Ingvar Kristensen

A QUANTITATIVE INVESTIGATION OF THE ECHINODERM FAUNA OF THE CENTRAL NORTH SEA

BY

ERIK URSIN

Reprint from

MEDDELELSER FRA
DANMARKS FISKERI- OG HAVUNDERSØGELSER
NY SERIE, BD. 2, NR. 24

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C. A. REITZELS FORLAG
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1960

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København, den 30. december 1959.

H. H. Ussing
h. a. dec.

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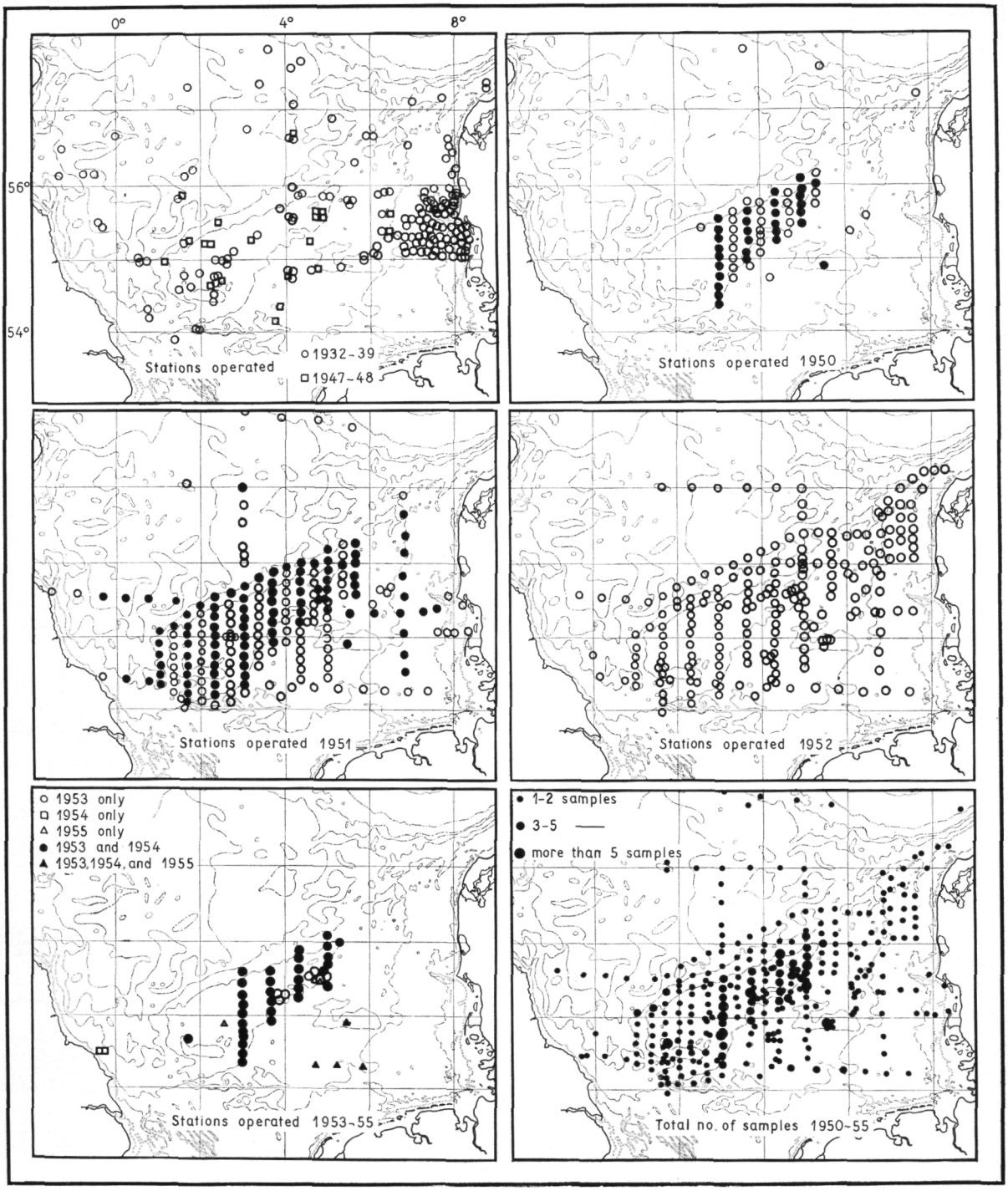

Fig. 1. Grab stations operated by Danish research ships in 1932-55. Full dots on the 1950 chart indicate the situation of 30 stations operated in April-May of each of the years 1950-54. Full dots on the 1951 chart indicate 120 stations operated in April-May 1951 and 1952. A few stations situated north or south of the area covered by the charts are omitted.

A Quantitative Investigation of the Echinoderm Fauna of the Central North Sea.

Introduction.

Material.

Bottom samples. The material was collected by Danish research vessels, primarily the "Dana", in 1932—55. Until 1948 a 0.2 m² PETERSEN bottom sampler was usually employed. In 1948 a 0.2 m² modified VAN VEEN bottom sampler with fixed chains was introduced. Small numbers of samples were collected by means of 0.1 m² samplers of PETERSEN's, VAN VEEN's and KNUDSEN's design. The big PETERSEN and VAN VEEN grabs and the KNUDSEN sampler were pictured in previous papers and the efficiency of these instruments was discussed (URSIN 1954, 1956 b). The stations operated are indicated on the charts, Fig. 1, and listed in Appendix 1 (p. 164).

In 1932—39 two samples were usually taken on each station. In 1947—55 the normal number of samples per station was reduced to one. The material from 1932—39 was collected from April to September. 233 stations were operated. They provided 502 samples covering an area of 93.5 m². After the second world war the work was continued on a small scale in 1947—48. 21 scattered stations were operated, all in May. 22 samples were collected, covering a total of 3.7 m². In 1950—55 a more extensive grab survey of the central North Sea was made:

1950:	68	stations,	70	samples	covering	14.0	m².
1951:	225	–	256	–	–	50.0	–
1952:	207	–	238	–	–	47.6	–
1953:	39	–	71	–	–	14.2	–
1954:	37	–	59	–	–	10.9	–
1955:	9	–	20	–	–	4.0	–
Total, 1950—55:	585	stations,	714	samples	covering	140.7	m².

551 of these stations were operated from 26th April to 28th May. 6 were operated in June, 8 in July, 16 in August, and 4 in December. 659 samples were taken with the 0.2 m² modified VAN VEEN grab, 34 with the 0.2 m² PETERSEN grab, 12 with the 0.1 m² modified VAN VEEN grab, and 9 with the 0.1 m² KNUDSEN sampler. 53 positions operated in April—May 1950 were operated again in April—May 1951. Similarly, 120 positions were operated in April—May 1951 and again in April—May 1952. 30 positions were operated in April—May of each of the years 1950—54 (cf. Fig. 1).

Table 1 shows the average contents of bottom material in 0.2 m² PETERSEN and VAN VEEN grabs. Obviously, the PETERSEN grab was not quite so efficient as the VAN VEEN grab. Pre-war samples were less satisfactory than post-war samples (see also URSIN 1954).

In Fig. 2 the number of species of echinoderms obtained in individual 0.2 m² samples is plotted against the quantity of bottom material in the grab. The samples were taken in the Dogger Bank and White Bank regions in April—May 1951—54 (see Fig. 69 (the poor area)

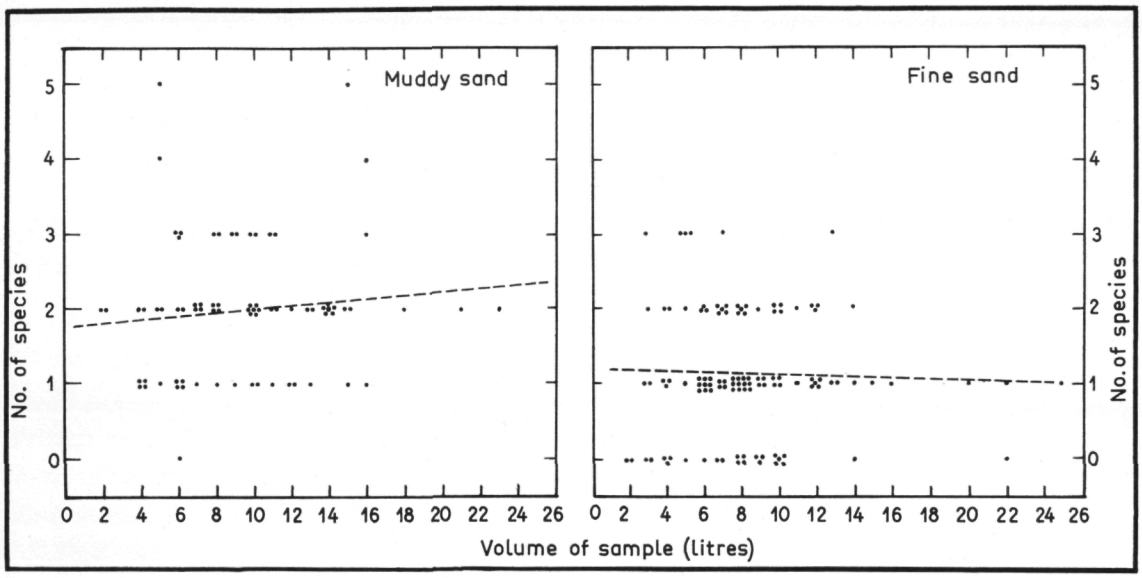

Fig. 2. Number of species of echinoderms per sample plotted against quantity of bottom material in the grab. 75 samples of muddy sand and 113 samples of fine sand from the central North Sea. 0.2 m² grabs. April and May 1951-54. The slope is not significant.

Table 1.

Mean volume of sample. 0.2 m² grabs. In 1951—54 the samples were measured to nearest litre. In previous years was the volume roughly estimated.

Grab	Years	Mean volume in litres					
		Coarse sand	Fine sand	Muddy sand	Clayey sand	Sandy clay	All grades
PETERSEN	1932-39	5.7	3.6	4.5	3.2	8.2	4.3
—	1951-53	7.0	5.0	6.7	7.0	12.2	6.5
VAN VEEN	1950	7.4	8.5	7.1	6.0	16.0	8.8
—	1951	10.0	6.5	7.8	9.7	13.5	8.4
—	1952	14.6	9.9	11.1	11.4	21.6	12.0
—	1953	17.0	9.2	9.9	12.2		10.5
—	1954		10.6	14.8	24.3		12.8
—	1950-54	12.2	8.6	9.8	11.1	16.7	10.3

p. 112). 113 samples of fine sand and 75 samples of muddy sand were considered. The slope of the estimated regression lines is not significant. Thus, the number of species of echinoderms per sample may be considered independent of the size of the bottom sample within the range of sample size in the present material. The smallest samples contained 2 l corresponding to an average digging depth of 1 cm. The largest sample contained 25 l corresponding to an average digging of 12.5 cm. Samples taken with the KNUDSEN sampler on fine sand on the Dogger Bank revealed that the number of additional species obtained in samples with an all-over digging of 18—26 cm is very low (URSIN 1956 b). It is more doubtfull whether the samples taken with the PETERSEN grab in 1932—39 are fully reliable as far as the number of species is concerned. Many

of these samples are of the same size as the smallest samples in the post-war material and several contain less than one litre.

In samples from the east coast of North America R. E. LEE (1944 p. 86) found the total number of species independent of the volume sampled. The grab used dug to an average depth of 1—10 cm which is similar to the efficiency of the VAN VEEN grab in the North Sea in 1950—54.

The dependence of the number of specimens upon volume of sample is more difficult to investigate. For this purpose is required a set of samples from an area within which the density of echinoderms is the same everywhere. An approach towards this condition is established when the samples of fine sand from the Dogger Bank area in 1951—54 are pooled. 170 samples from the statistical squares G 7—9, H 8—10, and J 9—10 are available. (For interpretation see p. 104 and Fig. 80, p. 134). Fig. 3 shows the number of specimens plotted against volume of sample. The skew distribution of the observations makes interpretation difficult. An approach towards normal distribution is obtained, however, by plotting the number of specimens on a cube root scale. The regression line is indicated on Fig. 3. The slope is not significant. In the present case, therefore, the dependence of the number of specimens of echinoderms upon volume of bottom material is negligible.

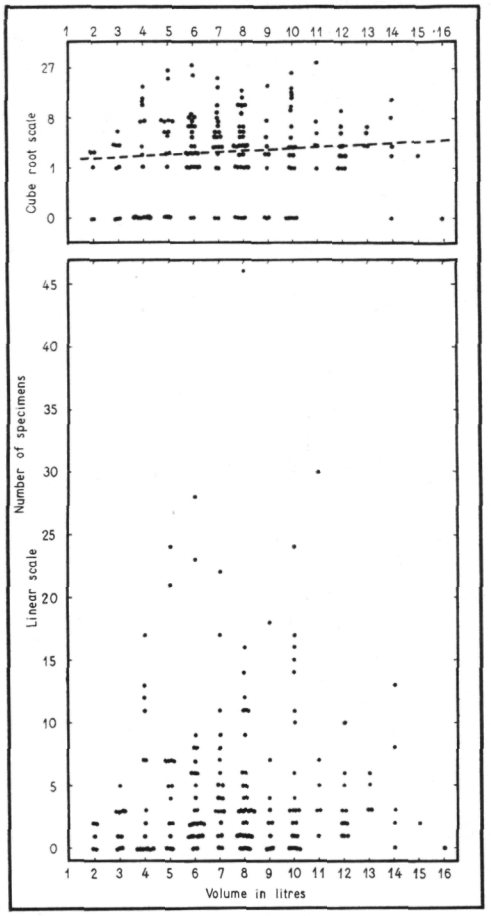

Fig. 3. Number of specimens of echinoderms per sample plotted against quantity of bottom material in the grab. Linear scale below, cube root scale above. 170 samples of fine sand from the Dogger Bank area. 0.2 m² grabs. April and May 1951-54. The slope (cube root scale) is not significant.

Another set of samples from an area of approximately equal density of echinoderms is obtained by pooling of soft-bottom samples from the eastern and south-eastern North Sea, taken in April—May 1951—54 (squares J 7—9, K 7—11, and L 7—11). Another 170 samples are available. Fig. 4 D shows the dependence of the number of specimens upon volume. Again, an approach towards normal distribution is obtained by plotting numbers on a cube root scale (Fig. 5) and again, the slope of the linear regression line is not significant. A comparison of the regression lines for the two sets of samples investigated revealed that the lines have the same slope and that the common slope is—with the higher number of degrees of freedom now available—significant at the 5 % level. A look at the diagrams (cube root) gives the impression that in the present material there are perhaps twice as many specimens of echinoderms in large samples as in small ones. R. E. LEE (1944 p. 87) found a considerably greater difference between small and large samples and, consequently, rejected the smallest and the largest samples. Even in the remaining material there were four times more specimens in large samples than in small ones. LEE pooled all groups of animals. Perhaps the echinoderms in the North Sea live closer to the surface than several other animal groups. The fact, that the two sets of samples from the North Sea are sufficiently well described by straight lines which are far from passing through 0,0

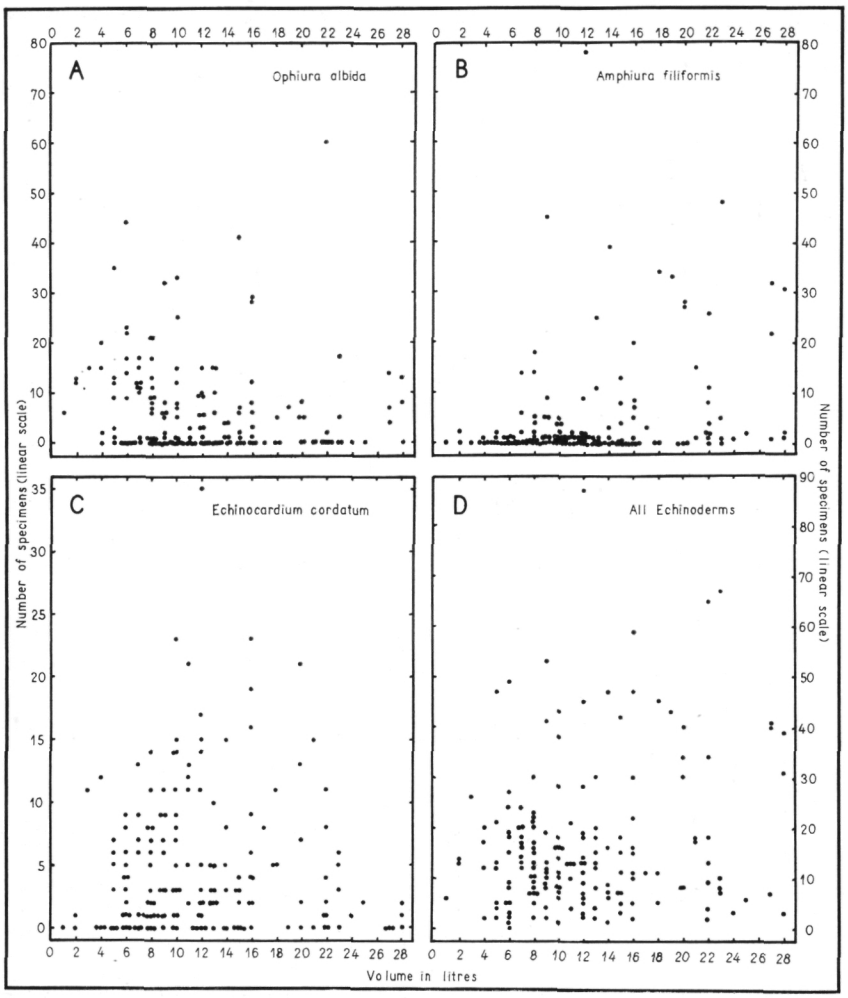

Fig. 4. Number of specimens in individual 0.2 m² samples plotted against quantity of bottom material in the grab. 170 soft-bottom samples from the eastern and south-eastern North Sea. April and May 1951-54.

(cf. the diagrams) seems to indicate that a high proportion of North Sea echinoderms are surface dwellers. When samples of 2 or 3 l., corresponding to an average digging depth of 1—1.5 cm., produce reasonably good catches of echinoderms it is rather obvious that the curve would slope steeply for still smaller samples. Probably, several of the small pre-war samples measuring 1 l. or less are not reliable.

Although the total density of echinoderms may remain reasonably constant over larger areas the occurrence of individual species is more patchy. In the absence of better material the soft-bottom samples from the eastern North Sea in April—May 1951—54 may provide some information on the dependence of the number of specimens upon volume for some of the more abundant species (Fig. 4 A—C).

In *Ophiura albida* there is no indication of dependence of number upon volume of sample. Known as a surface dwelling form *O. albida* is perhaps always caught quantitatively provided that the grab scrapes the bottom with the full breadth of its jaws. *Echinocardium cordatum* apparently also is taken quantitatively in small samples although zero observations are perhaps slightly more frequent in small samples than in large ones. Evidently, this species lives in the

upper few centimetres of the bottom. The observation made by CUENOT (1912) in the tidal zone on the French Atlantic coast, that *E. cordatum* lives buried 10—20 cm down in the sand should not, obviously, be generalized. *Amphiura filiformis* is underrepresented in samples of less than,

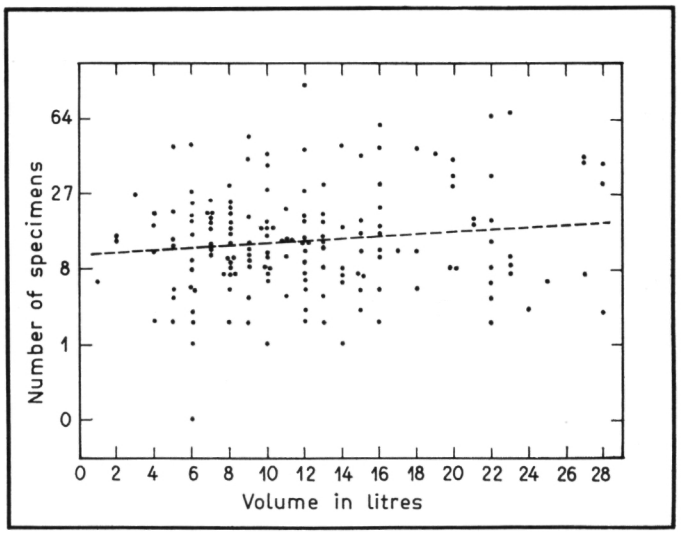

Fig. 5. The same material as in Fig. 4 D, but with the number of specimens plotted on a cube root scale.

say, 8 l. However, the smallest samples of bottom material are not distributed at random over the area investigated. Several originate from the more sandy grounds which although classified as muddy sand are perhaps not entirely satisfactory for *A. filiformis*. A large number of samples taken together within an area of high density of *A. filiformis* might produce more reliable information.

Among the species of echinoderms represented in the grab material there may be some which dig so deep into the bottom that they are caught quantitatively in the largest samples only. Some species may even have managed to escape the grab. The material available is not sufficient for a detailed investigation. Since the density of the more abundant species depends upon volume to such an extent that the dependence can be ascertained with difficulty only it was decided to consider all samples taken in 1950—55 equally reliable.

Trawl, seine, and dredge catches. The contents of invertebrates in hauls made by Danish research vessels in 1922—55 was listed on board and sometimes material was kept. The value of the lists varies from one year to another according to the interest payed to invertebrates, or to individual groups of invertebrates, by the biologists on board. Sometimes only the more abundant and easily recognizable forms were noticed while on other voyages the invertebrates were carefully identified. In 1952—55 the invertebrates were usually listed by the present author and

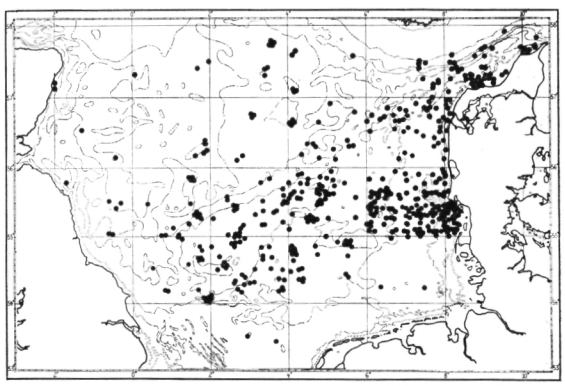

Fig. 6. Danish trawl, seine and dredge stations in the North Sea, 1922-55. Voyages during which invertebrates apparently were not carefully listed, or kept, are discarded.

samples were kept. Although not very useful for quantitative studies such material may supply important information on the general distribution of the larger surface dwelling species which are seldom obtained in bottom samples. About 500 stations seem to have produced reliable information on occurrences of echinoderms. The station chart, Fig. 6, gives a general idea of the distribution of these stations. It should be borne in mind, however, that some stations do not produce reliable records for all species. For example, records of *Psammechinus* and *Strongylocentrotus* are considered reliable only when material is kept or when a biologist with particularly good knowledge of echinoderms was in charge of the invertebrates.

Treatment of Bottom Samples.

The contents of the grab was poured into a bath and immediately or after a few hours washed through a series of three sieves. The fine-meshed sieve had 1.8 mm. mesh aperture. The material left in the sieves was sorted on board and the animals kept in 4 % formalin saturated with borate of sodium. Unfortunately, scarcity of store room made it necessary to identify on board some of the larger specimens which could not be kept. Further sorting and identification was carried out in the laboratory after the end of the voyage. The author is indebted to colleagues who took part in the laborious sorting of the material on board. A grant from the "Danish State Research Foundation" greatly facilitated the sorting out of the echinoderms later on.

Undamaged echinoderms obtained in bottom samples in the years 1950—55 were measured to "millimetre below" or to "half millimetre below". Correspondingly, 0.50 mm. or 0.25 mm. was added to mean values. The length of broken specimens was estimated by comparison with undamaged ones. The wet (formalin) weight was determined for each length group of each species. Graphs showing the length/weight relationship were prepared. The weight of specimens not actually weighed was taken from graph. The weight determination of broken specimens was based on the supposed length of the unbroken animal. Fragments of asterids, however, were considered fully representative of the part of the animal situated on the sampled area. Samples of *Amphiura* and *Acrocnida* were just weighed.

Navigation.

In 1950 the "Decca Navigator System" was introduced on board the "Dana" so that in 1950—55 a high accuracy of navigation was obtained. Theoretically, a maximum error of some 200 m might be expected. Owing to drifting of the ship on the station it may be advisable to consider two stations listed with the same position to be alike within a range of one nautical mile. As far as the echinoderm material is concerned this accuracy proved satisfactory (p. 148).

Soundings.

In 1950—55 the depth was read to nearest metre on an echo sounding apparatus. Major differences between readings on the same position in successive years may be ascribed to errors of navigation. However, some peculiar disagreements of successive readings were observed. The mean depth for 28 stations operated on the Dogger Bank in each of the years 1950—54 was (in metres): 37.1, 35.4, 37.1, 34.2, and 32.5. The mean difference between 1952 and 1954 is 4.6 ± 0.7 which deviates significantly from zero ($t = 6.833$; $f = 27$). The small difference between 1953 and 1954 is almost significant (1.7 ± 0.8; $t = 2.126$; $f = 27$). It is hardly credible that the water

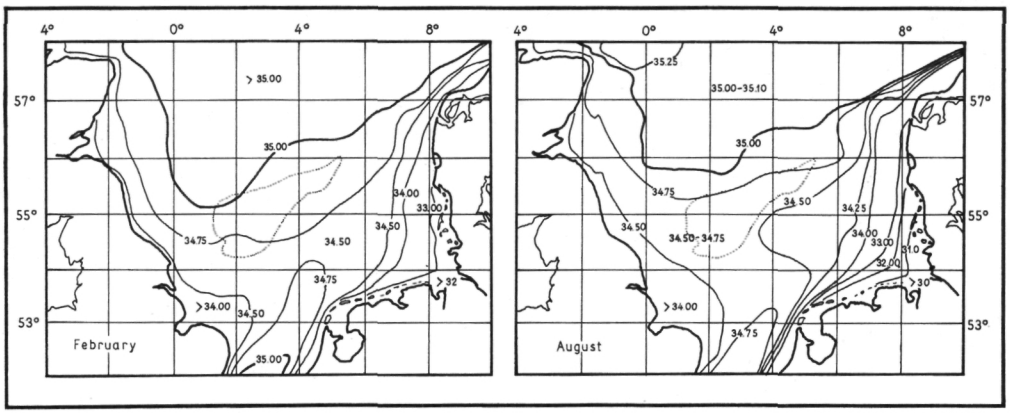

Fig. 7. Mean salinity in permille at the bottom. (Deutsche Seewarte 1927, redrawn).

depth on the Dogger Bank varies to such an extent from one year to another. The variation may be due to deficiency of the apparatus employed. In the present paper the observed values are adopted because the error introduced scarcely causes serious misinterpretation of the biology of the species.

Classification of Bottom Deposits.

Analyses of bottom deposits are not available. The samples were roughly classified as coarse sand, fine sand, muddy sand, clayey sand, sandy clay, and clayey coarse sand. "Fine sand" and "coarse sand" do not contain appreciable amounts of mud or fine-graded minerals. "Clayey sand" and "sandy clay" are always muddy although, for convenience, this is not stated. "Muddy sand" is a soft, loose, blackish material, usually without conspicuous smell. When mud and clay are mixed with coarse-graded material (which rarely occurs) the term "clayey coarse sand" was used. The presence of shells was indicated by the terms "few shells", "shells", and "many shells". Similar terms indicate the presence and quantity of stones. A few samples containing nothing but stones were obtained; the grab was closed so that washing out of the finer grades of soil apparently had not occurred. Samples containing more than 50 $^0/_0$ shells were not seen in 1950—55.

Hydrography.

Survey. The salinity of the bottom water in the North Sea was charted by "Die Deutsche Seewarte" (1927). The salinity is lowest in the German Bight and increases as the northern North Sea or the English Channel is approached (Fig. 7). Usually, salinities below 30 $^0/_{00}$ are not found except in the Waddensea (Smidt 1951 p. 10) and in estuaries. In offshore waters of the northern North Sea the salinity usually is above 35 $^0/_{00}$. Sometimes 35 $^0/_{00}$ water extends southward over the Dogger Bank (Andersen 1954, 1956).

"Die Deutsche Seewarte" (1927) charted the mean bottom temperature in February, May, August, and November. The chart for February may represent the winter condition and the chart for August may represent the summer condition. However, February is not the coldest month all over the North Sea and August is not everywhere the warmest. For biological purposes isotherms indicating localities with the same mean maximum or minimum temperature may prove more usefull than isotherms indicating temperature conditions in individual calendar months.

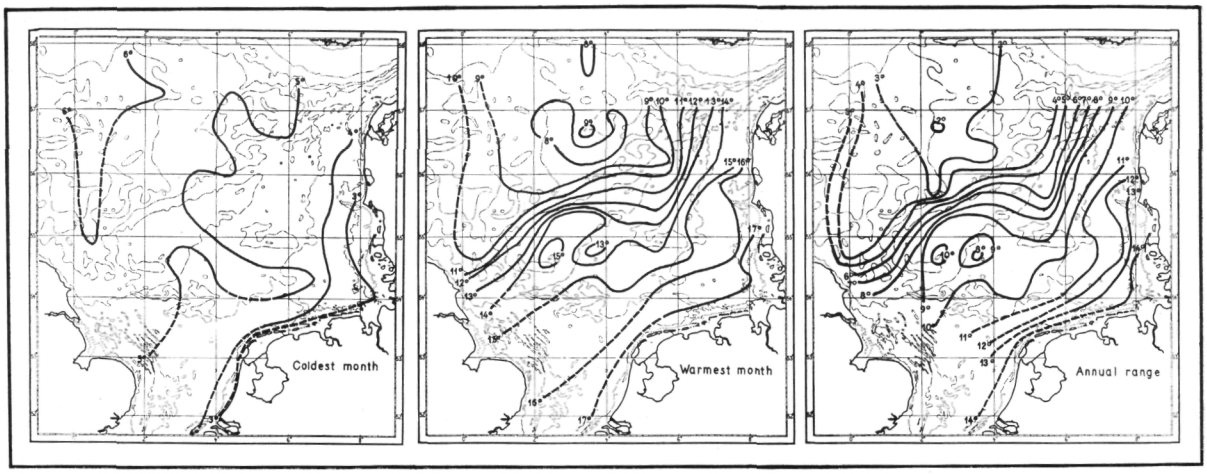

Fig. 8. Isoterms indicating the mean temperature in any locality in the coldest and the warmest month of the year. The annual range of temperature, as here understood, is the difference between the mean temperature of the coldest month ("the winter temperature") and the mean temperature of the warmest month ("the summer temperature").

Mr. K. P. ANDERSEN, M. Sc., most kindly placed at my disposal mean values (as yet unpublished) for the temperature in each month for each statistical square between 54° N. and 57° N. and east of 2° E. Is was desirable, however, to enlarge the area of investigation. Therefore, the observations available in the hydrographical card index of "The International Council for the Exploration of the Sea" were worked up by the present author to such an extent that isotherms covering most of the area of the North Sea between 54° N. and 58° N. could be drawn very roughly. Valuable records on lightvessel observations were published by GOEDECKE (1954). The isotherms[1]) on the charts, Fig. 8, show the mean bottom temperature in the warmest and the coldest month, and the difference between the temperature of the warmest and the coldest month. For convenience, the terms "summer temperature" and "winter temperature" will be used. On the Dogger Bank and in the south-eastern North Sea August or September is the warmest month. North and west of the Dogger Bank and on the Bløden Ground the warmest month is October, November or even December. In the fairly homothermal area north of the Dogger Bank there are two distinct temperature maxima, one in July and another in November—December; the latter is the more conspicuous. In most localities March is the coldest month but on the Dogger Bank and in parts of the Danish and German coastal waters February is colder. In the deep northern and north-western North Sea and on the Bløden Ground the lowest temperatures usually are observed in April.

The summer temperature varies from above 17° on the Danish, German, and Dutch coasts to 8° in offshore parts of the northern North Sea. Another maximum (15°) is found on the Dogger Bank. The winter temperature varies from below 3° on the Danish, German, and Dutch coasts to above 6° in deep water off Scotland. The winter temperature of the Dogger Bank is not so low as the shallowness of the Bank might suggest. On the Dogger Bank the difference between summer temperature and winter temperature is, therefore, less marked than at corresponding depth on the coast of the south-eastern North Sea.

Perhaps attention should be called to the hydrographical conditions in an interesting

[1]) In the present paper all temperatures are expressed in degrees centigrade.

locality, the "Helgoländer tiefe Rinne", the fauna of which in several respects differs from that of neighbouring localities in the south-eastern North Sea. The Rinne, situated a few nautical miles south of the island of Helgoland, is 60 m. deep and covers about 10 square miles. The depth of the surrounding sea is about 35 m. The hydrography was discussed in detail by CASPERS (1939). The bottom temperature is about the same as in neighbouring shallower localities. In 1936 the bottom temperature rose to 16.9°; in the following winter it decreased to 3.5°. The salinity is somewhat higher in the Rinne than elsewhere in the German Bight. This is due to retention in the deep basin of saline water occasionally penetrating into the German Bight. While outside the Rinne the salinity occasionally decreases to 28—30 $^0/_{00}$ the bottom water of the Rinne apparently maintains a salinity above 32 $^0/_{00}$. Another interesting point is that a swirl in the surface water above the Rinne tends to gather live and dead material which either keeps floating on the surface or settles on the bottom of the Rinne.

Another locality with peculiar hydrographical conditions is the Bløden Ground between the Dogger Bank and the Danish coast. The hydrography of this area was investigated by ANDERSEN (1954, 1956, 1957). In late autumn gales usually cause a thorough mixing of the whole water column, but when in spring the heating of the surface water begins a stratification develops so that during the summer the bottom temperature increases a few degrees only. For instance, in early June 1955 the bottom temperature was about 6.5° and rose to 7.5° in September. The surface water temperature in the same period rose from 8° to 17°. The stability of the bottom water causes a decrease in oxygen saturation in summer. In May saturation or oversaturation was observed while in August and September the saturation was 60—80 $^0/_0$.

Climatic changes. Changes in surface temperature of the North Sea in 1902—39 were investigated by SMED (1949 p. 23) who found that the annual mean had increased about 0.5° during the period 1921—39. GOEDECKE (1952) confirmed SMED's results so far as the German Bight is concerned and pointed to the fact that winter temperature remained constant while the summer temperature increased about 1°. The increase was found to begin in 1915 and to be very distinct in 1924.

Unfortunately, similar investigations of the bottom temperature are not available. In a recent paper SMED (1954) has shown that in March the difference between surface temperature and bottom temperature in the North Sea is almost negligible. As March is in most parts of the North Sea the coldest month it is thus possible to investigate indirectly the winter temperatures of the bottom layers by means of surface observations for March. Mr. SMED most kindly placed at my disposal the detailed tables on which the anomalies for the year (SMED 1949) were based. The following anomalies for surface temperature in March in the North Sea (SMED's areas A—E) were found:

1901—10:	−0.8°
1911—20:	0.3°
1921—30:	0.0°
1931—39:	0.2°

Apparently, an increase in the winter (March) temperature of the surface and, owing to the homogeneity of the water column, also of the bottom has occurred. The result is not in accordance with GOEDECKE (1952) who found that the winter surface temperature at lightvessels in the southern North Sea remained almost constant. GOEDECKE, however, made the interesting observation that long-term changes of the surface temperature in the North Sea depend not only

upon similar changes in North Atlantic water penetrating into the North Sea, but also upon changes in the temperature of river water expelled into the North Sea from the continent. Thus, the most conspicuous increase in summer temperature was observed at lightvessels situated in the estuary of the river Elbe. It seems as if continental influence caused an increase in summer temperature, but not in winter temperature, of the surface waters on the continental coast while Atlantic influence brought about an increase, even in winter, of the surface temperature in other parts of the North Sea.

Further information on changes in the bottom temperature may be obtained from observations made on the Horn's Reef lightvessel. In the years 1880—1939 this lightvessel was anchored on 55° 34′ N. 7° 20′ E. in 30 m. It was withdrawn from May 1917 to October 1920. Bottom temperature observations were made every day and published in extenso in the Danish Nautical-Meteorological Annual. Bottom temperature anomalies for the winter, the summer, and the year are given in Table 2. The winter temperature is defined as the mean for February and March observations because in some years February and in other years March is the coldest month. Similarly, the summer temperature is defined as the mean for August and September observations. Apparently, the bottom temperature in summer as well as in winter decreased during the first years of observation, but in recent years increased about 1°. The increase in summer temperature began later than the increase in winter temperature. These results are in good accordance with those based on SMED's tables (see above). As might be expected, the bottom temperature from the lightvessels on the continental coast is not influenced as much as the surface temperature by the temperature of river outflow.

Table 2.

Bottom temperature at Horn's Reef lightvessel. Mean anomalies for 10-year periods.

	Winter	Summer	Year
Mean temperature 1881—1939	*3.3*	*15.1*	*8.7*
1881—1890	−0.3	0.2	−0.1
1891—1900	−0.4	−0.3	−0.2
1901—1910	−0.2	−0.5	−0.1
1911—1920	0.2	−0.8	0.1
1921—1930	0.0	0.3	0.1
1931—1939	0.6	0.3	0.6

Daily hydrometer observations were made on the Horn's Reef ligthvessel. In 1881—96 the mean salinity at the bottom was 33.5 $^0/_{00}$. In 1922—30 it was the same and in 1931—39 it was 33.6 $^0/_{00}$. Changes, if any, apparently were minute.

The climatic development in the North Sea in post-war years is as yet incompletely known. SMED (1953) found that in Scottish waters of the North Sea the surface temperature culminated in the forties.

Years with unusual temperature conditions. The temperature development during two particularly cold winters (1927 and 1947) was investigated by LUMBY and ATKINSON (1929), by VAUX (1953), and by the present author (1956 a, p. 10). It seems as if the 3° bottom isotherm for the coldest season of the year was not as usual situated close to the continental coast but passed from north Jutland toward south-west along the north-western edge of the Dogger Bank. The effect of this extraordinary cooling upon the bottom fauna and the stock of fish was discussed by

LUMBY and ATKINSON (1929), JOHANSEN (1929), SIMPSON (1953), ZIEGELMEIER (1953) and the present author (1956 a). Further remarks are made in the present paper (p. 102).

Information about years with unusual temperature conditions may be gathered from observations made on the Horn's Reef lightvessel. Anomalies for summer and winter bottom temperature in particularly warm and particularly cold years are shown in Table 3. Surface

Table 3.

Bottom temperature anomalies at Horn's Reef lightvessel in cold years and in warm years. Bracketed: March anomalies for the surface temperature of the North Sea (from SMED's unpublished tables, areas A—E).

	Year	Winter (Febr. -March)	Summer (Aug.-Sept.)
Mean temperature	*1881—1939*	*3.3*	*15.1*
Cold winters	1888	−2.4	−1.5
	1895	−2.5	0.7
	1929	−2.5 (−1.8)	0.1
Cold summers	1888	−2.4	−1.5
	1899	1.6	−1.4
	1914	1.3 (0.8)	−2.1
Warm winters	1882	1.9	1.1
	1925	1.7 (0.6)	0.7
	1927	1.9 (1.2)	0.3
Warm summers	1934	1.3 (0.5)	1.5
	1936	0.2 (0.1)	1.3
	1939	0.9	1.3

temperature anomalies for the North Sea in March are indicated as far as information is available in SMED's tables referred to above. The accordance of the two sources of information shows that Horn's Reef bottom observations indicate the temperature condition over large parts of the North Sea. Two extremely severe winters occurred before the cold winter of 1929, namely in 1888 and 1895. The lowest annual mean (7.1° against an average of 8.7°) was obtained in 1888. In 1929 the annual mean was 7.8°. In Scottish waters, at least, the winter of 1879 was very cold (SMED 1953, Table 1).

Currents will be briefly discussed in connection with plankton communities.

Zooplankton Communities.

According to RUSSELL (1939) and FRASER (1939, 1952) an Atlantic zooplankton community with *Sagitta serratodentata* as important indicator species is transported by currents into the North Sea from the north-west. The Atlantic water masses become mixed with North Sea coastal water with the effect that several Atlantic animals soon perish and another community with *Sagitta elegans* becomes established. Upwelling cold water with the deepwater chaetognath *Sagitta maxima* may penetrate into the North Sea from the north and join the *elegans* water. As a warm current the mixed water of predominantly Atlantic origin moves south along the British coast until it turns eastward joining smaller quantities of Channel water. The Atlantic water component is rich in nutrients and supports a rich and varied fauna. The farther the *elegans*

water penetrates into the North Sea the poorer it becomes in species and in specimens. Gradually, it changes into the poor *Sagitta setosa* community which dominates the central North Sea. The Channel water with which it is mixed originates from the true Atlantic *Sagitta serratodentata* community which in the Celtic Sea changes into a *Sagitta elegans* community. The latter, on its part, soon changes into a *Sagitta setosa* community which dominates the Channel water. The two Atlantic water masses entering the North Sea from the north-west and the south-west, respectively,

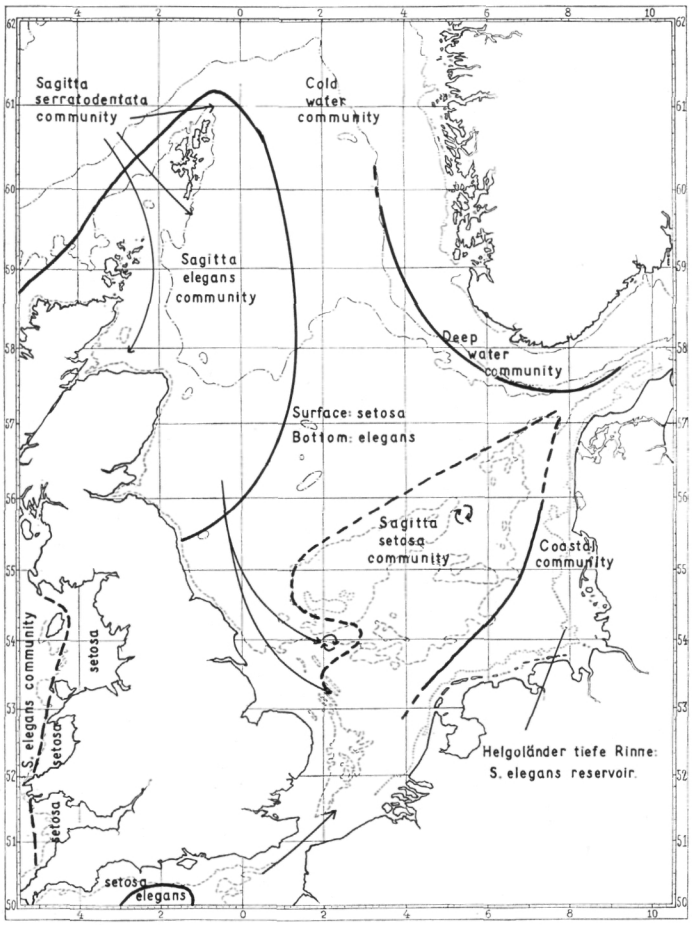

Fig. 9. Plankton communities in the North Sea region. Mainly based on RUSSELL's chart (1939).

thus are liable to the same metamorphosis as far as the zooplankton is concerned. Together these water masses move east in the southern North Sea and, finally, move north along the Danish coast. Along the continental coast the Channel influence is stronger than farther offshore and continental influence (river outflows etc.) cause the establishment of a poor coastal plankton community, vaguely characterized by the medusa *Sarsia tubulosa*. North of the Dogger Bank, west of the *elegans* zone proper, the surface water contains a *setosa* community while deep hauls reveal the existence of an *elegans* community at the bottom (FRASER 1939).

Occasionally, *elegans* water penetrates deep into the southern North Sea. RUSSELL (1939 p. 184) points out that in the slowly moving water masses of the southern North Sea the effects of

such a deep penetration of *elegans* water may last for several years. Swirls above deep basins in the southern North Sea apparently tend to maintain an *elegans* community for a longer time than does the area as a whole. Thus, the south-west Dogger Bank swirl fairly regularly carries an *elegans* plankton community (RUSSELL 1939, with further references). More astonishing is the fact that similar observations are made in the Helgoländer tiefe Rinne (CASPERS 1939). Fig. 9 illustrates the general principles of the distribution of zooplankton communities, mainly based on a chart given by RUSSELL (1939).

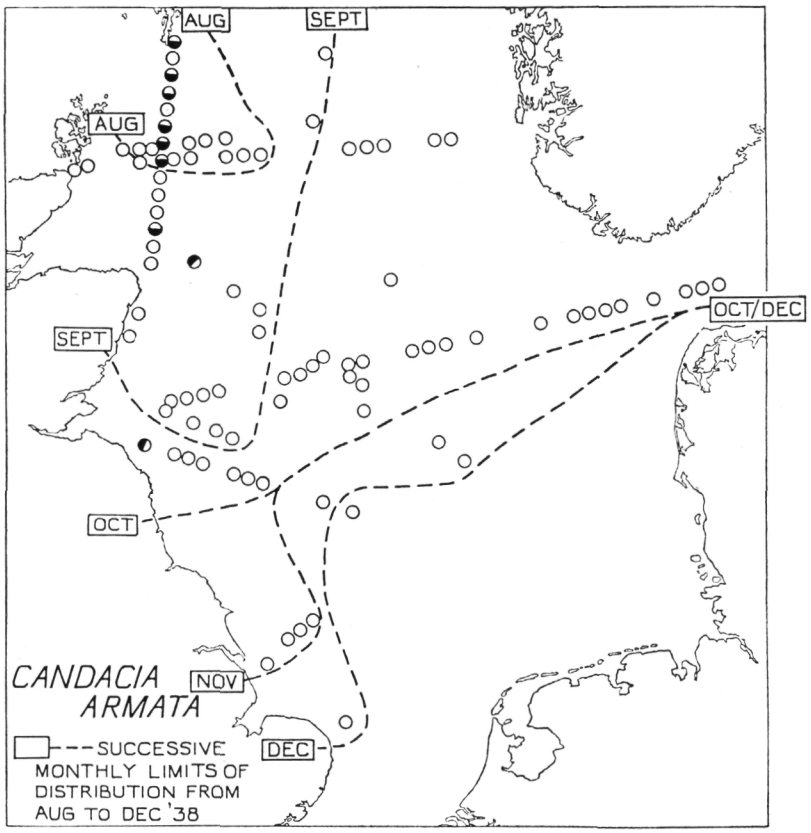

Fig. 10. The penetration of a *Sagitta elegans* water copepod, *Candacia armata*, into the North Sea. From RAE and REES (1947, Textfig. 4, p. 115).

