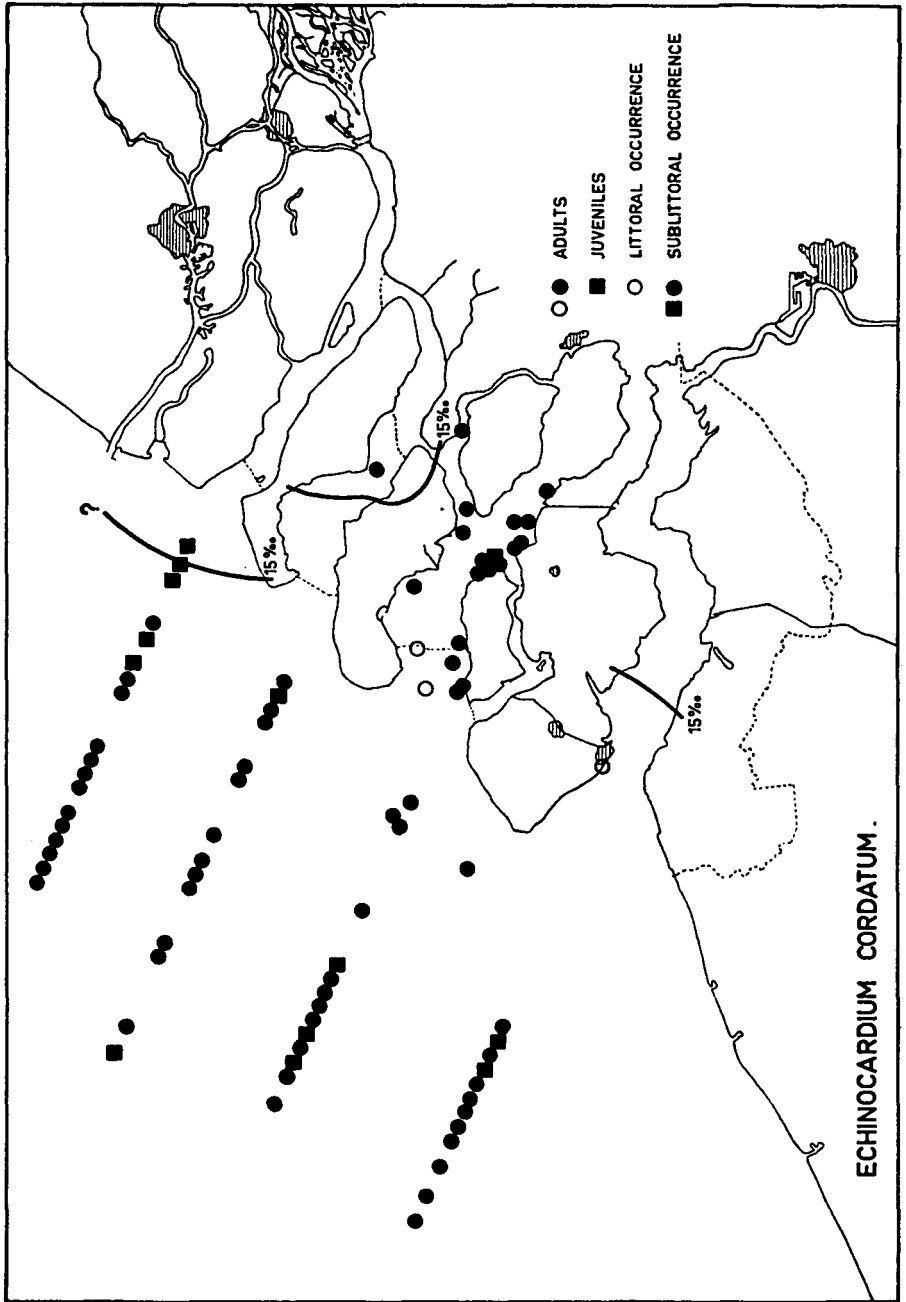


Fig.10 Distribution of *Echinocardium cordatum*.