RAE and REES (1947) investigated the distribution of copepods in the North Sea. They found five types of distribution and with reference to literature showed that several other groups of plankton animals fit into the scheme based on the distribution of copepods. The five groups are:

1. Species fairly regularly distributed over the North Sea.
2. Species confined to the northern and western North Sea. Apparently these forms occur where *elegans* influence is traceable (cf. Fig. 9).
3. Species confined to the central North Sea (the *setosa* region).
4. Species confined to continental coastal waters (easily referable to the coastal plankton community).

5. Species confined to the Norwegian Channel and the Skagerrak. They are deep water forms seasonally migrating into surface waters. Although not considered by RUSSELL (1939) and FRASER (1939, 1952) this deep water plankton community seems well established. Its distribution is indicated on Fig. 9.

RAE and REES (1947) found that the *setosa* community and the coastal community in the south-eastern North Sea probably are self-contained. The *elegans* community seems highly dependent upon the plankton of the Shetland region. Fig. 10 illustrates the distribution of the copepod *Candacia armata* at various seasons of the year. In August this species is confined mainly to the region in which *Sagitta serratodentata* water penetrates into the North Sea between the Orkney and the Shetland Isles. In September it is distributed along the north British coast, thus covering the area dominated from surface to bottom by the *Sagitta elegans* community. In November—December *Candacia armata* has spread everywhere in the northern North Sea where influence of *Sagitta elegans* water may be traced (cf. Fig. 9). It does not, however, penetrate into the true *setosa* region. Obviously, larvae of bottom animals spawned in the Shetland region may settle in the North Sea within an area determined by the duration of larval life. Species able to survive, but not able to propagate, in the North Sea may have a different distribution in the North Sea even if they originate from larvae spawned at the same time and in the same locality.

The penetration of the *Sagitta elegans* plankton into the English Channel seems to vary considerably. There is evidence (see WILSON 1951 p. 1, with references) that in the years prior to 1930 a rich *elegans* community penetrated beyond Plymouth while in recent years the Plymouth water carries only a sparse plankton, primarily of the *setosa* type. In the Plymouth laboratory the observation was made that in the years after 1930 larvae of some marine bottom invertebrates failed to develop under laboratory conditions while in the years prior to 1930 rearing of such larvae was successful. WILSON (1951, 1952, 1954) related these observations to the change of plankton community and found that larvae of certain species develop less successfully in filtered *setosa* water than in filtered *elegans* water. Larvae of *Echinus esculentus*, for instance, usually developed abnormally when reared in Plymouth *setosa* water under laboratory conditions. Nevertheless, this species maintains a stock in the *setosa* water off Plymouth so that, obviously, laboratory conditions were less suitable to the larvae than natural conditions. In this connexion it is interesting to note that *E. esculentus* is absent from the central part of the *setosa* region in the North Sea (cf. below, p. 68). Several attempts have been made to identify the obscure but essential constituent of either the *setosa* water or the *elegans* water which produces the difference between these waters (COOPER 1951, COWEY 1956). The problem, however, remains unsolved.

Previous Investigations.

Survey. Trawl and dredge investigations of the distribution of echinoderms in the North Sea were made by German investigators in 1872 ("Pommerania"), in 1889—90 ("Sophie", "August Bröhan") and in 1902—07 ("Poseidon"). The echinoderm material from these expeditions was published by MÖBIUS and BÜTSCHLI (1875), MEISSNER and COLLIN (1894), and by SÜSSBACH and BRECKNER (1911) who surveyed the literature and made comments on the zoogeographical position of the echinoderm fauna of the North Sea. The German trawl and dredge stations are shown on Fig. 11. A Dutch research vessel, the "Wodan", listed the invertebrates in otter trawl hauls made predominantly on the Dutch coast and in the Southern Bight in 1902—11. The echinoderm material was partly worked up by TESCH (1906). The "Jaarboek van het Rijks-

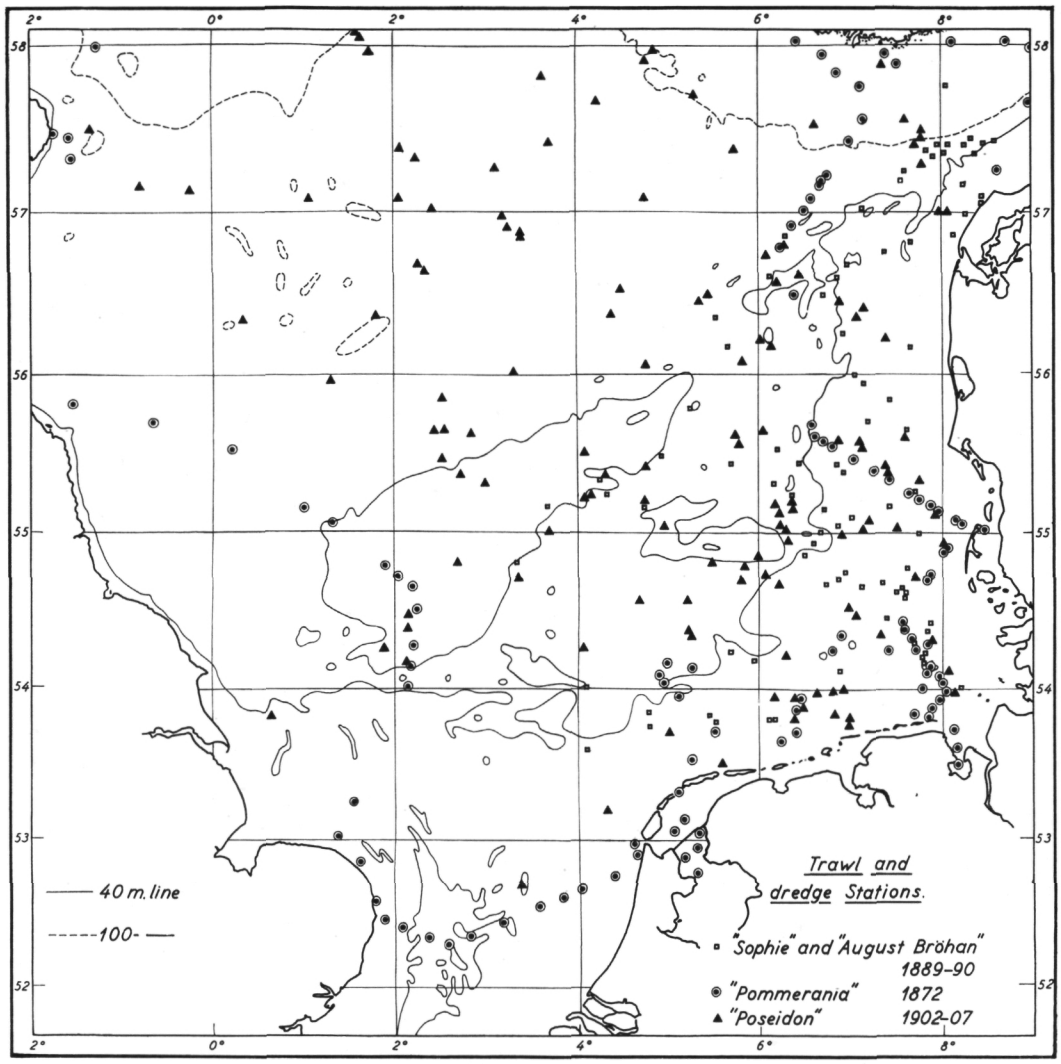

Fig. 11. Stations operated in the North Sea south of 58° N. by German research vessels in 1872-1907.

instituut voor het Onderzoek der Zee" for the years 1905—12 give lists of invertebrates from each station. Fig. 12 shows the stations operated by the "Wodan".

Quantitative investigations of the North Sea bottom fauna were invented by PETERSEN (1914) in 1911. PETERSEN worked a few stations in the north-eastern North Sea. In the early twenties quantitative sampling with the PETERSEN grab was continued on a larger scale by several investigators. The southern and central North Sea was surveyed in 1921—24 by BLEGVAD (1922) and DAVIS (1923, 1925). Fig. 13 shows the stations operated by these authors. HAGMEIER (1925) in 1923—24 made a grab survey of the German Bight. Unfortunately, HAGMEIER's material was not published in such a way that individual occurrences can be plotted on a chart. The grab material from an extensive grab survey of the northern North Sea carried out in 1922—25 was published summarily by STEPHEN (1934). Among the local investigations in coastal waters CASPER's (1939, 1950) studies on the bottom fauna near the island of Helgoland are the most important, as far as echinoderms are concerned.

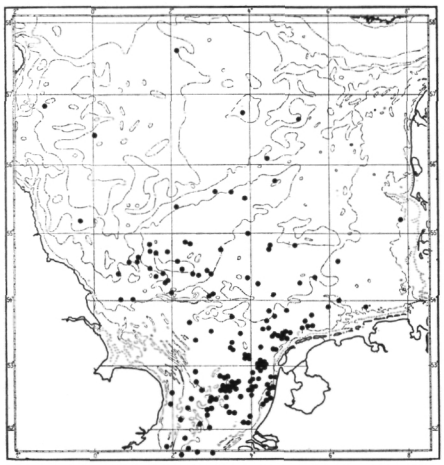

Fig. 12. Otter trawl stations operated by a Dutch research vessel, the "Wodan" in 1902-11.

Timing with climatic changes. The extensive grab surveys of the North Sea (DAVIS, HAGMEIER, STEPHEN) in 1921—25 were made about the onset of the temperature increase referred to above (p. 13). Nevertheless, they were timed with three severe although not exceptional winters (Horn's Reef lightvessel anomalies (cf. Table 3, p. 15): 1917: —2.2°; 1922: —2.1°; 1924: —1.8°). The old trawl and dredge investigations (1872—1911) probably were carried out in a cold period. CASPERS's samples from the Helgoland area in 1936—38 were collected during the warm period. It is further noticeable that the voyages of the "Sophie" and the "August Bröhan" in 1889—90 took place soon after an unusually severe winter (1888). The winters of 1886 and 1889 were fairly cold, too.

Comparability of results. It is almost impossible to compare on a quantitative basis the catches in trawl and dredge hauls with the catch in grab samples. To illustrate the situation it may be mentioned that almost every trawl or dredge haul made in the North Sea produced *Asterias rubens*, and often in quantities. Grab sampling revealed that *A. rubens* is one of the more rare forms in the North Sea. Evidently, the availability of this species to fishery with trawl or dredge is exceptionally high.

Even grab investigations are difficult to compare. In 1952 the present author wrote to the editors of "Nature" that the composition of the bottom fauna of the Dogger Bank had greatly changed since DAVIS's survey in 1921—24. It was said that the number per square metre of numerous species of bottom invertebrates had increased about 10 times while the bivalve *Spisula subtruncata*, found in enormous numbers by DAVIS, had almost disappeared. The disappearing of *S. subtruncata* might be ascribed to normal fluctuations within a species with planktonic larval development while the increase of most other species was rather astonishing. BIRKETT (1953) suggested that the increase was at least partly due to failing efficiency of the PETERSEN grab employed by DAVIS as compared with the modified VAN VEEN grab employed on the "Dana". However, grabs of both designs were used on the "Dana" and the difference in efficiency was small (URSIN 1954). This does not prove that BIRKETT is wrong in his assumption, that the observed "change" is not a real one, but due to failure of sampling during DAVIS's investigations.

The problem may be attacked in the following way: From the voyages of BLEGVAD, DAVIS, STEPHEN, and HAGMEIER some series of stations were selected which as far as possible cover each other in time and space. They were compared with series of stations operated within the same areas by the "Dana" in 1951—52. Much caution is needed in interpreting the results because the stations compared were neither operated at exactly the same positions, nor were they operated at random within the areas selected for the comparison. Further, the number of comparable hauls is small.

In Table 4 is presented the material available from the area immediately north of the Dogger Bank. Molluscs and echinoderms only are considered because STEPHEN's publications (1933, 1934) do not cover other groups of animals. The following stations are compared:

DAVIS: Voy. LXV, st. no. 24—66; voy. LXXXIV, st. no. 3—103. 50.1 m². May—June.
STEPHEN: "Offshore zone" (1933, 1934, Tables I b), 23 stations from squares C 10—11, D 9—10,

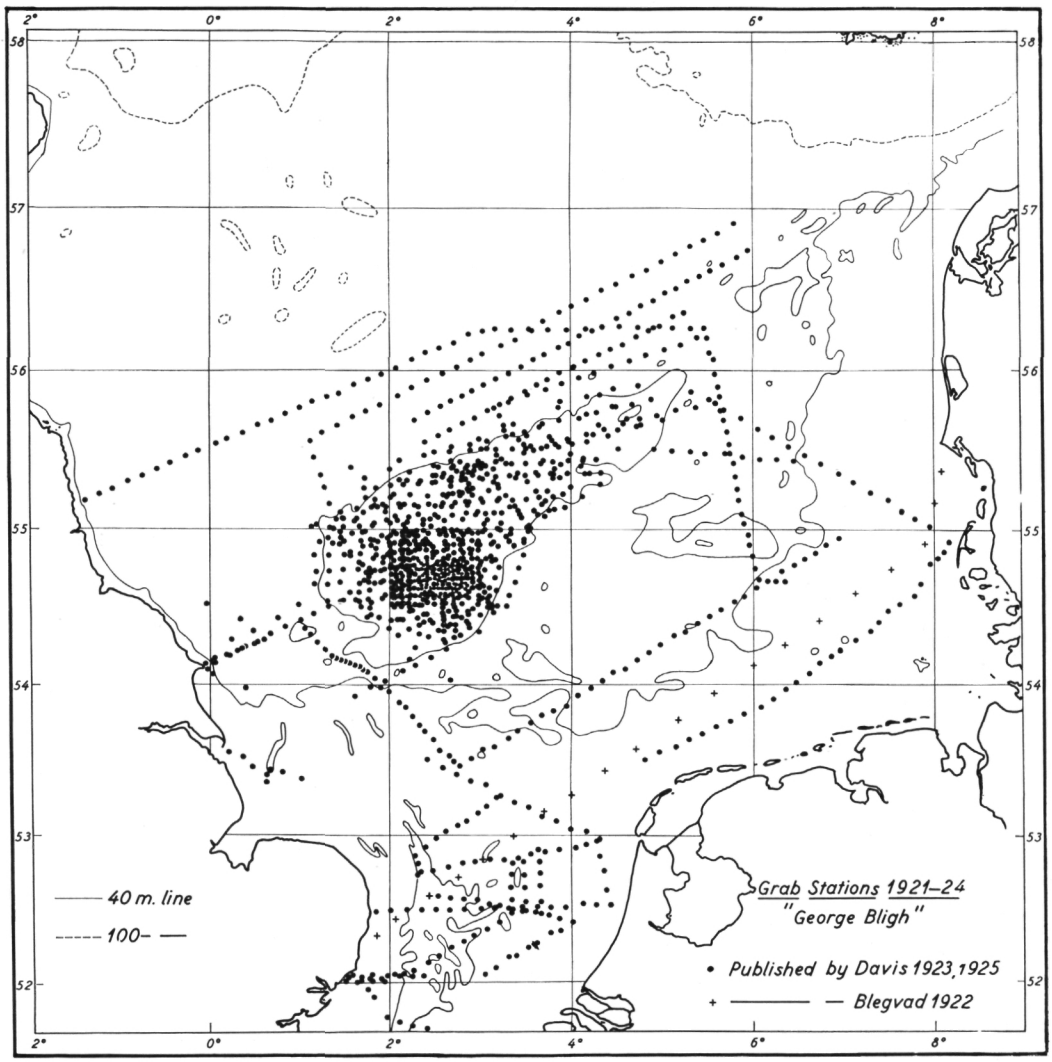

Fig. 13. Grab stations operated during the English investigations in 1921-24.

Table 4.

Number of molluscs and echinoderms per square metre in the North Sea immediately north of the Dogger Bank.

Reference	Month	Year	Grab used	Area sampled (m^2)	Depth (m)	Number per square metre							
						Ophiura	*Amphiura*	*Echinocardium*	Other echinoderms	Lamellibranchs	Gastropods	*Dentalium*	Echinoderms & molluscs, total
Davis 1925	V–VII	1923–24	0.2 m^2 Petersen	50.1	49–92	1	1	3		6	1	3	15
Stephen 1934 a, b..		1922–25	0.1 m^2 Petersen	4.6		9	6	4	1	10	4	6	40
The "Dana"	IV–V	1951–52	0.2 m^2 v. Veen, 60 kg[1])	11.4	40–82	15	21	5	11	33	7	5	97

[1]) Mean volume of sample, 10.6 litres.

F 9, G 10—11, H 10—11, J 11—12, and K 11—12 (for interpretation of the terms of squares, see p. 133). 4.6 m². Season of the year not stated.

"DANA": 55 stations situated in the same squares as the above mentioned stations operated by STEPHEN and DAVIS. 11.4 m². April—May.

The number of animals per square metre obtained by STEPHEN is intermediate between that found by DAVIS and that found by the "DANA". One would rather expect STEPHEN's figures to be lower than DAVIS's because STEPHEN used a 0.1 m² grab. A grab of similar design and size was discarded as inefficient by DAVIS. The difference between the results obtained by STEPHEN and by the "Dana" is quite reasonable on account of the difference in gear (0.1 m² PETERSEN as against 0.2 m² VAN VEEN).

Table 5.

Number of bottom animals per square metre in the German Bight.

Community	Reference	Month	Year	Grab used	Area sampled (m²)	Depth	Number per square metre						
							Echinoderms	Lamellibranchs	Gastropods	Polychaetes	Crustaceans	Other groups	Total
Venus, NE.	DAVIS, sts. 91–104 ..	X	1924	0.2 m² PETERSEN	5.6	15–32	3	6		15	4		28
	HAGMEIER	V	1924	0.1 m² PET., 75 kg	3.1	15–25	3	13		41	58	1	116
	BLEGVAD	VII	1921	0.1 m² PETERSEN	0.6	17–28	17	47		13	63		140
Venus, SW.	DAVIS, sts. 111–114 ..	X	1924	0.2 m² PETERSEN	1.6	28–30	4	13	1	14	6	2	40
	HAGMEIER	VII	1923	0.1 m² PET., 50 kg	1.8	16–35	22	30	2	24	89	4	171
Ech.-fil.	DAVIS, sts. 105–110 ..	X	1924	0.2 m² PETERSEN	2.4	33–44	5	37	2	4	1		49
	HAGMEIER	VII	1923	0.1 m² PET., 50 kg	1.4	36–41	85	211	41	32	32	6	407
	BLEGVAD.....	VII	1921	0.1 m² PETERSEN	0.8	38–41	140	36	14	28	12	1	231
	The "Dana"	IV, V	1951–52	0.2 m² v. V., 60 kg[1])	2.4	32–40	80	244	33	60	6	24	447
Total	DAVIS	X	1924	0.2 m² PETERSEN	9.6	15–44	4	15	1	12	4		36
	HAGMEIER	V, VII	1923–24	0.1 m² PETERSEN	6.3	15–41	27	62	10	34	61	3	197
	BLEGVAD	VII	1921	0.1 m² PETERSEN	1.4	17–41	87	41	8	21	34	1	192
	The "Dana"	IV, V	1951–52	0.2 m² VAN VEEN[1])	2.4	32–40	80	244	33	60	6	24	447

[1]) Mean volume of sample, 10.5 litres

The German Bight is another area of overlapping of several investigations. HAGMEIER (1925) compiled his stations into several animal communities for each of which was given the number of animals per square metre. The same arrangement is adopted in Table 5. BLEGVAD (1922) also adopted the concept of communities while DAVIS did not. Therefore, the present author had to arrange DAVIS's stations in communities in order to make them comparable with HAGMEIER's. The following series of stations are compared:

DAVIS: Voy. XCI, st. no. 91—114. 9.6 m². October.

HAGMEIER: "*Venus* community" (1925, Tables 5 and 6); "*Echinocardium-filiformis* community with some "*Venus*" animals". 6.3 m². May and July.

BLEGVAD: St. no. 12—18. 1.4 m². July.

"Dana": 12 stations within the area covered by HAGMEIER. 2.4 m². April—May.

The number of animals obtained by DAVIS is far below that found by the other investigators whose results are in good accordance with each other when, again, the difference in gear is

taken into consideration. The difference between the results of BLEGVAD and DAVIS is of special interest because these authors used the same ship (the "George Bligh"). In fact, BLEGVAD came on board to give advice on the use of the apparatus (DAVIS 1923 p. 4). DAVIS's intensive grab survey of the North Sea began a few days after the departure of BLEGVAD. During his first voyage DAVIS employed the same instrument as BLEGVAD did (a 0.1 m² PETERSEN grab), but he soon realized that "this was too small and light an instrument to be used satisfactorily in the open sea" and, therefore, replaced it by a 0.2 m² grab of the same design. The area (square G 8, on the Dogger Bank) investigated during DAVIS's first voyage in which the 0.1 m² grab was employed is covered by three later voyages during which the 0.2 m² grab was used. The number of specimens per square metre obtained during the four voyages to square G 8 is shown in Table 6. *Spisula subtruncata* is kept separate owing to its locally high

Table 6.

Comparison of DAVIS's results with 0.1 m² and 0.2 m² PETERSEN grabs on the Dogger Bank (square G 8).

Area sampled (m²)	Voyage No.	Month	Year	Size of grab (m²)	No. per square metre	
					Spisula subtruncata	Other bottom invertebrates
11	22	VIII	1921	0.1	16	12
16	26	IX	1921	0.2	90	24
7	29	XI	1921	0.2	213	24
33	39	VI	1922	0.2	77	17
56	26, 29, and 39	VI-XI	1921-22	0.2	98	20

density. It seems as if the results were actually improved when the larger instrument was introduced. This, however, makes the difference between the results obtained by BLEGVAD and DAVIS even more striking because DAVIS used the 0.2 m² grab within the area covered by BLEGVAD with the smaller one.

The evidence is in favour of the opinion of BIRKETT (1953) that DAVIS's results are not entirely reliable. However, the comparability of the almost simultaneous investigations may easily be questioned. Until further evidence is presented it is no doubt advisable to be cautious when comparing DAVIS's catches with those of other investigators.

Identification of Juveniles.

The specific characters of juveniles of several species of echinoderms differ essentially from those of adults. The investigator will learn by experience how to identify the young stages but it may be convenient to describe the juveniles of a few species.

Ophiura albida. Fig. 14 shows oral and aboral views of an adult and of a juvenile. The young one has few of the characters normally used for the identification of the adult as described by MORTENSEN (1927). In the juvenile the dorsal arm plates are small and widely separated except in the proximal part of the arms. The heart-shape of the innermost dorsal arm plate is not developed and there is no notch above the base of arms. Arm combs are not developed. The dorsal side of the disk is covered by radial shields and primary plates only. There are no tentacle scales except in the second (i. e., the first visible) foot pore. On either side of the jaw there are

two broad mouth papillae, very different from the short and acute mouth papillae of the adult. The juvenile pictured measures 1.1 mm across disk. The adult measures 9.5 mm.

The youngest specimens of *Ophiura affinis* obtained in the bottom samples measured 0.5—1.0 mm. They had the characters of the adult and, thus, were easily distinguishable from juvenile *O. albida*. Juvenile *O. texturata* were not recognized. It is suspected that they resemble juvenile *O. albida*.

Spatangus purpureus. (Fig. 15 B). The characteristic purple colour is conspicuous even in the smallest specimens seen (length of test 1.5 mm). The test is more elongate than in the adult. The spines are long and protruding although the heavy dorsal spines of the adult are not developed. The subanal fasciole is very conspicuous, not much broader than long, as in the adult

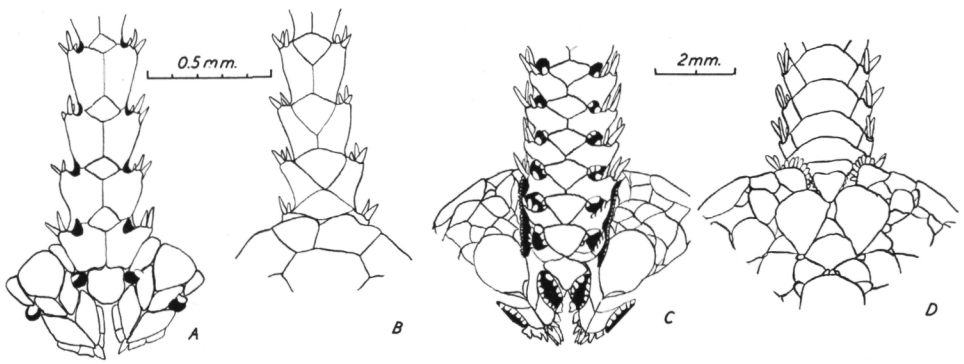

Fig. 14. *Ophiura albida*. Oral and aboral views of juvenile (1.1 mm; st. no. 7403) and adult (9.5 mm; st. no. 7436).

Spatangus raschi Lovén. In fact, there is no proof that the material does not belong to *S. raschi*. It was referred to *S. purpureus*, however, because *S. raschi* is not recorded from the North Sea. In some of the smallest specimens a large number of ophicephalous pedicellariae are situated within the subanal fasciole. Ophicephalous pedicellariae are found in the ventral ambulacra, too. They are more conspicuous and probably more numerous in the two posterior ambulacra (cf. Fig. 15 B). Globiferous pedicellariae, few in number, may occur on the dorsal side.

Echinocardium flavescens. (Fig. 15 C). In fresh material juveniles of the present species are easily distinguished from young *Spatangus* owing to the purple colour of the latter. In preserved material which has been exposed to daylight this character cannot be used. In *E. flavescens* the test is slightly widened anteriorly while the test of juvenile *Spatangus* has an almost faultless oval shape. The peristome is placed more anteriorly in *Spatangus* than in *E. flavescens*. Both species have ophicephalous pedicellariae on the ventral side and they may have a few globiferous ones on the dorsal side. In *E. flavescens* the long dorsal spines seem to develop at about 10 mm length of test.

Echinocardium cordatum. (Fig. 15 A). The test is still more widened anteriorly than in *E. flavescens*. The frontal ambulacrum is only very slightly deepened. The difference in shape of test between *S. purpureus*, *E. flavescens*, and *E. cordatum* is not as useful in practice as Fig. 15 seems to indicate. Very often the outline of the test is obscured by the spines and by adhering particles and mucus from other animals in the sample. In the North Sea a consistent character of *E. cordatum* seems to be the absence of ophicephalous and globiferous pedicellariae. The *E. cordatum* of the Mediterranean Sea possesses globiferous pedicellariae (Mortensen 1927 p. 332). The spines of *E. cordatum* are slender and curved backwards except, perhaps, in the smallest

specimens (up to 2 mm). The subanal fasciole is not so marked as in *S. purpureus* and *E. flavescens*. The two posterior ventral ambulacra are almost barren. The peristome is more rounded than in the two other species pictured. The anterior sloping of the test is not conspicuous in specimens less than about 10 mm long. Generally, juvenile *E. cordatum* bear some resemblance to adult *E. flavescens*.

Juvenile *Echinocardium pennatifidum* and *Brissopsis lyrifera* were not recognized.

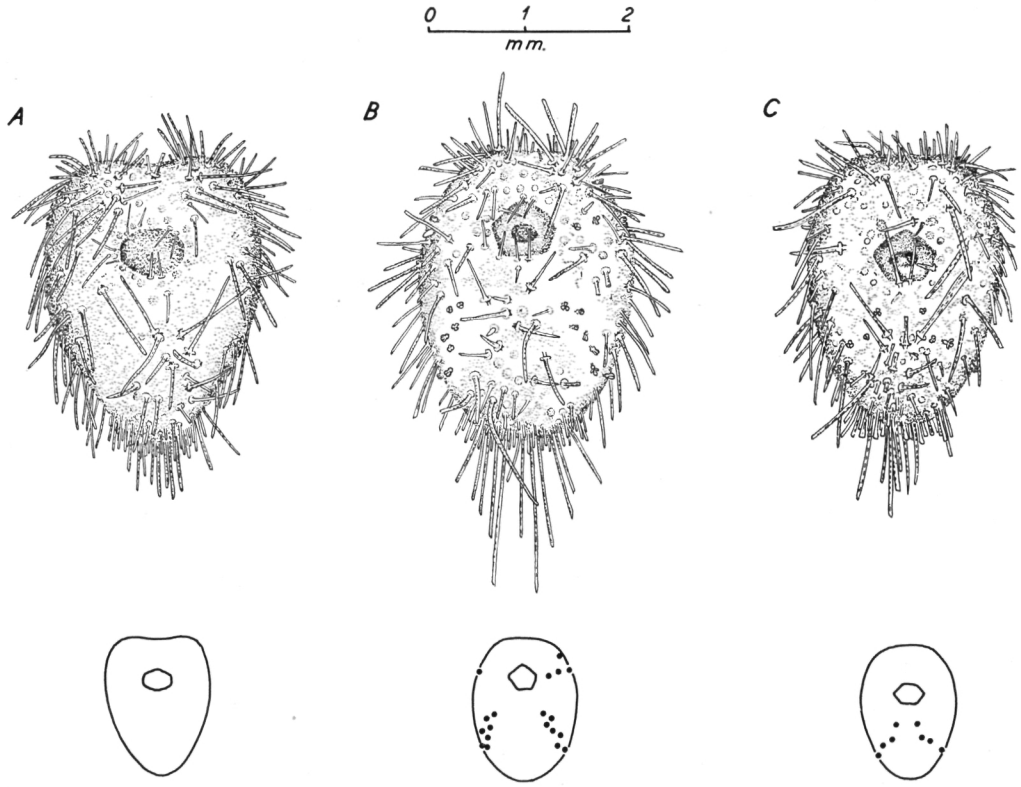

Fig. 15. Juvenile *Spatangidae*. *A. Echinocardium cordatum*. *B. Spatangus purpureus*. *C. Echinocardium flavescens*. The contour drawings below indicate the shape of test, the situation of the peristome and the situation of ophicephalous pedicellariae. The absence of pedicellariae from the anterior part of the test in *E. flavescens* is not of systematic value. (E. LEENDERS del.).

The Species.

The present section contains a short account of each species of echinoderms occurring in the North Sea above the 100 m line and south of 58° N. A straight line from Cape Lindesnæs in Norway to Hanstholm in Jutland marks the boundary between the Skagerrak and the North Sea. On the charts of distribution Skagerrak records are plotted only as far as they concern species also recorded from the North Sea within the 100 m line and only as far as they are available in the same sources of information as the North Sea records. An asterisk (*) before the specific name indicates that new material from the North Sea is not presented. A dot (°) indicates that material was not obtained during the Danish grab surveys in 1932—55. 57 species are listed. With the exception of *Cucumaria planci* they are all recorded from the North Sea or the Skagerrak by previous authors. 37 species are represented in the present material from the North Sea. 29

species were found during the Danish grab surveys. *Marthasterias glacialis* and *Pontaster tenuispinus* are not listed although North Sea records exist. The records of *M. glacialis* are discarded on evidence by SÜSSBACH and BRECKNER (1911 pp. 232, 235). The record of *P. tenuispinus* is discarded on the authority of MORTENSEN (1924 p. 40).

Information on the general distribution of the species is derived from MORTENSEN (1927), KOEHLER (1921, 1924—27), BRATTSTRÖM (1941) and EINARSSON (1948). North Sea records are usually referred to the original source of information. Several older British faunistic works, however, are quoted from MORTENSEN (1927) only.

The species are listed in the same sequence as by MORTENSEN (l. c.), and the same nomenclature is adopted. Station numbers refering to the list of grab stations, Appendix 1, and the number of specimens in each haul (bracketed) are given for each species.

Crinoidea.

**Antedon bifida* (PENNANT).

A shallow water species known from Portugal to the Shetland Isles. According to MORTENSEN (1927) it is the only crinoid known with certainty from the North Sea, in which it occurs on the North British coast down to Northumberland. It also occurs in the English Channel (Plymouth Marine Fauna, 1957). It is one among several southern species which penetrate into the North Sea from the north only. In some cases the temperature conditions (high winter temperature) perhaps account for such distributional patterns. However, the coincidence of the distribution around the British Isles of *Antedon bifida* and of the *Sagitta elegans* plankton community (RUSSELL 1939, cf. above, p. 15) is striking.

Asteroidea.

Astropecten irregularis (PENNANT).

Danish grab records 1932—55 are listed in Appendix 1.

All available records, published and unpublished, from bottom samples and from trawl and dredge hauls are gathered in Fig. 16 A. The species was found at many stations in the northern and eastern part of the area investigated. However, finds are few in number on the Dogger Bank and in the Horn's Reef area off the Jutland coast. This becomes even more apparent when the Danish grab records are isolated (Fig. 16 B). A comparison with the station charts (Fig. 1, p. 4) shows that *Astropecten* was not found regularly where sampling was most intense. On the Dogger Bank the 40 m line and in the Horn's Reef area the 20 or 30 m line delimit the distribution. The more scattered sampling north and east of the Dogger Bank produced a large number of finds.

In 1950—54 *Astropecten* occurred in samples of soft deposits and in samples of coarse sand. Records from fine sand are few:

	Total no. of samples	Samples with *Astropecten* No.	%
Coarse sand	68	8	12
Fine sand	255	4	2
Muddy sand	175	14	8
Clayey sand	84	15	18
Sandy clay	47	6	13
Clayey coarse sand	18	1	6
All grades of soil	647	48	7

Two of the four samples of fine sand in which *Astropecten* was found originated from the northern North Sea at depths of 65 m and 67 m. Obviously, the point is that *Astropecten* is absent from the grounds of fine sand in the Dogger Bank region. This may be due to some property of the fine sand on the Dogger Bank. It is not at all likely that animals respond in the same way to contact with everything which during the present investigation obtained the designation of "fine sand". WILSON's experience (1955, and previous contributions) with settling of *Ophelia* larvae on different sands may be recalled. However, as shown below there are other species of echinoderms that avoid the Dogger Bank region and which do not even penetrate onto the softer grounds in the vicinity of the bank. In such cases the distribution of plankton communities and "water

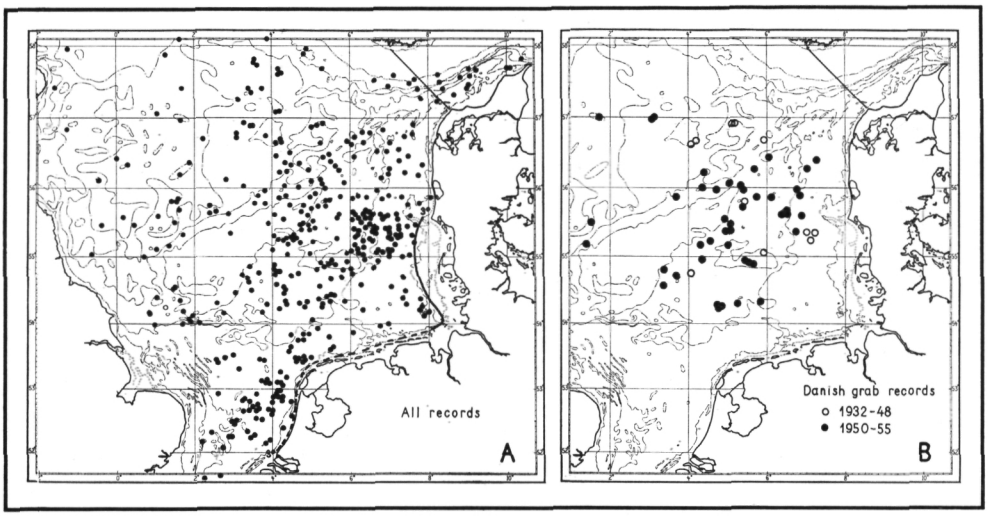

Fig. 16. *Astropecten irregularis*. The 3° isotherm for the coldest month is indicated on chart A.

types" (cf. p. 15) are rather brought in mind. It might be suggested that *Astropecten* avoids the central part of the area characterized by the *Sagitta setosa* plankton community. When *Astropecten* is studied separately there is not much in favour of the water type influence. However, evidence gathered in the study of other species of echinoderms repeatedly points toward a connexion between the distribution of plankton and benthos species in the North Sea (see also p. 99).

The absence of *Astropecten* from the shore region in the Horn's Reef area is more likely to be explained by temperature requirements. The shoreward limit of distribution approximately coincides with the 3° isotherm for the coldest month (Fig. 16 A). Further evidence of sensitivity of *Astropecten* to winter temperatures was gathered after the severe winter of 1946—47 during which in the major part of the eastern and central North Sea were recorded, at one time or another, temperatures below 3° (cf. p. 14). Accordingly, *Astropecten* was scarce in the eastern North Sea in the first years after the cold winter. This is shown in Fig. 17 in which records from Danish trawl and seine catches are plotted. Similar observations were made on the bivalve *Chlamys opercularis* which has, in the North Sea, approximately the same distribution as *Astropecten irregularis* (cf. URSIN 1956 a). A comparison of charts of distribution (*A. irr.:* BRATTSTRÖM 1941 p. 239; *Chl. operc.:* URSIN l. c. p. 5) shows that even in the transitional area between the North Sea and the Baltic the distributional patterns of the two species are almost identical.

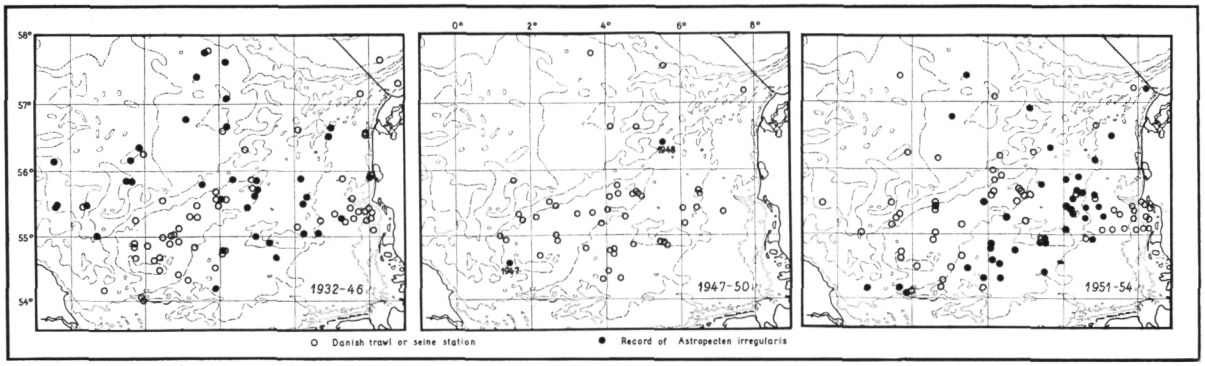

Fig. 17. Evidence of the decrease of *Astropecten irregularis* in the southern North Sea during the severe winter of 1947, and the subsequent recovery.

The distribution in the transitional area was found to correspond to a tolerance of a mean salinity down to 25 $^{0}/_{00}$, of a mean winter temperature down to 3° and of a mean summer temperature up to 16°. Off the island of Helgoland *A. irregularis* apparently occurs at somewhat higher summer temperatures (mean about 17°). This difference between the temperature range of the species in the North Sea and in the transitional area is probably not real because in the transitional area it is difficult to find suitable localities with summer temperatures above 16° but without winter temperatures below 3°. Besides salinity winter temperature is probably an important determining factor for the shoreward limit of distribution of *A. irregularis* in Danish waters. The species is distributed from the warmest part of Iceland to the Mediterranean and West Africa. Nowhere, apparently, does it occur at lower winter temperatures than in Danish waters.

MORTENSEN (1927) recognizes three forms of *A. irregularis:* var. *serratus* with several large spines on the upper marginals, var. *typicus* with a single spine on several or all marginals, and var. *pentacanthus* without conspicuous spines on the marginals. 170 specimens from North Sea trawl catches made in 1952—55 were referred to variety. There is some overlapping of the characters, but 64 specimens were referred to var. *pentacanthus* and the remaining 106 to var. *typicus*. Var. *serratus* was not observed. Fig. 18 shows the distribution of the two forms in the North Sea. All specimens from the northern North Sea were referred to var. *pentacanthus*. In the southern and eastern North Sea the typical form dominates. Several *pentacanthus* from the southern and eastern North Sea are rather dubious. On some marginals there may be a tendency towards dominance of the central spines. The *pentacanthus* from the northern North Sea have a large number of small and uniform spines on the upper marginals. The results roughly cor-

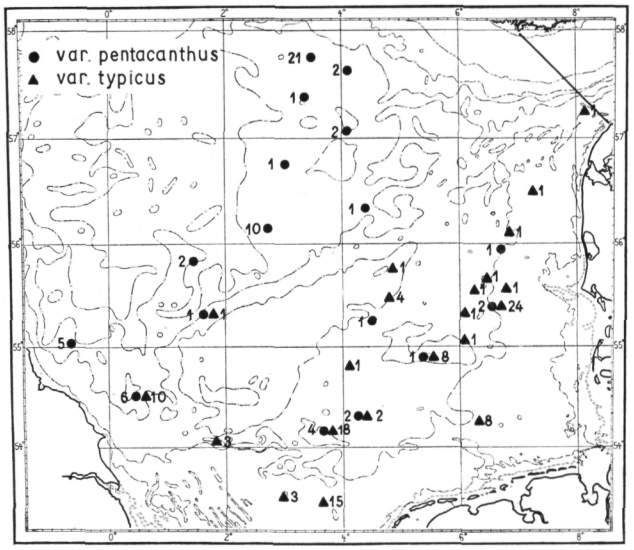

Fig. 18. The occurrence of two forms of *Astropecten irregularis* in the North Sea. Trawl catches 1952-55. The number of specimens referred to each variety is indicated.

respond with those of ENGEL (1934) who found, additionally, that the *A. irregularis* of the Dutch coast is of the *serratus* form. Material from the coast of the southern North Sea is not available from the present investigation. ENGEL (l. c.) points to depth as the important factor for the development of the three varieties: *serratus* occurs in shallow water, the typical form in moderate depths, and *pentacanthus* in the deepest part of the North Sea. Another possibility is that *serratus* is connected with the coastal plankton community of the southern North Sea, the typical form with the setosa water region of the central North Sea, and *pentacanthus* with the elegans water (of more recent Atlantic origin) in the northern North Sea. The systematic value of the characters is doubtful. Superficially, the three forms in the North Sea constitute a "Rassenkreis" (RENSCH 1929) as known from many terrestrial animals. Since *A. irregularis* has pelagic larvae it does not seem likely, however, that each of the three regions depend for reproduction entirely upon their own stock of adults. Probably, the three forms are in the North Sea mere modifications without systematic value. This does not imply that the differences have not become genetically fixed elsewhere, for instance in the Mediterranean in which *pentacanthus* occurs almost to the exclusion of other varieties.

The largest radius (the "R" of MORTENSEN (1927) and previous authors) was measured on 54 specimens from bottom samples taken in April and May 1951—54. The size frequency was:

R in mm	1—4	5—9	10—14	15—19	20—24	25—29	30—34	35—39	40—44	45—47
Number	8	4	4	4	12	12	3	3	2	2

The smallest size groups probably represent the 0-group. The dominating size groups (20—24 mm and 25—29 mm) may represent the I-group. Other age groups are not recognizable. The size frequency is approximately the same as observed in the North Sea by SÜSSBACH and BRECKNER (1911 p. 204) and in the southern Kattegat and the Sound by BRATTSTRÖM (1941 p. 159). The biggest specimen (47 mm) was caught in 1951 within the area in which the stock was probably exterminated or reduced during the severe winter of 1947.

**Psilaster andromeda* (MÜLL. et TROSCH.).

In the North Sea, on the edge of the Skagerrak, a single find was made in 1905 at a depth of 57 m (SÜSSBACH and BRECKNER 1911). Further finds in the Skagerrak and in the Norwegian Channel were made by the same authors and during the voyages of the "Dana" (Fig. 19). *P. andromeda* is distributed from the Barents Sea to the Cape Verde Islands but usually at depths of 100 m or more. The North Sea may be rather shallow to a species with such preferences.

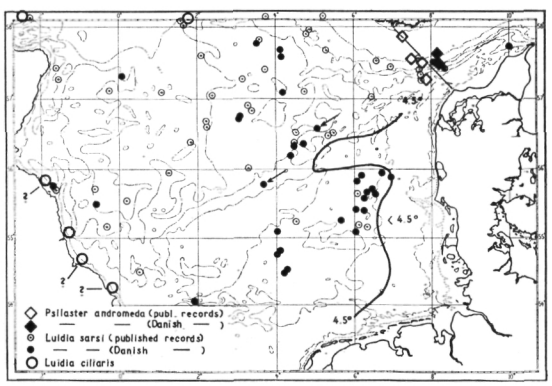

Fig. 19. The two grab records of *L. sarsi* are indicated by arrows. The 4.5° isotherm for the coldest month follows roughly the shoreward limit of distribution of *L. sarsi* on the Jutland coast. A question-mark indicates that the exact locality (particularly the distance from land) is not known.

Luidia sarsi DÜB. et KOR.

Danish grab records 1932—55: 7443 (1), 8081 (1).

A large number of finds (Fig. 19) are available from trawl and dredge stations in the northern and eastern part of the area investigated. *L. sarsi* is seldom found in bottom samples because the density of the species is low. The Danish grab

records refer to localities north of the Tail End of the Dogger Bank. In the preceding century and in the first years of the present century few finds were made in the shallower parts of the North Sea (in depths less than 60 m) in spite of the intensive trawling and dredging in the southern and eastern North Sea by German and Dutch investigators. In more recent years, however, trawlings by the "Dana" fairly regularly produced *L. sarsi* from depths of 40—50 m, particularly on the Bløden Ground in the eastern North Sea. Such records are available from 1922, 1930, 1938, and 1951—55. Although really quantitative evidence is not available there is not much doubt that the distribution or abundance of *L. sarsi* in the North Sea has changed since the beginning of the present century.

The North Sea is not far from the northern limit of distribution of the species. It is recorded from Trondheim (Norway) and once from the Faroe Bank (LIEBERKIND 1929). A comparison of the hydrographic section and the zoogeographical section in BRATTSTRÖM's paper (1941) shows that *L. sarsi* in the Kattegat occurs at a mean salinity not much below 30 $^0/_{00}$, at a mean summer temperature not above 15° or 14° and at a mean winter temperature not below 4° or 4.5°. Thus, it may be expected that the salinity in the North Sea is sufficiently high everywhere except in estuaries, etc. In the North Sea *L. sarsi* is found only at mean summer temperatures below 15° and at mean winter temperatures above 4.5° (cf. the hydrographic charts, Figs. 7—8); that is, at approximately the same temperature interval as in the Kattegat. This points toward temperature as a limiting factor in distribution. However, the species is absent from a large part of the southern North Sea although the temperature should be suitable there. In the English Channel, also at suitable temperatures (cf. charts issued by Deutsche Seewarte 1927), *L. sarsi* appears to be relatively rare (Plymouth Marine Fauna 1931). Evidently, factors other than summer and winter temperature have some limiting influence. In the North Sea *L. sarsi* occurs on coarse sand and on muddy and clayey bottom. Like *Astropecten irregularis* it is absent from grounds of fine sand. The fine sand localities on the Jutland coast are situated within the winter-cold area in which *L. sarsi* cannot be expected to occur. On the Dogger Bank the temperature is more satisfactory. As for *A. irregularis* a special property of the Dogger Bank deposits may account for the absence of *L. sarsi* from this area. However, the larva of *L. sarsi* is listed among the indicators of the *Sagitta elegans* plankton community (RUSSELL 1939 p. 175). As mentioned in the introduction (p. 16) this plankton community occurs from surface to bottom along the north British coast and extends along the bottom over the larger part of the northern North Sea; occasionally, it may push in to the southern North Sea, probably entering through the depressions south-west and east of the Dogger Bank. It seems reasonable that the southern North Sea stock of *L. sarsi* originates from larvae occasionally introduced with *elegans* water. If so, the absence of the species from the Dogger Bank may be due to the strong predominance of *Sagitta setosa* water in the bank region. Accordingly, changes in the distribution of *L. sarsi* in the North Sea perhaps to some extent reflect the varying penetration of *elegans* water.

There are no records of *L. sarsi* from the southern North Sea in 1947—50. Like *A. irregularis*, *L. sarsi* may have suffered from the severe winter of 1947 during which the bottom temperature in the southern North Sea decreased several degrees below the temperature at which *L. sarsi* is normally found.

**Luidia ciliaris* (PHILIPPI).

Old British authors (FORBES 1841 p. 139, NORMAN 1865 p. 118, BELL 1892 p. 72) record *L. ciliaris* from localities on the British coast from Berwick to Scarborough. Depths or exact finding places are not stated. On the chart, Fig. 19, these records are accompanied by a question-mark. Dr. J. A. ALLEN, Cullercoats, informs me (1957) that *L. ciliaris* is still fairly common on

the Northumberland coast from 10—45 fathoms. SÜSSBACH and BRECKNER (1911) have records from the North Sea north of 58° N. It is recorded from the Skagerrak and from the Norwegian coast off Bergen (MORTENSEN 1924); also from the southernmost part of the Faroe shelf (LIEBERKIND 1929). Toward the south *L. ciliaris* is distributed to West Africa and the Mediterranean. It occurs at the western entrance to the English Channel. Most North Sea records are from fairly deep water (mostly about 100 m). Elsewhere, *L. ciliaris* seems to be a shallow water form. Perhaps it requires high winter temperatures (5 or 6° ?) or perhaps its larva penetrates into the North Sea with Atlantic water masses only.

°*Hippasteria phrygiana* (PARELIUS).

SÜSSBACH and BRECKNER (1911) found this species on many stations in the northern North Sea. South of 58° N. it was repeatedly found by these authors within a small area in the midst of the North Sea, down to 57° N. It was taken by the "Wodan" in 1908 and in recent years regularly by the "Dana", still within the small area between 57° N. and 58° N. (see Fig. 20). The old British authors (FORBES 1841 p. 126, NORMAN 1865 p. 123, BELL 1892 p. 78) record *H. phrygiana* from several localities on the British coast—depth and distance from land not stated. The vagueness of these records is indicated on the chart. In a letter (1957) Dr. J. A. ALLEN, Cullercoats, informs me that *H. phrygiana* is still fairly common on the Northumberland coast from 10—45 fathoms. Thus, the species seems to occur only within two fairly distinct areas in the North Sea. It is difficult to see why it does not occur in the western North Sea except on the British coast. On the British coast it probably occurs at mean temperatures ranging from 5° in winter to 13° in summer. In the offshore occurrence it is exposed to temperatures ranging from 5—9° only. The mean salinity probably is above 34 ‰ on the British coast and above 35 ‰ in the offshore area of occurrence.

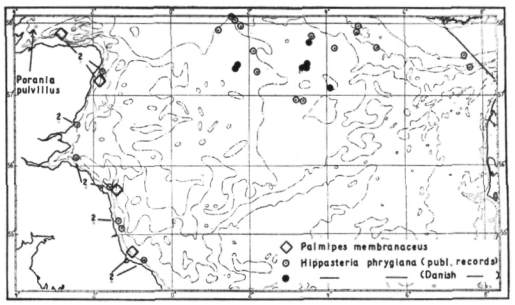

Fig. 20. There are no grab records of these three species. A question-mark indicates that the exact locality (particularly the distance from land) is not known.

In the Kattegat the species apparently (BRATTSTRÖM 1941) occurs at mean temperatures ranging from 5° in winter to 13° in summer and at mean salinities down to 33 ‰. Thus, the minimum temperature at which the species is found is approximately the same in the North Sea and in the Kattegat. It occurs, however, off North Iceland and West Greenland. Such distribution is scarcely reconcilable with a requirement of minimum temperatures not much below 5°. Obviously, temperature or salinity is not the determining factor for the distribution of *H. phrygiana* in the North Sea. The distributional pattern recalls that of *Amphiura chiajei* (which see) and other species which abound on the British east coast and in the transitional area between the North Sea and the Baltic, but which in offshore parts of the North Sea are confined to the extreme north.

**Porania pulvillus* (O. F. MÜLLER).

MORTENSEN (1927) without further reference records it from the Moray Firth (Fig. 20). SÜSSBACH and BRECKNER (1911) got it at several stations in the northernmost North Sea, between the Shetlands and Norway. *P. pulvillus* is distributed from Iceland to the Atlantic coast of France. It occurs in the English Channel and on the west coast of Sweden. Whatever the reason for the

absence of the species from the area covered by the present investigation it is rather obvious that the absence cannot be explained by temperature requirements.

**Palmipes membranaceus* LINCK.

A decidedly southern species (not known father north than the Shetlands) which in the literature is recorded thrice from the British North Sea coast: Moray Firth (NORMAN 1865 p. 121), Aberdeen (BELL 1892 p. 85) and Hartlepool, England (FORBES 1841 p. 118) (Fig. 20). Dr. J. A. ALLEN, Cullercoats, informs me (1957) that *P. membranaceus* was taken in 1933 east of the Farne Islands in about 30 fathoms. It is also known from the Straits of Dover (KOEHLER 1921) and from several localities in the English Channel (BELL 1892, Plymouth Marine Fauna 1957). It may be suggested that *P. membranaceus* either requires a high winter temperature (5—6° ?) or that it is confined to the *Sagitta elegans* water masses which penetrate into the North Sea around Scotland and through the English Channel. Unlike *Porania pulvillus* it is not known from the Skagerrak or the west coast of Sweden.

°Solaster papposus (L.).

S. papposus is listed regularly from Danish trawl and dredge hauls (1922—55) in shallow water in the Skagerrak and on the coast of north Jutland. Farther south, in the Horn's Reef area, unidentified *Solaster*, most probably the present species, are recorded at three stations. In the same inve tigation two finds are recorded from Scottish offshore waters (off the Firth of Forth,

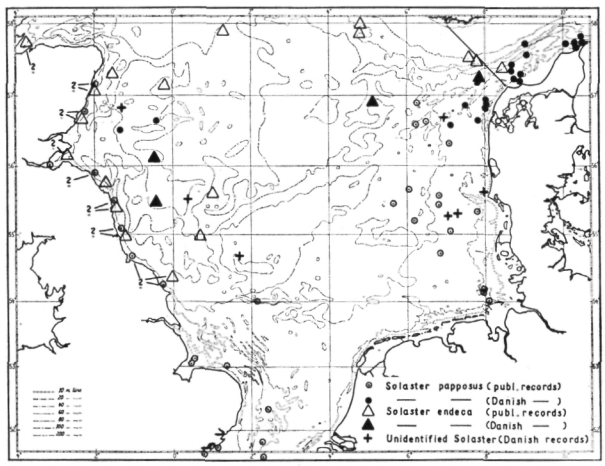

Fig. 21. There are no grab records of *Solaster*.

cf. Fig. 21). The old German investigators and the "Wodan" found it in the same areas and in the Southern Bight, on the English side. It was observed to be abundant on *Chlamys* beds in the Firth of Forth (FULLARTON 1889), on oyster beds in the estuaries of the rivers Roach and Crouch, south England, (WALNE 1956), and in Helgoland waters (tiefe Rinne, Austernbank, CASPERS 1939, 1950). Apparently, *S. papposus* occurs in two distinct regions in the North Sea. It occurs on the Danish and German coast down to Helgoland. It is not abundant on the Dutch coast (absent from the numerous trawlings by the "Wodan" in 1902—11) but reappears on the English coast of the Southern Bight. The south English and the Scottish occurrences are connected by vague records (without reference to depth or distance from land) by FORBES (1841 p. 115) and BELL (1892

p. 90). On the chart, Fig. 21, these records, except one from the tidal zone at Scarborough (FORBES), are accompanied by question-marks. The species seems to be absent from the whole offshore region of the North Sea so that, apparently, there is no connexion between the eastern and the western area of distribution.

S. papposus has a decidedly northern circumpolar distribution. On the European coast it penetrates south to the English Channel. It might be expected, perhaps, that an animal so distributed would show a pronounced sensitivity to temperature in the North Sea. The approximate temperatures to which *S. papposus* is exposed in British, German, and Danish waters are listed below:—

	Mean bottom temperature (°C)	
	Winter	Summer
The English Channel	6—8	14—16
The rivers Crouch and Roach	2	20
The Firth of Forth	4	14
Scottish offshore waters	5	11
Helgoländer tiefe Rinne	3	17
Off north Jutland	4	11
The Limfjord (north Jutland)	1	18
The Kattegat and the Belt Sea	3—4.5	13—16

Obviously, there is not in the present species any particular demand for low summer or winter temperatures, nor for homo-thermal environment. In the Kattegat and the Belt Sea the salinity seems to determine the southern limit of distribution. In the adult stage *S. papposus* apparently tolerates salinities down to 20 $^{0}/_{00}$ although temporarily only (BRATTSTRÖM). Thus, salinity probably is out of the question as a limiting factor in the North Sea. Several authors point to the hard bottom affinities of *S. papposus*. However, the bottom of the North Sea is so varied that suitable grades of soil most probably exist within the area of the North Sea not inhabited by the species. In some way or another the species may be tied up with the rheophile fauna element (on which see further p. 101). The abundance in the south-western Kattegat (BRATTSTRÖM 1941), on the *Chlamys* beds in the Firth of Forth (FULLARTON 1889) and in the English Channel (E. J. ALLEN 1899 p. 464), and on the oyster beds in the estuaries of the rivers Crouch and Roach (WALNE 1956) points in this direction. As suggested by ALLEN (l. c.) it probably feeds on the large epifaunal molluscs which often dominate rheophile faunas (cf. URSIN 1956 a p. 6). Such large molluscs, however are particularly scarce within the area of distribution of *S. papposus* in the eastern North Sea because *Mytilus* is confined to the Waddensea region and *Chlamys opercularis* and *Modiolus* to more offshore waters. The distribution of *S. papposus* in the North Sea bears resemblance to that of *Echinus esculentus*. There are reasons to believe that *E. esculentus* is particularly sensitive to differences between water masses supporting different plankton communities. It is therefore reasonable to relate the distribution of both species to the distribution of water masses in the North Sea.

50 German trawl and dredge stations operated off the Danish coast between 55° N. and 56° N. in the period 1872—1907 produced 7 finds of *S. papposus*. In 1922—55 about 120 trawl stations were operated in the same area by Danish research vessels. These 120 stations produced 3 finds only. It seems as if the species has become more rare in this region. BRATTSTRÖM (1941 pp. 162, 164) finds that *S. papposus* has decreased in number in the Sound, too.

°*Solaster endeca* (L.).

Recorded by the old German investigators and TESCH (1906) from trawl and dredge catches in the northern North Sea. FORBES (1841), NORMAN (1865) and BELL (1892) have it from several localities on the British North Sea coast with Scarborough as the most southern locality. They are persistent that on the British coast *S. endeca* occurs in deeper water than *S. papposus;* they do not give exact positions of capture (Fig. 21). The trawl surveys of the "Dana" in 1922—55 produced several finds in the northern North Sea. There are no records of the species from the central part of the northern North Sea. This is scarcely accidental because the density of trawl and dredge stations (German and Danish) in the northern North Sea decreases from east toward west (cf. Figs. 6 and 11). Therefore, a scarcity of records might rather be expected in north British waters. Both species of *Solaster* seem to be largely confined to the extreme eastern and the extreme western part of the North Sea. *S. endeca* does not approach the shore as much as *S. papposus* and it does not penetrate so far south (Fig. 21).

Like *S. papposus, S. endeca* has a predominantly northern distribution. Neither species penetrates south beyond British waters. While *S. papposus* is known from the Celtic Sea, the English Channel, and the southern North Sea, *S. endeca* goes to Ireland and the northern North Sea only. It seems reasonable to think of summer temperature as a limiting factor in the distribution of *S. endeca*. At any rate, the species is not usually found in localities with mean summer temperatures above 13 or 14°. Higher summer temperatures prevail in the English Channel, in the southern North Sea and in the littoral zone on the British coast. In the transitional area between the North Sea and the Baltic (BRATTSTRÖM) *S. endeca* like a good many marine species penetrates approximately to the 30 $^{0}/_{00}$ isohaline but, apparently, it avoids localities with mean summer temperatures above 14°, even when the salinity is well above 30 $^{0}/_{00}$.

°*Henricia sanguinolenta* (O. F. MÜLLER).

The trawl and dredge surveys regularly produced *H. sanguinolenta* from stations in the northern North Sea (Fig. 22). MÖBIUS and BÜTSCHLI (1875) record it from the German Bight, off the island of Wangeroog, and CASPERS (1939 p. 52) records it from the Helgoländer tiefe Rinne. The most southerly find in the western North Sea was made in 1956, in a herring trawl catch by a Danish research vessel. The herring trawl usually captures very few bottom invertebrates but in the present case there was represented a rich and varied fauna, apparently similar to that found more northerly on the British coast. The depth was 26 m. MORTENSEN (1897, 1924) records the species from several localities in the Limfjord.

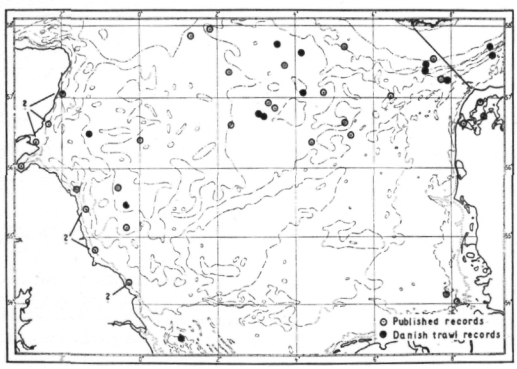

Fig. 22. North Sea records of *Henricia sanguinolenta*, as understood by MORTENSEN (1927). As in the other charts, the question-marks indicate that the exact localities are unknown.

The temperature range of *H. sanguinolenta* in the North Sea and adjacent seas is:—

	Mean temperature	
	Winter	Summer
The Firth of Forth	4	14
The northern North Sea, offshore	5	9
The German Bight	3	17
The Limfjord (north Jutland)	0—2	17—18
The Kattegat and the Belt Sea	3—5	13—16
The mouth of the English Channel	8	14

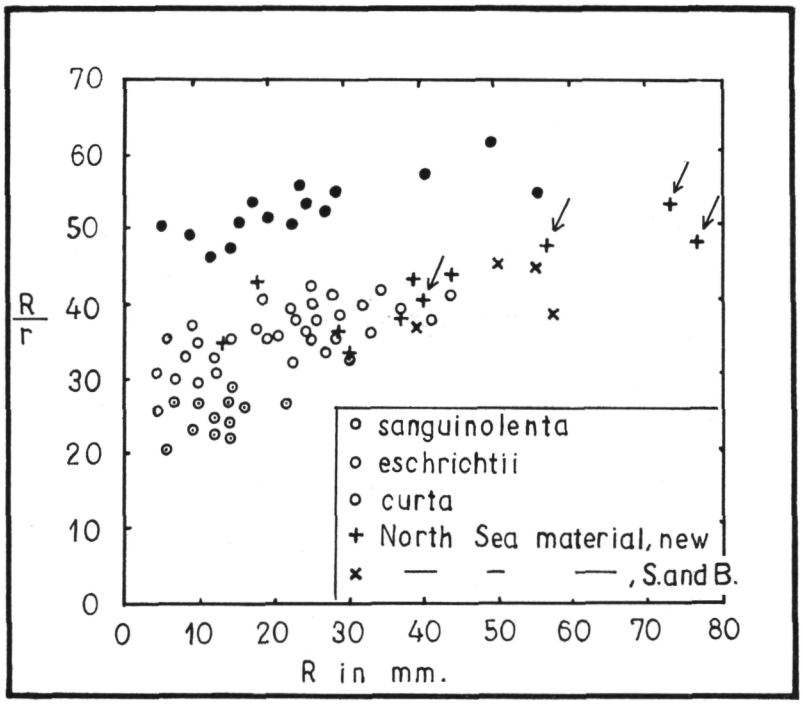

Fig. 23. The R/r ratio in *Henricia*, plotted against R. Redrawn from HEDING 1935, Fig. 5, with the addition of North Sea material from the present investigation and from SÜSSBACH and BRECKNER 1911. "Spiny" specimens from the present investigation are indicated by arrows.

Although the species has a predominantly northern distribution there is no indication of distinct temperature requirements in the North Sea. In the Belt Sea *H. sanguinolenta* tolerates salinities down to 25 $^0/_{00}$ or even less (BRATTSTRÖM 1941 p. 239) and occurs on soft bottom as well as on shells and gravel (l. c. p. 166). Apparently, neither temperature nor salinity nor bottom deposit accounts for the limited distribution of *H. sanguinolenta* in the North Sea. The species appears confined to localities regularly influenced by *Sagitta elegans* water. The rather isolated occurrence in the Helgoländer tiefe Rinne and its surroundings probably points in this direction.

HEDING (1935) is of the opinion that several species are pooled under the name of *Henricia sanguinolenta*. He describes several forms mainly distinguishable by the armature of the dorsal spines and by the arm length. In the present material 11 specimens from 8 stations in the North Sea (1954—56) are available for examination. 4 specimens from 3 stations have dorsal spines of the "spiny" type (HEDING l. c. p. 19). The remaining have "bristly" spines. The R/r

ratio is plotted against R in Fig. 23. The diagram was redrawn from HEDING's Fig. 5 and the North Sea observations were included. The North Sea specimens have the same arm length as *H. eschrichtii* (MÜLL. et TROSCH.), known from Greenland, Iceland, and the Faroes. "*H. eschrichtii*" is a form with "bristly" spines. HEDING recognizes one species only with "spiny" spines, namely, *H. scabrior* (MICHAILOVSKY), known from the Arctic and, perhaps (HEDING l. c. p. 34) from the entrance to the Skagerrak. *H. scabrior* apparently has the same R/r ratio as *H. eschrichtii*. If HEDING's systematics is adopted the North Sea material must be referred partly to *H. eschrichtii* and partly to *H. scabrior*. It occurs to the present author, however, that if *H. sanguinolenta*, as traditionally understood, shall be split into quite a number of species a similar splitting of most species of echinoderms adopted by MORTENSEN (1927) could easily be made and was made, actually, by nineteenth century authors.

**Stichastrella rosea* (O. F. MÜLLER).

S. rosea has a very limited geographical distribution. It is known from Lofoten in north to the Atlantic coast of France (sublittoral, KOEHLER 1921) in south. It occurs in the western part of the English Channel, on the British coast of the northern North Sea (FORBES, NORMAN, BELL), see Fig. 24, offshore in the northernmost North Sea (SÜSSBACH and BRECKNER), in the Skagerrak, and on the Swedish west coast. It seems to have a restricted temperature range because it is not found in localities with very low winter temperatures or with very high summer temperatures. It is not very likely, however, that the absence of *S. rosea* from the larger part of the northern North Sea is due to special temperature requirements. More probably, perhaps, the species is very particular about some other factor as for instance food supply or chemical environment.

Perhaps it has now a more restricted distribution in the North Sea than formerly. Dr. J. A. ALLEN in a letter (1957) informs me that the most recent record available to him is from 1872 when *S. rosea* was recorded off Coquet Island in 25 fathoms.

Asterias rubens L.

Danish grab records 1932—55: 4542^{I} (1), 4558^{I} (1), 4735 (2), 5196 (1), 5214^{P} (1), 5227 (1), 5231 (1), 6036—49 (2), 6045^{9} (1), 6050^{13} (1), 6050^{16} (1), 6843 (1), 6072^{II} (1), 7387 (1), 7402 (1), 7506 (1), 7535 (1), 7603 (1), 7870 (1), 8022 (2).

Almost every trawl haul made in the North Sea produced *A. rubens*. The species is seldom wanting in more than two successive trawl hauls of the "Dana" (1922—55). It is also abundant in trawl catches from the Limfjord (POULSEN 1951) and from the German and Danish Waddensea (HAGMEIER and KÄNDLER 1927, SMIDT 1951, and own observations). Obviously, *A. rubens* is particularly easy to catch in trawls and dredges.

In grab samples the species is less abundant. 9 specimens only were obtained in the grab surveys of 1950—55. 141 m^2 were sampled so that the average density was 0.06 specimens per square metre. DAVIS (1923, 1925) in about 2500 bottom samples found only two juvenile *Asteroidea*, perhaps referable to *A. rubens*. STEPHEN (1934) who published his finds in terms of absence from or presence in individual statistical squares records the species from most Scottish coast squares but not from a single offshore square. 543 stations were operated in the shore region (12 squares) against 126 stations only in 35 offshore squares. Thus, a difference in sampling efficiency may partly, although probably not fully, account for the accumulation of records in Scottish coastal waters. In the Horn's Reef area there apparently exists a similar tendency toward accumulation of grab records in shore waters. *A. rubens* also occurs in grab material from the German Bight (HAGMEIER 1925, CASPERS 1939, 1950), the Waddensea (HAGMEIER and KÄNDLER

1927, SMIDT 1951), and the estuaries of the rivers Crouch and Roach in south England (MISTAKIDIS 1951). The grab records are plotted on Fig. 24. Probably, *A. rubens* is actually more abundant in the coastal zones of the North Sea than farther offshore. It seems to be wanting in the deepest parts of the North Sea (below 215 m, SÜSSBACH and BRECKNER 1911) and the Kattegat (BRATTSTRÖM 1941 p. 167). In this connexion it is interesting to note that *A. rubens* remains positively phototactic during the whole larval life while larvae of most other marine bottom invertebrates become negatively phototactic in the later stages. This peculiarity which *A. rubens* shares with several littoral forms like *Mytilus edulis* and *Pygospio elegans* increases the probability of settling in shallow water (THORSON 1950 p. 17).

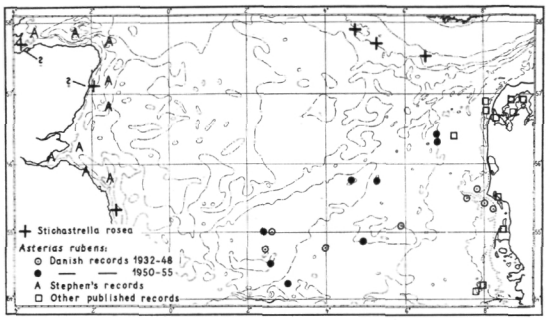

Fig. 24. Only grab records of *Asterias rubens* are plotted. The species is so abundant in trawl catches that plotting of trawl records would be almost to repeat the station charts. STEPHEN's grab records, specially indicated, refer to occurrence within individual statistical squares. *Stichastrella rosea* is known from trawl and dredge only. Two records, indicated by question-marks, are uncertain as to the exact locality in which the finds were made.

The arm length (R) in 9 specimens taken in bottom samples in April—May 1950—55 is 10, 10, 18, 20, 39, 46, and 60 mm. VEVERS (1949 p. 175) found that in Plymouth waters it is not possible to tell the age of an *Asterias* from its size because lack of food stops growth. An *Asterias* one year old may measure anything between one and nine centimetres. Well-fed specimens, however, attains a size (R) of more than 6 cm in the first year. It is probable, therefore, that the grab-caught North Sea material consists of specimens not more than a year old. Older (larger) specimens obviously are so few in number that they are difficult to trace in a grab survey.

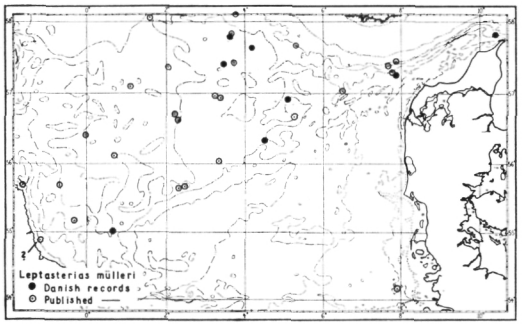

Fig. 25. All records refer to trawl and dredge catches. The exact position for one of the British coast records is not known.

°*Leptasterias mülleri* (M. SARS).

A northern form which has its southern limit of distribution in British waters. It is frequently recorded from trawl and dredge catches in the northern North Sea (Fig. 25). NORMAN (1865) and TESCH (1906) has it from the British coast (Durham and Holy Island). Most other records are from the central part of the northern North Sea. It may or may not be accidental that no records are available from Scottish waters. MEISSNER and COLLIN (1896) records *L. mülleri* from Helgoland. The species has brood protection so that accidental transport of larvae does not account for the isolated Helgoland record. The identification may be erroneous, of course, but it may be brought in mind that similar records exist for another brood-protecting asterid, *Henricia sanguinolenta*. Perhaps these species, otherwise confined to the northern North Sea, have or had an isolated occurrence in Helgoland waters which in many respects show affinity to northern North Sea water masses (cf. pp. 17 and 123).

Apparently, *L. mülleri* does not occur in the North Sea or elsewhere at mean winter temperatures above 6°. In most localities the mean summer temperature is below 13°. If the Helgoland occurrence and a few finds in shallow water in the Kattegat (see BRATTSTRÖM 1941) are to be

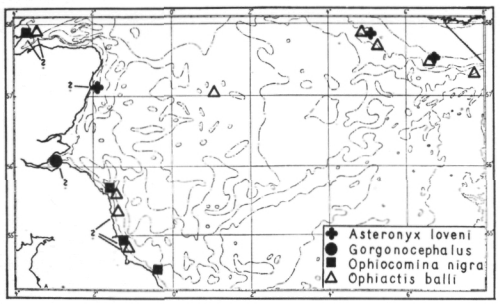

Fig. 26. Question-marks indicate that the exact locality, particularly the distance from land, is unknown. Records of *Asteronyx* and *Gorgonocephalus* refer to trawl and dredge catches (literature only). Records of *Ophiocomina* without "?", are Danish grab records 1951—52. There is one Danish grab record (1951) of *Ophiactis* (on the British coast, 55°38′ N.); the other records are from trawl and dredge catches originally published by other authors.

trusted, the coincidence of low summer temperature and occurence of *L. mülleri* is accidental only. In Helgoland waters the bottom temperature in summer usually approaches 17°.

Ophiuroidea.

**Asteronyx loveni* MÜLL. et TROSCH.

BELL (1892) records *A. loveni* from Aberdeen. SÜSSBACH and BRECKNER (1911) made several finds in the northern North Sea and on the edge of the Norwegian Channel, mostly at depths about 100 m (Fig. 26). *A. loveni* is distributed from northern Norway to Portugal. It occurs in the Skagerrak. It is usually confined to depths of 100 m and more. Thus the species might hardly be expected to penetrate into the North Sea beyond the 100 m contour. It is a suspension feeder, commensal with pennatulids. On commensalism in North Sea ophiuroids, see further p. 101.

**Gorgonocephalus caput-medusae* (L.).

Recorded from the Firth of Forth (MORTENSEN 1927), see Fig. 26. The species is known from Iceland, Norway, the Skagerrak, and the British west coast. Like the preceding species it is usually confined to water deeper than found in the North Sea.

Ophiothrix fragilis (ABILDG.).

Danish grab records 1932—55 are listed in Appendix 1.

All available records are plotted on the chart, Fig. 27. The majority of the records refer to trawl and dredge catches. The only grab record published seems to be one from the English coast (DAVIS 1925). The Danish grab survey 1932—39 produced 4 finds, 1 in the Horn's Reef area and 3 in the central North Sea. In 1950—55 *O. fragilis* was taken at 26 grab stations which produced a total number of 194 specimens. 167 specimens were obtained in 4 samples containing 96, 39, 23, and 9 specimens, respectively (see Fig. 27). The grab records seem to indicate an increase in number in recent years. In trawl catches *O. fragilis* has been abundant since the earliest investigations. It may be advisable not to stress too much weight on the apparently increasing abundance in grab samples.

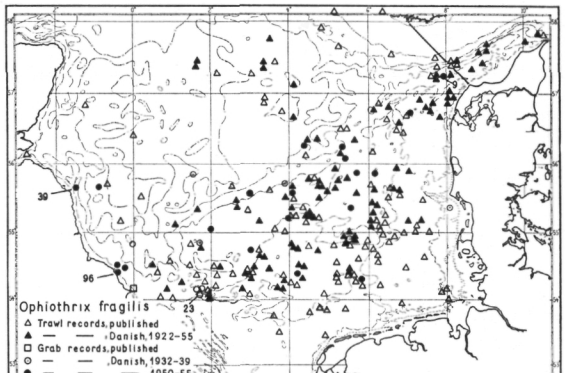

Fig. 27. Four large catches in bottom samplers are indicated (number of specimens on 0.2 m²).

O. fragilis is usually attached to stones, large shells, or sponges. In 10 cases, however, the bottom sample in which it was found did not contain coarse material or large epifaunal species to which the *Ophiotrix* might have been attached. 8 of these samples contained arm fragments only and the remaining 2 samples produced a single example each. The animals may have been

attached to some larger object which was not grabbed. In the eastern and south-eastern North Sea *O. fragilis* is usually (in trawl catches) found attached to live sponges[1]) or *Alcyonium* while in the northern North Sea and on the British coast it may be attached to either live or dead objects. In the 4 cases in which a bottom sample produced a large number (9—96) of *O. fragilis* the specimens were attached to dead objects: stones in three cases and a large *Neptunea* shell (23 specimens) in the fourth case.

The 4 samples with high numbers of *O. fragilis* were taken in localities characterized by a rich plankton. 2 were taken on the British coast within reach of the rich *Sagitta elegans* plankton community and in places with strong tidal currents (cf. DIETRICH's chart, 1950, his Fig. 11). Another sample (with the *Neptunea* shell) was taken within the south-west Dogger Bank swirl, also known to support an *elegans* plankton. The last of the 4 samples originates from the edge of the Norwegian Channel, probably in upwelling water from the deep. *O. fragilis* is not particularly abundant in the main body of the northern North Sea.

WINTZELL (1918 p. 41) pointed out that *O. fragilis* is—in the terminology of HUNT (1925)—a suspension feeder which on the Norwegian coast occurs in enormous quantities in narrow and shallow sounds with strong tidal streams. Similar observations were made by VEVERS (1952) in Plymouth waters. Underwater photography (VEVERS) revealed that *O. fragilis* collects food by stretching one or several arms upwards in the water. Evidently, the amount of food entering the space covered by the moving arms depends upon the density of plankton and detritus in the water and upon the rate of water renewal. Within the poor *Sagitta setosa* plankton community of the central North Sea the demand for food is perhaps met only in the whirling water about the body of sponges and corals. In the northern North Sea in which the richer *elegans* plankton predominates at the bottom *O. fragilis* apparently finds sufficient food everywhere in the presence of live or dead objects which it may climb to avoid the stagnant water immediately above the bottom. In strong tidal streams, swirls, or upwelling water masses on channel edges a biotope is produced which enables it to flourish almost to the exclusion of other species (cf. WINTZELL 1918 p. 38). Thus, *O. fragilis* is a decidedly current-dependent (rheophile) animal. The facultative commensalism of *O. fragilis* with sponges, corals, and other colonial suspension feeders bears strong resemblance to the obligate commensalism of *Asteronyx loveni* with pennatulids and similar tall corals.

O. fragilis is not distributed over the whole southern and central North Sea. It appears rather scarce in the central part of the Dogger Bank. In the Horns Reef area the Danish coast is not approached beyond the 20 m line except for an isolated grab record in the Graa Deep at 17 m. Investigations by the "Wodan" in 1902—11 revealed the absence of *O. fragilis* from the Southern Bight. Outside the Southern Bight *O. fragilis* was found regularly by the "Wodan". Owing to the commensal mode of living in some localities the presence of *O. fragilis* may depend on the presence of suitable hosts. Apparently, the shoreward limit of distribution in the Horn's Reef area coincides with the 3° isotherm for the winter. Probably, *O. fragilis* does not within its entire area of distribution occur at lower winter temperatures than in the Horn's Reef area. It is likely, therefore, that it is sensitive to lower temperatures. In the transitional area between the North Sea and the Baltic *O. fragilis* has approximately the same distribution as *Astropecten irregularis* (p. 27). Astonishingly, ENGEL (1932 p. 32) records *O. fragilis* from the Zuiderzee, in entirely brackish water and apparently at very low winter temperatures. Unfortunately, the original paper in which the find was published (ENGEL 1922 p. 418) is not available to the present author.

[1]) Mr. G. R. FORSTER, Plymouth, examined some specimens and found they were probably *Axinella distorta* (BWK.).

182 specimens taken in bottom samples from 28th April to 24th May (1950—54) were measured to millimetre below (Table 7). It seems as if most specimens are fairly young, representing two or three year classes. A few larger specimens may be considerably older. In the North Sea the occurrence of pelagic larvae of *O. fragilis* is confined to June—October (Rees 1954, p. 55). Accordingly, the youngest specimens in the grab material probably settled in the year preceding capture.

Table 7.

Size frequency in *Ophiothrix fragilis* from bottom samples. April and May 1950—54.

	No. of specimens in each millimetre group																			Total number
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
4 stations with high densities	1	2	6	3	2	5	2	1	..	..	..	..	..	..	..	..	..	1	..	23
	2	11	15	15	10	6	10	9	6	3	5	3	2	..	..	..	..	..	..	97
	..	..	..	1	4	1	1	6	7	8	5	4	..	1	1	..	..	..	..	39
	..	..	..	1	..	1	2	1	..	1	1	3	..	..	..	..	..	..	..	10
Other stations.....	..	1	1	..	4	..	1	2	..	..	..	..	1	1	1	..	..	..	1	13
Total.....	3	14	22	20	20	13	16	19	13	12	11	10	3	2	2	..	..	1	1	182

Ophiocomina nigra (Abildg.).

Danish grab records 1932—55: 7570 (2), 8866[I] (1).

Bell (1892) has *O. nigra* from the east coast of Rossshire, and Mortensen (1927) records it from the Durham coast. The Danish grab records (May, 1951 and 1954, depth 45 m and 51 m) refer to stations on the English coast (Fig. 26). 5 samples are available from these localities. They contained a total of 145 *Ophiothrix fragilis* and 3 *O. nigra*. On the *Ophiothrix* beds in the English Channel Vevers (1952) found a ratio of less than 1 *O. nigra* to 100 *O. fragilis* which is almost the same ratio as in the samples from the English North Sea coast. *O. nigra* is able to feed on carcass (Wintzell 1918) but usually it seems to rely upon the same source of food as *O. fragilis* and to feed in essentially the same way (Wintzell 1918, Mortensen 1927). Apparently *O. nigra* is not less rheophile than *O. fragilis*. Commensalism with sponges, corals, etc., is not recorded for *O. nigra*.

It is a shallow water species known from southern Norway to the Azores and the Mediterranean. It is also known from a few localities in the Kattegat and the Sound (Brattström 1941) at mean winter temperatures not below 4°. The minimum temperature to which it becomes exposed in normal years probably is about 3.5°. Apparently, this is the lowest temperature at which the species occurs within its known range of distribution. The mean summer temperature in the Kattegat and Sound localities of the species is 12—15°, much as in British coastal waters. The 3 specimens available measured 5, 11, and 15 mm.

Ophiactis balli (Thompson).

Danish grab records 1932—55: 7570 (9).

The grab material was obtained on the English coast (see Fig. 26) in 45 m. The animals were concealed in minute cavities in a stone. Some specimens may have escaped attention. The species is recorded from the British coast by Norman (1865) and Hodge (1872). Hodge (cited from Mortensen) states, that on the Durham and Northumberland coast *O. balli* is numerous in magnesian limestone from deeper water. The habit of *O. balli* of concealing itself in rock crevices

or cavities in stones is mentioned by several authors. SÜSSBACH and BRECKNER (1911) record several finds in trawl and dredge hauls from the northern North Sea: a single specimen was taken in the deep basin in the central part of the northern North Sea (92 m); other finds were made on the edge of the Norwegian Channel in depths between 64 m and 148 m. The shallowest station in the Norwegian Channel is situated almost on the spot in which one of the larger grab samples of *Ophiothrix fragilis* was obtained (cf. Figs. 26 and 27). The bottom sample from the English coast in which 9 *O. balli* were found also contained 39 *O. fragilis* and 2 *Ophiocomina nigra*. Ecologically, *O. balli* apparently is closely connected with these species. However, the feeding method of *O. balli* has not been investigated. The rock crevice in which the animal is concealed usually is so small that the animal scarcely is able to move about within the crevice. Thus, it probably does not feed on detritus sedimented in sheltered cavities or crevices. The only possibility seems to be that it conceals the disk and several arms in the hole and feeds on suspended matter gathered by one or several outstretched arms, that is, in essentially the same way as *Ophiothrix fragilis*. Thus, it seems warranted to include *O. balli* in the group of rheophile suspension feeding ophiuroids in the North Sea.

The coincidence of distribution of *O. balli* and *Asteronyx loveni* on the edge of the Norwegian Channel is striking (Fig. 26). Above (p. 39) there was pointed to the ecological similarity of *Asteronyx loveni*, which is an obligate commensal with pennatulids, and *O. fragilis*, a facultative commensal with sponges, *Alcyonium*, etc. The commensalism in *O. fragilis* was found to be developed particularly in localities in which the "natural" water renewal caused by currents, tidal activities, or turbulence is not sufficient to supply the animal with the quantity of food required. On this background it seems likely that the coexistence of *A. loveni* and *O. balli* on the edge of the Norwegian Channel is caused by favourable conditions of food intake for animals gathering organisms or detritus from the passing water. The tendency toward commensalism with other invertebrate species which produce water movement seems to be established in *O. balli*, too. MORTENSEN (1927) states that *O. balli* is often found between the membranaceous layers of *Chaetopterus* tubes. This polychaete maintains a current of water through the U-shaped tube in which it lives (MACGINITIE 1939).

O. balli is distributed from the Faroes and southern Norway to West Africa. It does not occur in the Kattegat. It is usually confined to moderate depths. The shallowest record perhaps is one from 15 fathoms in the English Channel (Plymouth Marine Fauna 1957). It may be noted that it is not recorded from the southern North Sea although *Chaetopterus variopedatus* with which it might be commensal is frequently taken in soft bottom samples there.

The mean winter temperature in the North Sea localities of *O. balli* is about 5°. The mean summer temperature is about 12° on the British coast and about 7° on the edge of the Norwegian Channel.

4 specimens from the bottom sample taken on the English coast (May, 1951) were measured to half millimetre below: 1.5, 2.0, 2.5, and 3.0 mm.

Ophiopholis aculeata (L.).

Danish grab records 1932—55: 6244 (1), 7569 (1), 8866[I] (4).

The first mentioned grab record refers to a northern North Sea station, the others to a locality on the English coast (Fig. 28). The trawl and dredge surveys of the "Dana" (1922—55) produced the species on scattered stations in the northern North Sea. It occurs quite regularly in trawl catches from an area about 57° N. and between 2° E. and 4° E., often together with *Hippasteria phrygiana* (cf. Fig. 20). The northern North Sea grab record is from the same area.

A similar distributional pattern was observed by MEISSNER and COLLIN (1894) in 1889—90, by SÜSSBACH and BRECKNER (1911) in 1902—07, and during the "Wodan" investigations in 1902—11. MÖBIUS and BÜTSCHLI (1875), however, in 1872 found *O. aculeata* at several stations in the southern North Sea and even once in the Zuiderzee. There is no particular reason to doubt the statements of MÖBIUS and BÜTSCHLI. It was found advisable, however, to use a special signature for these records. MORTENSEN (1924) records *O. aculeata* as a recent immigrant to the Limfjord.

It is a northern form which in the North Sea is very near its southern limit of distribution. It occurs off the west coast of Ireland (FARRAN 1913), but not on the French Atlantic coast. Its occurrence in the English Channel seems problematic (see KOEHLER 1924 p. 302). It is not listed in the Plymouth Marine Fauna (1957). In the transitional area between the North Sea and the Baltic *O. aculeata* is widely distributed, apparently at a range of mean temperatures from 2° in winter to 17° in summer, and in salinities down 20—25 ‰. There is evidence, however, that the population in the Sound depends upon transport of larvae from the Kattegat. The true salinity range of the species may be more restricted, therefore, than appears from the distribution of adults in the transitional area (THORSON 1946 p. 349). In the western part of the Limfjord the species probably is exposed to the same temperatures as in the transitional area. Apparently, the limited distribution in the North Sea is not accounted for by temperature or salinity requirements. It seems more promising to suggest a dependence upon the *Sagitta elegans* plankton community, either as a source for food or as a suitable environment for the larvae.

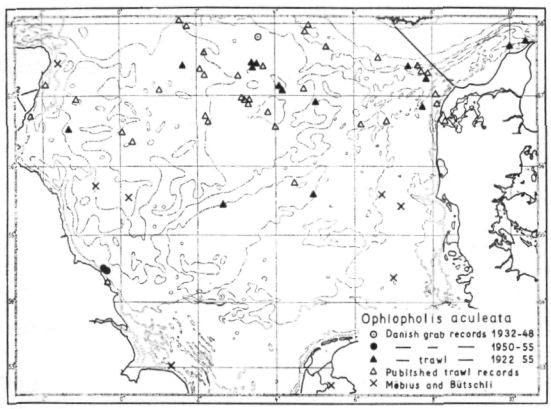

Fig. 28. Dredge records published by MÖBIUS and BÜTSCHLI (1875) are given separate signature (see text above).

REES (1954 p. 55) found the larvae abundant in the northern North Sea in March, April, and May, namely, when the water is coldest. The winter temperature from surface to bottom is about 6° in this area. Apparently, *O. aculeata* does not elsewhere occur at higher winter temperatures than in the northern North Sea. Perhaps a requirement for low breeding temperature is among the factors limiting the distribution of this species toward the south on the European coast.

WINTZELL (1918) in laboratory experiments found that, like *Ophriothrix fragilis*, *O. aculeata* for its food supply relies upon a flow of suspended material. Accordingly, he found *O. aculeata* in great abundance in a locality (Solsvik Sound off Bergen) with great tidal activity in which the bottom—in a depth of 5–10 m—consists of a carpet woven by *Lima hians* in shell-sand. Various species of *Lima* are known as frequent members of rheophile faunas (URSIN 1956 a p. 6). Thus, the current-dependence of the Solsvik bottom fauna—in which also *Ophiocomina nigra* is listed—scarcely may be doubted. *O. aculeata* is the dominating echinoderm in the predominantly rheophile *Modiolus* epifauna in the Belt Sea and the Sound between Denmark and Sweden (PETERSEN 1913). The North Sea grab records from the English coast also point toward the rheophile affinities of the species.