It is an interesting phenomenon that *E. cordatum* occurs in the tidal zone on some sandflats exposed to wave-action, at the entrances of the Oosterschelde and the Westerschelde. Further inland, however, the species is not found above the low-water level. This is probably due to the higher silt and clay content of the intertidal areas further inland (compare BUCHANAN, 1966). The same phenomenon is also known for the amphipods *Haustorius arenarius* and *Bathyporeia pelagica* (VADER, 1965). In view of URSIN's statement (*l.c.*) that *E. cordatum* does not penetrate into the Wadden Sea, it is remarkable that it occurs so abundantly in the Delta area. We are unable to offer an explanation for this phenomenon.

*E. cordatum* penetrates to about the 15‰ Cl' isohaline in the estuaries of the Delta area, although URSIN (*l.c.*) records it from about 11‰ Cl'. Here again, however, the difference between an estuary and the gradually decreasing salinity in non-tidal water is concerned. *E. cordatum* was found at depths of between 0 and 35 m, few deeper places having been sampled.

The medium grain-size of the sediments in which *E. cordatum* was found, ranges from 100  $\mu$  to 450  $\mu$ . The data of BUCHANAN (*l.c.*) fall in this range. As BUCHANAN also remarked, the distribution of *E. cordatum* indeed seems to be fairly independent of the type of sediment, although it is absent in soft muds.

### 13. *Thyonidium commune* (Forbes, 1841) (Fig. 4)

*Thyonidium commune*—Mortensen, 1927: 412, fig. 250.

Our specimens of *Thyonidium commune* were taken by a trawl-fisher about 30 km offshore (Buitenbank). These are apparently the first records from the Southern Bight of the North Sea.

## VI. DISCUSSION

The Delta area and the adjacent part of the North Sea prove to be poor in species. Not counting those recorded only once or twice, only ten species of echinoderms inhabit this region. In the Delta area this may be due to the coastal environment: the water covering extensive areas of shallows during flood may undergo rapid changes in temperature. Moreover, this shallowness leads to higher water temperatures in summer and lower ones in winter as compared to the adjacent part of the North Sea. Temperature conditions in the Delta area are therefore fairly extreme as compared to the North Sea.

Salinity conditions there are also less favourable for echinoderms. In the first place, these coastal waters always have a slightly lowered salinity. Moreover, temporary influxes of brackish and even of fresh water occur at irregular times, especially in spring and winter. Hence, mean salinity is lower and relatively larger salinity fluctuations occur in the Delta area than in the North Sea.

Because the water of the shallow flats runs through the large tidal channels (up to 50 m deep) during falling tide, essentially the same conditions prevail there as in the shallows: rapid changes of temperature, extreme values of winter and summer temperatures, a rather low mean salinity, and fairly large fluctuations in salinity. Therefore, conditions at a depth of 30 m somewhere in the Delta area are quite different from those at the same depth somewhere in the central North Sea. For this reason many sublittoral species do not occur in the Delta area, although at first glance circumstances would seem to be favourable. KUDERSKII (1964) describes a very similar situation in the White Sea, and explains it on the basis of the same factors.

The adjacent part of the North Sea has more stable temperature and salinity conditions, but has the disadvantage of a substratum of shifting coarse sands. Only very few species of echinoderms seem to be adapted to such an environment. Moreover, it should be borne in mind that the Southern Bight of the North Sea may seem to be a stable environment when compared to the Delta area, but if its environmental conditions are compared with the northern North Sea, for example, it still is a rather unstable area with adverse conditions for echinoderms.

In the estuaries of the Delta area only three species occur commonly on loose substrates: *Asterias rubens*, *Ophiura texturata*, and *Echinocardium cordatum*. On hard substrata are observed: *Asterias rubens*, *Ophiothrix fragilis*, (*Amphipholis squamata*), and *Psammechinus miliaris*. *Asterias rubens* occupies a more or less intermediate position due to its large ecological range.