The 5 specimens from bottom samples on the English coast probably were young, measuring 2, 3, 4, 8, and 11 mm.

Amphiura chiajei FORBES.

Danish grab records 1932—55: 5250[I] (1), 5798 (1), 7744 (2), 7849 (1).

The Danish grab records refer to stations with depths of 120—150 m. STEPHEN (1923, 1934) during his grab survey of the northern North Sea found *A. chiajei* in great numbers in Scottish waters (Fig. 29), particularly in the Moray Firth. The area in which STEPHEN found *A. chiajei* was not covered by the Danish grab surveys. Astonishingly, however, DAVIS (1923, 1925) records the species from many stations in the Dogger Bank area, particularly towards the northern edge of the bank and off the south-western edge. Confusion with *Acrocnida brachiata* may have taken place because that species, in recent years abundant on the western edge of the bank, is not listed by DAVIS. German investigators also record *A. chiajei* from the Dogger Bank region although not from the bank proper, and even from the eastern North Sea and the German Bight. MÖBIUS and BÜTSCHLI (1875), MEISSNER and COLLIN (1894) and HAGMEIER (1925) do not record *Acrocnida brachiata* so that, again, there is a risk of confusion. SÜSSBACH and BRECKNER (1911) were aware of the resemblance of the two species and found both. Their finds of *A. chiajei* approximately cover the area in the central and eastern North Sea from which the species was recorded by other German authors. All specimens of *A. chiajei* found by SÜSSBACH and BRECKNER in the south-eastern North Sea were juvenile and were supposed to originate from larvae transported into the area from the northern North Sea. Even if DAVIS's records are not entirely reliable there is not much doubt that *A. chiajei* has had a sporadic occurrence in the south-eastern North Sea.

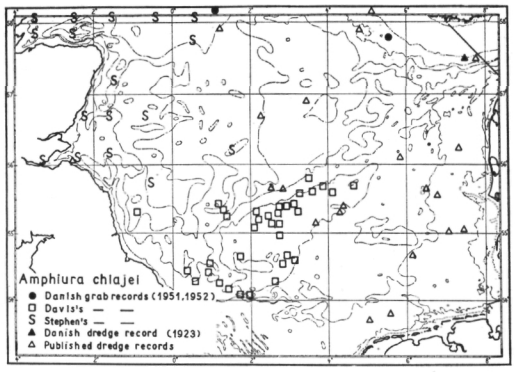

Fig. 29. There are only three records of *A. chiajei* in the present material. On the validity of other records, see text. STEPHEN's records are given separate signature because they refer to statistical squares rather than to exact localities.

A. chiajei is elsewhere distributed from southern Norway to West Africa. In the Mediterranean it is predominantly a shallow-water form which is often found among sea-weeds in a few metres depth (KOEHLER 1924 p. 283). It is often littoral on the French coast of the Atlantic as well (KOEHLER, l. c.). In the English Channel it seems to occur sporadically only. It abounds in the eastern Kattegat and the Sound, apparently at summer temperatures not much above 15°, at winter temperatures not much below 4° and at mean salinities down to 25 $^0/_{00}$ (probably corresponding to an annual range from 20 to 30 $^0/_{00}$). The reason for the absence of the species from the south-western Kattegat and the Belt Sea seems somewhat obscure. BRATTSTRÖM (1941) as previously PETERSEN (1918) points to the accordance of the occurrence of very soft clayey bottom and of *A. chiajei* in the Kattegat. However, if the species is so selective as to substratum it is difficult to understand how it is able to thrive as a littoral form on the French Atlantic coast or in the algal zone in very shallow water in the Mediterranean. The temperature and salinity in the south-western Kattegat apparently are as suitable as in the Sound and the south-eastern Kattegat. In any case, the present limited distribution of *A. chiajei* probably cannot be explained by lack of suitable substratum or temperature. It is true that *A. chiajei* in Danish waters and in the North Sea is near its northern limit of distribution and that low winter temperature may prevent occurrence in the winter-cold water on Danish coasts. Winter temperatures above 4° are found,

however, within large areas not inhabited by *A. chiajei*. High summer temperatures are not required by this species. On the Scottish coast and in the Kattegat it flourishes at summer temperatures about 12°. Apparently, *A. chiajei* belongs to the group of echinoderms which in the North Sea are largely confined to the *Sagitta elegans* plankton region on the north British coast but reappear in the transitional area between the North Sea and the Baltic. It seems as if the demand of these species for food or for a particular chemical environment is met only in these two distinct parts of the North Sea—Baltic region.

An increase in abundance of *A. chiajei* in the Sound in recent years (Brattström 1941 pp. 177, 281) may be ascribed either to a change in the apparently unknown factor responsible for the limited distribution of the species in the North Sea—Baltic region, or to an increase in winter temperature. The mean bottom temperature (20 m) at the Lappegrund lightvessel, situated in the northern part of the Sound, has increased from 4.3° in 1903—26 to 4.8° in 1933—38 (Brattström 1941 p. 95). The increased abundance was observed in the warm period. Despite a similar temperature increase in the North Sea (cf. above, p. 13) a decrease or withdrawal of *A. chiajei* apparently took place simultaneously with the increase in the Sound.

4 specimens from bottom samples from the northern North Sea, taken at various seasons of the year, measured 2, 3, 4, and 7 mm.

Amphiura filiformis (O. F. Müller).

Danish grab records 1932—55 are listed in Appendix 1.

The grab records, published and unpublished, of *A. filiformis* in the North Sea are plotted on Fig. 30. The species is distributed over the major part of the area investigated. On the North British coast it seems to be less abundant than *A. chiajei* (cf. Stephen 1923). Davis (1923, 1925) found large quantities at stations all round the Dogger Bank. Bank records, however, are scarce

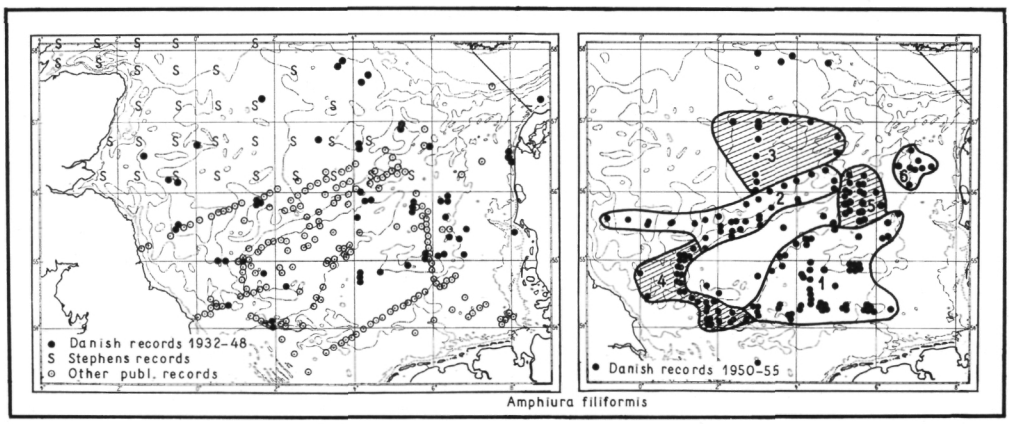

Fig. 30. Grab records of *Amphiura filiformis*. The division of the central North Sea into smaller areas on the right chart refers to differences in density and growth rate (p. 46). Areas with high densities in 1950—55 are shaded. Stephen's records (the left chart) are given separate signature because they refer the finds to statistical squares only.

and usually refer to finds of single specimens. Hagmeier (1925) and Caspers (1939, 1950) found high densities in the German Bight while Ziegelmeier (1953) in 1949 observed that *A. filiformis* had disappeared from German waters. Records from the Horns Reef area of the Danish coast are few in number.

The scarcity of records from the Dogger Bank and the Horn's Reef area is probably partly due to a preference by *A. filiformis* for soft (muddy or clayey) bottom. However, as far as the Horn's Reef area is concerned this explanation is not entirely satisfactory. Fig. 31 shows the

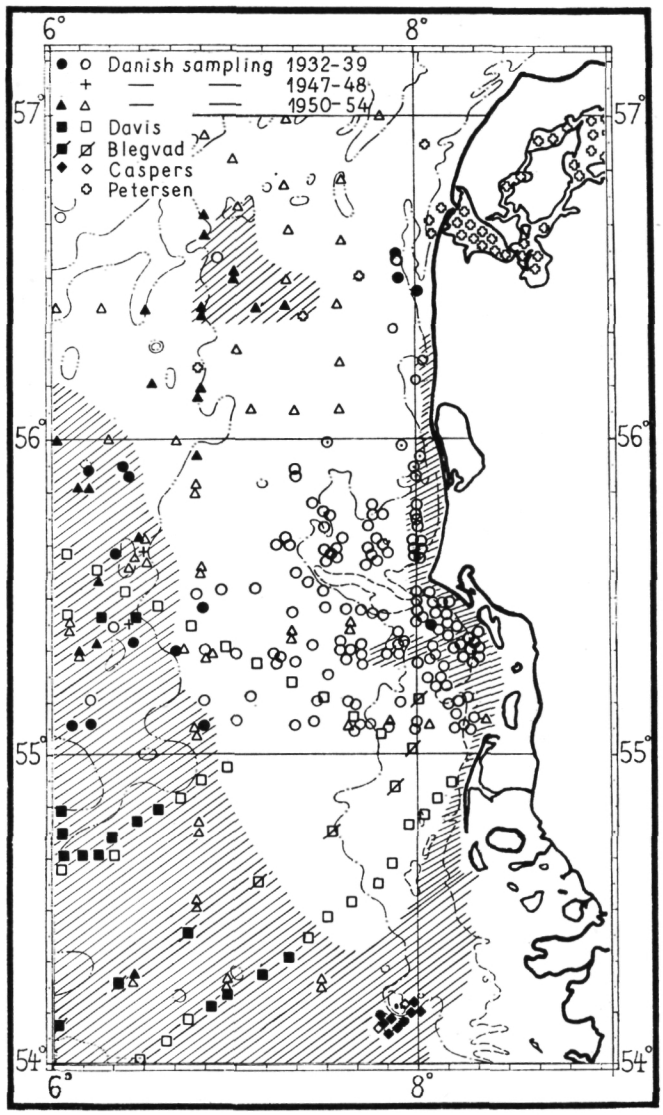

Fig. 31. Grab records of *Amphiura filiformis* (full symbols) from the eastern North Sea in 1911-54 (PETERSEN 1914, BLEGVAD 1922, DAVIS 1925, CASPERS 1939, 1950, and unpublished Danish material). Open symbols indicate stations on which *A. filiformis* was *not* taken. Soft bottom areas are shaded.

grab stations operated in the eastern North Sea. The finds of *A. filiformis* and the approximate distribution of soft-bottom areas are indicated. It is possible to distinguish between an offshore and an inshore soft-bottom zone. The soft-bottom zones are separated by a broad zone in which coarse sand and clean fine sand dominate. *A. filiformis* is largely confined to the offshore soft-bottom zone. On the French coast of the Atlantic the species may be dug out at low tide (KOEHLER

1921). Thus, the reason for its absence from soft bottom at 10—20 m in the Horn's Reef area is not quite obvious. ZIEGELMEIER (1953) suggests that the disappearance of *A. filiformis* from the German Bight, observed in 1949, was an effect of the cold winter in 1947. In favour of this hypothesis is that *A. filiformis* is a southern form, distributed toward north to south-west Iceland and southern Norway, apparently not occurring at winter temperatures much below 4°. In the Kattegat and the Sound it occurs at mean winter temperatures of 4—5°, corresponding to minimum temperatures not below 3°. In Helgoland waters it apparently occurs (or occurred) at a mean winter temperature of 3.5°, again corresponding to a minimum temperature of 3° in normal years. In 1947 the temperature over the major part of the southern North Sea decreased below 3° with the effect that the stocks of several species of fish and invertebrates were destroyed (cf. p. 14). It seems reasonable to suppose that *A. filiformis* is one of the species that did not tolerate the unusual drop in temperature. In the Horn's Reef section of the Jutland coast the winter temperature in normal years is below 3° (cf. Fig. 8, p. 12). If it is true that the cold winter of 1947 had the destructive effect upon the southern North Sea stock suggested by ZIEGELMEIER, it is reasonable to suppose that the low winter temperature in the coastal soft-bottom zone of the Horn's Reef area prevents the occurrence of *A. filiformis* even in normal years. Unfortunately, the Danish trawl and seine surveys do not provide information on the timing of the destruction of the southern North Sea stock; *A. filiformis* is seldom listed in the trawl catches. The scattered bottom sampling in 1947 and 1948 produced *A. filiformis* on northern North Sea stations only. Seven stations were operated on soft bottom in the southern North Sea.

In 1950—55 there was observed within the area investigated a considerable local variation in density and size frequency of *A. filiformis*. For the purpose of an analysis of stock composition it was found convenient to subdivide the area within which the species was found into six smaller areas characterized by density and size frequency of *A. filiformis*. Fig. 30 shows the area limits and the localities in which material was obtained. The few specimens taken on the Dogger Bank were omitted.

The density and size frequency in each area in 1950—55 (April—May), based on measurements of 1962 specimens, are shown in Table 8 and, diagrammatically, in Fig. 32. For comparison

Table 8.

Amphiura filiformis. Abundance and size frequency in individual areas of the North Sea (cf. Fig. 32) in 1932—38 and 1950—55. Number per square metre and size group. Bottom samples. See also Fig. 33.

Period	1932–38 (April–July)						1950–55 (April–May)					
Area number	1	2	3	4	5	6	1	2	3	4	5	6
Area sampled (m²)	2.2	1.4	2.0	2.3	1.6	0.4	29.2	14.0	2.8	11.0	5.4	2.2
Diameter of disk (mm) 1	1.4	..	..	..	..	..	2.6	0.8	0.7	0.1	..	1.4
2	11.4	0.7	1.5	2.6	1.9	..	2.2	0.7	0.7	0.7	1.5	0.9
3	15.9	..	0.5	4.8	4.4	..	2.3	0.6	2.9	3.3	3.3	0.9
4	55.9	2.1	2.0	4.3	15.0	..	2.8	1.4	5.7	5.9	9.6	1.8
5	43.2	2.1	5.5	7.4	23.8	..	2.2	1.4	13.6	11.4	15.0	2.3
6	6.8	..	11.5	7.4	20.6	..	1.8	1.0	23.6	22.7	18.7	4.1
7	0.5	..	5.5	5.2	1.2	..	1.0	0.1	15.0	22.8	13.0	0.9
8	..	..	3.0	3.0	..	..	0.1	0.1	2.1	9.7	5.7	0.9
9	..	..	1.0	0.9	..	..	0.1	..	0.7	1.5	0.7	..
Total	135.1	4.9	30.5	35.6	66.9	0	15.1	6.1	65.0	78.1	67.5	13.2

is given the information available from material collected in the same areas in 1932—38 (557 measurements). In both periods fairly big animals were found in high densities (30—80 per square metre) in area 3 (central part of the northen North Sea), area 4 (western edge of the Dogger Bank), and area 5 (eastern edge of the Dogger Bank). Small animals in low densities (13 per square metre or less) were found in area 2 (immediately north of the Dogger Bank) and

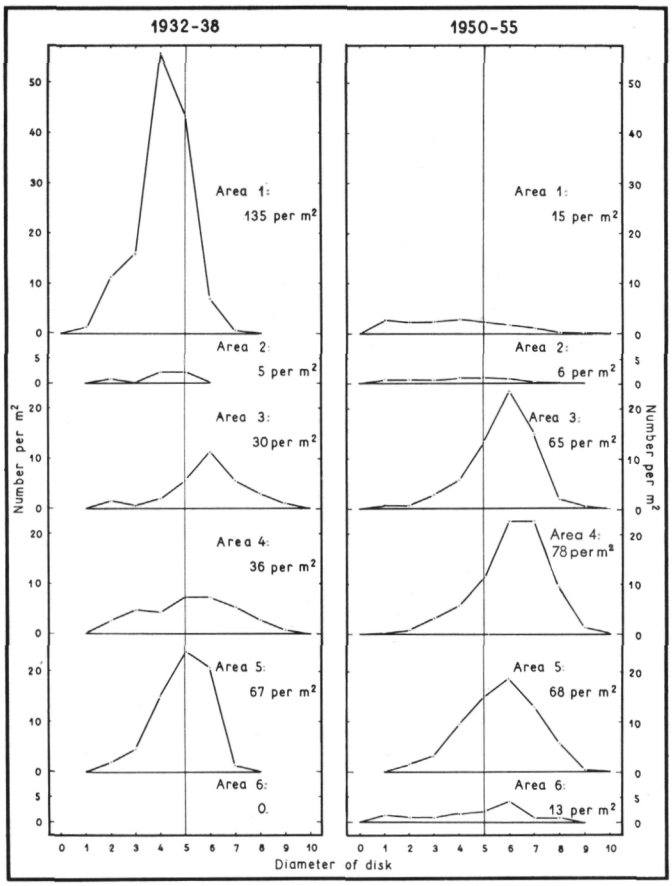

Fig. 32. *Amphiura filiformis*. Density and size frequency in various parts of the North Sea (cf. Fig. 30) in 1932—38 and 1950—55. Bottom samples. Based on Table 8.

in area 6 (off north Jutland). In area 1 (southern North Sea) a considerable change occurred from the first period to the second: the large quantities of small *A. filiformis* found in 1932—38 had almost disappeared in 1950—55.

The development of the stock within each area in 1950—55 is shown in Table 9. In the south-eastern North Sea (area 1, Fig. 33) *A. filiformis* was not found in 1950. In 1951—54 a small stock accumulated until, in 1955, the 1932—38 density was suddenly reached again. Apparently, two age groups dominate the catches. According to Rees (1954 p. 55) *Amphiura* larvae were in 1949—51 present in the North Sea plankton from June to November. Large numbers were observed from July to September only. There is not much doubt that the youngest age group (1—2 mm) found in area 1 in April and May 1950—55 is the brood of the preceding year, the 0-group. The slightly larger animals, measuring 4 or 5 mm, probably represent the I-group. It is

Table 9.

Amphiura filiformis. Density and size frequency in individual areas of the North Sea (cf. Fig. 32). Number per square metre and size group. Bottom samples.

Area number		1						2				
Year		1950	1951	1952	1953	1954	1955	1950	1951	1952	1953	1954
Area sampled (m²)		3.2	9.4	8.8	3.0	3.0	1.8	0.8	6.0	6.4	0.4	0.4
Diameter of disk (mm)	1.....	..	0.5	1.7	1.0	0.7	28.3	..	0.5	1.2	..	..
	2.....	..	1.3	3.3	0.7	4.7	3.9	..	0.5	1.1	..	..
	3.....	..	0.4	2.4	1.7	3.0	16.1	..	0.5	0.9	..	..
	4.....	..	0.3	0.2	1.0	3.3	35.0	..	1.2	2.0	..	..
	5.....	..	0.1	0.1	1.7	4.0	24.4	..	0.8	1.9	..	0.5
	6.....	..	0.2	0.1	0.7	4.0	20.6	..	0.8	1.2	..	0.2
	7.....	..	0.2	0.1	1.7	1.7	8.3	..	0.2	0.2	..	..
	8.....	..	..	..	0.3	0.3	1.1	1.2	..	..	..	..
	9.....	..	..	..	..	1.0	..	..	..	..	..	..
Total.....		0	3.0	7.9	8.8	22.7	137.7	1.2	4.5	8.5	0	0.7

Area number		3		4				5			6	
Year		1951	1952	1951	1952	1950	1951	1952	1953	1954	1951	1952
Area sampled (m²)		1.2	1.6	6.6	4.4	0.8	2.6	1.6	0.2	0.2	0.6	1.6
Diameter of disk (mm)	1.....	0.8	0.6	0.2	0.9	..	..	..	..	..	1.7	1.2
	2.....	0.8	0.6	0.6	4.1	6.3	0.8	0.6	..	..	1.7	0.6
	3.....	2.5	3.1	2.7	5.0	2.5	5.4	1.2	..	..	1.7	0.6
	4.....	9.2	3.1	6.5	8.6	7.5	14.2	3.8	..	15	..	2.5
	5.....	22.5	6.9	13.2	20.0	1.2	24.2	20.6	..	..	..	3.1
	6.....	23.3	23.8	24.5	11.4	1.2	26.5	19.4	..	..	..	5.6
	7.....	11.7	17.5	30.5	2.3	..	6.5	33.1	..	..	1.7	0.6
	8.....	..	3.8	14.7	..	..	..	19.4	..	..	..	1.2
	9.....	..	1.2	2.4	..	..	..	2.5	..	..	..	..
Total.....		70.8	60.6	95.3	52.3	18.7	77.6	90.6	0	15	6.8	15.4

rather obvious that the 0-group is under-represented in the catches. These tiny things are extremely fragile and are easily broken up during the sieving operations. The size frequency diagram for area 1 in 1932—38 (Fig. 33) indicates a dominance of the I-group. The O-group is almost absent from these catches. A slightly more wide-meshed sieve may have been employed, or the washing of the samples may have been more rough.

In area 5 (Fig. 34) a small stock, apparently dominated by the O-group and the I-group, occurred in 1950. During the two following years a large stock appeared, apparently based on spat-falls in 1948—49. The under-representation of the smaller size groups is evident: the older (bigger) the animals, the higher the density. The mortality is not known. A comparison with the size frequency diagrams in Fig. 33 reveals, however, that the 1952 stock in area 5 consisted of unusually large animals; yet, they apparently are only 4 years old. Probably, *A. filiformis* does not in the North Sea normally grow much older than 4 years. In the south-eastern North Sea (area 1) 2 years may be a better estimate of the life span.

In areas 2, 3, 4, and 6 there is no evidence of a recent accumulation of the stock. Area 1 and area 5 in which such accumulation was demonstrated are situated within the region of the southern and eastern North Sea which was affected by the severe temperature decrease in the

winter of 1947. It seems as if the recovery of the population after the temperature check took place during the years investigated. East of the Dogger Bank the recovery was effected by successive spat-falls as early as 1948—49. In the south-eastern North Sea no satisfactory recovery occurred until 1954—55.

In areas 2 and 6 (northern edge of the Dogger Bank and off north Jutland) the rate of settlement is poor and the survival into adult stage is low. Apparently, *A. filiformis* does not find entirely satisfactory environments within these areas.

Quite different conditions are met with in the southeastern North Sea in which small specimens are found in high densities. The small size might be caused by retarded growth

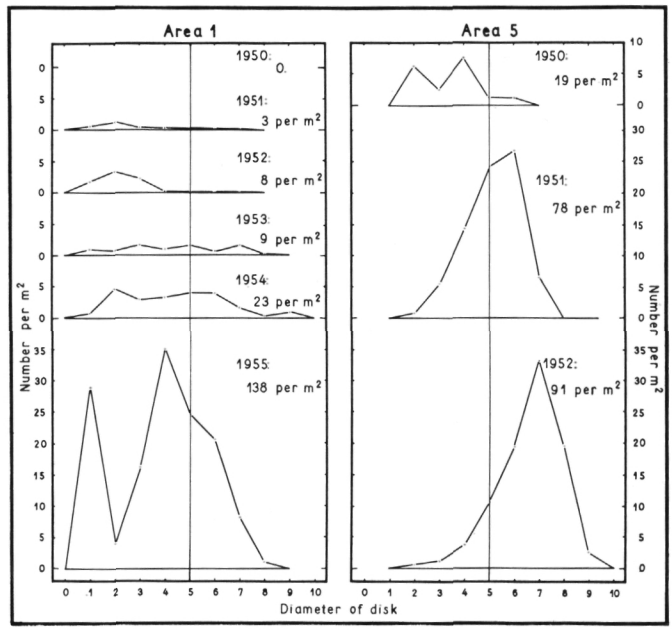

Fig. 33. *Amphiura filiformis*. Density and size frequency in two areas in the North Sea (cf. Fig. 30) in April–May of successive years. Based on Table 9.

resulting from overpopulation. However, CASPERS (1939 p. 58) in a very dense population in the Helgoländer tiefe Rinne found the same rapid growth as indicated in Fig. 33 and demonstrated a dying-off of the year classes at the end of their second year.

There is evidence in literature of a similar occurrence of large numbers of small (young) *A. filiformis* in the south-eastern North Sea in years prior to the Danish grab surveys. HAGMEIER (1925 p. 268) in his "*Ech.-Fil.*-Gemeinschaft, untermischt mit Tieren der *Venus*-Gemeinschaft" found 65 *A. filiformis* per square metre with an average weight of 41 mg per specimen. For comparison may be mentioned that an apparently pure I-group collection from area 4 in 1952 (110 specimens) averaged 100 mg. In his "*Ech.-Fil.*-Gemeinschaft, untermischt mit Tieren der *Scrob. alba*-Gemeinschaft" he found 583 per square metre, with a mean weight of 109 mg. Also in the German Bight BLEGVAD (1922) in July 1921 observed a mean weight of 33 mg. Going farther back in time we find SÜSSBACH and BRECKNER's report on the collections made by the "Poseidon" in 1902—07: *A. filiformis* abounded in the whole northern and eastern North Sea (the Dogger Bank and the western North Sea were not investigated). The material was divided into the groups "postlarval, juv., klein, mittelgross, gross", and "voll erwachsen". 40 pct. of the

specimens collected in the northern North Sea were referred to the groups "gross" and "voll erwachsen". 20 % only of the specimens collected in the south-eastern North Sea were referred to these groups. The percentages are not entirely reliable because only parts of the material were kept and divided into size groups. However, it seems as if the size frequency of *A. filiformis* in the North Sea was in 1902—07 not very different from that observed in 1921—38.

Heavy grazing by fishes and other predators may cause the rapid dying off of the year classes of *A. filiformis* in the south-eastern North Sea. It is also possible, however, that the chemical environment or perhaps the nature of the food supply is not in the south-eastern North Sea sufficient for the adult stage. As demonstrated above there is no evidence that temperature is a limiting factor in offshore waters of the North Sea, except in years with exceptionally low winter temperatures. In this connexion it may be mentioned that if the southern North Sea stock of *A. filiformis* was destroyed during the cold winter of 1929, as it probably was during the cold winter of 1947, a rapid replenishment of the stock apparently occurred. In 1933 two bottom samples (0.2 m² each) from area 1 produced 38 and 30 specimens, respectively, corresponding to a density of 170 per square metre.

Acrocnida brachiata (MONTAGU).

Danish grab records 1932—55 are listed in Appendix 1.

The present species is not recorded from any of the previous grab surveys of the North Sea although confusion with *Amphiura chiajei* may have occurred. SÜSSBACH and BRECKNER record 3 finds from off the Jutland coast and MORTENSEN (1924) two from the same area. LESLIE and HERDMAN (1881) record the species from the Firth of Forth. Danish grab finds are fairly numerous and reveal a rather peculiar distributional pattern in the North Sea. Besides in

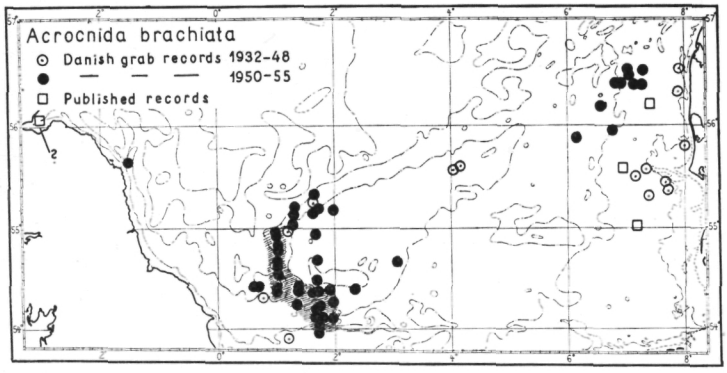

Fig. 34. The area with the greatest abundance is shaded. The exact locality for LESLIE and HERDMAN's find in the Firth of Forth is unknown.

British and Danish coastal waters whence previous authors got it, too, it occurs—and even in considerable densities—on the western edge of the Dogger Bank in depths between 40 and 60 m. The grab records and SÜSSBACH and BRECKNER's finds are indicated on the chart, Fig. 34. In the western Dogger Bank area more than a single specimen per sample (0.2 m²) was found only within the framed area. Within this area 28 samples were taken in May 1951—52, 18 of which contained *A. brachiata.* The density of the population on various types of bottom deposit was as follows:—

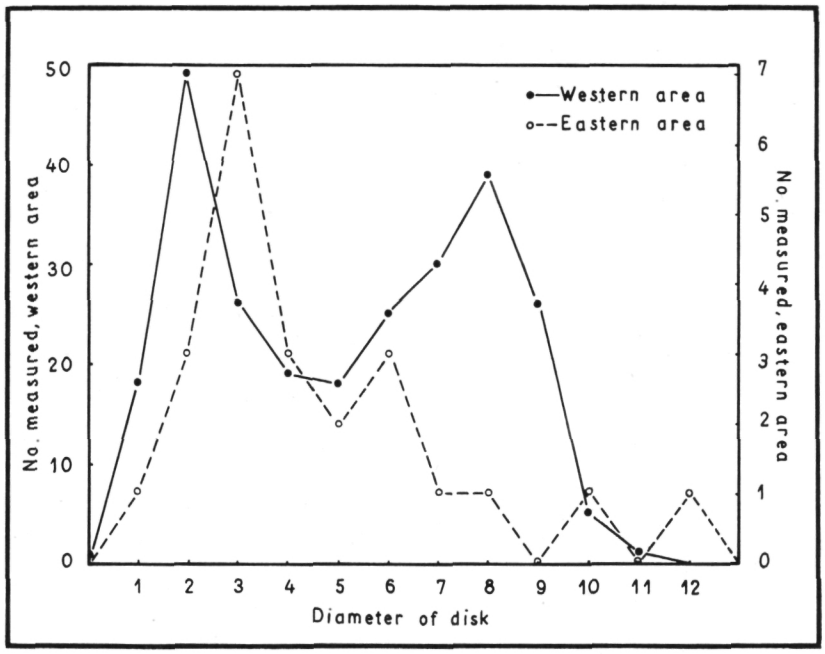

Fig. 35. *Acrocnida brachiata*. Size frequency in the North Sea 1951–52 (April–May). The two distinct areas of distribution (Fig. 34) are kept separate.

	No. of samples	Litres per sample	No. of *A. brach.* per sample	No. of *A. filif.* per sample
Coarse sand	3	11	2	4
Fine sand	4	14	15	1
Muddy sand	16	11	11	21
Clayey sand	4	8	1	27
Clayey coarse sand	1	7	0	15
All grades together	28	11	9	17

A. brachiata seems to occur primarily on fine sand and muddy sand while *Amphiura filiformis*, the density of which is shown for comparison, is confined to muddy sand and clayey sand. In the eastern area of distribution (off Jutland, in 17—48 m) the density of *A. brachiata* is low; 5 specimens is the highest number obtained in a single sample. The 18 finds available from the eastern area were made on grounds of coarse sand (4), fine sand (3), muddy sand (6), clayey sand (4) and clayey coarse sand (1).

273 specimens collected in May 1951—52 were measured. The measurements give little information about the growth rate. The brood of the preceding year apparently produces a conspicuous mode on the curves (see Fig. 35 and below). It is not possible to estimate the age of the larger specimens:—

Diameter of disk (mm):	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
Western area 1951, no.:	1	4	22	13	15	10	14	8	19	13	3			122
– – 1952, - :		7	27	13	4	8	11	22	20	13	2	1		128
Eastern area 1951, - :		1	1	1		1	1							5
– – 1952, - :			2	6	3	1	2	1	1		1		1	18

GISLÉN (1926 p. 4) found that mature specimens from the English Channel (Salcombe) measured 10—17 mm. Specimens from the Swedish west coast did not exceed 5 mm. The corresponding figures for the North Sea (6—12 mm, approximately) are intermediate.

The depths in which *A. brachiata* is taken in the North Sea, particularly on the edge of the Dogger Bank seem to be higher than elsewhere within the area of distribution of the species. On the Atlantic coast of France (KOEHLER 1921) the west coast of Ireland (SOUTHERN 1915) and on the English coast of the Channel (GISLÉN 1926, Plymouth Marine Fauna 1957) it occurs between tide marks. In the North Sea the shallowest find was made in 17 m. The Swedish west coast records refer to depths about 25 m and so do the few records from the Kattegat.

The shallowest North Sea finds probably were made in a salinity about 32 $^0/_{00}$. In a Swedish west coast locality GISLÉN observed 31.7 $^0/_{00}$. The Kattegat finds apparently were made at similar salinities. British authors list the species from estuaries, but apparently at high salinities. In the Salcombe estuary, for instance, the salinity is about the same as in the English Channel (ALLEN and TODD 1900). Thus, *A. brachiata* may be rather particular about the salinity. The limited distribution in the North Sea and the transitional area between the North Sea and the Baltic are not, however, fully explained by the salinity requirements of the species.

A. brachiata is a decidedly southern form which has its northern limit of distribution on the Swedish west coast. Temperature, therefore, might be expected to be important as a limiting factor in the North Sea and adjacent waters. The submergence of the species in the North Sea (absence from the tidal zone, etc.) might point in this direction. On the Jutland coast *A. brachiata* apparently does not occur shorewards to the 3° winter isotherm. Probably, it does not occur at temperatures much below 3° in other seas either. A comparison of the distribution of *A. brachiata* in the North Sea (Fig. 34) with the bottom isotherms for the warmest month (Fig. 8, p. 12) shows that the species is absent from the part of the North Sea that has summer temperatures below 10 or 11°. Thus the absence of the species from the Danish shores and from the central body of the northern North Sea is understandable on the assumption that a species which in the North Sea lives at its northern limit may have to avoid localities with extremely low summer temperatures or with extremely low winter temperatures.

Apart from the absence of the species from summercold areas the distribution of *A. brachiata* in the North Sea bears resemblance to the distribution of several other species as for instance the more northern forms *Solaster papposus* and *Echinus esculentus* which have two distinct areas of distribution, a western (British waters) and an eastern (Danish waters). In the North Sea these species are almost absent from a broad zone roughly limited by longitudes 2° E. and 6° E. There is some evidence that such distribution may be correlated with the distribution of plankton communities or explained by a requirement for a particular chemical environment. These problems are discussed below, pp. 97 ff.

**Paramphiura punctata* (FORBES).

The species is known from two specimens only. The type originates from the stomach of a cod caught near the Dogger Bank and was described by FORBES in 1841 as *Ophiocoma punctata*. Another specimen was dredged in the Pas de Calais and described and figured by KOEHLER (1895).

Amphipholis squamata (D. CHIAJE).

Danish grab records 1932—55: 7577 (1), 7880 (1).

The Danish grab finds were made on the northern edge of the Dogger Bank (see Fig. 36) in 1951 and 1952, on coarse sand in 34 m and 43 m. The two specimens measured 1.5 mm and

2.0 mm. Owing to the small size of the species it may have been overlooked sometimes, particularly in samples of coarse sand.

HAGMEIER and KÄNDLER (1927) found *A. squamata* in bottom samples from a channel, 14—20 m deep, in the German Waddensea. CASPERS (1950 p. 143) records a grab find from the Helgoländer Austernbank. Dredge records are available from the German Bight and from the Southern Bight (MEISSNER and COLLIN 1894, SÜSSBACH and BRECKNER 1911). There are also several records from the British North Sea coast (FORBES 1841, BELL 1892, NEWELL 1954, cf. Fig. 37) where *A. squamata* seems to be abundant near low water mark.

In the major part of its area of distribution *A. squamata* seems to occur particularly in the littoral zone where it is found under stones, etc. In the eastern North Sea and in the transitional area between the North Sea and the Baltic it is apparently confined to deeper water. MORTENSEN (1924 p. 134) suggests the submergence to be caused by the low salinity of the surface layers in Danish waters. As *A. squamata* does not penetrate into the Arctic region low winter temperature may be a limiting factor, too. In the Kattegat and the Sound *A. squamata* seems to occur at mean winter temperatures of 3—5° and at mean salinities down to 30 ‰. In the Waddensea locality the salinity seems to range from 30 to 31 ‰ (HAGMEIER and KÄNDLER 1927 pp. 14, 19). The mean winter temperature in the deep channels in the Waddensea may be estimated as 2°; at any rate, it must be less than 3° which is the mean winter temperature farther offshore in about 25 m (Vyl lightvessel). The absence of the species from the Limfjord (MORTENSEN 1924) may or may not be due to the low winter temperatures prevailing there. Apparently, the present knowledge of the biology of *A. squamata* is not sufficient for the proper understanding of the distribution. It may be important that, having no pelagic development, *A. squamata* probably must be a resident in the localities in which it occurs. The replenishment of the stock after destruction caused by unusual environmental conditions may last for a longer series of years.

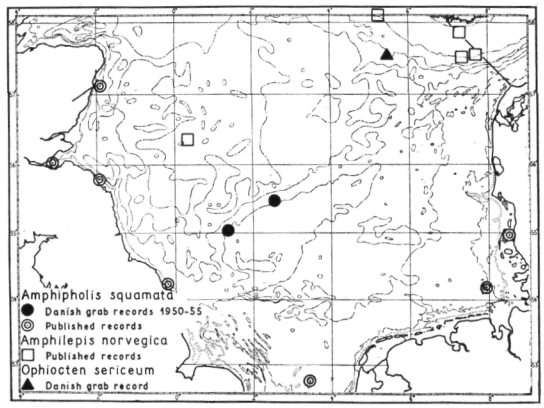

Fig. 36.

**Amphilepis norvegica* LJUNGMAN.

SÜSSBACH and BRECKNER (1911) and PETERSEN (1915) found *A. norvegica* in several localities in the Norwegian Channel, in depths of more than 100 m; a single find was made in the northern North Sea, in 80—90 m (Fig. 36). The species abounds in the Skagerrak (MORTENSEN 1924) and is elsewhere distributed from Norway to West Africa, usually in considerable depths. Being rather a deep water form *A. norvegica* cannot be expected to be common within the area covered by the present investigation.

Ophiura texturata LAMARCK.

Danish grab records 1932—55 are listed in Appendix 1.

German, Dutch, and Danish trawl and dredge surveys made in 1872—1930 produced a large number of finds of *O. texturata* scattered over the North Sea (Fig. 37 A). Apparently, however, the species was absent from the Dogger Bank and from the British side of the Southern Bight. It was obtained most frequently on the Danish and Dutch coasts. The Danish trawl,

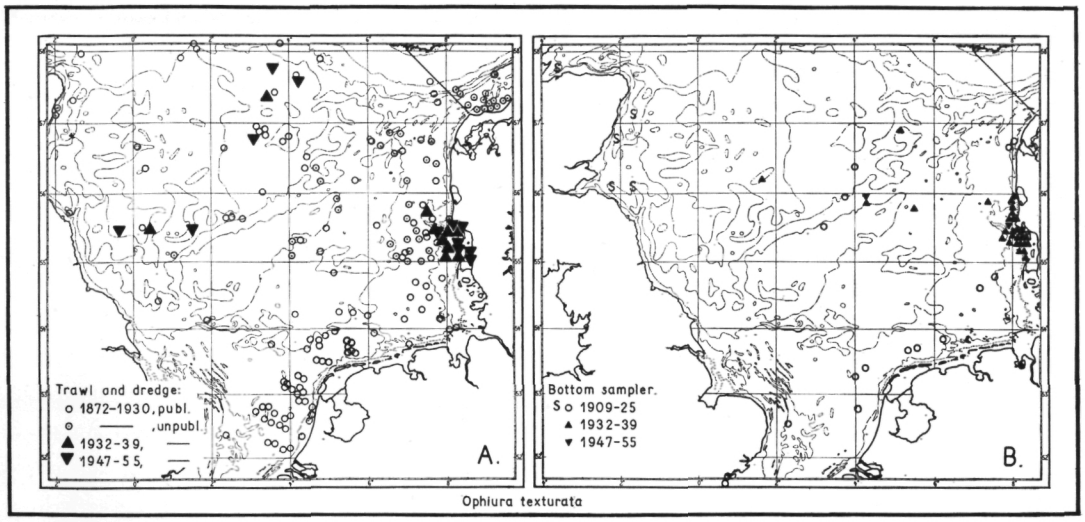

Fig. 37. In order to appreciate the difference between the situation of trawl and dredge records in 1872–1930 and in 1932–55 it is necessary to compare with the station charts, particularly with Fig. 6, p. 9. STEPHEN's grab records are given separate symbol (S) because they do not refer to exact localities, but to statistical squares. Grab records from 1909–25 are gathered from literature. Those from 1932–55 are new except one in the German Waddensea (LINKE 1939).

dredge, and seine surveys in 1932—39 and 1946—55 added few records of *O. texturata*. Finds were made in the northern North Sea and at shallow depths in the Horn's Reef area, including the Danish part of the Waddensea (Fig. 37 A). The German and Dutch coasts were not covered by these investigations. The difference between the results obtained in 1872—1930 and in 1932—55 is so persistent that the species must have diminished its area of distribution (or abundance) in the North Sea about 1930.

The grab records (Fig. 37 B) do not add much further evidence. Finds were made in Scottish coastal waters and along the shore of the eastern and southern North Sea. Several finds were made within a fairly small area north of the Dogger Bank. In the 1950—55 grab survey two finds only were made, one in the Horn's Reef area in which few samples were taken, another on the northern edge of the Dogger Bank, not far from the offshore localities in which the species was found by DAVIS (1925) and during the 1932—38 grab survey. HAGMEIER (1925) has *O. texturata* in several communities in the German Bight. The finds are not published in such a way that they can be plotted on a chart. CASPERS (1939, 1950) did not find *O. texturata* in the Helgoländer tiefe Rinne or on the Helgoländer Austernbank. *Mistakidis* (1951) has it from the estuaries of the rivers Crouch and Roach on the south English coast.

O. texturata is among the few echinoderms which penetrate into the Waddensea where it may be found even between tide marks (MORTENSEN 1924, LINKE 1939). The species often appears in young plaice trawl catches in the Danish Waddensea, most regularly between Jutland and the island of Rømø. Most Waddensea specimens are juvenile but, occasionally, a gathering of adults is met with. The biggest Waddensea specimen obtained in 1950—56 measured 19 mm (Rømø, August 1955).

Most of the sparse material from the northern North Sea (north of the Dogger Bank) consists of large animals (20—26 mm) while most Horn's Reef specimens are small, measuring less than 10 mm across disk (max.: 19 mm).

The growth rate of *O. texturata* in the Limfjord was investigated by MORTENSEN (1897 p. 321). Three distinct year classes were found besides a few larger specimens of unknown age (see the diagram, Fig. 38). The size frequency in the Horn's Reef material, also shown in Fig. 38, leaves not much doubt that most specimens caught in June—July belong to the brood of the preceding year. The age of the big ones from north of the Dogger Bank could not be estimated. It might be expected, perhaps, that like the gigantic *Asterias rubens* found in deep water in the Sound (THORSON 1946 p. 347), these large *O. texturata* are senile animals with reduced gonads. However, a few specimens examined (collected in May) had well developed gonads. BLEGVAD

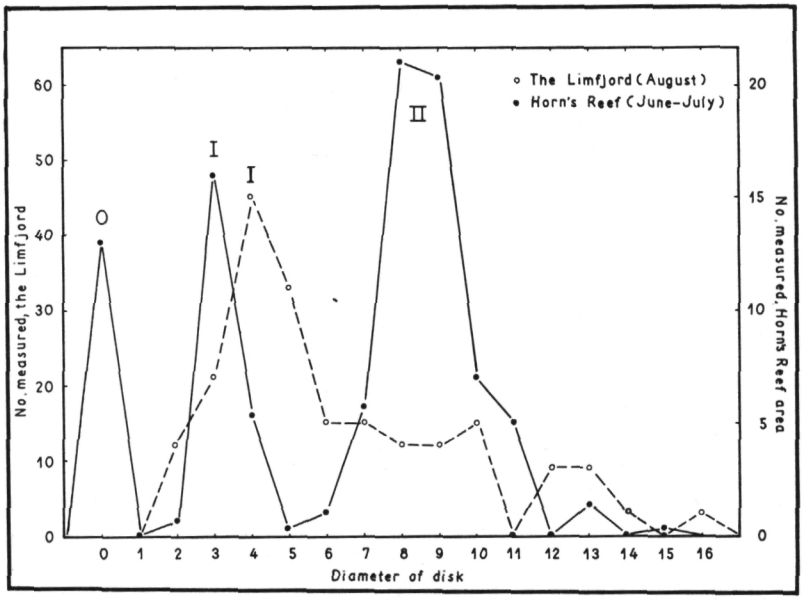

Fig. 38. *Ophiura texturata*. Size frequency in the Limfjord (MORTENSEN 1897) and in the Horn's Reef area (grab records 1932–38). Age groups indicated.

(1914 p. 62) observed that in the Limfjord in which *O. texturata* occurs in high densities but does not grow very large most specimens contain detritus. In the Kattegat, with few but large-sized examples, the species was found to be carnivorous. Thus, the growth rate and the maximum size may depend upon the diet of the animal.

O. texturata penetrates far into the transitional area between the North Sea and the Baltic where it seems to occur even at a mean salinity of 20 $^0/_{00}$. The lowest salinity tolerated by the species must be several per mille lower. However, it is not quite certain that *O. texturata* is able to reproduce at such low salinities. THORSON (1946 p. 351) failed to find the larva in the Sound, probably because the local population is recruited mainly from the Kattegat, from a rather small number of older larvae just ready to metamorphose and settle. In the Jadebusen (German Waddensea) *O. texturata* apparently is found at salinities ranging from 21 $^0/_{00}$ to 31 $^0/_{00}$.