In the adjacent North Sea, where only loose sediments are available, the following species are found: *Ophiura albida*, *O. affinis*, *Echinocyamus pusillus*, *Echinocardium cordatum*, and in low numbers probably also *Asterias rubens* and *Astropecten irregularis*.

It is not surprising to see that all species abundant in the Delta region are among those assigned by URSIN (*l.c.*) to the species common in the southern North Sea.

#### VII. LIST OF THE ECHINODERMS FOUND ALONG THE COAST OF THE NETHERLANDS, UP TO A DISTANCE OF ABOUT 30 km OFFSHORE

Since the publication of ENGEL's (1932) paper, as many as nine species new to the Dutch fauna have been found along the coasts of The

Netherlands and it therefore seems useful to give a list of the species presently known to occur in this area. We think it preferable to exclude the following species from the Dutch list, because ENGEL already questioned their occurrence and since then no other specimens have been found: *Luidia sarsii* Düben & Koren, 1845; *L. ciliaris* (Philippi, 1837); *Solaster endeca* (Linnaeus, 1771); *Henricia sanguinolenta* (O.F. Müller, 1776); *Stichastrella rosea* (O.F. Müller, 1788); *Ophiopholis aculeata* (Linnaeus, 1766); *Amphiura filiformis* (O.F. Müller, 1776); *Strongylocentrotus droebachiensis* (O.F. Müller, 1776); *Echinocardium flavescens* (O.F. Müller, 1776); *Brissoopsis lyrifera* (Forbes, 1841); *Cucumaria planci* Von Marenzeller, 1874; *Thyone fusus* (O.F. Müller, 1788); *Psolus phantapus* (Strussenfeldt, 1765), and *P. squamatus* (Koren, 1844).

*Antedon bifida* (Pennant, 1777)\*

Juvenile stages occurring on floating objects have been found washed ashore several times. On the basis of the seaweeds washed ashore at the same time, these specimens probably originated from the English Channel. This species is not known to occur autochthonously on the coast of the Netherlands. The material is preserved in the Rijksmuseum van Natuurlijke Historie in Leiden and in the Zoölogisch Museum in Amsterdam (ANONYMOUS, 1942; STOCK, 1948).

*Solaster papposus* (Linnaeus, 1767)

Very rare along the coast of the Netherlands. Most records probably originate from material carried from the northern part of the North Sea to the Dutch coast by fishermen, although we would not exclude the possibility that the species lives in low densities in the vicinity of the Dutch coast.

*Astropecten irregularis* (Pennant, 1777)

Fairly common in the coastal waters of the Netherlands. Nevertheless, very rare in the Waddensea and the estuaries of the Delta area.

*Marthasterias glacialis* (Linnaeus, 1758)\*

Known only from a single specimen obtained from the harbour of Scheveningen in 1928 (LACOURT, 1938). This individual was probably caught by a fishing boat in the northern part of the North Sea and transported to the coast of the Netherlands. It certainly does not occur autochthonously in Dutch coastal waters.

*Asterias rubens* (Linnaeus, 1758)

Very common in the coastal waters of the Netherlands and also in the Wadden Sea and the estuaries of the Delta area.

\* Species not previously recorded by Engel (1932) are marked with an asterisk.

*Hippasteria phrygiana* (Parelius, 1768)\*

The collections of the Rijksmuseum van Natuurlijke Historie in Leiden include one specimen, washed ashore near Noordwijk aan Zee in 1938. This specimen was probably also caught by a fishing boat in the northern part of the North Sea and transported to the Dutch coast. This species certainly is not autochthonous (WOLFF, 1965).

*Asterina gibbosa* (Pennant, 1777)\*

Washed ashore twice on stipes of *Himantalia lorea*. Since this alga does not occur in the southern part of the North Sea, it must have originated from the English Channel, bringing *Asterina gibbosa* with it. This species apparently does not occur autochthonously in the coastal waters of The Netherlands. The material, collected by Mr. J.A.J. Metz, is preserved in the collection of the Hydrobiologisch Instituut, afd. Delta-Onderzoek, in Yerseke (WOLFF, 1965).