The temperature tolerance of the species is high. In the Limfjord in which it is very abundant it occurs at a mean winter temperature not much above zero and at mean summer temperatures about 18°.

In the Horn's Reef area it seems to occur on all grades of soil (coarse sand, fine sand, muddy sand, clayey sand) so that it is probably not very particular on this point either. The absence of the species from a large part of the central North Sea is difficult to understand. If the

distribution of plankton communities or of particular water masses (cf. p. 15) has any bearing upon the distribution of *O. texturata* in the North Sea it might be said that the species abounds in the coastal water community of the south-eastern North Sea and occurs scattered within the area in which *Sagitta elegans* water can be traced at the bottom at least. Unlike most other species of echinoderms *O. texturata* seems to occur in deeper water on the north English coast of the North Sea than in Danish waters. At Scarborough, at least, it seems to be confined to deep water (FORBES 1841 p. 25). The general distribution of the species is rather southern (South Iceland to the Mediterranean). The temperature increase that occurred almost simultaneously with the reduction of the area of distribution of *O. texturata* in the North Sea (cf. p. 13) cannot very well, therefore, be supposed to be disadvantageous to the species.

°*Ophiura sarsi* LÜTKEN.

O. sarsi seems to abound in the Skagerrak and the Norwegian Channel. Some few finds have been made in the North Sea proper (Fig. 42, p. 63): 2 in the German Bight (1872, MÖBIUS and BÜTSCHLI 1875; 1889—90, MEISSNER and COLLIN 1894) and 2 on the Dogger Bank (1872, MÖBIUS and BÜTSCHLI 1875; 1924, DAVIS 1925). During the present investigation *O. sarsi* was not obtained except in a few dredge hauls from the Norwegian Channel at the entrance to the Skagerrak, in 1922—26. If the records from the central and southern North Sea are reliable the species apparently became more rare about 1930, simultaneously with the decrease of *O. texturata*. Most records from the Kattegat and the Sound, in which *O. sarsi* is confined to the deep channel, are old, too (BRATTSTRÖM 1941).

O. sarsi has its southern limit of distribution in the Sound and the North Sea. In the Kattegat and the Sound it occurs where the mean summer temperature is below 12°. In the Skagerrak localities the summer temperature is even lower. However, if the southern and central North Sea finds are valid the species tolerates considerably higher mean summer temperatures, probably about 16°. At any rate, the absence of records from the central part of the northern North Sea cannot be explained by definite temperature requirements because the temperature of the warmest month is there below 12°. The winter temperature in this area is probably about the same as in the Skagerrak and northern Kattegat localities. The distributional pattern of *O. sarsi* in the North Sea and the transitional area bears some resemblance to that of *Marthasterias glacialis* and other Atlantic forms which penetrate far into the transitional area but have a very restricted distribution in the North Sea. As this type of distribution is found in decidedly northern species (*O. sarsi*) as well as in decidedly southern ones (*M. glacialis*) the species in question apparently are confined rather to certain water masses than to certain temperatures. The distribution of *O. sarsi* corresponds to that of the deep water plankton community (cf. p. 18).

Ophiura albida FORBES.

Danish grab records 1932—55 are listed in Appendix 1.

O. albida is one of the most abundant bottom animals in the central North Sea. Fig. 39 shows the grab records of the species. Trawl records add but little further information. SÜSSBACH and BRECKNER (1911, Tafel 3) charted the distribution based on material collected during the cruises of the "Pommerania" in 1872 and of the "Poseidon" in 1902—07. The species was common in the central North Sea but scarce at depths exceeding 60 m. A similar distribution was found during the grab surveys. DAVIS (1923) in his Dogger Bank grab survey found *O. albida* tending rather towards the edges of the bank. The same tendency appears in the Danish grab records from 1932—54: the highest densities were obtained on the eastern part of the Dogger

Bank and immediately south of the bank. South of the White Bank there seems to be an area not inhabited by *O. albida*. DAVIS, BLEGVAD, and the "Dana" made comparatively few finds in this locality. The scarcity of grab records from the region off the Dutch coast probably cannot be explained exclusively by low sampling efficiency. The "Wodan", too, made very few finds in this region. *O. albida* occurs close to the Danish North Sea coast except in the Waddensea in which larvae only have been observed (SMIDT 1951 p. 106). In the Limfjord it occurs at least in the western part (the Nissum Broad, BOYSEN JENSEN 1919, Table 3). MISTAKIDIS (1951) found it occasionally in the estuary of the river Roach, South England.

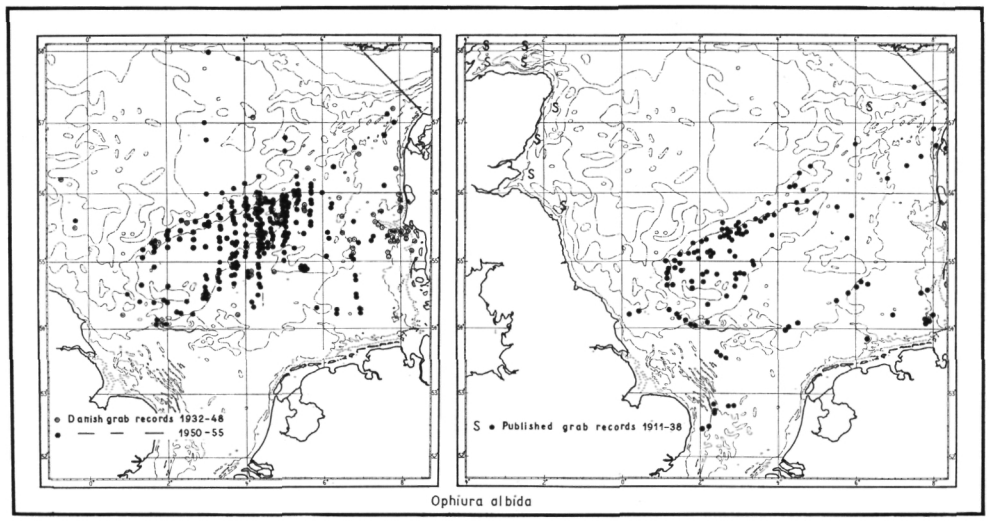

Fig. 39. STEPHEN's records are given a separate symbol (S) because they refer to statistical squares, not to exact localities.

Off the Scottish coast and on the northern edge of the Dogger Bank *O. albida* is exposed to salinities about 35 $^0/_{00}$, to mean winter temperatures about 5°, and to mean summer temperatures down to about 10°. In the western part of the Limfjord it occurs in salinities about 30 $^0/_{00}$, at mean winter temperatures about 1°, and at mean summer temperatures about 18°. These are the extreme conditions to which it is exposed in the North Sea region. In inner Danish waters it seems to occur at mean salinities down to 20 $^0/_{00}$ or perhaps even 15 $^0/_{00}$. The temperature range is from a mean of about 2° in winter to at least 16° in summer. On this background it is difficult to understand the absence of *O. albida* from the Waddensea. Perhaps the species does not tolerate the rapidly changing ecological conditions in a tidal region with vast intertidal areas and narrow channels. At least in the Danish Waddensea the channels are probably at falling tide entirely filled up with water which a few hours before formed a thin layer (about one metre deep) over the intertidal sands where they are exposed to sun or may be mixed with rain. The species seems to be sublittoral outside the North Sea, too.

Like *O. texturata*, *O. albida* does not penetrate into the Arctic region, despite its tolerance for low winter temperatures. Perhaps it requires for breeding a temperature which is obtained in boreal and warmer waters only. In the southern North Sea it breeds predominantly in June (REES 1954 p. 57). *O. albida* is one of the few species of echinoderms which are in the North Sea largely confined to the Dogger Bank and the waters south and east of it. The distribution in the North Sea approximately covers that of the *Sagitta setosa* plankton community.

Table 10.

Size frequency in *Ophiura albida* from the North Sea. All bottom samples taken in April—May 1950—54.

Diameter of disk (mm)	1950		1951		1952		1953		1954		1950–54 total		1951–52 Depth >60 m	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0	..	..	51	5	8	1	1	1	1	1	61	3	3	16
1	80	25	267	26	85	15	4	3	8	9	444	21	12	63
2	29	9	145	14	80	14	7	6	8	9	269	13	2	10
3	15	5	61	6	51	9	10	8	4	4	141	7	2	10
4	19	6	17	2	34	6	6	5	1	1	77	4	..	..
5	15	5	26	3	15	3	1	1	..	..	57	3	..	..
6	44	14	70	7	31	5	19	15	5	6	169	8	..	..
7	43	13	147	14	82	14	41	33	26	30	339	16	..	..
8	49	15	155	15	96	17	19	15	26	30	345	16	..	..
9	17	5	60	6	72	12	16	13	7	8	172	8	..	..
10	6	2	10	1	20	4	1	1	2	2	39	2	..	..
11	3	1	7	1	4	1	..	..	..	..	14	1	..	..
12	1	0	1	0	..	..	..	..	..	..	2	0	..	..
Total	321	100	1017	100	578	101	125	101	88	100	2129	102	19	100

The diameter of the disk was measured in the grab material from 1932—54. Table 10 and Fig. 40 show the size frequency of all specimens available from April and May 1950—54. There are two distinct size groups with little overlapping. One has its mode about 1 mm, another has it

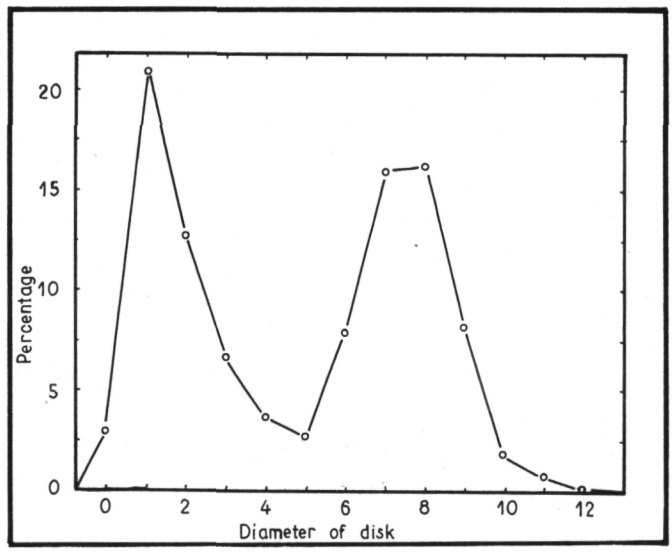

Fig. 40. *Ophiura albida*. Size frequency in 1950–54 (April–May). Based on Table 10.

at 7—8 mm. Each group contains about 50 % of the specimens. The first mode obviously is produced by juveniles from the preceding year, because the spat-fall of the year of sampling scarcely has occurred yet in May (Rees, l. c.). The smallest size group and, therefore, the young-

Table 11.

Ophiura albida from sets of stations operated in successive years (April—May).
On the calculation of the number of 0-group animals, see text.

	30 stations operated in 5 successive years											120 stations operated in 2 successive years				
	All stations						7 stations without (?) 0-group in 1950					All stations			15 stations without (?) 0-gr. in 1951	
Year	1950	1951	1952	1953	1954	1950 —54	1950	1950	1952	1953	1954	1951	1952	1951 —52	1951	1952
Area sampled (m^2)	6.0	6.0	6.0	6.0	6.0	30.0	1.4	1.4	1.4	1.4	1.4	24.0	24.0	48.0	3.0	3.0
Diameter of disk (mm) 0	..	16	..	1	1	18	..	14	..	..	..	23	3	26	..	..
1	54	42	18	2	7	123	..	5	5	..	3	95	56	151	..	18
2	9	49	10	5	8	81	..	5	5	..	..	68	58	126	..	17
3	3	19	10	7	4	43	..	..	1	..	..	25	23	48	..	5
4	9	..	7	4	1	21	3	..	1	1	..	7	16	23	..	2
5	9	1	7	1	..	18	9	1	1	..	..	4	11	15	..	1
6	34	11	24	4	5	78	13	10	17	3	..	20	25	45	4	3
7	27	20	34	26	26	133	13	17	33	20	6	57	62	119	9	15
8	15	14	27	16	25	97	5	6	23	8	8	80	78	158	23	33
9	5	4	19	12	6	46	..	..	4	7	1	22	54	76	4	27
10	5	5	3	..	2	15	..	..	..	..	..	8	12	20	3	4
11	1	1	1	..	..	3	..	..	..	..	..	3	2	5	2	..
12	1	1	..	..	..	2	..	..	..	..	..	1	..	1	..	..
Total number	172	183	160	78	85	678	43	58	90	39	18	413	400	813	45	125
No. of 0-group	79	127	49	20	21	296	0	24	12	1	3	220	161	381	0	42
No. of older	93	56	111	58	64	382	43	34	78	38	15	193	239	432	45	83
No. per m^2, all ages	28.6	30.5	26.7	13.0	14.2	22.6	30.7	41.4	64.3	27.9	12.9	17.2	16.7	16.9	15.0	41.7
No. per m^2, 0-group	13.3	21.2	8.0	3.3	3.5	9.9	0	17.1	8.6	0.8	2.2	9.2	6.7	7.9	0	14.0
No. per m^2, older	15.3	9.3	18.7	9.7	10.7	12.7	30.7	24.3	55.7	27.1	10.7	8.0	10.0	9.0	15.0	27.7
Mean size, 0-group	2.23	2.09	2.87	3.20	2.36	2.35	..	1.12	2.33	4.50	1.50	2.06	2.55	2.27	..	2.29
Mean size, older	7.58	8.12	7.91	8.12	8.09	7.92	6.69	7.32	7.65	8.00	8.17	8.23	8.31	8.27	8.48	8.63

est age group is probably under-represented in the samples. The individuals may escape through the meshes of the sieve or they may escape attention.

In order to find out how may year classes are pooled in the second mode on the frequency diagram it is necessary to remove the 0-group. A separation of the two groups seems to be approached when all specimens measuring less than 5 mm and 50 % of those measuring 5 mm are considered belonging to the 0-group. In Table 11 it is tried to trace the growth rate and mortality of the remaining, older, individuals. The first columns show the size frequency in the entire material collected on 30 stations operated annually in 1950—54 (April—May). The number of specimens more than a year old varies greatly. A statistical test, however, showed that the difference between the number obtained in successive years is not significant, not even at the 10 % level. The same result was obtained on comparing the number of adults caught on 120 stations operated in April—May of both the years 1951—52 (cf. Tab. 11). The mean size of specimens more than a year old increased from 1950 to 1951 (sign. at the 5 % level) in the series of 30 stations but did not change significantly during the years 1951—54. The increase in size observed in the series of 120 stations (see the table) is not significant.

In the series of 30 stations there are 7 stations which in 1950 produced only or almost exclusively animals more than a year old. The stock development at these 7 stations is shown in Table 11. The change from one year to another in the density of adults is not significant. The recruitment of 0-group animals was poor so that it may be supposed that the stock of adults observed in 1950 survived the period of observation (1950—54) without conspicuous reduction. The mean size at the 7 stations referred to increased as follows from one year to another (size in mm): 6.7—7.3—7.6—8.0—8.2. The increase from 6.7 mm to 7.3 mm is significant at the 1 %

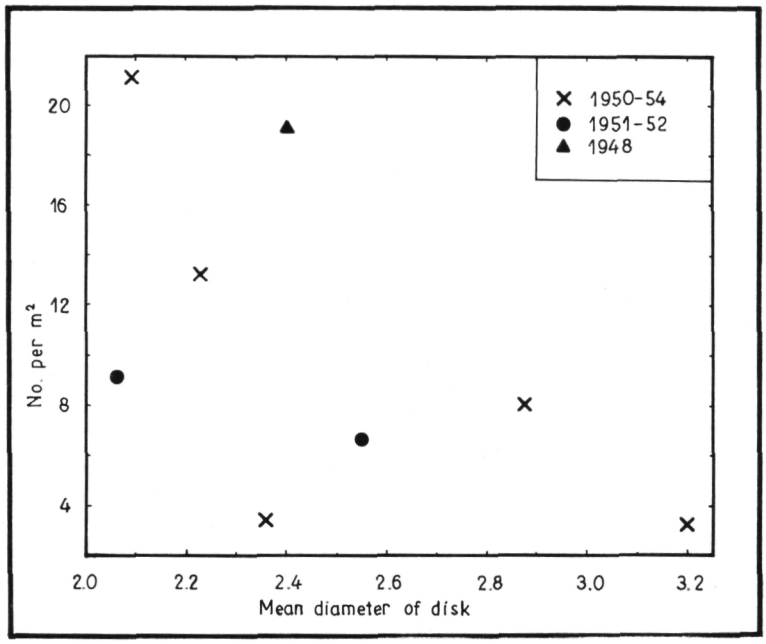

Fig. 41. 0-group *Ophiura albida*. The relation between abundance in grab samples and mean size. Two sets of stations operated annually (1950–54 and 1951–52) in April–May. On the 1948 value, see text, p. 62.

level. The increase from 7.6 mm to 8.0 mm is significant at the 5 % level. Although the evidence gathered is perhaps not entirely satisfactory it seems as if the majority of specimens more than a year old occurring in the central North Sea in 1950—54 originated from one or several spat-falls prior to 1949. A heavy spat-fall in the summer of 1949 probably would have been traced in the spring of 1950 when regular sampling was initiated.

In the spring samples from 1950—54 there was some variation from one year to another in the observed density of 0-group animals. For instance, in the set of 30 stations operated annually in 1950—54 (Table 11) there was a decrease in the total number of 0-group animals from 127 in 1951 to 49 in 1952. When the decrease is calculated for each station separately the mean decrease is different from zero at the 1 % level of significance. It is doubtful, however, whether the difference in the observed density of the 0-group from one year to another is due to different strength of individual year classes. Apparently, a correlation exists between the density of the 0-group in April—May and the mean diameter of the disk (Fig. 41). Perhaps the density of the 0-group in April—May remained approximately constant. Sampling, however, was in some years carried out on a population of slightly younger (smaller) animals than in other years.

According to REES (1954 p. 56) there occurred in the south-eastern North Sea in 1950—51 vast numbers of larvae of *O. albida*. This occurrence is in accordance with the simultaneous existence of a dense stock of adults. Settling, however, was unsatisfactory as, as shown above, the brood of these years did not conspicuously influence the stock of adults.

Table 12.

Density of *Ophiura albida* in the central and southern North Sea, as observed in various grab surveys.

Reference	Month	Year	Bottom sampler	Mean vol. of sample (l per 0.2 m²)	Area sampled (m²)	No. of *O. albida* per m²
BLEGVAD 1922	VII	1921	0.1 m² PETERSEN grab	..	4.0	0.2
DAVIS 1923, 1925	II, III, V, VI, VIII–XII	1921–24	0.1 & 0.2 m² PETERSEN grabs	..	410	0.6
DAVIS 1923, voy. 48	X	1922	0.2 m² PETERSEN grab	..	52	0.9
HAGMEIER 1925	V, VII	1923–24	0.1 m² PETERSEN grab	..	13.5	7.0
CASPERS 1939, 1950	I–IV, VI–X	1936–38	0.1 m² — –	..	4.9	72.9
— 1939	IV	1937	0.1 m² — –	..	1.3	108.5
Danish ships	IV–VII	1932–39	0.1 & 0.2 m² PETERSEN grabs	4	67.6	1.3
– –	V	1947	0.2 m² PETERSEN; 0.1 m² VAN VEEN	..	1.0	6.0
– –	V–VI	1948	0.2 m² VAN VEEN grab	5	2.8	22.1
– –	IV–V	1950–54	0.2 m² PET.; 0.2 m² v. V.; 0.1 m² KNUDSEN	10	125.7	16.9
– – [1]	V	1951	0.2 m² VAN VEEN	7	11	11.0

[1] A selected set of stations, reasonably comparable with DAVIS's voyage 48.

Table 12 gives a chronological survey of the available information on the density of *O. albida* in the North Sea in various years. BLEGVAD and DAVIS in 1921—24 found densities below 1 per square metre. Similar densities (1.3 pr. m²) were observed in 1932—39 by Danish research vessels. In the German Bight HAGMEIER in 1923—24 found densities about 10 times higher than observed in the same years by other investigators in the central North Sea. CASPERS records extremely high densities (about 100 per m²) in the German Bight in 1936—37 when the numbers in the central North Sea were still low. The Danish sampling in 1948 (15 samples scattered over the North Sea excl. the German Bight) showed a situation different from that observed in 1921—39. With a density of about 22 per m² 1948 is similar to the period 1950—54 (17 per m²).

The size frequency observed during various investigations reveals several points of interest (Table 13). During DAVIS's survey of the Dogger Bank in October 1922 adults were almost absent. The majority measured less than 5 mm. CASPERS's investigations in the German Bight showed a somewhat similar size frequency although a small but distinguishable stock of adults was found. Danish sampling in April—July 1932—39 showed besides the supposed 0-group, a stock of very large adults. 27 % of all specimens measured more than 10 mm. They may have been survivors of a single strong year class. They were found particularly in 1932—34 so that they may originate from a spat-fall that occurred soon after the end of DAVIS's sampling in 1924. The sampling in May—June 1948 revealed, besides a small stock of adults, a fairly strong

Table 13.

Ophiura albida. Percentage size frequency in the North Sea as observed by various investigators and in various years.

Reference	Davis 1923	Caspers 1950	Caspers 1939	Danish sampling		
Month and year	Oct. 1922	Oct. 1938	Apr.-June 1936–37	Apr.-July 1932–39	May-June 1948	Apr.-May 1950–54
Locality	The Dogger Bank	Helgoländer Austernbank	Helgoländer tiefe Rinne	Central and eastern North Sea	Central North Sea	Central North Sea
Area sampled (m^2)	52	?	?	67.6	2.8	125.7
Specimens measured	42	117	506	86	62	2129
Diameter of disk (mm) 0	..	..	..	..	..	3
1	19	14	11	7	22	21
2	45	47	26	13	45	13
3	19	9	26	21	11	7
4	10	7	8	14	2	4
5	5	5	10	5	2	3
6	2	2	7	4	5	8
7	..	3	8	..	2	16
8	..	3	3	7	2	16
9	..	5	1	4	5	8
10	..	5	..	12	5	2
11	..	..	..	8	..	1
12	..	..	..	7	..	..
Percentage < 5 mm	93	77	71	55	80	48
Percentage > 10 mm	0	5	0	27	5	3
Total no. per m^2	0.9	(50.8)[1]	(91.7)[1]	1.3	22.1	16.9

[1]) The density apparently does not refer to exactly those samples from which material was measured.

0-group in the central North Sea. The average density of this 0-group (representing the spat-fall of 1947) was 19.2 per m^2. The mean diameter of the disk was 2.40 mm (cf. Fig. 42). The dense stock of adults found in 1950—54 perhaps partly originates from the 1947 spat-fall. It cannot very well be older because adults were scarce in 1948. However, it may originate from a spat-fall in 1948 which would have appeared as a 0-group in 1949 if material was available.

The evidence presented above points to the conclusion that the variation in density and size frequency which in 1922—54 occurred in the North Sea stock of *O. albida* does not result from any continuous change in the environment. It seems more likely that the fluctuations observed merely indicate the normal variation in stock size and composition in a bottom invertebrate species with planktotrophic larval development. There is other evidence, however, which points in another direction. Unlike most other species mentioned above *O. albida* is largely confined to the central North Sea, to the region characterized by the *Sagitta setosa* plankton. Not only are the densities obtained in the central North Sea higher than in the northern North Sea, but even the size frequency in the sparse northern North Sea material (juveniles only, see Table 10) indicates that *O. albida* does not find suitable conditions in the northern North Sea. As shown below (p. 103) there has been, in recent years, a tendency among the less abundant species

towards withdrawal from the central North Sea. At the same time, species like *O. albida* which were already abundant further increased in abundance. On this background the hypothesis of the purely accidental fluctuations in the size of the North Sea stock of *O. albida* does not seem quite satisfactory.

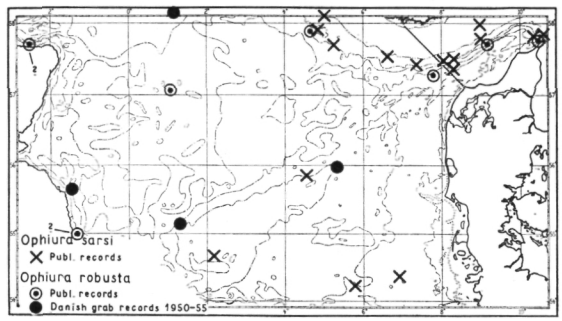

Fig. 42. The records from literature refer to trawl and dredge investigations except a record of *O. sarsi* from the Tail End of the Dogger Bank (grab record by DAVIS). On *O. sarsi*, see text, p. 56.

Ophiura robusta AYRES.

Danish grab records 1932—55: 7570 (2), 7579 (1), 7744 (1), 7986 (1).

O. robusta has approximately the same geographical distribution as *O. sarsi*. Both have their southern limit of distribution in the North Sea and the transitional area between the North Sea and the Baltic. Neither are recorded from the British west coast nor from the English Channel. The available records of *O. robusta* from the area investigated are plotted on the chart, Fig. 42. All records are from the northern North Sea and, particularly, from the Norwegian Channel and the Skagerrak. The 5 specimens in the Danish grab material are small, probably juvenile: 1.5, 1.5, 2.0, 2.0, and 3.5 mm. Adults were found in the northern North Sea by SÜSSBACH and BRECKNER (1911). Perhaps the species is not indigenous in the central and western part of the northern North Sea. The population may be recruited from larvae transported by currents from the Norwegian Channel. RAE and REES (1947 p. 125) suggested such transport for several other forms.

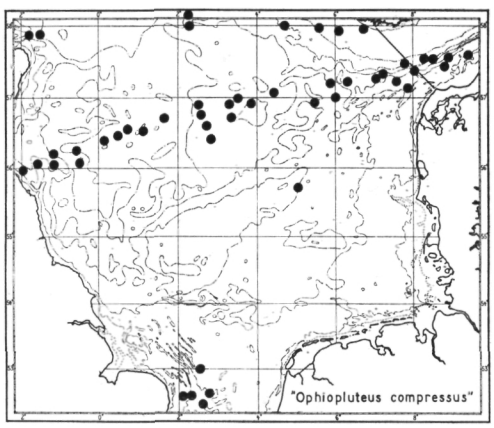

Fig. 43. The distribution in the North Sea (after REES 1954) of the larva ascribed to *Ophiura robusta*. Compare with the charts of distribution of *O. robusta* (Fig. 42) and *O. affinis* (Fig. 44).

In 1950—51 REES (1954) found considerable numbers of the ophiuroid larva *Ophiopluteus compressus* in the North Sea. *O. compressus* is at present considered the larva of *Ophiura robusta* (THORSON 1946, p. 352) and is accepted as such by REES. REES, however, found the larva not only in the northern North Sea but also in the Southern Bight although metamorphosed *O. robusta* are not recorded from the southern North Sea. In other cases it might be suggested that the larvae in the southern Bight originate from spawning in the English Channel. *O. robusta*, however, is one of those few North Sea echinoderms which have never been found west or south of the British Isles. Naturally, a small stock of adults in the Southern Bight may have escaped attention or the larvae may have been introduced with northern North Sea water. The Southern Bight occurrence seems so isolated (cf. Fig. 43) that, nevertheless, a slight doubt arises as to the affinity of *Ophiura robusta* and *Ophiopluteus compressus*. THORSON (l. c.) has shown convincingly that *O. compressus* may develop into *O. robusta*. All the same, another species may have larvae which are not distinguishable from the larva of *O. robusta*. Attention may be called to the rather striking fact that the larva of *Ophiura affinis* is not known with certainty. The distribution of *O. affinis* in the North Sea is shown in Fig. 44.

In the North Sea bottom stages of *O. robusta* have been taken where the salinity is not much below 35 ‰, where the mean summer temperature is above 8° but below 12°, and where the mean winter temperature is between 4° and 6°. Within the transitional area between the North Sea and the Baltic *O. robusta* abounds in the southern Kattegat and in the northern part of the Sound and the Great Belt. In this region it seems to occur at mean salinities down to 20 ‰, at mean summer temperatures of 12—14° and at mean winter temperatures of 3—5°. In the North Sea it is difficult to find localities with winter temperatures below 4° except where the mean summer temperature is very high (above 15°). The combination of low winter temperature and low summer temperature which is found in the transitional area may be advantageous to a species of decidedly northern distribution, like *O. robusta*. However, BRATTSTRÖM (1941 p. 286) may be right in his suggestion that the conditions of nourishment are important to the density of *O. robusta* in the Sound. The density is particularly high within the *Modiolus* community and the *Haploops* community (PETERSEN 1918). These communities probably to a great extent depend upon a rapid water renewal because the dominating forms have a particularly high demand for food (cf. URSIN 1956 a p. 6). Perhaps the oxygen consumption of *O. robusta* increases so much with temperature that the species does not find entirely satisfactory conditions in temperate waters except where the amount of nourishment is above normal. If this suggestion is right a similar case has been described by THORSON (1936 p. 112). It was observed that a bivalve, *Pecten groenlandicus*, the oxygen consumption of which increases extraordinarily rapidly with temperature, is in East Greenland waters confined to depths between 25 and 60 m. This depth range was found to cover the region in which the amount of nourishment is high and the temperature low.

Ophiura affinis LÜTKEN.

Danish grab records 1932—55 are listed in Appendix 1.

The various German investigations in 1872—1907 produced *O. affinis* at numerous stations in the northern North Sea and also at several stations in the southern North Sea (Fig. 44). Grab surveys revealed conspicuous fluctuations in density. In the northern North Sea high densities were found in 1911 by PETERSEN (1914) and in 1922—25 by STEPHEN (1934). PETERSEN sampled off the Jutland coast and found an overall density of 17 *O. affinis* per m². STEPHEN sampled in offshore waters and found 9 *Ophiura* (as it seems, almost exclusively *O. affinis*) per m². Very low densities were found in offshore waters of the northern North Sea during the Danish grab surveys in 1932—39. 13 m² were sampled, showing a density of 0.4 *O. affinis* per m². In 1947—48 four samples taken within the same area produced 2, 3, 8, and 10 specimens, corresponding to a density of 29 per m². In 1950—54 20.2 m² were sampled in offshore waters of the northern North Sea. The density of *O. affinis* was 2.7 per m². In the same period 5.6 m² were sampled off the north Jutland coast. One specimen (0.2 per m²) was found. In the same area PETERSEN in 1911 got 30 per m² (6 m² sampled). The above evidence does not leave much doubt that the numbers of *O. affinis* in the northern North Sea are strongly fluctuating.

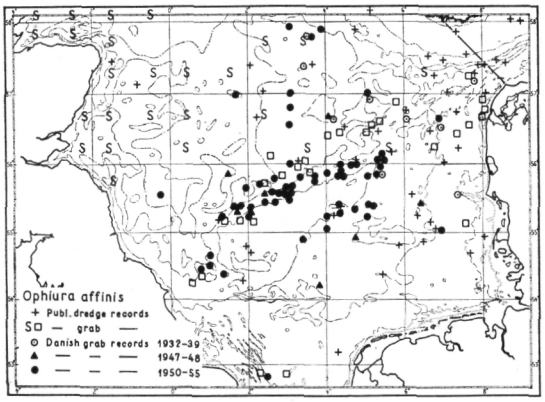

Fig. 44. STEPHEN's grab records are given a separate symbol (S) because they refer to statistical squares, not to exact localities.

In the southern North Sea (south of the northern edge of the Dogger Bank) DAVIS (1923, 1925) in 1921—24 found 0.02 *O. affinis* per m². As there is some evidence that DAVIS's sampling technique was somewhat deficient (cf. above, p. 21) we may perhaps multiply by 10, getting a density of 0.2 per m². The same figure, 0.2 per m², was found in the Danish investigation 1932—39. In 1947—48, however, 2.8 m² of sampling (17 stations) produced 50 specimens (17.9 per m²), 43 of which originated from a single station. Leaving this station out of consideration the remaining stations (2.4 m² sampled) gave 2.9 per m². The highest number taken in a single haul in 1950—54 was 4 (on two occasions only). The overall density in the southern North Sea in this period was 0.7 per m². The occurrence was patchy. (Fig. 44). One patch was situated between the Dogger Bank and the White Bank, another west of the Dogger Bank. Within the patches the densities were 1.4 and 3.0 per m², respectively.

It seems as if *O. affinis* has usually been less abundant in the southern North Sea than in the northern North Sea. During all investigations the species was found to be absent from the central part of the Dogger Bank, from the Danish coast at depths of less than 20 m, and from the inner part of the German Bight. The highest mean summer temperature and the lowest mean winter temperature at which *O. affinis* occurs in the North Sea are probably 16° and 3.5°. In the Sound between Denmark and Sweden the corresponding values seem to be 14° and 4°. *O. affinis* is not known with certainty from the French Atlantic coast or farther south. Thus, the high summer temperatures prevailing in the southern North Sea may de disadvantageous to the

Table 14.

Ophiura affinis. Size frequency in the North Sea. Danish grab material.

Diameter of disk (mm)	1950–54 April–May		1932–48 May–June		August–September	
	No.	%	No.	%	No.	%
1.0	2	2			1	4
1.5	7	9	1	1	2	8
2.0	13	16	6	8	2	8
2.5	20	25	14	20	5	21
3.0	15	18	15	21	6	25
3.5	10	12	14	20	4	17
4.0	6	7	12	17	2	8
4.5	6	7	7	10	1	4
5.0	2	2	2	3	1	4
No. measured	81		71		24	

species. Toward the north *O. affinis* does not penetrate into the arctic region so that it might have a rather restricted tolerance for low temperatures. It is not so, apparently, because the southern North Sea stock was not destroyed during the cold winter of 1947. The absence of *O. affinis* from the Danish and German North Sea coasts cannot, therefore, very well be due to the low winter temperatures on these coasts. All things considered, the importance of temperature to the distribution of *O. affinis* in the North Sea is rather problematic. It might as well be suggested that *O. affinis* has some affinity with the *Sagitta elegans* plankton water and, therefore, does not always find suitable conditions in the central and southern North Sea in which the *Sagitta setosa* water and the coastal plankton water predominate.

The size frequency of North Sea *O. affinis* is shown in Table 14. During all periods of observation the size frequency distribution is unimodal. The diameter of the disk ranges from

1.0 mm to 5.0 mm with the mode about 2.5—3.0 mm. The distinctly bimodal size frequency diagram with an easily recognizable 0-group which was found in *O. albida* (Fig. 40, p. 58) is not repeated here. The scarcity of specimens of *O. affinis* measuring less than 2 mm may be due to deficiency of the sampling technique adopted. *O. affinis* is a small and delicate animal, likely to be broken up and washed through the sieve. The most probable explanation of the unimodal size frequency perhaps is that the 0-group was partly or completely lost during sieving and sorting of the material. If so, the specimens kept may represent the stock of older individuals corresponding to the second mode in the size frequency diagram of *O. albida*.

On the possible affinity of *O. affinis* and the larval type known as *Ophiopluteus compressus*, see above (p. 63).

Ophiocten sericeum (FORBES).

Danish grab record 1932—55: 7383 (1).

This find was made on the edge of the Norwegian Channel (Fig. 36, p. 53) on coarse sand at 90 metres depth. According to MORTENSEN (1924) the species is fairly abundant in the Skagerrak although it was not taken by PETERSEN (1915) or during the old German investigations. It is also recorded from great depths in Shetland waters (BELL 1892). The geographical distribution of the animals which are usually pooled under the name of *O. sericeum* is rather unusual. The species is extremely abundant in shallow water on arctic coasts (see for instance THORSON 1933, 1934). In boreal seas it is generally rare and confined to greater depths. Astonishingly, however, it appears again in the Mediterranean in which it has a great depth range (TORTONESE 1949). Originally, the Mediterranean form was described as a distinct species, *O. abyssiculum* (FORBES), but systematists like KOEHLER (1924 p. 324) and MORTENSEN (1927 p. 248) do not recognize *O. abyssiculum*, owing to the vague nature of the characters distinguishing the two species. To the present author it seems rather as if two species do actually exist. If so, there is a cold water form abounding in arctic shallow water and perhaps with southern outposts in deeper water in temperate seas as the Skagerrak and the Bay of Biscay. The northern form (the true *O. sericeum*) apparently does not occur at temperatures above 8 or 10°. The southern form (*O. abyssiculum*) may or may not be restricted to the Mediterranean in which it seems to occur at temperatures ranging from 13° to 25°. An alternative explanation of the "bimodal" distributional pattern of *O. sericeum* (in the wide sense of this name) is that it competes well with other species only in areas with a low level of production, like the arctic seas and the Mediterranean.

Echinoidea.

Psammechinus miliaris (GMELIN).

Danish grab records 1932—55: 6050[I] (1), 7495 (2), 7596[III] (1), 8024 (1), 8866[I] (2).

SÜSSBACH and BRECKNER (1911) found that *P. miliaris* is mainly confined to the southern and eastern North Sea, particularly the Dogger Bank. HAGMEIER and KÄNDLER (1927) and SMIDT (1951) found it abundant in the German and Danish Waddensea, especially on rough ground (oyster banks, HAGMEIER and KÄNDLER l. c.). Trawlings in the Danish Waddensea in 1952—56 produced numerous finds. A few grab records were published by DAVIS (1923, 1925), HAGMEIER and KÄNDLER (1927) and CASPERS (1939, 1950).

The chart, Fig. 45, shows all available North Sea records. When the sampling efficiency in different parts of the area is taken into consideration (cf. Figs. 1, 11—13) it may be concluded that *P. miliaris* is most abundant in the Waddensea region, in the south-western part of the Dogger Bank and in the Southern Bight. It is scarce in the northern North Sea. In offshore waters of

the southern North Sea there is less than one per square metre. In the German Waddensea HAGMEIER and KÄNDLER locally found several per square metre. In most broads of the Limfjord the density is about one per square metre (BOYSEN JENSEN 1919).

P. miliaris is a southern species which is distributed toward the north to the Faroes and southern Norway only. However, it has a high tolerance for low temperatures. This is ascertained by its abundance in the Limfjord, at winter temperatures not far from zero. The North Sea distribution suggests a dependence upon high summer temperatures (15—17°). Observations by HAGMEIER and KÄNDLER (1927) and REES (1954) to the effect that *P. miliaris* is a summer breeder in the North Sea (as it is in the Sound and the Belt Sea, THORSON 1946 p. 354) point toward the

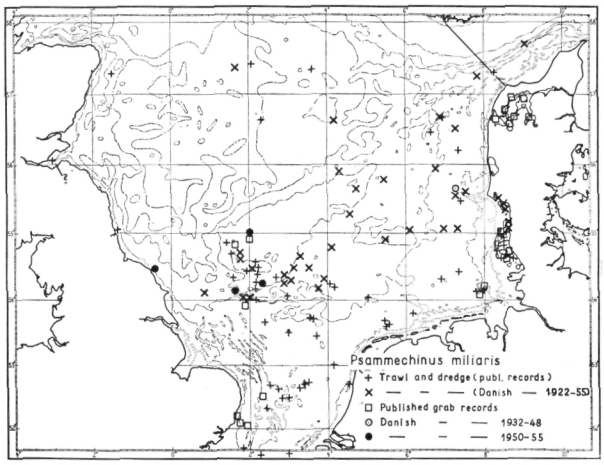

Fig. 45. The exact locality for BELL's record from the Firth of Forth is not known.

importance of the maximum temperature. In Faroe waters the species seems to be very common, especially in fjords and sounds from the shore to a depth of 30 m (LIEBERKIND 1929). Thus, it is able to live and reproduce at localities in which the summer temperature scarcely exceeds 11° (cf. KIILERICH 1928). In the transitional area between the North Sea and the Baltic there are localities in which it occurs (and reproduces ?) at summer temperatures only slightly higher than in Faroe waters. Thus, the correlation in the North Sea between high summer temperature and abundance of *P. miliaris* may be accidental. If so, it seems rather difficult to explain the distributional pattern of the species in the North Sea. Naturally, it may be dependent upon high summer temperature in the North Sea but not elsewhere. Other environmental factors may interfere with its temperature tolerance. The combined effect of several factors is often difficult to trace at the present stage of development of marine sciences.

The salinity requirements are low. *P. miliaris* occurs and obtains maturity in the Little Belt (THORSON 1946, quoting KRAMP), apparently at a salinity about 20 $^0/_{00}$.

During the Danish grab surveys of 1950—55 6 specimens were obtained. They were taken in depths of 34—59 m. There are three records (5 specimens) from stoney grounds and one from muddy sand. The specimens measured 2, 7, 8, 16, 17, and 25 mm diameter of naked test. In 1932—39 a single specimen (13 mm) was taken in the bottom samples, namely, on coarse sand with stones off Horn's Reef at 33 m. HAGMEIER and KÄNDLER (1927) observed that *P. miliaris* grows larger in the Waddensea than in Helgoland waters. CASPERS (1950 p. 144) gives 11 mm as maximum size for Helgoland waters. In the south-west Dogger Bank area many

specimens obtained during the Danish trawl survey in May 1954 measured more than 30 mm. The biggest specimen had a diameter of 46 mm which is not far from the maximum size for the species (MORTENSEN 1943, III, 3 p. 131). Investigations by BULL (1939) and others have shown that the rate of growth is rapid under favourable conditions. Thus, the specimens in the Danish bottom sampler material (see above) may be less than a year old. Only the speciemen measuring 25 mm is likely to be older.

°*Echinus esculentus* (L.).

In the North Sea the present species is too rare to be expected to occur in bottom samples. Trawl and dredge surveys, however, have produced numerous records (Fig. 46). Like *Solaster papposus* (Fig. 21, p. 32). *E. esculentus* occurs within two rather distinct areas of the North Sea. Almost every investigation of the echinoderm fauna of the North Sea made in 1872—1955

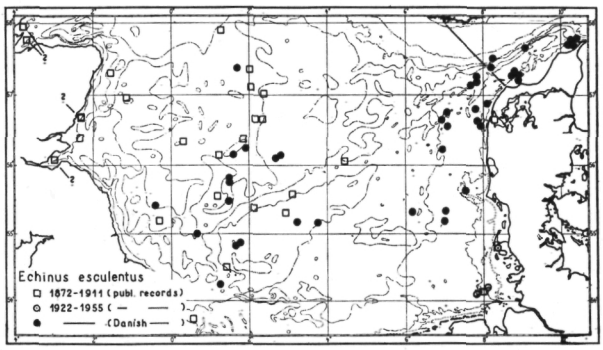

Fig. 46. Question-marks indicate that the exact localities, particularly the distances from land, are unknown.

produced records of *E. esculentus* from the north-western North Sea, from the Dogger Bank and northwards. In the eastern North Sea, east of 7° E., and on the Danish coast of the Skagerrak several finds were made during recent investigations (1922—55). Astonishingly, the extensive German and Dutch trawl and dredge surveys in 1872—1911 failed to produce *E. esculentus* in the Skagerrak or in the eastern North Sea except in Helgoland waters. MORTENSEN (1897), however, records the species from the Limfjord. A comparison of Fig. 46 with the station charts (Figs. 6, 11, 12) shows that changes in sampling efficiency do not account for the increased abundance in the Skagerrak and the eastern North Sea in recent years.

Before the distributional pattern of *E. esculentus* in the North Sea can be understood it is necessary to clear up some misunderstandings as to the systematic position of the North Sea stock. MORTENSEN (1907 p. 173) described a new variety from the North Sea: *E. esculentus* var. *fuscus*. According to the most recent description (MORTENSEN 1943 p. 37) the variety is distinguishable from the typical form by the shape of the test which is generally lower in the variety, and by the length of the spines which in the variety "appear to be in general a little longer and stouter than in the typical form". SÜSSBACH and BRECKNER (1911)—not aware of MORTENSEN's description—named the same form var. *depressa* and stated that it was the only form of *E. esculentus* obtained by them in the North Sea (i. e., in the western North Sea). Off Helgoland, however, the typical form should occur. The latter observation seems to be based on a find published by MEISSNER and COLLIN (1894). A large, actually rather flat, specimen from the Limfjord is referred by MORTENSEN to the typical form. Thus, it might seem as if the typical *E. esculentus* occurs in the eastern North Sea while the north-western North Sea stock is made up

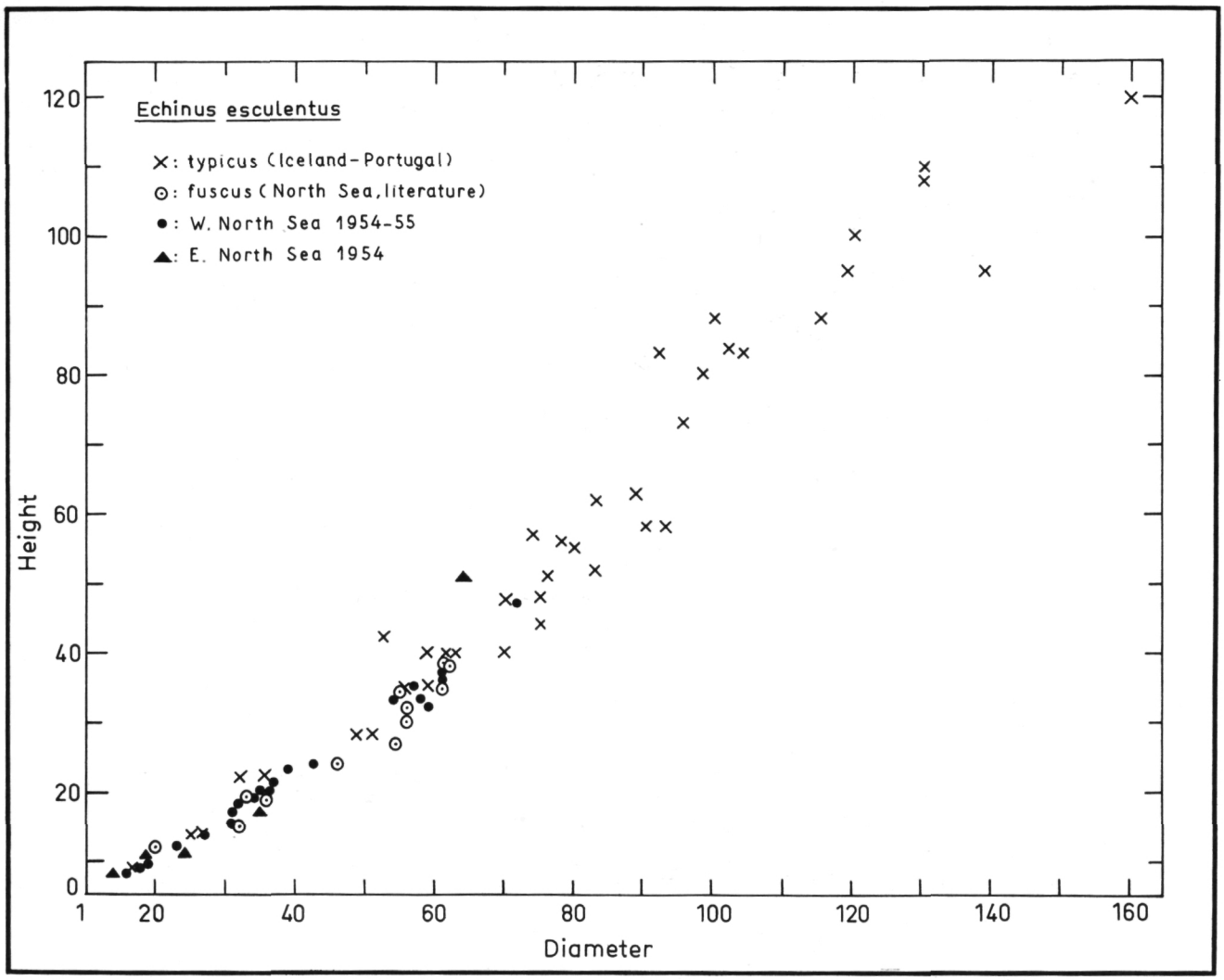

Fig. 47. Height of test in *E. esculentus* from the North Sea and elsewhere.

by the variety. An analysis of the available material is difficult owing to the vagueness of the existing descriptions of the difference between the two forms. The height of the test apparently is the only character the value of which is accepted by all authors. Fig. 47 shows the height of the naked test plotted against diameter. Measurements by MORTENSEN (1943 pp. 31, 37), by SÜSSBACH and BRECKNER (1911 pp. 184—5), and by the present author are used. Apparently, the height/diameter ratio increases with size from about 0.5 in small specimens (20 mm diameter) to about 0.8 in large specimens (100 mm diameter). The impression that the north-western North Sea stock of *E. esculentus* has a lower test than material from other localities is produced by the fact that in the north-western North Sea *E. esculentus* does not grow to any great size. The tendency among systematists to focus attention upon the biggest specimens available probably led to the misinterpretation of a biological difference (in growth rate or longevity) for a systematic one. Fig. 48 shows that in young *Echinus esculentus* the test is not higher than in *Psammechinus miliaris* of the same diameter.

The distribution of *E. esculentus* in the North Sea is scarcely explicable by temperature or salinity requirements. The species occurs at mean winter temperatures ranging from about 6° in the north-western North Sea to about zero in the Limfjord and at mean summer temperatures ranging from 8° in the north-western North Sea to about 18° in the Limfjord. The salinity to which it is exposed in the North Sea ranges from more than 35 $^0/_{00}$ in offshore waters to less than 30 $^0/_{00}$ in the Limfjord. Thus, there is probably no locality in the North Sea which does not fulfil the temperature or salinity requirements of *E. esculentus*.

During the discussion in the present paper of the distribution of individual echinoderm species in the North Sea there is repeatedly pointed to a correlation between the distribution of

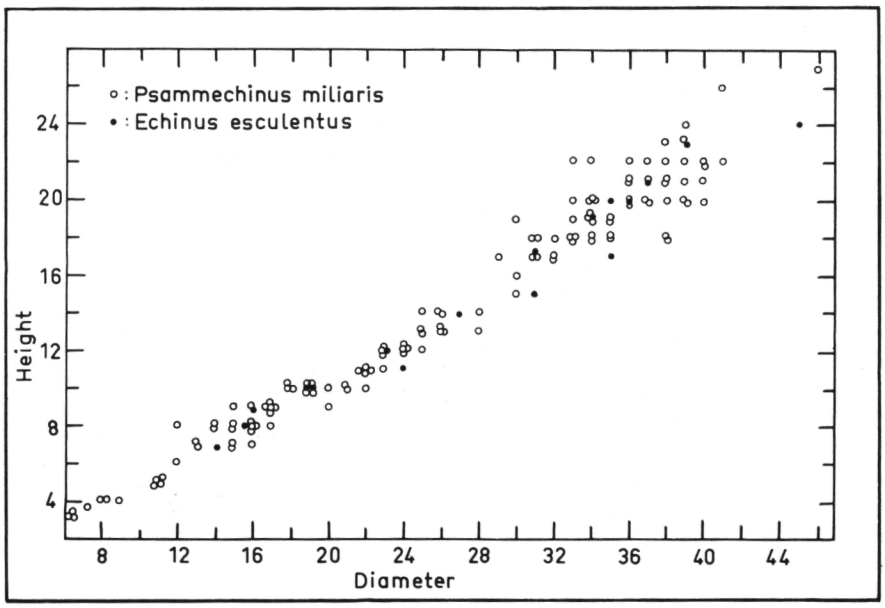

Fig. 48. Height of test in *P. miliaris* and *E. esculentus* of the same size. The North Sea, 1952–55.

bottom animals and the distribution of zooplankton communities. In the introduction (p. 15) it is mentioned that two plankton communities, one characterized by *Sagitta elegans*, another characterized by *Sagitta setosa*, are of great importance in the North Sea. Attention was also called to WILSON's experiments to the effect that even after sieving seawater supporting a *Sagitta elegans* fauna constitutes a more suitable medium for the rearing under laboratory conditions of larvae of certain bottom animals.

E. esculentus proved particularly sensitive to the water type. Larvae reared in *setosa* water collected off Plymouth usually degenerated while larvae reared in *elegans* water from the Celtic Sea developed normally. Nevertheless, adult *E. esculentus* abound in the sea off Plymouth, in *setosa* water. Occasionally, satisfactory results of rearing were obtained with Plymouth water (WILSON 1953 p. 348) probably implying that at times this water is sufficient for the development of *Echinus* larvae. The water used in laboratory experiments apparently was collected at the surface. YONGE (1949 pp. 164, 274) points out that in *elegans* water localities *E. esculentus* can be collected on the shore while in *setosa* water localities it is restricted to the sublittoral. Perhaps, the shore (i. e., surface) water at Plymouth is not suitable to the species while in deeper layers the inflow of *elegans* water from the Celtic Sea is sufficient for the maintenance of an *elegans*

bottom fauna. Plymouth seems to be situated where the west British *elegans* water changes into the south-east British *setosa* water. Probably a slight influence of *elegans* water occurs everywhere in the Plymouth region. Extreme *setosa* conditions are likely to be met with in the central North Sea only. The area immediately north of the west end of the Dogger Bank within which *E. esculentus* is obtained in almost every trawl haul is probably less influenced by *elegans* water than the so-called *setosa* water of Plymouth. Obviously, *E. esculentus* is absent from localities in which extreme *setosa* conditions prevail. It is interesting to note that, as mentioned above, the Helgoland *elegans* water reservoir (described by CASPERS 1939, cf. pp. 13 and 17 in the present paper) held adult *E. esculentus* in 1890, many years before the species became established elsewhere in the eastern North Sea.

The comparatively recent establishment of an eastern North Sea stock of *E. esculentus* cannot be explained at present. The phenomenon occurred after the investigations from the "Poseidon" came to an end in 1907 but before the voyages of the "Dana" began in 1922. There is no indication of an extension of the *elegans* water region into the eastern North Sea. It must be remembered, however, that the *setosa-elegans* system is a local British phenomenon. Apparently, the system breaks down at the entrance to the transitional area between the North Sea and the Baltic. In the transitional area and in the western Baltic there may be as close a connexion between distinct water masses and their fauna as in the North Sea. Sufficient knowledge about these problems is not yet available although recent contributions by BANSE (1955, 1956) are promising. Several species of bottom invertebrates which in the North Sea appear more or less confined to *elegans* influenced water are widely distributed in the transitional area. Some of these species seem to extend their distribution from the transitional area along the Danish North Sea coast. Perhaps the factor determining the distribution of *E. esculentus* in the North Sea—Baltic region is found in *elegans* water around the British Isles and in coastal water on the Danish coasts. Perhaps a parallel may be drawn to an observation made by WILSON (1951 p. 18) that larvae of the polychaete *Ophelia bicornis* did better in *elegans* water from the Celtic Sea than in "outside" Plymouth *setosa* water. However, the natural environment of *O. bicornis* at Plymouth is the inshore estuarine water which—like the Jutland coastal water—cannot be referred to the *setosa-elegans* system.

°*Echinus acutus* LAMARCK.

Several finds in the northern North Sea, particularly on the edge of the Norwegian Channel (Fig. 49), were recorded by MÖBIUS and BÜTSCHLI (1875) and by SÜSSBACH and BRECKNER (1911). Trawlings by the "Dana" in 1922—39 added a few finds from the same area. BELL (1892) records *E. acutus* from Tynemouth on the English coast. East of the Shetlands STEPHEN (1934) found the

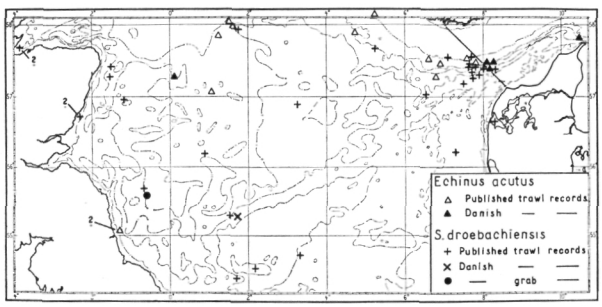

Fig. 49. Question-marks indicate that the exact localities, particularly the distances from land, are not known.

species abundant enough to be taken regularly in grab samples. REES (1954) in 1949—51 found the larva scattered over the area from which adults have been obtained.

In the North Sea few finds are recorded from depths less than 100 m. In the Kattegat (BRATTSTRÖM 1941) and in the English Channel (Plymouth Marine Fauna 1957) *E. acutus* occurs or occurred at the 40 m line. In the Kattegat it seems to occur at mean summer temperatures of 12—14°, at mean winter temperatures about 5°, and at mean salinities not below 33 or 32 $^0/_{00}$. It is not too obvious why *E. acutus* does not penetrate deep into the North Sea. Its distribution in British and Danish seas bears much resemblance to that of *Marthasterias glacialis* although *M. glacialis* is a decidedly southern species while *E. acutus* is more widely distributed toward both north and south. Again, a dependence for food or chemical environment upon particular water masses may be suggested. In this connexion it should be noticed that *E. acutus* seems to have disappeared from Plymouth waters since 1930 (Pl. Mar. F. 1957).

Strongylocentrotus droebachiensis (O. F. MÜLLER).

Danish grab record 1932—55: 7885 (2).

The old German and Dutch investigators found *S. droebachiensis* fairly regularly at stations in the northern North Sea, particularly at the entrance to the Skagerrak. More recently it has been recorded by BLEGVAD (1922) from the Southern Bight. This record, refering to a single specimen which was not kept, may not be entirely reliable and is omitted from the chart, Fig. 49. No other record is available from the Southern Bight, from the English Channel, or from the British west coast. Other records considered unreliable are those from the trawl surveys of the "Dana" in 1932—51. Like BLEGVAD's most of these records refer to localities within the area of abundance of *Psammechinus miliaris*. The trawl material collected in 1952—54 was more carefully examined. Only a single find of *S. droebachiensis* was made, namely, on the north-western edge of the Dogger Bank. However, not every specimen of *P. miliaris* was examined microscopically so that a few *Strongylocentrotus* may have escaped attention. The single grab record refers to two small specimens (1 mm and 8 mm diameter) the smaller of which could not be identied with certainty.

S. droebachiensis has a wide distribution within the transitional area between the North Sea and the Baltic. On the shallow Aalborg Plateau it occurs at salinities down to about 20 $^0/_{00}$. As to temperature requirements it does not seem very particular either. Although a northern species which has its southern limit of distribution in Danish waters it tolerates high mean summer temperatures: at least 16° on the Aalborg Plateau and about 18° in the Limfjord. Both of these localities have low mean winter temperatures, 2—3° and about zero, respectively. However, in the northern North Sea the species occurs where the temperature seldom sinks below 5° or even 6°. This is another case in which there is no direct and obvious relation between temperature and southern limit of distribution (cf. *Solaster papposus*, p. 32). The distributional pattern of *S. droebachiensis* in the North Sea region is that of a species restricted to the *Sagitta elegans* water masses, except for the fact that it occurs in the Limfjord. REES (1954) in 1949—51 found the larva in the extreme north-western part of the North Sea only.

Echinocyamus pusillus (O. F. MÜLLER).

Danish grab records 1932—55 are listed in Appendix 1.

During the investigations carried out from 1872 to 1939 *E. pusillus* was mainly found in the coastal regions of the North Sea and on the south-western end of the Dogger Bank (see

Fig. 50). It was almost absent from offshore waters north of 54° N. Even within the coastal region the occurrence seems to have been rather local. Off the Jutland coast, for instance, the German investigators in 1872—1907 found it about 55° N. and about 57° N. In the area between, so intensely fished, the species was not found.

During the Danish grab surveys 1932—39 *E. pusillus* was found particularly in the Horn's Reef area in which previous investigators failed to obtain it. Although it abounds at a few metres depth in the Limfjord (SPÄRCK and LIEBERKIND 1921) it was not taken on the Jutland coast in less than 20 m. In 1947 two finds were made on the northern edge of the Dogger Bank. In 1950 several more appeared and in 1951—52 the number of finds on the Dogger Bank increased considerably (see Fig. 50). Table 15 shows the density within three areas of the North Sea in April and May 1951—52. The areas are framed on Fig. 50. The average density was 31 per m² off the Jutland coast and 12 per m² in the other two areas. Off Jutland and on the northern part of the Dogger Bank the species seems to aggregate on the coarser grounds (fine sand and coarse sand). In the south-western area, however, muddy sand apparently is an adequate substratum, too. Perhaps the deposit called muddy sand is not the same all over the North Sea. It is also possible that *E. pusillus* does not actually require clean sand but needs something which is in parts of the North Sea found only where the sand is clean.

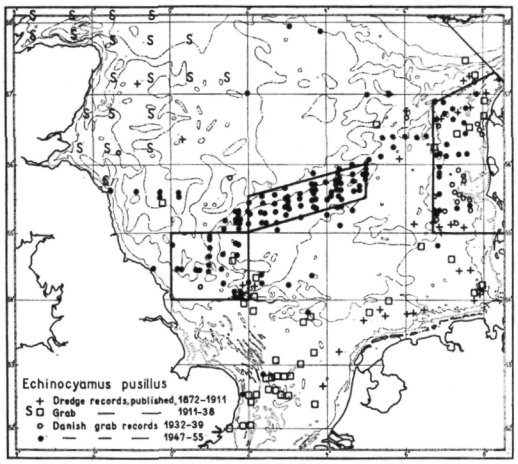

Fig. 50. The frames refer to the area division in Table 15. STEPHEN's grab records are given separate symbol (S) because they refer to statistical squares in stead of exact localities.

PETERSEN (1914) in 1911 found 14 *E. pusillus* per m² off the north Jutland coast (15.5 m² sampled). STEPHEN (1923) got 30 per m² in Scottish coastal waters (about 6 m² sampled). DAVIS (1925) in 1921—24 found 0.5 per m² (86 m² sampled) in the Southern Bight where his finds were most numerous. CASPERS (1939, 1950) records it from the Helgoland area. In the "tiefe Rinne" he in 1936—37 observed an overall density of 159 per m² (3.0 m² sampled). On the "Austernbank" he in 1938 found 8 per m² (1.9 m² sampled). HAGMEIER (1925) did not find *E. pusillus* during his grab survey of the German Bight in 1923—24. The "Dana" also failed to find it there in 1951—52, when scattered stations were operated within the area. SÜSSBACH and BRECKNER (1911) noticed its absence from dredge stations in the German Bight in 1902—07. It was recorded, however, from several German Bight localities by MÖBIUS and BÜTSCHLI (1875) in 1872 and by MEISSNER and COLLIN (1894) in 1889—90. The occurrence of *E. pusillus* in the German Bight is obviously either temporary or local, or both.

The material from the grab surveys 1932—54 was measured to nearest half millimetre below, on a glass rule. The spines were on so that the length of the test proper could not be measured. The longer spines that are so wide apart that the rule could be seen between them were omitted. Table 16 and Fig. 51 show the size frequency. 80—90 % of the specimens measured less than 5 mm. The mean size seems to have increased from 1951 to 1952. This development becomes more conspicuous when series of stations operated on the same positions in successive years are considered (Table 16). On 30 stations operated in April—May each year from 1950 to 1954 a single specimen only was obtained in 1950. In 1951 a stock of small specimens appeared and the number increased to 23. In 1952 the mean size had increased and the total number

Table 15.

Echinocyamus pusillus. Density in three sections of the North Sea (framed on Fig. 50) in April and May 1951—52. 0.2 m² grab. l (= litres) indicates the mean volume of sample.

Bottom deposit	Jutland coast					North Dogger Bank				
	l	Number of hauls		% of hauls with *E. p.*	No. of *E. p.* per haul	l	Number of hauls		% of hauls with *E. p.*	No. of *E. p.* per haul
		in all	with *E. p.*				in all	with *E. p.*		
Coarse sand	13.7	18	11	61	9.9	7.5	4	1	25	0.5
Medium sand	11.0	5	4	80	8.2	4.5	2	1	50	8.5
Fine sand	15.6	5	5	100	8.2	7.2	59	38	64	2.6
Clean sand, all grades	13.5	28	20	71	9.3	7.1	65	40	62	2.6
Muddy sand	12.1	8	2	25	0.8	8.7	7	0	0	0
Clayey sand	9.2	4	0	0	0	..	..	..	..	..
Sandy clay	10	1	1	100	3.0	..	..	..	..	..
Soft bottom, all grades	11.1	13	3	23	0.7	8.7	7	0	0	0
Clayey coarse sand	8.7	3	2	67	1.3	4	1	0	0	0
All grades of bottom dep.	12.5	44	25	57	6.2	7.2	73	40	55	2.4

Bottom deposit	South-western area					All 3 areas together				
	l	Number of hauls		% of hauls with *E. p.*	No. of *E. p.* per haul	l	Number of hauls		% of hauls with *E. p.*	No. of *E. p.* per haul
		in all	with *E. p.*				in all	with *E. p.*		
Coarse sand	9.6	7	5	71	5.9	11.8	29	17	59	7.6
Medium sand	9.6	5	2	40	4.2	9.3	12	7	58	6.6
Fine sand	9.1	16	4	25	1.0	8.1	80	47	59	2.6
Clean sand, all grades	9.3	28	11	39	2.8	9.1	121	71	59	4.2
Muddy sand	11.5	17	9	53	2.2	11.1	32	11	34	1.4
Clayey sand	9.6	5	0	0	0	9.4	9	0	0	0
Sandy clay	..	..	..	..	..	10	1	1	100	3.0
Soft bottom, all grades	11.1	22	9	41	1.7	10.7	42	12	29	1.1
Clayey coarse sand	7	1	0	0	0	7.4	5	2	40	0.8
All grades of bottom dep.	10.0	51	20	39	2.3	9.5	168	85	51	3.4

caught further increased to 48. In 1953 and 1954 the species again became more scarce and in 1954 the mean length decreased. 53 stations operated both in 1950 and 1951 and 119 stations operated both in 1951 and 1952 show the same features. The two latter series include the 30 stations operated in all five years. There is not much doubt that *E. pusillus* was scarce in the central North Sea in 1947—48 and in 1950. A successful spat-fall caused a stock to appear in 1951. The species is an autumn breeder in the North Sea (Rees 1954). Thus the spat-fall may have occurred in the autumn of 1950 or even earlier because the 0-group specimens are perhaps

Table 16.

Length frequency in *Echinocyamus pusillus* from the North Sea. Bottom sampler material 1932—54. Total number measured.

Length of test (mm)	May-June	All stations April-May							Apr.-Sept.		30 stations operated in 5 successive years April-May					53 sts. operated both years April-May		119 sts. operated both years April-May	
	1947–48	1950	1951	1952	1953	1954	1950–54		1932–39		1950	1951	1952	1953	1954	1950	1951	1951	1952
	No.	No.	No.	No.	No.	No.	No.	%	No.	%	No.	No.	No.	No.	No.	No.	No.	No.	No.
1.0 ...	..	..	3	..	..	..	3	0	..	..	..	..	..	..	..	..	..	..	..
1.5 ...	..	2	29	3	..	..	34	4	1	1	..	1	..	..	..	2	1	6	1
2.0 ...	..	1	38	34	..	2	75	9	10	5	1	5	..	..	..	1	4	15	20
2.5 ...	..	..	73	74	4	1	152	19	23	12	..	7	2	3	2	..	12	26	48
3.0 ...	1	..	66	92	3	1	162	20	36	18	..	5	9	2	1	..	6	16	48
3.5 ...	..	..	44	74	4	3	125	16	40	20	..	4	12	1	1	..	7	16	51
4.0 ...	1	..	21	72	4	3	100	12	25	13	..	1	17	2	3	..	6	11	47
4.5 ...	1	1	11	58	2	2	74	9	18	9	..	..	5	2	2	1	..	1	40
5.0 ...	..	..	5	28	1	1	35	4	8	4	..	..	3	1	1	..	..	6	9
5.5 ...	..	..	7	8	1	..	16	2	16	8	..	..	..	1	..	..	1	1	1
6.0 ...	..	..	1	12	1	..	14	2	7	4	..	..	..	1	..	..	..	1	..
6.5 ...	..	1	3	5	..	..	9	1	3	2	..	..	..	..	..	1	..	..	..
7.0 ...	..	..	..	3	..	..	3	0	5	3	..	..	..	..	..	..	1	..	2
7.5 ...	..	..	..	1	..	..	1	0	1	1	..	..	..	..	..	..	..	..	1
8.0 ...	..	..	..	..	..	..	..	..	2	1	..	..	..	..	..	..	..	..	..
Total no...	3	5	301	464	20	13	803	..	195	..	1	23	48	13	13	5	38	99	268
Area sampled (m^2)	3.7	12.8	47.6	45.6	14.2	10.9	131.1	..	94.7	..	6.0	6.0	6.0	6.0	6.0	10.6	10.6	23.8	23.8
No. per m^2	0.8	0.4	6.3	10.2	1.4	1.2	6.1	..	2.1	..	0.2	3.8	8.0	2.2	2.2	0.5	3.6	4.2	11.3
Mean length of test	4.08	3.45	3.17	3.82	3.97	3.79	3.58	..	4.13	..	2.25	2.95	3.99	4.13	3.79	3.45	3.37	3.26	3.70

too small to be retained in the sieve. The 1951 catches apparently represent an almost pure collection of a single year class the smaller size groups of which may be underrepresented in the catches owing to mesh selection in the sieve. Thus, the observed mean size (13.17 mm) may be above the actual mean size within the population. The larger size of the animals collected in 1952 might be caused by a better growth of a new spat-fall, the previous one having entirely or almost vanished. However, the area populated by *E. pusillus* in the central North Sea in 1952 was approximately the same as in 1951. There is one exception: on a section operated west of the Dogger Bank (6 stations on 1° E.) one specimen only was taken in 1951 while in 1952 42 specimens were taken. The mean size of the 42 specimens was 3.24 mm. This is about the expected size of specimens settled a year later than the 1951 stock. Thus, the pattern of distribution observed in 1952 indicates that the 1951 stock survived the winter and was augmented by another spat-fall. It seems impossible to separate the two groups where they occur together. However, none of them was long-lived. This is indicated by the low density of the species in 1953 and 1954.

CASPERS (1939, 1950) gathered some evidence that *E. pusillus* may occasionally become fairly old in the North Sea. The dense stock observed by him in Helgoland waters in 1936—38 consisted almost exclusively of large animals. About 85 % measured 5 mm or more. Young specimens did not turn up in quantity in the period of investigation.

In 1949—51 high concentrations of *Echinocyamus* larvae were observed by REES (1954). They occurred off the Scottish coast and in the southern North Sea about the position 54° N. 4° E. The distribution in Scottish waters is in accordance with the distribution of adults which were

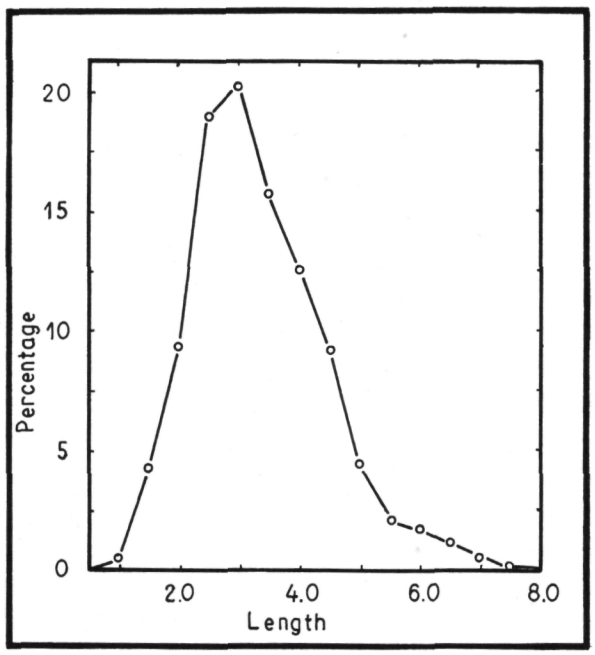

Fig. 51. *Echinocyamus pusillus*. Size frequency in the North Sea in 1950–54. April–May. Material from bottom samples. Cf. Table 16.

found by STEPHEN (1923) to abound in Scottish waters. The concentration in the southern North Sea in a place where adults are not known to be common is more astonishing. Even more queer is the total absence of records of larvae from the north Dogger Bank area within which a heavy spat-fall probably occurred either in 1949 or in 1950.

The occurrence of *E. pusillus* in the North Sea in 1872—1939 shows the distributional pattern of a species largely confined to coastal waters. It might be said that, being a predominantly southern form, *E. pusillus* occurred in localities with a fairly high summer temperature, although on the Dogger Bank the distribution was more restricted than explicable by temperature conditions. In 1947—54 the species occurred in most localities with high summer temperature. The 10° isothern or the 11° isotherm for the bottom temperature in summer approximately delimits the region within which the species is at times abundant. Naturally, the correlation between summer temperature and distribution may be accidental. Several interesting features must be left unaccounted for, namely: the absence of the species from sand grounds on the south-eastern part of the Dogger Bank and off Jutland, shoreward to the 20 m contour; the avoiding of muddy and clayey bottom except on the western and south-western edge of the Dog-

ger Bank where muddy sand seems to be suitable; the appearance of the species on the northern part of the Dogger Bank in recent years.

In the Kattegat, the Sound, and the Belt Sea the species is found under temperature conditions similar to those at which it occurs in the North Sea: the mean summer temperature ranges from 12° (eastern Kattegat) to 16 or 17° (western Kattegat); the mean winter temperature ranges from 5° (eastern Kattegat) to 2 or 3° (western Kattegat and the Little Belt). The lowest mean salinity is about 20 $^{0}/_{00}$ (western Kattegat and the Little Belt). In the western part of the Limfjord the annual temperature range is even higher than in the Kattegat: 0—19°, approximately.

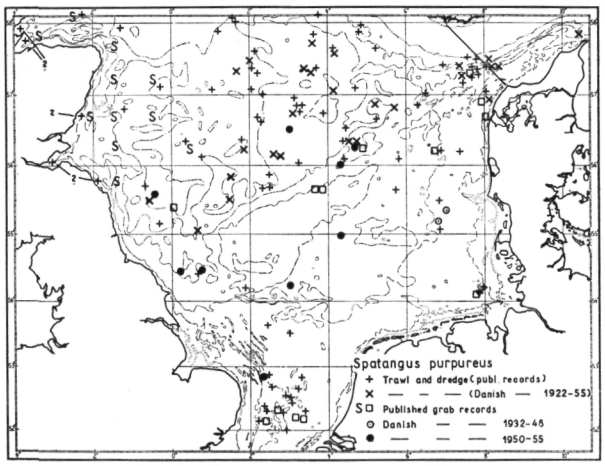

Fig. 52. As in other charts, question-marks indicate that the exact localities, particularly the distances from land, are unknown. STEPHEN's records are given a separate symbol (S).

Spatangus purpureus (O. F. MÜLLER).

Danish grab records 1932—55: 4749 (1), 5209^{K} (1), 7527 (1), 7609 (3), 7885 (3), 7887 (1), 7888 (1), 7983 (1), 8022 (1), 8043 (1), 9418^{I} (1).

The various trawl and dredge surveys produced numerous records in the northern North Sea from the northern edge of the Dogger Bank and northwards (Fig. 52). *Spatangus* seems to be common in the Southern Bight, too. Scattered finds only were made in the south-eastern North Sea although the German investigations in 1872—1907 operated a dense net of stations there. CASPERS (1939), however, records the species as at times common in dredge hauls from the Helgoländer tiefe Rinne. The grab finds confirm the knowledge already gained. PETERSEN (1914) took the species off northern Jutland. STEPHEN (1934) found it to be widely distributed in Scottish waters. DAVIS (1925) took it in the Southern Bight and off the northern edge of the Dogger Bank. CASPERS (1939) has a single grab record from Helgoland. The Danish grab surveys in 1932—39 produced two finds (besides a dubious one, specimen not kept) in the Horn's Reef area in 35 m and 37 m, both on coarse sand. The 2 specimens caught were juveniles, 5 mm and 13 mm. In 1950—55 the bottom sampler produced 13 specimens. The species was represented in 9 hauls, all from April—May. The measurements were:—

Millimetres.....	1	2	4	35	69	71
No. of specimens	2	7	1	1	1	1

The three adults were taken on clayey coarse sand (2 records) and on clean coarse sand (1 record). The juveniles are from fine sand (2 records), muddy sand (3 records) and from clayey sand (1 record). They were found scattered around the Dogger Bank. The adults were taken north of the Dogger Bank, off the southern edge of the Dogger Bank, and in the Southern Bight. REES (1954) in 1949—51 found *Spatangus* larvae fairly common in the northern North Sea. In the southern North Sea the occurrence was rather local. Larvae were obtained from June to September. Thus, the youngest bottom stages caught in April and May should originate from a spat-fall in the year preceding capture. However, most of them are so small (2 mm) that it may be suspected, that they actually represent the new brood.

S. purpureus seems to abound in the northern and western North Sea. It is not quite clear whether the area of abundance in the Southern Bight is connected with that in the northern North Sea. The absence of records by FORBES (1841) and BELL (1892) from the English North Sea coast south of Berwick perhaps indicates a scarcity of the species in the central part of the western North Sea. It is practically absent from the Dogger Bank in spite of the predominantly coarse-graded bottom which might be expected to be suitable. Records from the Skagerrak are markedly few. Although the species is recorded from sand grounds off the Danish North Sea coast it is apparently not abundant there. The occurrence in the Helgoländer tiefe Rinne seems rather isolated.

Apart from the Southern Bight occurrence *S. purpureus* has the distribution of a species that avoids the *setosa* water region. The occurrence in the Helgoländer tiefe Rinne, known as a refuge for *Sagitta elegans* plankton, points in this direction. Very few, if any, other echinoderms which show affinity to *elegans* water penetrate into the North Sea from the English Channel. Most *elegans* water echinoderms vanish somewhere between Plymouth and the Straits of Dover. However, for an *elegans* water species *S. purpureus* penetrates rather deep into the North Sea from north. Therefore, it may also be expected to penetrate comparatively far beyond Plymouth.

In the Kattegat *S. purpureus* is restricted to the comparatively homothermal eastern part. The mean winter temperature at the Kattegat localities is 4—5°. The mean summer temperature is 12—13° and the mean salinity seems to be above 31 $^{0}/_{00}$. In the larger part of the North Sea it occurs at similar temperatures and at higher salinities. In the Helgoländer tiefe Rinne the difference between summer and winter mean temperature is more conspicuous, with summer temperatures about 17° and winter temperatures about 3.5°. CASPERS (1939 p. 5) states that considerable quantities of *S. purpureus* were dredged in March 1929 after (or rather, during) an extremely cold winter. It is doubtful whether this observation actually indicates that the stock survived the cold winter.

On the Irish west coast (SOUTHERN 1915) and on the French coast of the Atlantic (KOEHLER 1921) *S. purpureus* occurs between tide marks. Such observations have not been made in the North Sea or in inner Danish waters, and not at Plymouth either. Locally, the absence of the species from the tidal zone and from very shallow water may be explained by low winter temperatures or by low salinity (east coast of Jutland, the Limfjord, the Waddensea). However, the geographical distribution of the species in the littoral zone resembles that of *Echinus esculentus* (cf. p. 70) which was correlated by YONGE (1949 p. 274) with the distribution of Atlantic water at the surface and, thus, on the shore.

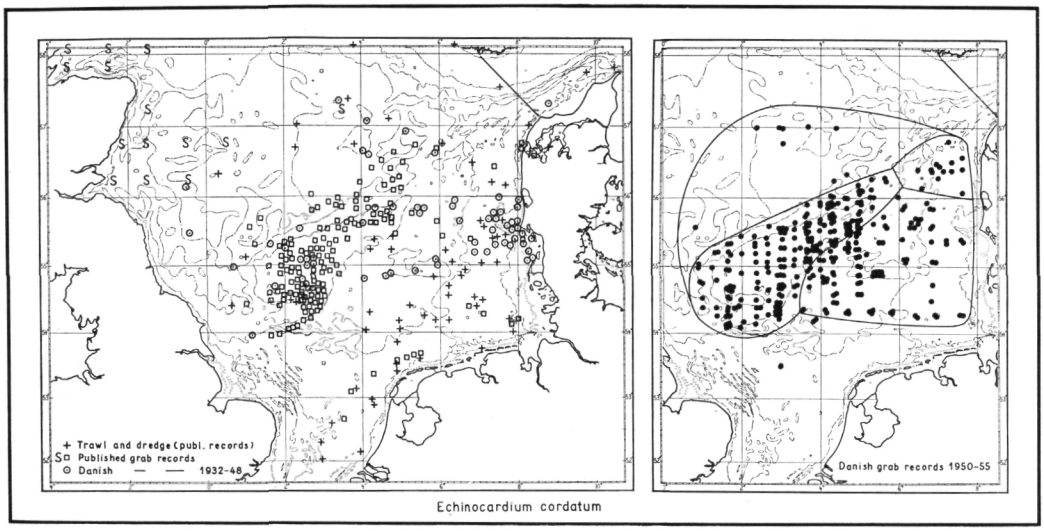

Fig. 53. The frames on the right chart refer to the area division adopted in Table 17 and Fig. 54. As usual, STEPHEN's grab records are given a separate symbol (S).

Echinocardium cordatum (PENNANT).

Danish grab records 1932—55 are listed in Appendix 1.

The old German and Dutch investigators, who collected most of their material in the southern and eastern North Sea, in 1872—1911 found *E. cordatum* fairly common along the German and Dutch coasts (see Fig. 53). The results from the few stations operated in the Dogger Bank region indicate that the species was fairly common there, too. Quite a few finds were made at the deep stations north of the Dogger Bank. Off the coast of northern Jutland, however, records were scarce although numerous stations were operated. In north Jutland coastal waters PETERSEN (1914) got juveniles only (in the grab).

In 1921—25 the various grab surveys of the North Sea disclosed populations off the Scottish coast (STEPHEN 1934), in the south-western part of the German Bight and off the Dutch coast (BLEGVAD 1922, DAVIS 1925, HAGMEIER 1925) and on the Dogger Bank (DAVIS 1923, 1925). It seems as if, during these investigations, the species was absent from the White Bank—Clay Deep region. It was also scarce in the Southern Bight. During the Danish grab surveys in 1932—39 it occurred all over the area investigated. In the Horn's Reef area it occurred even at the shallowest stations, in about 7 m. The density cannot be told with certainty because not all material was kept and because the original identifications proved not entirely reliable.

The grab surveys in 1950—55 produced quantities of medium-sized and large *E. cordatum* in the central and eastern North Sea (Fig. 53). Table 17 and Fig. 54 shows the size frequency expressed in numbers per square metre in different parts of the North Sea (for area boundaries, see Fig. 53). April and May records only were used. On the Dogger Bank and in the immediate vicinity of the bank the stock was dominated by large animals. The overall density is not very high: 8.7 per m^2. In the south-eastern North Sea large animals were scarce. The majority of the specimens range from 19 mm to 26 mm. The density is high: 26.9 per m^2. It was not possible to make a sharp distinction between the two areas because on the border-line stations there were frequently several medium-sized specimens and a few large specimens in the same sample. For closer examination were selected all stations operated in 1951—54 on the Dogger Bank at depths

Table 17.

Echinocardium cordatum. Density and length frequency in the North Sea, 1951—54. Area boundaries are indicated on Fig. 53.

Length (mm)	Number per square metre in each length group				The Dogger Bank, depth ≤ 35 m				
	Dogger Bank area 1951–54 70.5 m²	South-eastern area 1951–54 29.4 m²	Off north Jutland 1951–52 5.4 m²	N. & N.W. North Sea 1951–52 8.6 m²	1951 13.2 m²	1952 8.2 m²	1953 9.0 m²	1954 6.5 m²	1951–54 36.9 m²
0– 4	0.2	0.4	..	..	..	0.4	..	..	0.1
5– 9	0.5	2.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
10–14	0.3	0.7	0.4	..	0.1	0.2	..	..	0.1
15–19	0.3	3.0	1.3	..	0.2	..	0.1	..	0.1
20–24	0.8	12.1	0.9	..	0.3	0.2	..	..	0.2
25–29	1.0	5.8	2.6	0.1	0.9	1.0	0.2	0.2	0.6
30–34	1.2	1.8	2.2	0.2	0.4	0.7	0.9	0.2	0.5
35–39	1.5	0.5	1.8	0.5	1.1	1.2	2.1	1.8	1.5
40–44	2.0	0.3	0.7	0.1	2.6	2.1	2.6	2.8	2.5
45–49	0.9	0.1	0.9	..	1.1	1.0	1.9	1.5	1.4
0–49	8.7	26.9	11.1	1.2	7.0	7.1	8.0	6.6	7.2

of 35 m or less and, for comparison, material collected on the White Bank in 1951—55 within a distance of three nautical miles from the position 54° 55′ N. 5° 28′ E. Even then a few stations with medium-sized animals remain in the Dogger Bank series because although rather tending

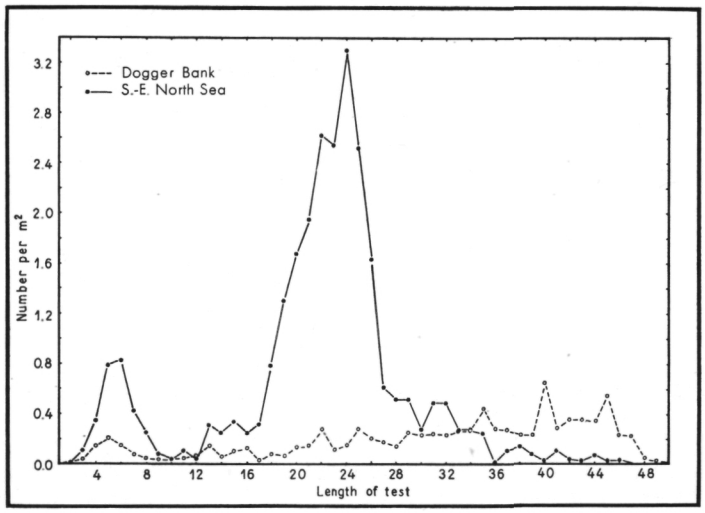

Fig. 54. *Echinocardium cordatum*. Size frequency (no. per m² and length group) in two parts of the North Sea in 1951–54 (April–May). For area boundaries, see Fig. 53.

toward the southern edge of the bank the smaller specimens occur scattered over the area. In Table 17 is shown the density per square metre of each 5 mm group on the selected part of the Dogger Bank. The density of small and medium-sized specimens apparently decreased during the period of observation (1951—54) while the density of large specimens (40—44 and 45—49 mm

Table 18.

Echinocardium cordatum. Length frequency in a locality on the White Bank. April—May of six successive years.

		Length frequency in successive years					
		1950	1951	1952	1953	1954	1955
Length in millimetres	9	1	..	..	..	..	..
	10	..	..	..	..	..	..
	11	..	..	..	..	..	..
	12	..	..	..	..	..	..
	13	1	..	..	..	..	..
	14	..	..	..	..	..	..
	15	..	..	..	..	..	..
	16	1	..	..	..	..	..
	17	..	..	..	..	..	..
	18	1	..	..	..	..	..
	19	1	3	1	..	..	..
	20	..	3	2	.	..	..
	21	..	3	9	2	..	..
	22	1	8	14	4	2	1
	23	1	6	13	5	2	3
	24	1	5	22	18	5	4
	25	1	..	7	16	8	12
	26	..	..	5	16	4	9
	27	..	..	2	3	5	5
	28	..	..	1	1	3	7
	29	..	..	..	..	..	2
	30	..	..	..	..	1	..
	31	..	..	..	..	..	2
	32	..	..	..	..	..	..
	33	..	..	..	..	..	..
	34	..	..	..	..	..	..
	35	..	..	..	..	..	..
	36	..	..	..	..	..	1
	37	..	..	..	1	1	..
	38	..	..	..	..	..	..
	39	..	..	..	..	1	..
	40	..	..	..	1	..	..
	41	..	..	..	..	..	..
	42	..	..	..	..	..	..
	43	..	..	..	..	..	..
	44	..	..	..	1	..	..
Total number		9	28	76	68	32	46
Area sampled (m^2)		0.2	0.4	1.2	1.2	1.2	1.2
Mean vol. of sample (l)		7	9.0	12.2	10.7	15.3	12.8
< 35 mm Length	Number	9	28	76	65	30	45
	— per m^2	45	70	63	54	25	38
	Mean length	(18.8)	21.929	23.290	24.646	25.188	25.956
	Stand. dev. of single obs.	..	1.585	1.750	1.452	1.871	1.977
	Increase in mean length	(3.1)	1.361	1.357	0.542	0.768	
	Level of significance		1 ‰	1 ‰	> 10 %	10 %	
	Mean weight in grammes	(3.8)	5.1	6.1	7.2	7.9	8.4

long) remained remarkably constant. A minute growth of the big ones and a slow dying-off may have occurred, but the material is not sufficient for an analysis of these points.

In Table 18 is shown the size frequency in the material collected at the above mentioned locality on the White Bank. In 1951—55 the samples were dominated by specimens 20—30 mm long, obviously representing the stock of medium-sized *E. cordatum* found all over the south-eastern North Sea. In 1950 there were also representatives of a stock of smaller specimens which either disappeared or soon reached the size of the main stock and, thus, became indistinguishable from that. In the catches from 1953—55 a few larger specimens appeared. *E. cordatum* is able to migrate short distances (MOORE 1936 p. 661), but it is not a convincing explanation that the animals in question entered the White Bank locality by active migration. It is more likely that they represent the stock of large animals which dominated the Dogger Bank catches. By mere accident, they may have escaped the grab in 1950—52. Another explanation is that some specimens belonging to the medium-sized stock became senile and used their surplus of nourishment for vegetative growth, not for reproduction. Such cases are described by MORTENSEN (1920 p. 146) in *Brissopsis lyrifera* and by THORSON (1946 p. 347) in *Asterias rubens*. An examination of 30 *E. cordatum* from the White Bank (May, 1954) showed that in the smaller specimens (22—30 mm long) the gonads were grey-brown and swollen while two larger specimens (37 mm and 39 mm long) had thin, black gonads as described in senile *Brissopsis* (MORTENSEN l. c.). Two specimens from the same locality, collected in May 1953 and measuring 37 and 40 mm, were available for examination. One had reduced, black gonads while in the other the gonads were well developed. Three other large specimens (37—42 mm) collected elsewhere in the south-eastern North Sea (May, 1952) had well developed gonads, too. Thus, although some of the larger specimens found in the south-eastern North Sea may have been senile there is no reason to believe that they grew large due to senility. Unfortunately, the material of big *E. cordatum* from the Dogger Bank was not kept, except for a single specimen, 43 mm long. It had big, swollen gonads so that, apparently, the Dogger Bank population did not consist of senile animals either.