*Acrocnida brachiata* (Montagu, 1804)\*

Two specimens were obtained simultaneously from the stomach of a sole caught near the island of Texel on 5 July 1956. The material is preserved in the Rijksmuseum van Natuurlijke Historie in Leiden. SPAINK (1958) referred to the same specimens, when he recorded this species from Den Helder.

*Ophiothrix fragilis* (Abildgaard, 1789)

Common species on firm substrates in the coastal waters, the Wadden Sea and the estuaries of the Delta area.

*Ophiactis balli* (Thompson, 1840)\*

Once (1938) found washed ashore on a piece of cinder. The material is preserved in the Rijksmuseum van Natuurlijke Historie in Leiden. The species is not autochthonous in Dutch coastal waters (STOCK, 1948).

*Amphipholis squamata* (Delle Chiaje, 1828)

Rather commonly washed ashore on floating objects. Rare on dikes and moles in the Wadden Sea, along the North Sea, and in the estuaries of the Delta area.

*Amphiura chiajei* (Forbes, 1843)\*

Once found washed ashore on a piece of latex on the island of Texel on 23 July 1963. The material, collected by Mr. W. Luijt, is preserved in the collection of the Hydrobiologisch Instituut, afd. Delta-Onder-

zoek, in Yerseke. This species does not occur autochthonously in the Dutch coastal waters.

*Ophiura texturata* Lamarck, 1816

Common species in the coastal waters of The Netherlands. It penetrates in some years into the Wadden Sea and is fairly common in the estuaries of the Delta area.

*Ophiura albida*, Forbes, 1839

Fairly common species in the coastal waters of The Netherlands. Some specimens have been found in the entrances of the estuaries of the Delta area.

*Ophiura affinis* Lütken, 1859

SÜSSBACH & BRECKNER (1911) recorded a specimen from 53°11'N, 4°19'E. We found it in large numbers 10 to 15 km offshore in the southern part of the North Sea (this paper).

*Psammechinus miliaris* (Gmelin, 1778)

In some years a very common species in the Wadden Sea, coastal waters of the North Sea, and the estuaries of the Delta area.

*Echinus esculentus* Linnaeus, 1758

No records of observations since the publication of ENGEL (1932). Possibly most of the older records concerned material brought ashore by fishing boats from the northern North Sea, although we would not exclude the possibility of some autochthonous occurrences in earlier years.

*Echinocyamus pusillus* (O.F. Müller, 1776)

Common species in the Southern Bight of the North Sea, about 15 km offshore. Empty tests are washed ashore frequently.

*Spatangus purpureus* (O.F. Müller, 1776)

Sparsely distributed in the North Sea, but not very close to the shore. The species may have declined in numbers since the nineteenth century.

*Echinocardium cordatum* (Pennant, 1777)

Very common species in some parts of the Wadden Sea, the coastal waters of the North Sea, and the estuaries of the Delta area.

*Thyonidium commune* (Forbes, 1841)

In this paper recorded for the first time from the Southern Bight of the North Sea, about 30 km from the island of Schouwen (Buitenbank).

The specimens are preserved in the collection of the Hydrobiologisch Instituut, afd. Delta-Onderzoek, in Yerseke.

*Cucumaria frondosa* (Gunnerus, 1767)

In 1899 one specimen was found northwest of the island of Texel, according to REDEKE (1899). Since no description is given, the material was apparently not preserved, and the species is absent from the southern and central parts of the North Sea according to URSIN (*l.c.*), this record can better be discarded.

### VIII. SUMMARY

The ecology and distribution in the Delta area (The Netherlands) are described for the echinoderm species *Astropecten irregularis*, *Solaster papposus*, *Asterias rubens*, *Ophiothrix fragilis*, *Amphipholis squamata*, *Ophiura texturata*, *O. albida*, *O. affinis*, *Psammechinus miliaris*, *Echinocyamus pusillus*, *Spatangus purpureus*, *Echinocardium cordatum*, and *Thyonidium commune*.

A list is given of the species of echinoderms occurring in Dutch coastal waters.

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