The mean length of the White Bank animals belonging to the main stock (19—31 mm long) increased slightly from one year to another[1]). However, the difference between the mean size observed in two successive years is significant only in the comparison of 1951 with 1952 and of 1952 with 1953. It is difficult to estimate the age of these animals owing to the extremely slow growth (about 1 mm per year) during the period of observation. With an approximately straight line weight increment corresponding to that observed in 1951—55 (cf. Table 18) they would have been born about 1946. This may be a high estimate of their age. They may originate from a spat-fall even as late as 1948 so that they would have appeared for the first time in catches from the spring of 1949, if such were available. Scattered sampling (5×0.2 m^2) in the south-eastern North Sea in 1948 produced 5 *E. cordatum* measuring 35, 35, 13, 12, and < 10 mm, respectively.

The big examples (35—45 mm long) that occurred on the Dogger Bank and scattered in the south-eastern North Sea must have been extremely old if they grew at the same speed as medium-sized specimens from the White Bank. However, it is possible that the high density on the White Bank caused a slowing down of the growth rate so that, usually, the growth is more rapid. The size frequency diagrams, Fig. 54, indicate that besides the two dominating size groups described above several others occur in the material. A separation of individual groups was not possible. It should be born in mind that the two dominating groups do not necessarily represent one year

[1]) *Added in proof:* If the slight increase is considered due to increasing digging depth of the grab (cf. BIRKETT 1958, Journ. Cons., **23**: 206) the White Bank main stock may each year represent the I-group resulting from a spat-fall which occurred immediately after the previous year's sampling. This explanation of the dynamics is not in accordance with all available facts. Yet, it seems worth reflection.

class each. By accident, heavy spat-falls may have occurred in two or more successive years. Owing to slow growth such successive spat-falls may later on produce a single mode in the size frequency distribution. For instance, the size frequency of the combined White Bank material obtained in 1951—55 shows an almost faultless normal distribution when specimens more than 35 mm long are omitted.

As regards areas other than the south-eastern North Sea and the Dogger Bank Table 17 shows that a fairly dense stock occurred off northern Jutland in 1951—52. The size of the animals varied considerably from one station to another. Perhaps scattered settling occurred almost every year during a long period. In the northern and north-western North Sea *E. cordatum* was only sparsely represented in 1951—52.

In the material collected in April and May 1950—54 a small group of juveniles regularly appears (Fig. 54). They range from 2—9 mm with a mode of 5—6 mm. Larvae of *E. cordatum* occur in the North Sea plankton from April to September and they are abundant from May to August (Rees 1954). The scattered juveniles caught in April and May may originate from the first spawned larvae of the year of capture or from spawning in the preceding summer. The concentration of the investigation upon the spring months renders the interpretation difficult. 10 samples from August 1952 produced 20 very small juveniles, 1—6 mm long and averaging 3 mm. They must represent the 1952 year class. If during the period August—April these animals manage to grow only 2 mm the growth will be incredibly slow. A more likely explanation is that in 1950—54 the main spawning failed to produce good spat-falls but that occasional settling of small numbers of larvae occurred at various seasons. These minor settlings did not affect the main stock of *E. cordatum*. Apparently, the juveniles were soon destroyed by predators or otherwise.

Perhaps the most astonishing point is that no heavy spat-fall of *E. cordatum* occurred in the North Sea in 1950—54 although Rees (1954) in 1949—51 found immense numbers of larvae in the southern North Sea. From previous investigations it is known that high densities of juveniles may be found in late summer and autumn. Davis (1925) in October 1924 found a dense patch of juvenile *E. cordatum* on the south-western part of the Dogger Bank. Densities above 250 per m^2 were found within an area covering 250 square miles (900 km^2). In August 1938 the Danish grab survey of the Horn's Reef area disclosed a patch covering about 60 square miles (200 km^2) in which the density of juveniles reached a similar level. In April—May 1954 the overall density of specimens less than 10 mm long was 1 per m^2 and there were few samples with more than two or three specimens.

Particularly in autumn samples Davis (1923) found three size groups of *E. cordatum* on the Dogger Bank. The smallest size group ranged from the size of a pin's head to that of a small pea. Apparently, this is also the size of the juveniles taken in August samples in 1952 (cf. above). The medium-sized specimens found by Davis ranged in diameter from that of a sixpence to rather larger than a halfpenny. They may have been the I-group and probably correspond to the smaller specimens taken in 1950 on the White Bank (Table 18). The third size group Davis describes as large adults.

In the Limfjord Boysen Jensen (1919 p. 28) found a much faster growth. A heavy spat-fall occurred in 1912. Already in September the juveniles weighed 0.7 g which corresponds to a length of about 10 mm. In April 1913 they weighed 1.7 g and may have been 15 mm long. In September 1913, when little more than a year old, they weighed 7.4 g and probably measured 25 mm.

In west British waters (Port Erin; Millport) Moore (1936 p. 659) observed in *E. cordatum* a growth rate during the first two years of life similar to that found by Boysen Jensen in the Limfjord.

The occurrence of the species in the Limfjord and on the shallow Aalborg Plateau in the Kattegat indicates that it tolerates low winter temperatures, high summer temperatures, and a low mean salinity (about 20 $^0/_{00}$ on the Aalborg Plateau). Perhaps it is more particular about low summer temperatures since it is not recorded from Iceland or from the Faroes. The geographical variation of the breeding season points in the same direction because, apparently, *E. cordatum* is a summer breeder. In the Sound between Denmark and Sweden in which maximum temperatures occur late in the year the main breeding season is August—September (THORSON 1946 p. 357). In the North Sea and in Manx waters maximum temperatures are, on the whole, found earlier in the year than in the Sound. Accordingly, most breeding takes place from May to August (REES 1954, MOORE 1936).

In the Waddensea larvae only have been observed (SMIDT 1951 p. 107) while on the open shores of Jutland the species abounds even at the shallowest stations operated (about 7 m). Unfortunately, shore collections have not been made. It is difficult to see the reason for the absence from the Waddensea in which several channels are 10—20 m deep. Elsewhere, *E. cordatum* is considered a littoral form. At Port Erin, Isle of Man, it is even most abundant between low water of ordinary and spring tides. It is fairly common throughout Port Erin Bay in depths down to 10 m and occasional specimens were taken as deep as 34 m (MOORE 1936 p. 661). In the North Sea the highest density was observed in about 40 m. Thus, there is in *E. cordatum* in the North Sea a general tendency toward submergence, as compared with western European seas. Nevertheless, the absence of the species from the Waddensea seems to be a separate phenomenon because it is absent from the Waddensea in depths suitable elsewhere in the North Sea.

Echinocardium flavescens (O. F. MÜLLER).

Danish grab records 1932—55 are listed in Appendix 1.

In the period 1872—1911 this species apparently was fairly common in the greater part of the North Sea (Fig. 55). The German investigations produced more finds of *E. flavescens* than of *E. cordatum*. However, the large number of stations operated in the German Bight by German vessels and in the Southern Bight by the Dutch "Wodan" produced few records of *E. flavescens*.

During the British grab surveys in 1921—25, published by DAVIS (1923, 1925) and STEPHEN (1934), *E. flavescens* was still abundant but tended more towards the northern North Sea in which densities about 8 per m² were obtained by STEPHEN and 2 per m² by DAVIS. On the Dogger Bank the species was restricted to the northern edge.

Records from the Danish trawl and dredge surveys in 1922—39 are not plotted on the chart because not all identifications are fully reliable. There were many finds in the northern North Sea and on the Danish Skagerrak coast, in depths over 30 m. The grab surveys in 1932—39 (Fig. 55) showed the same distribution as the British grab investigations some ten years before. In the Horn's Reef area, shoreward to the 40 m line, a single find only (juveniles) was made in spite of the large number of stations operated.

The Danish trawl investigations in 1952—55 produced a considerable number of *E. flavescens*. The material was identified by the present author. Although most sampling effort was made in the central North Sea, particularly on the Dogger Bank and south-east of it, the records are heavily concentrated upon the northern North Sea. There is a striking difference between the distribution in 1952—55 and in 1872—1907 when SÜSSBACH and BRECKNER (1911 p. 193) found that *E. flavescens* occurred "in sehr grossen Mengen und zwar fast überall in der Nordsee". The density of *E. flavescens* in the central North Sea seems to have gradually decreased while the

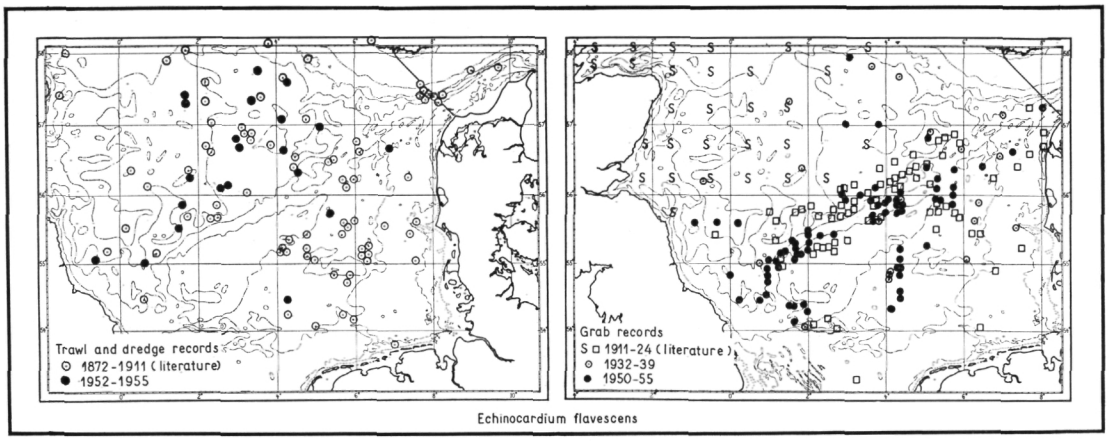

Fig. 55. STEPHEN's records ("S") are given a separate symbol, as usual.

density of *E. cordatum* increased. The grab surveys in 1951—52 produced some finds in the Clay Deep area. As shown next page the stock there could be referred to a spat-fall in 1951 and, thus, consisted of fairly young animals.

Even in recent years *E. flavescens* penetrates farther into the southern North Sea than usual for species which have their greatest abundance in the northern North Sea. A similar penetration from south, through the English Channel, is not recorded. The species occurs off Plymouth, but vanishes somewhere between Plymouth and the Straits of Dover. It is not recorded from Helgoland waters in which several northern North Sea forms have an isolated occurrence.

While *E. cordatum* is in parts of its distribution a littoral form *E. flavescens* is everywhere restricted to the sublittoral. In the southern North Sea and in the eastern part of the English Channel the mean summer temperature is 15—17° which is more than usually met with in European seas except in the surface and in sheltered places on the coast. Perhaps *E. flavescens* does not tolerate these high temperatures. If so it is understandable that although a northern North Sea form it does not occur in the *elegans* water of the Helgoländer tiefe Rinne. The Rinne is characterized particularly by holding northern North Sea water in southern North Sea temperatures (cf. p. 13). Accordingly, the retreat of *E. flavescens* toward the northern North Sea in the present century may have been induced by the simultaneous increase in summer temperature discussed above (p. 13). One fact is against the hypothesis that *E. flavescens* is sensible to high temperatures in the North Sea: the species occurs in the Mediterranean, even in fairly shallow water (KOEHLER 1927, TORTONESE 1949). In the Mediterranean it must be exposed to temperatures definitely above North Sea summer temperature. The Mediterranean stock may be physiologically distinct from the northern European stock and, thus, adapted to higher temperatures. Such a differentiation was suggested for the bivalve *Chlamys opercularis* (URSIN 1956 a p. 13). However, the resemblance between the distributional patterns in the North Sea of *E. flavescens* and *Brissopsis lyrifera* (see below) is difficult to explain on the assumption that temperature is the limiting factor in the distribution of *E. flavescens* in the North Sea.

Table 19 shows the length frequency in material collected during the extensive grab surveys in April and May 1951—52. In 1951 there were two distinct size groups, one consisting of juveniles a few millimetres long, another consisting of large adults. In 1952 there appeared a third group of medium-sized individuals. In the Clay Deep there were in 1951 juveniles only.

Table 19.

Echinocardium flavescens. Length frequency in bottom sampler material collected in April and May 1951—52.

Length in mm.	Length frequency			
	North Sea, total		Clay Deep only	
	1951	1952	1951	1952
2	..	4	..	..
3	4	5	..	..
4	21	2	..	..
5	8	..	1	..
6	9	2	3	..
7	6	2	1	..
8	..	5	1	..
9	..	3	..	..
10	1	5	1	..
11	..	3	..	1
12	1	1	..	1
13	..	..	..	..
14	..	..	..	..
15	..	2	..	..
16	..	..	..	..
17	..	3	..	3
18	..	1	..	1
19	1	2	..	2
20	..	2	..	1
21	..	4	..	..
22	1	1	..	..
23	..	3	..	..
24	..	3	..	..
25	2	1	..	..
26	3	1	..	..
27	2	1	..	..
28	3	1	..	..
29	..	..	..	..
30	1	6	..	..
31	1	2	..	..
32	2	..	..	..
33	2	..	..	..
34	..	2	..	..
35	2	..	..	..
36	..	1	..	..
37	..	..	..	..
38	1	..	..	..
Total.....	72	70	7	9

In 1952 there were medium-sized only. Apparently, the juveniles some few millimetres long in April—May 1951 had attained a size of about 20 mm a year later. With such a rapid growth the juveniles found must be very young. REES (1954) in 1949—51 found the larva abundant in northern North Sea plankton from February to June. Thus the juveniles in bottom samples from April and May 1951 probably originate from a spawning in the first months of 1951. The age and growth of the large adults (25—38 mm long) cannot be estimated. The recruitment of *E. flavescens* in the North Sea in 1950—54 was better than the recruitment of *E. cordatum* in which no appreciable replenishment of the stock took place during the years investigated (cf. above, p. 80). Therefore, the size frequency data are easier to interpret in *E. flavescens* than in *E. cordatum*.

Echinocardium pennatifidum NORMAN.

Danish grab records 1932—55: 5773 (1), 6069 (1), 6070 (1), 7385 (2), 7466 (1), 8048 (1), 8062 (2).

HODGE (1872) records *E. pennatifidum* from Durham on the English North Sea coast. PETERSEN (1914) found juveniles at a single station off northern Jutland and MORTENSEN (1924) records the species from the Horn's Reef. MORTENSEN's record is not indicated on the chart, Fig. 56, because the exact locality is not stated.

During the grab surveys in 1932—39 one specimen was taken on each of three stations in the Horn's Reef area. They measured 12 and 15 mm (July) and 39 mm (April). The grab surveys in 1950—55 produced six more specimens one of which was taken on the western edge of the Dogger Bank. The others were taken off northern Jutland. Examples collected in April and May 1951—52 measured 10, 11, 18, 25, 37, and about 45 mm. The biggest one is from the Dogger Bank. All grab material originates from grounds of coarse sand in 15—41 m. The Danish trawl and dredge surveys in 1922—55 produced a single record only (from the entrance to the Skagerrak), but the species may have escaped attention sometimes.

The known distribution of *E. pennatifidum* is remarkably restricted. According to MORTENSEN (1951 p. 164) it is known with certainty only from Bergen (Norway) and the Faroes to the Channel Islands. Perhaps the distribution is not sufficiently known. BRATTSTRÖM (1941 p. 207) in the Kattegat finds *E. pennatifidum* confined to sand grounds. CRAWSHAY (1912 p. 339) found it on rough ground in the outer western part of the English Channel. Below (p. 97) it is pointed out that several species with a decidedly southern geographical distribution have approximately the same North Sea distribution as *E. pennatifidum*.

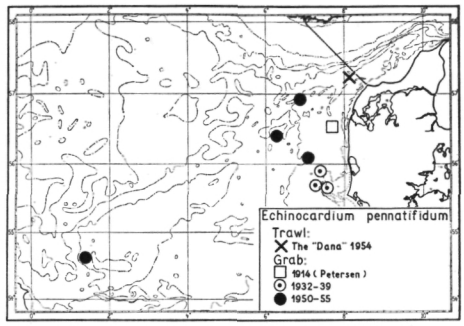

Fig. 56.

The mean winter temperature in localities inhabited by that species is 4—5° off Jutland and 5 or 6° on the Dogger Bank. The mean summer temperature is fairly high in both localities: 12—16° in Jutland waters and 12 or 13° on the Dogger Bank. In the Kattegat the species seems to occur at mean temperatures about 5° in winter and 12—13° in summer. The mean salinity for the year in the Kattegat localities seems to be over 32 $^{0}/_{00}$.

Brissopsis lyrifera (FORBES).

Danish grab records 1932—55: 4329 (1), 4332 (1), 4340 (2), 7395 (2), 7396 (3), 7401^{I} (1), 7612 (1), 7914 (1), 8088 (1).

B. lyrifera is recorded by most investigators of the echinoderm fauna of the North Sea (Fig. 57). It seems to abound in the Skagerrak and on the edge of the Norwegian Channel. It is also fairly common in about 50 m in the northern part of the Bløden Ground east of the Tail End of the Dogger Bank. More scattered finds are made in the western part of the northern North

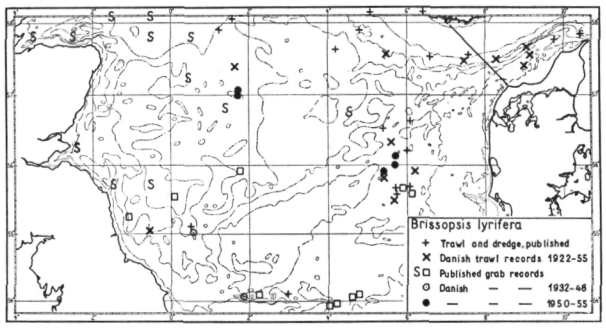

Fig. 57. STEPHEN's records, refering to statistical squares, are indicated by the usual "S".

Sea and in the channel immediately south of the western part of the Dogger Bank. Four records from the southern North Sea (DAVIS 1925) probably refer to a temporary occurrence.

The distribution of *B. lyrifera* in the North Sea resembles that of *Echinocardium flavescens*. Although penetrating deep into the North Sea from north these species do not approach the North Sea from the English Channel. *B. lyrifera* is not recorded from the Channel at all. However, in the tendency to maintain two distinct areas of distribution in the North Sea, a western and an eastern, *B. lyrifera* resembles species like *Echinus esculentus* and *Solaster endeca*. There is evidence that at least *E. esculentus* is sensible to differences between water masses (see p. 70). The

same may be the case with *B. lyrifera*. Like *E. flavescens*, *B. lyrifera* is everywhere absent from the litoral and from very shallow water. This might be due to a restricted temperature tolerance, as suggested above for *E. flavescens*. However, *B. lyrifera* abounds in the north-western Kattegat at temperatures similar to those met with in the southern North Sea and at depths of 20—40 m. This is not in favour of the assumption that temperature (or depth) is a limiting factor for *B. lyrifera* in the North Sea. Probably, the limited distribution rather must be considered in connexion with the dependence of the bottom fauna upon certain water types or certain plankton communities.

9 specimens from bottom samples collected in May 1951—52 measured 9, 20, 23, 27, 27, 28, 31, 34, and 39 mm. 42 specimens trawled on the Bløden Ground in May 1954 measured 31—43 mm (av. 39 mm). All grab records refer to samples from soft grounds (clayey sand, sandy clay, and in a single case, muddy sand). The species seems to be restricted to soft bottom in other seas, too.

Holothurioidea.

The identification of one or several specimens of each species in the present material was checked or made by Mr. BENT HANSEN, M. Sc.

**Cucumaria frondosa* (GUNNERUS).

Recorded from Montrose (see Fig. 58) on the east coast of Scotland (BELL 1892 p. 40). The species is widespread and abundant in northern waters. The Scottish coast seems to constitute the southern limit of distribution of the species.

Cucumaria elongata DÜBEN et KOREN.

Danish grab records 1932—55: 4340 (2), 4350 (6), 5235 (5), 7051 (1), 7396 (1), 7479 (3), 7480 (1), 7590 (4), 7874 (2), 7911 (2), 7913 (2), 7992^{II} (1), 7992^{III} (1), 8023 (2), 8074 (15), 8380 (1), 8878 (1).

In the central North Sea *C. elongata* is the only holothurian abundant enough to be taken regularly in bottom samples. The occurrence is rather restricted (Fig. 58). Several finds were made in the deep channel south of the Southwest Patch of the Dogger Bank (DAVIS 1925; Danish grab surveys). In 1950—54 2.4 m^2 were sampled there in 51—79 m. 2.5 specimens per m^2 were taken. The Bløden Ground between Jutland and the Dogger Bank is another area in which fairly high densities are obtained. The species was taken there by MEISSNER and COLLIN (1894), by DAVIS (1925), and during the Danish grab surveys. In 1950—54 6.4 m^2 were sampled within this area. The average density of *C. elongata* was 4.5 per m^2. However, 15 of the 29 specimens caught originate from a single sample. With this sample omitted the density is 2.3 per m^2. The depth range in the Bløden area was 44—54 m. MÖBIUS and BÜTSCHLI (1875), MEISSNER and COLLIN (1894) and DAVIS (1925) took the species in the German Bight, about the 40 m line. A single find (south-west of the White Bank) was made in this region during the Danish grab work. The species also occurs in Helgoland waters (MEISSNER and COLLIN 1894, CASPERS 1939) and in Scottish coastal waters (STEPHEN 1934). It is rather obvious, however, that it occurs in reasonable quantities only in the deep channel south of the Dogger Bank and on the Bløden Ground.

As probably everywhere the species is in the North Sea confined to soft bottom. It is absent, however, from many soft bottom localities, for instance in the northern North Sea, in the

Clay Deep, and in Jutland shore waters, both in the Waddensea and outside it. In the North Sea *C. elongata* occurs at mean summer temperatures between 9—10° and 16°. The mean winter temperatures are 3.5° to 5—6°. The distribution in the Kattegat and the Sound seems to correspond to a mean summer temperature of 12—15° and a mean winter temperature of 4—5°. The Helgoländer tiefe Rinne, with a winter temperature about 3.5°, perhaps is the coldest locality in which *C. elongata* occurs. The species has a pronounced southerly distribution, from the Mediterranean to southern Norway. The absence from the Waddensea and from soft grounds along the Jutland coast may be due to the low winter temperatures in these areas. On the French Atlantic coast it occurs between tide marks (KOEHLER 1921). The absence from—or scarcity in—offshore waters of the northern North Sea may perhaps be ascribed to the low summer temperatures prevailing there. We may here have a species which does not get on too well in the central North

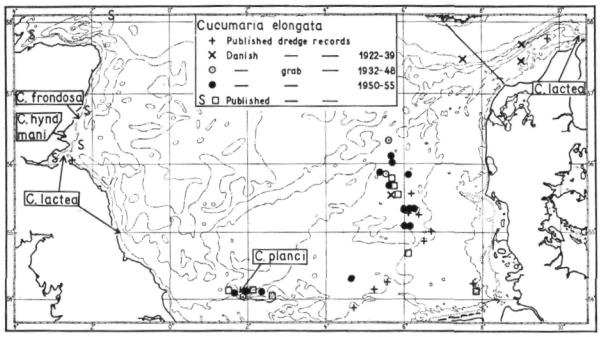

Fig. 58. The symbols refer to *Cucumaria elongata* (S = STEPHEN). Finds of other species of *Cucumaria* are indicated by arrows.

Sea (*setosa*) water, but which does not tolerate the temperature conditions in the northern North Sea (*elegans*) water or in the coastal water of the eastern North Sea. That may be why it is largely confined to localities in which northern North Sea water meets the central North Sea water. The distribution of *C. elongata* in the North Sea recalls that of the sand-dwelling forms *Acrocnida brachiata* and *Echinocardium pennatifidum* (cf. Figs. 34 p. 50, and Fig. 58).

Owing to the variably curved shape of the body the present species is difficult to measure. The weight of specimens preserved in formalin was used to indicate the size of the animal. The smallest specimens, weighing less than 50 mg, were 5—9 mm long. The larger ones, weighing about 2 g, usually were 40—60 mm long. The longest animal measured 63 mm (2300 mg) while the heaviest one (2900 mg) measured 40 mm. The weight frequency of 36 specimens collected in the North Sea in April and May 1950—54 was as follows:—

0— 49 mg:	4	1.1 g:	1
50— 99 - :	9	1.2 g:	1
100—149 - :	8	1.5 g:	1
0.2 g:	1	1.8 g:	1
0.3 g:	1	2.0 g:	2
0.4 g:	1	2.1 g:	1
0.6 g:	2	2.3 g:	1
0.8 g:	1	2.9 g:	1

The group of small animals (21 specimens weighing less than 150 mg, 80 mg on an average) apparently constitutes a 0- or I-group. The age of the larger ones cannot be estimated.

In the Sound between Denmark and Sweden *C. elongata* grows larger than in the North Sea. It has penetrated into the Sound in recent years only, probably owing to enrichment of the water by pollution and to an increase in temperature (BRATTSTRÖM 1941 pp. 281, 286). In the North Sea there is no sign of a recent increase either in density or in area of distribution.

**Cucumaria hyndmani* (THOMPSON).

Known from the Scottish east coast (St. Andrews, see Fig. 58) according to MORTENSEN (1927). It is fairly common on the Swedish Skagerrak coast and has been taken a few times in the eastern Kattegat (BRATTSTRÖM 1941). The general distribution is the same as that of *C. elongata*. Both occur from the Mediterranean to the Trondheim Fjord in Norway. Nevertheless, the distribution of the two species in the North Sea and within the transitional area between the North Sea and the Baltic is very different. This may be partly due to different habitat preferences. *C. elongata* is a soft bottom form while *C. hyndmani* is, according to MORTENSEN, confined to grounds of shells and gravel. This difference hardly accounts in full for the different degree of penetration of the two species into the North Sea—Kattegat area. If it is true, as suggested above, that *C. elongata* in the North Sea finds suitable conditions only in the transitional zone between the northern (*elegans*) water region and the southern (*setosa*) water region it seems reasonable that minute differences in the temperature or "water mass" requirements of the two species may cause the absence from the central North Sea of one species while the other is locally abundant.

(*)*Cucumaria lactea* (FORBES).

MÖBIUS and BÜTTSCHLI (1875) record *C. lactea* from the Firth of Forth. According to MORTENSEN it occurs on the British east coast down to Northumberland and Durham (see Fig. 58). Two juveniles taken in the bottom sampler in 1952 were referred with some hesitation to the present species by Mr. BENT HANSEN. They also resemble *C. planci*. One of these specimens were taken west of the Dogger Bank in 81 m, on clayey sand (St. 7886). The other was taken off northern Jutland, at the entrance to the Skagerrak in 50 m, on clayey coarse sand and stones (St. 8069^{V}). Both specimens weighed about 60 mg.

C. lactea is a littoral and shallow water species occurring from south-west Iceland (EINARSSON 1948) to Brittany (KOEHLER 1921). In the North Sea and the Skagerrak-Kattegat area it is slightly more widely distributed than *C. hyndmani*. In Danish waters it has not been found intertidally or in very shallow water.

(°)*Cucumaria planci* v. MARENZELLER.

C. planci is the only echinoderm in the present material which is not previously recorded from the North Sea. A single specimen 4 cm long was taken in the trawl by the "Dana" in May 1955, in the deep channel south of the Southwest Patch of the Dogger Bank (Fig. 58). The depth was 75—77 m. Two juveniles from bottom samples may belong to the present species or to *C. lactea* (which see).

According to MORTENSEN (1927) *C. planci* occurs from the British west and south coast to the Mediterranean and West Africa. It is not listed in the Plymouth Marine Fauna (1957). The safe North Sea locality is situated within the south-west Dogger Bank swirl which is known to support a *Sagitta elegans* plankton and a rich and varied echinoderm bottom fauna of northern

North Sea (Atlantic) affinity. The species has no pelagic development (MORTENSEN 1927) so that an accidental introduction with Atlantic water is out of question.

Thyone fusus (O. F. MÜLLER).

Danish grab records 1932—55: 8023 (1), 8065 (1).

MEISSNER and COLLIN (1894) records *T. fusus* from a single locality off the coast of northern Jutland. According to MORTENSEN (1927) it occurs along the British east coast down to Cullercoats. CASPERS (1939) took it regularly in the Helgoländer tiefe Rinne. There are two records (1939, 1956) from the Danish trawl and dredge surveys (see Fig. 59). During the Danish grab investigations it was taken twice in May 1952: once in the deep channel south of the Soutwest Patch of the Dogger Bank (65 m, clayey coarse sand with stones and shells) and once off

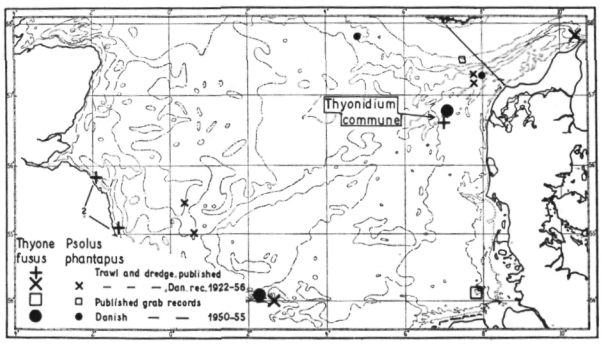

Fig. 59. The question-mark indicates that the exact localities for the British coast records of *Thyone fusus* are unknown. The single record of *Thyonidium commune* is indicated by the arrow.

northern Jutland (40 m, stones and sandy clay). The Jutland coast specimen was small (6 mm, 83 mg) and the Dogger Bank specimen was large (about 5 g, damaged).

The distribution in the southern and eastern North Sea recalls that of several predominantly northern North Sea animals. The absence of records from offshore waters of the northern North Sea may be due to insufficient sampling efficiency. However, the situation of the finds in places where *Sagitta elegans* water and *Sagitta setosa* water meet (including the Helgoland *elegans* water reservoir) also recalls the distribution of other southern echinoderms, such as *Acrocnida brachiata* (which see).

In the Kattegat *T. fusus* occurs scattered within an area characterized by mean summer temperatures between 12 and 15°, by mean winter temperatures about 4—5°, and by a mean salinity not much below 32 $^{0}/_{00}$.

**Thyone raphanus* DÜBEN et KOREN.

Like several other holothurians the present species is known to occur—in the North Sea —off the British east coast only. MORTENSEN (1927) records it for the stretch down to Northumberland. It is elsewhere distributed from south Iceland (EINARSSON 1948) to the Mediterranean. Apparently, it has not been taken in the Skagerrak or the Kattegat.

**Thyonidium pellucidum* (FLEMING).

In the North Sea known only from the British coast down to Northumberland (MORTENSEN 1927). According to BRATTSTRÖM (1941) *T. pellucidum* is rare in the Kattegat but fairly common in the Danish Belt Sea and in the Sound. It is a northern form the abundance of which

in the Sound may support the theory of a predominantly northern affinity of the fauna of the Sound (see discussion in BRATTSTRÖM 1941 p. 291). However, as pointed out by BRATTSTRÖM, the distributional pattern of *T. pellucidum* in the transitional area recalls that of *Cucumaria elongata* which is a southern form. BRATTSTRÖM is probably right in his suggestion that the abundance of both species in the Sound is primarily due to the good conditions of nourishment there. BRATTSTRÖM points especially to the recent enrichment of the Sound water by pollution from Copenhagen. However, the occurrence of *T. pellucidum* not only in the Sound but also in the Belt Sea in which the pollution is less pronounced points to natural conditions as regulators of the abundance. If BRATTSTRÖM is right that dendrochirote holothurians are dependent upon a rich food supply through the water, the rapid water renewal in the Sound and the Belt Sea may be particularly favourable to these species.

T. pellucidum tolerates very low salinities. Its southern limit of distribution in the Sound and the Great Belt coincides with the 25 $^0/_{00}$ isohaline for the year. This probably means that the species at least temporarily tolerates salinities about 20 $^0/_{00}$. In the Sound and the Belt Sea it seems to occur at mean summer temperatures between 12 and 15° and at mean winter temperatures about 3—4°. The summer temperature in the British North Sea localities of the species is approximately the same as in the localities in the Sound and the Belt Sea. The winter temperature probably is slightly higher in the North Sea localities, 5° rather than 4°. It is difficult to see how temperature conditions can prevent the species from occurring in offshore parts of the northern North Sea. It seems more likely that the conditions of nourishment or the chemical environment are not suitable.

Thyonidium commune (FORBES).

Danish grab records 1932—55: 7386 (1).

A holothurian fragment which was obtained off northern Jutland in a bottom sample in 1951 (see Fig. 59) was identified by Mr. BENT HANSEN as *T. commune*. The calcareous deposits in the mesentery were used for the identification. The ground was coarse sand with few shells and stones. The depth was 39 m.

The species is recorded from the Firth of Forth and the Northumberland coast. MORTENSEN (1927) does not consider these older records reliable because there has been much confusion of *T. commune* with other species. In the Kattegat and the Sound the species is rather rare and perhaps of temporary occurrence only. The general distribution of the species is not known because it is uncertain which records are actually reliable.

Psolus phantapus (STRUSSENFELT).

Danish grab records 1932—55: 7848 (2), 8069^{I-IV} (1).

Probably rather common off northern Jutland at the entrance to the Skagerrak. It was taken there by PETERSEN (1914) in a bottom sample and by the "Dana" in 1952—54 in a dredge haul and a bottom sample. The records by MEISSNER and COLLIN (1894) of *Psolus squamatus* probably refer to *P. phantapus* (cf. MORTENSEN 1924 p. 243). Another grab find was made farther west, on the edge of the Norwegian Channel, in 1952. The depth was 100 m and the bottom was sand with shells; the specimens measured 2 mm and 15 mm. The other grab find mentioned above was made in 50 m, on muddy coarse sand with stones (one specimen, 19 mm). Also available are two trawl records by the "Dana" (1932 and 1954) from the western North Sea, west and north-west of the Dogger Bank. According to MORTENSEN (1927) *P. phantapus* occurs along the

east British coast down to Yorkshire. The scarcity of records from offshore waters of the North Sea is striking (Fig. 59). Insufficient sampling hardly accounts for this, because the species is not easily overlooked in a trawl catch.

In the Kattegat and the Sound the distribution of *P. phantapus* resembles the distribution of *Cucumaria elongata, Thyonidium pellucidum,* and other apparently rheophile forms: a relative scarcity in the Kattegat, higher abundance in the Sound. The temperature and salinity at which *P. phantapus* occurs in the transitional area between the North Sea and the Baltic are approximately as for *T. pellucidum* (which see). In the North Sea *P. phantapus* occurs at mean winter temperatures between 4.5° and 6° and at mean summer temperatures between 10° and 14°. The species does not occur south of the North Sea. The most southern locality from which the species is recorded according to MORTENSEN (1927) is Blacksod Bay on the north-west coast of Ireland (54°N.).

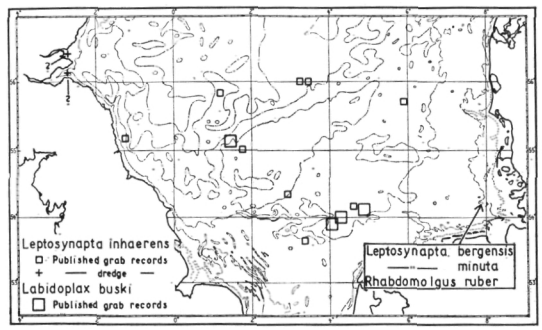

Fig. 60. The Scottish coast localities for *L. inhaerens* are not known exactly. The occurrence of three rare holothurians in Helgoland waters is indicated by the arrow.

**Leptosynapta inhaerens* (O. F. MÜLLER).

MEISSNER and COLLIN (1894) record this species from several localities in the central North Sea. However, according to MORTENSEN (1927) such old records are not reliable. DAVIS (1925) found *L. inhaerens* scattered over the central North Sea (see Fig. 60). It occurs on the Scottish coast (Firth of Forth and St. Andrews, MORTENSEN 1927). It is rather surprising that it seems to be absent from the present material. In fact, not a single synaptid was recognized in the Danish grab material. During the initial sorting of the material synaptids may have been erroneously referred to some other group of animals which is not worked up yet. Mr. BENT HANSEN most kindly went through the samples of gephyreans and animals of dubious affinity, searching in vain for synaptids. Thus, the chance that synaptids will turn up later is very small. Nevertheless, too much weight should perhaps not at present be placed upon the disappearance of the *Synaptidae* from the central North Sea.

**Leptosynapta bergensis* (ØSTERGREN).

Taken in Helgoland waters by BECKER (1910) and CASPERS (1939). Also known from southern Norway and the Kattegat.

**Leptosynapta minuta* (BECKER).

The present species was described on material from Helgoland waters (BECKER 1906). Other records, from the North Sea or elsewhere, are not reliable. The length of the animal scarcely exceeds 1 cm so that it may easily escape attention when traditional methods for macrobenthos sampling are used.

**Labidoplax buski* (M'INTOSH).

Like *Leptosynapta inhaerens* the present species is recorded by DAVIS (1925) from several localities in the central North Sea (see Fig. 60). Other North Sea records are not available. It is fairly abundant in the Kattegat, particularly in the north-western part (BRATTSTRÖM 1941).

**Rhabdomolgus ruber* KEFERSTEIN.

Recorded from shallow water on the Helgoland coast (BECKER 1907). Elsewhere known from Brittany only. Like *Leptosynapta minuta* it is a tiny and transparent little thing which is probably often overlooked.

General Remarks.

Non-quantitative Investigations.

Zoogeographical Affinities of the Echinoderm Fauna of the North Sea.

Table 20 shows the geographical distribution within the East-Atlantic region and in Greenland waters of the 57 species of echinoderms recorded from the North Sea in depths less than 100 m. 15 of these species (26 %) are known from Greenland waters and 28 species (49 %) from the West African—Mediterranean region. 2 species only (*Psilaster andromeda* and *Asterias rubens*) are so widespread that they occur from Greenland to West Africa or the Mediterranean.

Most of the echinoderms recorded from the North Sea in less than 100 m are also found in west British waters, on the Norwegian coast south of Lofoten, and in the transitional area between the North Sea and the Baltic. In the transitional area only 8 of the 57 North Sea species are missing, namely, 3 southern species (*Antedon bifida, Palmipes membranaceus, Cucumaria planci*), 1 northern species (*Cucumaria frondosa*), and 4 species which are rare or easily overlooked (*Paramphiura punctata, Thyone raphanus, Leptosynapta minuta, Rhabdomolgus ruber*). None of the 8 species missing in the transitional area is common in the North Sea. 8 species recorded from the North Sea (depths < 100 m) are not recorded from the Norwegian coast. 3 of these are rare or insufficiently known forms (*Paramphiura punctata, Leptosynapta minuta, Rhabdomolgus ruber*) and 5 are of distinctly southern distribution (*Antedon bifida, Luidia ciliaris, Palmipes membranaceus, Acrocnida brachiata, Cucumaria planci*). Only *Acrocnida* is abundant in the North Sea. There are 9 species recorded from the North Sea, but not from the British west coast. 5 are northern forms (*Ophiura sarsi, Ophiura robusta, Ophiocten sericeum, Strongylocentrotus droebachiensis, Thyonidium commune*) and 4 are rare or insufficiently known (*Paramphiura punctata, Leptosynapta bergensis, Leptosynapta minuta, Rhabdomolgus ruber*). Not one of the 9 species is abundant in the North Sea.

Thus, a comparison of the echinoderm fauna of the North Sea (depths < 100 m) with that of neighbouring areas shows that the North Sea fauna is of a slightly more northern character than that of the British west coast and slightly more southern than the fauna of the south Norwegian coast. The difference between the fauna of the North Sea and the fauna of the transitional area apparently is more of an ecological character than of a definitely zoogeographical nature.

One neighbouring area of the North Sea supports remarkably few North Sea echinoderms, namely, the English Channel. Only 39 of the 57 North Sea species are known from this well investigated area. Among the 18 species missing are 9 northern forms (*Leptasterias mülleri, Ophiopholis aculeata, Ophiura sarsi, Ophiura robusta, Ophiocten sericeum, Strongylocentrotus droebachiensis, Cucumaria frondosa, Thyonidium commune, Psolus phantapus*), 4 species usually requiring fairly deep water (*Psilaster andromeda, Asteronyx loveni, Gorgonocephalus caputmedusae, Amphilepis norvegica*) and 4 species rare or insufficiently known (*Leptosynapta bergensis, Leptosynapta minuta, Labidoplax buski, Rhabdomolgus ruber*). *Brissopsis lyrifera* is missing, too, although it is distributed from Iceland to West Africa. The dominating northern element among the species missing in the English Channel indicates that the echinoderm fauna of the Channel is of still more southern affinity than that of the British west coast. It must be noticed, how-

Table 20.

The geographical distribution in the East-Atlantic region and in Greenland waters of echinoderms recorded from the North Sea in depths less than 100 m.

	West Greenland	East Greenland	Iceland	Norway n. of Lofoten	South Norway, to Lofoten	The Faroes	The Skagerrak, the Swedish west coast	The Kattegat	The Sound, south of Elsinore	The Limfjord	The British west coast	The English Channel	The French Atlantic coast (Bay of Biscay)	The Azores	West Africa (Canary Isl., Cape Verde)	The Mediterranean	Occurrence between tide marks: French Atlantic coast	English Channel (Plymouth)	West Ireland	Iceland	Danish and German North Sea coast	Vertical distribution in the Mediterranean (TORTONESE 1949): 0—70 m	70—200 m	200—500 m	500— m
Antedon bifida	..	..	..	..	..	..	..	..	..	..	×	×	×	..	..	..	×	×	×	..	..	..	..	..	..
Astropecten irregularis	..	..	×	×	×	×	×	×	×	..	×	×	×	..	×	×	×	..	..	..	..	×	×	×	×
Psilaster andromeda	×	..	×	×	×	..	×	..	..	..	×	..	..	×	×	..	..	..	..	..	..	..	..	..	..
Luidia sarsi	..	..	..	..	×	×	×	×	×	..	×	×	×	×	×	×	..	..	..	..	..	×	×	×	×
— *ciliaris*	..	..	..	..	..	×	×	..	..	..	×	×	×	..	×	×	..	..	..	..	..	×	×	..	..
Hippasteria phrygiana	×	..	×	×	×	×	×	×	..	..	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..
Porania pulvillus	..	..	×	..	×	×	×	..	..	..	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..
Palmipes membranaceus	..	..	..	..	..	..	..	..	..	..	×	×	×	..	..	×	..	..	..	..	..	×	×	..	..
Solaster papposus	×	×	×	×	×	×	×	×	×	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..
— *endeca*	×	..	×	×	×	×	×	×	×	..	×	×	..	..	..	..	..	..	..	×	..	..	..	..	..
Henricia sanguinolenta	×	×	×	×	×	×	×	×	×	×	×	×	×	×	..	..	×	×	×	×	..	..	..	..	..
Stichastrella rosea	..	..	..	..	×	..	×	..	..	..	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..
Asterias rubens	×	..	×	×	×	×	×	×	×	×	×	×	×	..	×(×)	..	×	×	×	..	×	..	..	..	..
*Leptasterias müller*i	×	×	×	×	×	×	×	×	×	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Asteronyx loveni	..	..	..	×	×	×	×	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Gorgonocephalus caput-medusae	..	..	×	..	×	..	×	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Ophiothrix fragilis	..	..	×	..	×	×	×	×	×	..	×	×	×	×	×	×	×	×	×	×	..	×	×	×	×
Ophiocomina nigra	..	..	..	..	×	..	×	×	×	..	×	×	×	×	..	×	×	..	..	..	..	..	..	..	..
Ophiactis balli	..	..	..	..	×	×	×	..	..	..	×	×	×	..	×	?	..	..	..	..	..	..	..	..	..
Ophiopholis aculeata	×	..	×	×	×	×	×	×	×	×	×	..	..	..	..	..	..	..	..	×	..	..	..	..	..
Amphiura chiajei	..	..	..	..	×	..	×	×	×	..	×	×	×	×	×	×	×	..	..	..	..	×	×	×	×
— *filiformis*	..	..	×	..	×	×	×	×	×	..	×	×	×	×	..	×	×	..	..	..	..	×	×	×	×
Acrocnida brachiata	..	..	..	..	..	..	×	×	..	..	×	×	×	..	..	×	×	×	×	..	..	×	..	..	..
Paramphiura punctata	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..
Amphipholis squamata	..	..	×	..	×	×	×	×	×	..	×	×	×	..	×	×	×	..	×	..	..	×	×	×	×
Amphilepis norvegica	..	..	..	..	×	..	×	..	..	..	×	..	×	..	×	×	..	..	..	..	..	..	..	..	..
Ophiura texturata	..	..	×	..	×	×	×	×	×	×	×	×	×	..	..	×	×	..	×	..	×	×	×	×	..
— *sarsi*	×	×	×	×	×	×	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
— *albida*	..	..	×	×	×	×	×	×	×	×	×	×	×	×	..	×	..	..	..	..	..	×	×	×	×
— *robusta*	×	×	×	×	×	×	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
— *affinis*	..	..	×	×	×	×	×	×	×	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..
Ophiocten sericeum	×	×	×	×	×	×	×	..	..	..	..	..	?	..	..	?	..	..	..	..	..	×	×	×	×
Psammechinus miliaris	..	..	..	..	×	×	×	×	×	×	×	×	×	..	×	..	×	×	×	..	..	..	..	..	..
Echinus esculentus	..	..	×	×	×	×	×	×	×	×	×	×	×	..	..	..	×	..	×	×	..	..	..	..	..
— *acutus*	..	..	×	×	×	..	×	×	..	..	×	×	×	..	×	×	..	..	..	..	..	×	×	×	×
Strongylocentrotus droebachiens.	×	×	×	×	×	×	×	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Echinocyamus pusillus	..	..	×	×	×	×	×	×	×	×	×	×	×	×	×	×	..	..	..	..	..	×	×	×	×
Spatangus purpureus	..	..	×	×	×	×	×	×	..	..	×	×	×	..	×	×	×	..	×	..	..	×	×	×	×

(continued)

Table 20 (continued)

	West Greenland	East Greenland	Iceland	Norway n. of Lofoten	South Norway, to Lofoten	The Faroes	The Skagerrak, the Swedish west coast	The Kattegat	The Sound, south of Elsinore	The Limfjord	The British west coast	The English Channel	The French Atlantic coast (Bay of Biscay)	The Azores	West Africa (Canary Isl., Cape Verde)	The Mediterranean	Occurrence between tide marks: French Atlantic coast	English Channel (Plymouth)	West Ireland	Iceland	Danish and German North Sea coast	Vertical distribution in the Mediterranean (TORTONESE 1949): 0—70 m	70—200 m	200—500 m	500— m
Echinocardium cordatum	..	..	..	×	×	..	×	×	×	×	×	×	×	..	×	×	×	×	×	..	..	×	..	..	..
— *flavescens*	..	..	×	×	×	×	×	×	×	..	×	×	×	×	..	×	..	..	..	..	..	×	×	×	×
— *pennatifidum*	..	..	..	..	×	×	×	×	..	..	×	×	..	..	..	..	×	..	..	..	..	..	..	..	..
Brissopsis lyrifera	..	..	×	..	×	..	×	×	×	..	×	..	×	..	×	×	..	..	..	..	..	×	×	×	×
Cucumaria frondosa	×	×	×	×	×	×	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..
— *elongata*	..	..	..	..	×	..	×	×	×	..	×	×	×	..	..	×	×	..	..	..	..	..	×	..	..
— *hyndmani*	..	..	..	..	×	..	×	×	..	..	×	×	×	..	..	×	..	..	..	..	..	×	×	..	..
— *lactea*	..	..	×	..	×	×	×	×	..	..	×	×	..	..	..	..	..	×	×	×	..	..	..	..	..
— *planci*	..	..	..	..	..	..	..	..	..	..	×	×	..	..	×	×	..	..	..	..	..	×	×	..	..
Thyone fusus	..	..	..	..	×	×	×	×	..	..	×	×	×	..	..	×	..	..	..	..	..	×	×	..	..
— *raphanus*	..	..	×	..	×	..	..	..	..	..	×	×	..	..	..	×	..	..	..	..	..	×	×	×	×
Thyonidium pellucidum	?	?	×	×	×	×	×	×	×	..	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..
— *commune*	×	..	×	×	×	..	×	×	×	..	?	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Psolus phantapus	×	..	×	×	×	×	×	×	×	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Leptosynapta inhaerens	..	..	..	..	×	×	×	×	×	..	×	×	×	..	..	?	×	×	×	..	..	..	..	..	..
— *bergensis*	..	..	..	..	×	×	×	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
— *minuta*	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Labidoplax buski	..	..	..	×	×	..	..	×	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Rhabdomolgus ruber	..	..	..	..	..	..	..	..	..	..	..	..	×	..	..	..	..	..	..	..	..	..	..	..	..

ever, that none of the North Sea species missing in the Channel is abundant in the North Sea and the majority are very rare. It would appear from Table 20 that the echinoderm fauna of Iceland waters differs but little more from the North Sea fauna than does the fauna of the English Channel (24 North Sea species missing in Iceland waters against 18 in the Channel). However, the list of species absent from Iceland not only includes several species which are fairly abundant in the North Sea, but even includes the most important North Sea echinoderm, *Echinocardium cordatum*.

The above analysis of the zoogeographical position of the echinoderm fauna of the North Sea is rather brief. However, the author is not entirely satisfied with the traditional methods of zoogeographical analysis in European waters as practised, for instance, by BRATTSTRÖM (1941 pp. 294—319). The convenient classification of the species into arctic-boreal, boreal, Lusitanian-boreal, etc., used by many authors, involves a good deal of subjectivity on the author's part because the zoogeographical regions adopted are more or less arbitrary. Another disadvantage involving subjectivity is that species with an insufficiently known distribution must be omitted from the analysis. Further, it may be expected that more consistent results will be obtained if the relative abundance of the species is taken into consideration. A quantitative method of analysis involving less subjectivity is attempted in the present paper. For convenience the further discussion is deferred to p. 117.

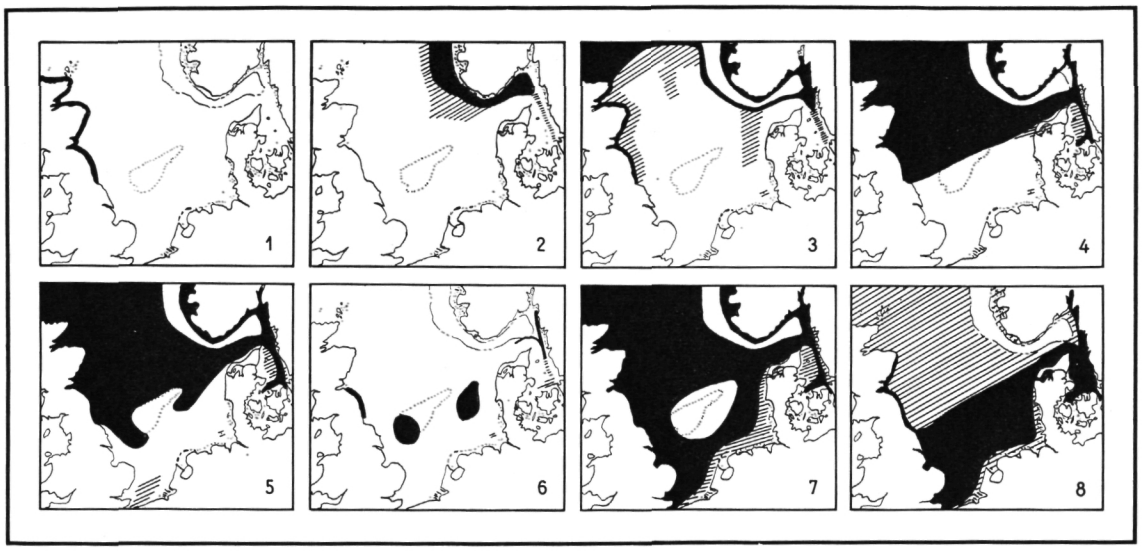

Fig. 61. Sketchy outline of distributional patterns of 46 species of echinoderms in the North Sea–Baltic region. Areas with fewer species are shaded.

1. *Antedon bifida, Palmipes membranaceus, Cucumaria frondosa, Thyone raphanus.*
2. *Psilaster andromeda, Amphilepis norvegica, Ophiura sarsi, Ophiocten sericeum.*
3. *A* (not on the North Sea coast of Jutland): *Luidia ciliaris, Hippasteria phrygiana, Porania pulvillus, Stichastrella rosea, Solaster endeca, Asteronyx loveni, Gorgonocephalus caput-medusae, Ophiocomina nigra, Ophiactis balli, Amphiura chiajei, Cucumaria hyndmani, Thyonidium pellucidum, Echinus acutus, Psolus phantapus.*
   B (penetrating toward south along the North Sea coast of Jutland): *Solaster papposus, Echinus esculentus.*
4. *Henricia sanguinolenta, Leptasterias mülleri, Ophiopholis aculeata, Ophiura robusta, Strongylocentrotus droebachiensis.*
5. *Luidia sarsi, Ophiura affinis, Spatangus purpureus, Echinocardium flavescens, Brissopsis lyrifera.*
6. *Acrocnida brachiata, Echinocardium pennatifidum, Cucumaria elongata, Thyone fusus.*
7. *Astropecten irregularis, Amphiura filiformis, Ophiura texturata.*
8. *Asterias rubens, Ophiura albida, Psammechinus miliaris, Echinocyamus pusillus, Echinocardium cordatum.*

Distributional Patterns in the North Sea.

If extensive and careful quantitative sampling had been carried out at random stations scattered over the whole North Sea or within the limits of the 100 m depth contour most important material would have been available for a survey of the distributional patterns of the more abundant species of echinoderms. In stead of this there are available accounts, often deplorably brief, of extensive but still more or less local, more or less careful, quantitative or non-quantitative investigations. Results based on such heterogenous information are difficult to interpret. A locality particularly well investigated by means of trawl and dredge shows a good representation of asterids and other large surface-dwelling forms. A locality particularly well investigated by means of bottom samplers will appear inhabited by amphiurids and other small burrowing forms. Naturally, by mere accident some northern North Sea forms may have been recorded from the southern North Sea although they are not more common there than several other northern North Sea species which are not yet recorded from the southern North Sea. As pointed out below (p. 123), there is reason to believe that most species apparently confined to the northern North Sea occur in low density in the southern North Sea, too.

Fig. 61 shows eight types of distribution of echinoderms in the North Sea. The sketches are based on the charts of distribution given in the preceding section. Information from Bratt-

STRÖM (1941) on the occurrence in the transitional area between the North Sea and the Baltic is incorporated. No two species have exactly the same distribution in the North Sea so that the gathering of species into groups becomes rather arbitrary and subjective. However, the sketches probably will do for a rough outline of the various patterns of distribution. Only the recent distribution is considered. Changes of distribution are dealt with below (p. 102).

46 of the 57 species recorded from the North Sea in depths less than 100 m fit reasonably well into one or another of the types of distribution shown in Fig. 61. The remaining 11 species are insufficiently known or do not share distribution with any other species. The eight types of distribution in the North Sea–Baltic area are thus characterized:—

1. Species occurring on the British coast only.
2. Species largely confined to the Norwegian Channel and the Skagerrak but penetrating slightly into the north-eastern North Sea; one species also penetrates into the Kattegat and the Sound.
3. Species with a decidedly bimodal distribution except, in some cases, in the extreme north. 2 species occur along the North Sea coast of Jutland while the majority are in the North Sea (except in the extreme north) confined to British waters and to the edges of the Norwegian Channel. One species (*Solaster papposus*) also enters the North Sea from the English Channel.
4. Species distributed over the entire northern North Sea. A few have an isolated occurrence in Helgoland waters.
5. Northern North Sea species penetrating into the southern North Sea east and west of the Dogger Bank. A few also enter the North Sea from the English Channel.
6. Species with a patchy distribution. They occur in the Skagerrak–Kattegat area, locally on the British coast, and east and west of the Dogger Bank. A comparison with the type 5 distribution shows similarities. It may be said, perhaps, that in the southern North Sea the animals referred to type 6 are distributed as animals predominantly belonging to the northern North Sea.
7. Species avoiding the central North Sea, including the major part of the Dogger Bank.
8. Species more abundant in the southern North Sea than in the northern North Sea.

In Table 21 the species referred to each group are arranged according to their general geographical distribution. The term "boreal species" covers species not recorded more northerly than Iceland and not more southerly than the French Atlantic coast. "Northern species" are also known from arctic waters. "Southern species" are known south of the French Atlantic coast but not more northerly than Iceland. "Widely distributed" are species occurring both north and south of the boreal region (Iceland–French Atlantic coast). It is striking that the northern species and the majority of the boreal species (which are, indeed, also rather northern) are confined to the northern North Sea and, occasionally, the Helgoländer tiefe Rinne (distributional types 1—4, Fig. 61). It is equally striking, naturally, that species more widely distributed in the southern North Sea (types 5—8) are almost exclusively of southern origin.

In the northern North Sea the summer temperature is generally low while in the southern North Sea it is generally high (cf. Fig. 8, p. 12). This corresponds to the predominance of northern species in the northern North Sea and of southern species in the southern North Sea. There are difficulties, however. One is that the Limfjord which is inhabited by several northern North Sea echinoderms, as for instance *Strongylocentrotus droebachiensis*, has higher summer temperatures than the southern North Sea. Topographically, however, the Limfjord is closely connected

Table 21.

The connexion between the general geographical distribution of North Sea echinoderms and their distribution in the North Sea–Baltic region.

Type of distribution (Fig. 61)	Total no. of species	General geographical distribution				No. of species occurring in			
		Northern species	Southern species	Boreal species	Widely distributed	The Limfjord	The Skagerrak	The Kattegat	The Sound
1	4	1	3	..	..	..	..	..	..
2	4	2	1	..	1	..	4	1	1
3	16	4	8	4	..	2	16	10	7
4	5	4	..	..	1	3	5	5	5
5	5	..	4	1	..	..	5	5	4
6	4	..	4	..	..	..	4	4	1
7	3	..	3	..	..	1	3	3	3
8	5	..	4	..	1	5	5	5	5
1—8	46	11	27	5	3	11	42	33	26
1—4	29	11	12	4	2	5	25	16	13
5—8	17	..	15	1	1	6	17	17	13

with the northern North Sea. Another difficulty is that there are isolated records from Helgoland waters, particularly from the tiefe Rinne, of several species with a limited distribution in the southern North Sea. Among these species are the typically northern North Sea asterids *Henricia sanguinolenta* and *Leptasterias mülleri*. Temperature conditions do not account for this peculiarity because the temperature in the Rinne does not deviate appreciably from the temperature in neighbouring more shallow localities in the German Bight. The Rinne, however, is known as a permanent or temporary reservoir of northern North Sea water reminiscent of the *Sagitta elegans* plankton community which is also known from the British coast of the northern North Sea and from the bottom water layers of offshore waters in the northern North Sea (cf. p. 16).

Another argument against the conception of temperature as the most important environmental factor in the distribution of echinoderms in the North Sea is the resemblance of the distributional patterns of echinoderms (Fig. 61) and of *Copepoda* (Rae and Rees 1947, Text-Figs. 3—8) several of which are known as indicators of plankton communities connected with distinct water masses. The distribution of "north-eastern forms" of *Copepoda* corresponds with the type 2 distribution in Fig. 61. They are connected with the deeper water layers of the Norwegian Channel and the Skagerrak. The "north-western forms" of copepods enter the North Sea from the Orkney-Shetland region with the *Sagitta elegans* water. As they spread south along the British coast and east in the northern North Sea, still with the *elegans* water, their distribution reminds first of type 1 (Fig. 61), then of type 4 and finally of type 5. The "central North Sea forms" of *Copepoda* are connected with the *Sagitta setosa* water. Their distribution recalls the type 8 distribution in Fig. 61. A "south-eastern form" is the copepod *Corycaeus anglicus* which is connected with the coastal plankton community of the south-eastern North Sea. A similar pattern of distribution is not shown in Fig. 61, but *Amphipholis squamatus* perhaps belongs to the same group and even *Psammechinus miliaris*, which is here (Fig. 61) referred to type 8, may be included. Of the remaining three types of distribution outlined in Fig. 61 type 7 is merely intermediate between type 5 and type 8 or between the "north-western forms" and the "central North Sea

forms" in the terminology of RAE and REES. Type 6 which contains decidedly southern forms only may be considered a gathering of animals requiring a slight influence of *Sagitta elegans* water but requiring higher summer temperatures than usually found within the *elegans* water region. Thus, they occur in the transitional zone between the *elegans* water region and the *setosa* water region. They also occur in *elegans* water on the British coast where the summer temperature is higher than farther offshore.

There is now one very important type of distribution left, namely, the bimodal distribution that was observed in 16 among 46 species of echinoderms in the North Sea (type 3). The bimodal distributional pattern was not observed by RAE and REES possibly, because they did not take into account the distribution of *Copepoda* in the transitional area between the North Sea and the Baltic. However, BRATTSTRÖM's contribution (1941) clearly shows that many species of echinoderms which penetrate only slightly into the North Sea are widely distributed and even abundant in the Kattegat, the Belt Sea and the Sound. Table 21 summarizes the penetration of each of the 8 types of echinoderms (Fig. 61) into the transitional area. As might be expected the species widely distributed in the North Sea are also widely distributed in the transitional area. More astonishing is that 7 species with a predominantly north-western distribution in the North Sea penetrate into the Sound. One of these, *Amphiura chiajei*, is even among the most abundant echinoderms on soft bottom in the Kattegat and the Sound. Another peculiarity is that *Ophiopholis aculeata* which does not penetrate into the southern North Sea (a type 4 animal) in the transitional area occurs even on the shallow, brackish Aalborg Plateau. It is quite obvious that these differences in penetration into the North Sea and into the transitional area cannot be explained by requirements for temperature or salinity. There is no indication that the grade of soil is important either. Perhaps the most likely explanation is that the system of water bodies characterized by plankton communities of the *Sagitta setosa* type or the *Sagitta elegans* type is important to the distribution of echinoderms. These plankton communities (i. e., water bodies), however, apparently are restricted to the waters surrounding the British Isles. The system is broken down already on the Danish North Sea coast (occurrence of *Solaster papposus* and *Echinus esculentus*) but particularly in the transitional area between the North Sea and the Baltic. In the transitional area a great number of distinct water bodies have been observed, each carrying a plankton population of its own (BANSE 1956). It cannot be expected that animals which in the North Sea are connected with either the *elegans* water or the *setosa* water will be connected with each other where the *elegans/setosa* system is not developed.

The reason why some plankton organisms and, apparently, even some bottom invertebrates are confined to certain water bodies remains obscure although several attempts have been made to trace the actual difference between such water bodies. It is assumed that the water type affects the bottom invertebrates in the larval stage. Observations to that effect were made by WILSON (cf. p. 18). However, several species of echinoderms which in the North Sea seem connected with the *elegans* water have a non-pelagic development. Examples are *Henricia sanguinolenta*, *Leptasterias mülleri*, and *Acrocnida brachiata*. This may indicate that even adult bottom invertebrates are dependent upon the water type. Another possibility is that the water type affects the animal during an early stage of development in species with a pelagic larval development as well as in species with a non-pelagic development. The choice between these possibilities is difficult because at present it is not known to which extent the biological difference between water bodies results from properties of the water itself and to which extent the difference is caused by local variation in productivity. For instance, it may be important to the development of the bottom fauna that the *elegans* plankton is, apparently, more productive than the *setosa* plankton.

Obviously, the abundance in the North Sea of several species of suspension feeding ophiuroids partly depends upon the food supply. Examples are *Ophiothrix fragilis, Ophiocomina nigra, Ophiactis balli,* and *Ophiopholis aculeata.* These forms are most abundant within the *Sagitta elegans* water region and particularly in localities with a rapid water renewal. They dominate the echinoderm fauna in certain localities on the British coast where the tidal streams are strong. Some also gather on the edge of the Norwegian Channel, apparently in upwelling water. Particulars about the distribution in the North Sea of each species are given above, in the preceding section. Within the transitional area between the North Sea and the Baltic they flourish in the northern part of the Sound and the Belt Sea, usually connected with the *Modiolus* epifauna community which is known (PETERSEN 1914) to be best developed in localities with strong currents. There is evidence (WINTZELL 1918, cf. p. 160 of the present paper) that the rheophile character of these species is caused by a high metabolic rate with the resulting high demand for food. As the friction of the water against the sea bottom reduces the strength of tidal streams and other currents in the lowest few centimetres of the water column, rheophile animals probably must climb live or dead objects in order to avoid the more stagnant (although turbid) water in which water already filtered remains in the vicinity of the filtering animal for some time.

Some species of rheophile ophiuroids (*Ophiothrix fragilis, Ophiactis balli*) are facultatively commensal with animals that produce water movement. *O. fragilis* is in the southern North Sea associated with sponges and corals. *O. balli* may be associated with a polychaete worm (*Chaetopterus*) although no case was observed in the present material. The obligate commensalism of *Asteronyx loveni* with pennatulids and other tall corals may be considered a further development of the tendency toward commensalism observed in other ophiuroids. Probably, *A. loveni* is a rheophile animal adapted to depths in which the natural water movement does not usually suffice for an adequate food supply.

Vertical Distribution in the North Sea and Elsewhere.

TORTONESE (1949) gives a survey of the vertical distribution of Mediterranean echinoderms. He recognizes four depth zones the shallowest of which covers 0—70 m. Table 20 shows that with a single exception all species common to the Mediterranean and the North Sea occur in the Mediterranean in the shallow zone. The exception is *Cucumaria elongata* which, however, in the Adriatic Sea has a depth range of 0—100 m (VATOVA 1949 p. 62). Evidently, the Mediterranean-boreal echinoderms do not submerge appreciably in the southern part of their area of distribution. The high summer temperature in Mediterranean shore waters (20—25°) does not damage these species. It is not known whether boreal and Mediterranean stocks of the same species are genetically identical. Geographical subspeciation, involving physiological differences, may be suspected.

The depths recorded for Icelandic echinoderms (EINARSSON 1948) show that some species which in the North Sea abound in shallow water or, at least, in depths about 50 m, in Iceland waters have a shoreward limit about the 100 m line. They are *Astropecten irregularis* (86—180 m), *Ophiura texturata* (100—122 m), *Echinocyamus pusillus* (110 m), and *Brissopsis lyrifera* (124—306 m). These four species represent a southern fauna element in Iceland waters and are restricted to the south and west coasts. It is relevant to suggest that temperature requirements necessitated the submergence. However, in a depth of 30 m off south-west Iceland the temperature seems to range from 6° in winter to 11° in summer. This would be rather a suitable temperature range to North Sea animals. In 100 m the temperature off south-west Iceland is almost

constant, 7—8°, throughout the year (THOMSEN 1938 p. 23). The submergence probably is caused by something other than temperature.

An interesting point is the scarcity of littoral echinoderms in the south-eastern North Sea. In Table 20 (p. 95) are listed data on intertidal occurrence on the French Atlantic coast (KOEHLER 1921), on the west coast of Ireland (SOUTHERN 1915, FARRAN 1915), on the Plymouth coast of the English Channel (Plymouth Marine Fauna 1957), and in Iceland (EINARSSON 1948). The value of the material is probably somewhat vitiated by unknown differences in sampling effort. The Plymouth coast is particularly well investigated. Yet only 9 species are recorded from the Plymouth littoral against 18 species from the French Atlantic coast, 13 from the Irish west coast, and 6 from Iceland. The absence of *Echinus esculentus* from the Plymouth littoral is particularly interesting and is discussed by previous authors. YONGE (1949 p. 274) suggests that the absence of *Sagitta elegans* water from the surface on the Plymouth coast is the reason for the submergence of *E. esculentus* in that area (on *E. esculentus,* see further p. 70).

The scarcity of the intertidal echinoderm fauna is still more pronounced in the south-eastern North Sea. Two species only, *Asterias rubens* and *Ophiura texturata,* are recorded from the littoral zone, the so-called waddens. Interesting is that even the deep (10—20 m) channels between the waddens give room to few additional species. Only *Asterias rubens* and *Psammechinus miliaris* are abundant and consistent in the channels. Other species recorded are *Amphipholis squamata, Ophiura albida, Ophiura texturata,* and *Echinus esculentus.* The sparseness of the Waddensea fauna may be due partly to low winter temperature. The waddens are often ice-covered in winter. In the channels which at low tide mainly contain water from the waddens the temperature must be low, too.

In the Limfjord the winter temperature is not much higher than in the Waddensea. Still, the Limfjord is inhabited by several species of echinoderms which in the south-eastern North Sea are found only well below tide marks on the open shores (i. e., outside the Waddensea). Such species are *Echinocardium cordatum* and *Echinocyamus pusillus.* On the Atlantic shores of Europe *E. cordatum* is particularly characteristic of the littoral infauna. In Port Erin Bay on the Isle of Man is it even more abundant in the littoral than below tide marks (MOORE 1936). This is in striking contrast to the condition in the southern North Sea where *E. cordatum* flourish best in moderate depths. In the German Bight it seems restricted to depths of more than 25 m (HAGMEIER 1925, the chart). The poorness of the littoral and shallow fauna in the south-eastern North Sea may be connected with the general reduction in the number of species of echinoderms that is observed when the interior of the North Sea is approached from the Atlantic (see below, p. 111). The deep water layers in the North Sea support a more varied fauna (with the *Sagitta elegans* plankton) than the upper water layers (see p. 16). The coasts of the southern North Sea are supplied mainly with water of the surface type. Thus, they may be expected to harbour rather a sparse echinoderm fauna which is also the case.

Changes in the Composition of the Echinoderm Fauna of the North Sea, 1872—1955.

As pointed out by BRATTSTRÖM (1941 p. 280) it is difficult to distinguish between real changes in the composition of the fauna and differences caused either by the invention of new sampling methods or by the varying skill of the investigator. Probably, some species or other escapes attention in any investigation because it is small and delicate, concealed in stones or in tubes of other animals, or utterly like another species that is abundant in the material. It is also difficult to estimate the influence of accidents of sampling. Observations on changes are always

under correction. The information given below is compiled from the accounts on individual species (pp. 25—94).

Three species (*Astropecten irregularis, Luidia sarsi, Amphiura filiformis*) apparently in the southern North Sea suffered severely from the cold winter of 1947 (on which see p. 14). They are all southern forms which extend beyond the boreal region towards the south only. Neither occur normally in the shore region of the Danish and German North Sea coast in which the winter temperature usually is so low that damaging effects upon these species may be expected. The destructive effects of the severe winter upon the *Astropecten* stock may probably be taken for granted. The other two species are more problematic.

Six species seem to have withdrawn themselves from the central North Sea and partly from the southern North Sea. Three are southern forms: *Amphiura chiajei* disappeared from the greater part of the North Sea in some year unknown, but prior to 1932; *Ophiura texturata* disappeared from offshore waters in the central North Sea about 1930; *Echinocardium flavescens* became less abundant in the central and southern North Sea after 1911 and probably before 1925. A timing of these happenings with changes in temperature and salinity is not indicated. It was suggested above that the distribution of the species in question is influenced by the occurrence of various plankton communities. The change of distribution in these echinoderms may or may not indicate that the distinction between the *Sagitta elegans* region and the *Sagitta setosa* region has become more marked. The remaining three species that have decreased are northern forms which penetrate beyond the boreal region in the north only: *Solaster papposus* became more rare in the Horn's Reef area on the Danish coast, apparently not before 1907 and probably not much later than 1922; *Ophiopholis aculeata* was recorded from several localities in the southern North Sea in 1872 and never since; *Ophiura sarsi* seems to have disappeared from the greater part of the North Sea about 1930. The withdrawal of *S. papposus* and *O. sarsi*, if real, occurred almost simultaneously with a temperature increase (cf. p. 13) but, naturally, the timing of these phenomena may be accidental. Three of the six species that have decreased in the central and southern North Sea also suffered reduction in the transitional area between the North Sea and the Baltic: *E. flavescens, S. papposus,* and *O. sarsi. Amphiura chiajei* increased in number in the transitional area (Brattström 1941 p. 281).

Five species seem to have increased in number in the southern and central North Sea. They are all southern forms, extending beyond the boreal region in the south only: *Luidia sarsi, Ophiura albida, Echinus esculentus, Echinocyamus pusillus,* and *Echinocardium cordatum.* The increase of *L. sarsi* and *E. esculentus* seems to have occurred at some time between 1907 and 1925. The other three species increased in recent years, perhaps about 1948—50. The temperature increase from 1920 onwards may be advantageous to these southern forms. However, a similar increase in density was not observed in the transitional area between the North Sea and the Baltic although a similar temperature increase occurred. *E. esculentus* and *E. pusillus* even decreased in the Sound (Brattström 1941 p. 282). It is not likely, therefore, that the increased abundance in the North Sea was caused by the temperature increase. Three of the five species (*O. albida, E. pusillus, E. cordatum*) are presently (1950—54) among the most abundant echinoderms in the North Sea. In large areas they actually flourish almost to the exclusion of other forms. What happened in the present century to the echinoderm fauna of the central North Sea perhaps is, if anything, that rare species became more rare and abundant species became still more abundant. The development perhaps indicates an increase in dominance of the *Sagitta setosa* water and the associated plankton community, also poor in species, in the central North Sea.

Quantitative Investigations.

The Number of Species per Unit of Area.

HOLME (1953 p. 13) pointed to the importance of information on the number of species in quantitative descriptions of marine bottom faunas. He showed that a given area is characterized by the curve obtained when the number of species found is plotted cumulatively against the area sampled. Plotting the area on a log scale transformed the curve into an approximately straight line.

The part of the North Sea investigated is divided into "squares" measuring one degree of longitude by half a degree of latitude (the socalled "international squares" or "statistical squares"

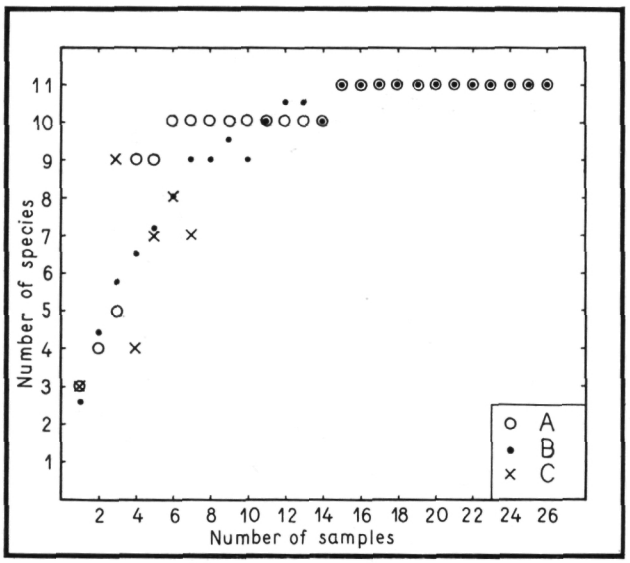

Fig. 62. Number of species of echinoderms obtained in 26 bottom samples from square K 11 in 1950–55, plotted against number of samples (1 sample = 0.2 m²). *A:* samples accumulated in random order. *B:* partly cumulative arrangement; mean values computed for number of samples < 14. *C:* strictly independent observations.

of British authors). The situation of each square is described by a letter indicating longitude and a number indicating latitude (G 8, F 4, etc., cf. Fig. 80, p. 134). With few exceptions all samples taken with a 0.2 m² grab in 1950—55 were used.

The species-area curve may be produced in several ways. HOLME (1953) arranged the samples in random order and prepared a cumulative curve in which sample no. 1 produced the value for the number of species in one sample while samples nos. 1 and 2 produced the value for the number of species in 2 samples, and so on. In Fig. 62 (A) is shown such a cumulative curve, based on 26 samples from square K 11. Much is left to accident when this method is adopted. If 1 out of the 26 samples happens to contain all species represented in the set of samples the slope of the curve depends primarily on the number this particular sample got in the set. If it is number 1 the curve has no slope at all. A more consistent and smooth curve is obtained when the number of species in one sample is computed as the mean for all samples in the set. Correspondingly, the mean number of species in 2 samples is found by taking the same samples 2 by 2, and so on. In the case of square K 11 (see Fig. 62 (B)) 26 mutually independent observations are available for the computation of the mean number of species in one sample. Available are further

13	observations	covering	2	samples	each
8	–	–	3	–	–
6	–	–	4	–	–
5	–	–	5	–	–
4	–	–	6	–	–
3	–	–	7– 8	–	–
2	–	–	9–13	–	–
1	observation	–	14–26	–	–

Curves prepared in this way are referred to as semi-cumulative curves. In the example chosen the values for the number of species in 14 to 26 samples are the same as in a strictly cumulative curve (Fig. 62 (A)). If the samples are arranged in another random order before the computation of another mean value the mutual dependence of successive values is diminished.

A set of strictly independent observations is obtained when sample no. 1 indicates the number of species in one sample, samples nos. 2 and 3 the number of species in 2 samples, and so on. The 26 samples from K 11 thus produce 6 strictly independent observations (cf. Fig. 62 (C)):—

Observation no.	1	2	3	4	5	6
No. of samples (i. e., unit of area) .	1	2	3	4	5	6
Total no. of samples required	1	3	6	10	15	21

21 samples only are required for 6 independent observations. The remaining 5 samples may be utilized by omission of the unit of 2 samples:—

Obs. no.	1	2	3	4	5	6
No. of samples	1	3	4	5	6	7
Total no. required	1	4	8	13	19	26

The method is not convenient when the number of samples is small. For instance, 20 independent observations require 210 samples. Curves based on independent observations may be made subject to statistical analysis.

A semi-cumulative curve was prepared for each square. The curves are not published in full, but extracts are given in Fig. 63 which shows, for individual squares, the number of species of echinoderms in one sample (0.2 m^2), in 5 samples (1.0 m^2), and in 20 samples (4.0 m^2). When mean values are available the numbers are given with one decimal. The number of samples from each square and the total number of species found in each square are shown in Table 22. Numbers below 2 species per sample are found particularly in two areas, near the 100 m line and in shallow water in the central North Sea. The number of species in the apparently poor area near the 100 m line may be under-estimated because the number of specimens is so low that seldom more than one specimen of each species was found in a sample. Perhaps, when more samples become available this area will turn out to be fairly rich in species. Similar conditions are met with in the Adriatic Sea (cf. p. 114). In the other poor area, in the central North Sea, the number of specimens is higher so that, probably, the number of species in one sample is not considerably affected by the number of specimens in the sample. Differences between areas become more evident with an increased number of samples (Fig. 63).

A more detailed comparison of the rich area and the poor area in the North Sea is difficult when the squares are treated individually because the number of samples from one square is

low in most cases. A reasonably good representation of the poor central North Sea fauna is perhaps obtained when the following 7 squares are pooled: G8, H8, J8, K8, H9, J9, and K9. Parts of the sand grounds of the Dogger Bank and of the soft grounds in the Clay Deep–White Bank area are included. The number of samples from these 7 squares, referred to as the poor area, is 232. In order to reduce subjectivity the corresponding rich area is given the same shape and size as the poor area. 7 squares situated in the north-eastern North Sea were selected: J11,

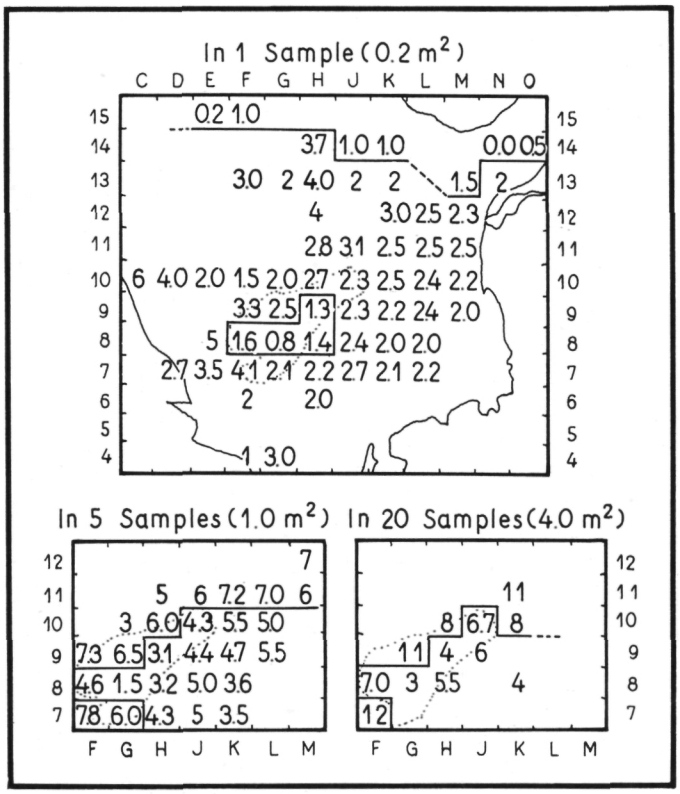

Fig. 63. (Mean) number of species of echinoderms in 1 sample, 5 samples and 20 samples in individual statistical squares. April and May 1950–55. Samples of 0.2 m² each. Areas poor in species are framed.

K11, L11, M11, K12, L12, and M12. 65 samples are available from these 7 squares which will be referred to as the rich area. The situation of the poor area and the rich area is indicated on Fig. 69, p. 112.

Fig. 64 shows the number of species obtained in the poor area and in the rich area plotted against number of samples of 0.2 m² each (see also Table 23). Both curves are semi-cumulative. The difference between the poor area and the rich area is conspicuous. Comparison is difficult because the theoretical shape of the curves is unknown. When the number of species is plotted, not against number of samples (n), but against log ($n + 1$), a straight line relationship is approached (Fig. 65). Unfortunately, confidence limits cannot be estimated for the regression line, but for individual points only. The points are not strictly independent of each other because they are based on the same set of samples. The confidence limits indicated in Fig. 65 are the 95 % limits of individual mean values (the standard deviation of the mean multiplied by the t value

Table 22.

Number of samples available from individual squares in the North Sea and total number of species of echinoderms found. April and May 1950—55.

Square	No. of samples	No. of species	Square	No. of samples	No. of species	Square	No. of samples	No. of species
C 10	1	6	G 4	2	4	K 11	26	11
D 10	3	8	H 14	3	5	K 10	30	11
D 7	3	5	H 13	3	6	K 9	16	7
E 15	4	1	H 12	1	4	K 8	37	6
E 10	4	4	H 11	6	5	K 7	10	5
E 8	1	5	H 10	26	9	L 12	4	7
E 7	4	6	H 9	59	4	L 11	10	9
F 15	2	2	H 8	43	7	L 10	17	8
F 13	2	5	H 7	16	6	L 9	12	7
F 10	2	2	H 6	2	3	L 8	4	3
F 9	19	10	J 14	2	2	L 7	4	3
F 8	42	8	J 13	1	2	M 13	4	5
F 7	21	12	J 11	8	9	M 12	9	8
F 6	1	2	J 10	63	9	M 11	6	6
F 4	1	1	J 9	33	8	M 9	4	3
G 13	1	2	J 8	14	6	M 7	2	2
G 10	5	3	J 7	9	7	N 14	2	0
G 9	24	11	K 14	3	3	N 13	1	2
G 8	24	5	K 13	1	2	O 14	2	1
G 7	15	9	K 12	2	4			

corresponding to the number of degrees of freedom). The curves may deviate from the straight line although the deviation is not conspicuous within the range of n investigated. If such deviation is of any importance extrapolation on the straight lines may be expected to produce improbable numbers of species, particularly for high values of n. The rich area covers approximately 24,300 km², or 122×10^9 samples. The poor area covers 25,400 km², or 127×10^9 samples. The difference is due to a decrease in size of the "squares" toward the north. Extrapolations of the lines in Fig. 65 are found in Fig. 73, p. 115. The number of species corresponding to the whole area investigated is 52 in the poor area and 112 in the rich area. In the present paper 57 species of echinoderms are listed as recorded from the North Sea in depths less than 100 m. It seems reasonable that most species recorded from the North Sea within the 100 m line, but scarcely many others, may sooner or later appear in catches from the central North Sea. The suggestion, that 52 species occur in the poor area may be a good estimate. MORTENSEN (1924) lists about 110 species of echinoderms as recorded from or likely to occur in Danish waters

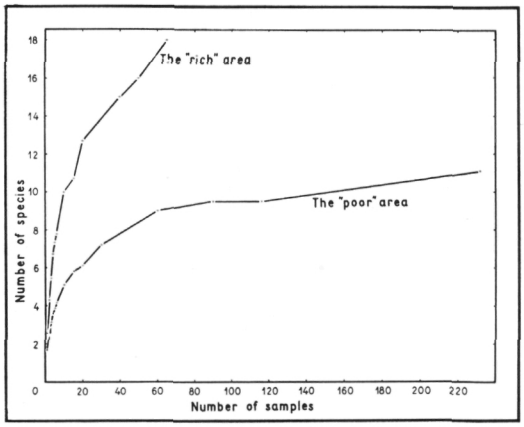

Fig. 64. Number of species of echinoderms in the rich area and the poor area (cf. text) plotted against number of samples. April and May 1950–55. Samples of 0.2 m² each. Semi-cumulative curves.

Table 23.

Number of species of echinoderms per unit of area.
Semi-cumulative curves for the poor area and the rich area (cf. Fig. 65 and text).
s_m is the standard deviation of the mean.

Unit of area (= no. of samples)	The poor area				The rich area			
	No. of observ-ations	Mean no. of species	s_m	95% con-fidence limit	No. of observ-ations	Mean no. of species	s_m	95% con-fidence limit
1	232	1.647	0.067	0.132	65	2.585	0.161	0.322
2	116	2.534	0.107	0.212	32	4.344	0.300	0.612
3	77	3.117	0.120	0.239	21	5.476	0.343	0.715
4	58	3.586	0.146	0.292	16	6.750	0.536	1.143
5	46	3.870	0.160	0.323	13	7.462	0.574	1.251
6	38	4.210	0.189	0.384	10	7.800	0.593	1.341
10	23	5.087	0.234	0.486	6	10.000	0.577	1.483
15	15	5.800	0.341	0.732	4	10.750	0.857	2.727
20	11	6.091	0.285	0.634	3	12.667	0.893	3.843
30	7	7.143	0.262	0.641				
60	3	9.000	0.577	2.485				
116	2	9.500	0.612	7.781				

(actually, in the Skagerrak). It seems probable that any species occurring in Danish waters, but scarcely many others, may be found within a sufficiently large area of the North Sea, situated near the edge of the Skagerrak and known to be rich in species. The graph estimate, 110 species, seems quite reasonable. Perhaps it may be concluded that both in the rich area and

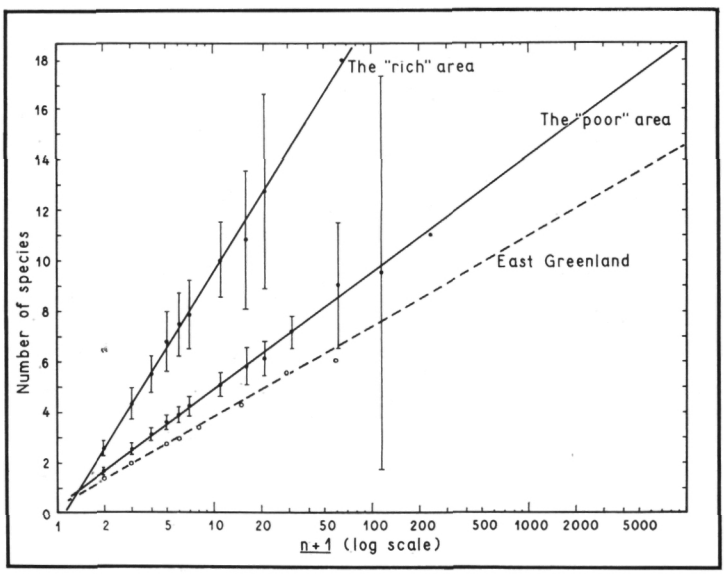

Fig. 65. Number of species of echinoderms in the rich area and the poor area (cf. text and Fig. 64) plotted against log $(n+1)$ where n is the number of samples. Semi-cumulative curves. 95 % confidence limits of mean values are indicated.
On East Greenland, see text, p. 113.

in the poor area the straight line relationship between the number of species and log $(n+1)$ continues far beyond the range of n investigated.

The 232 samples from the poor area may produce 21 strictly independent points on the curve. The 65 samples from the rich area suffice for 10 points only. Individual points and the estimated regression lines with 95 % confidence limits are plotted on Fig. 66 (number of species against log $(n+1)$. The standard deviation about the two lines is identical at the 5 % level of significance. The lines are significantly different from each other at the 1 % level ($t = 2.886$ for 27 degrees of freedom). Extrapolation to the size of the area investigated gives for the poor area 30—70 species (95 % confidence limits; $n = 127 \times 10^9$). The range is 59—204 species in the rich area ($n = 122 \times 10^9$). A comparison of the confidence limits shown in Figs. 65 and 66 shows that points on the ordinate (number of species) corresponding to low values of n probably are better identified on the semi-cumulative curves (Fig. 65).

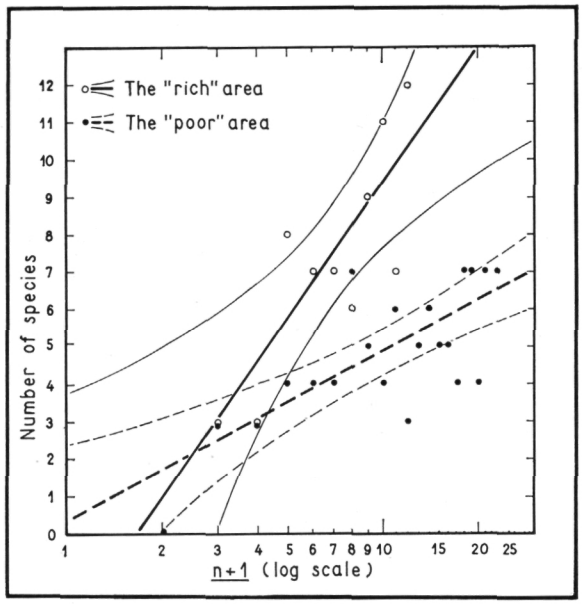

Fig. 66. Number of species of echinoderms in the rich area and the poor area, plotted against log $(n+1)$. Strictly independent observations. The estimated regression lines with their 95 % confidence limits are indicated. Cf. text and Figs. 64–65.

Table 24.

Number of species of echinoderms on various grades of soil in the North Sea. Cf. Fig. 67.

	Bottom deposit	No. of samples	No. of species found	No.[1]) of species in 10 samples	Mean depth (m)	Mean volume of sample (litres)	Number of species on various units of area (Mean values, when possible) Number of samples of 0.2 m² each: 1	2	3	4	5	6	10	15	20	30
The poor area	Sandy clay	7	7	8.4	47	10.9	2.43	3.33	4.50	4	6	6	..	..	..	..
	Clayey sand	30	6	6.2	43	10.0	2.43	3.40	4.10	4.57	4.83	5.40	6.00	6.00	6	6
	Muddy sand	75	9	5.3	41	9.5	2.05	2.92	3.35	3.72	3.93	4.25	5.14	6.20	6.67	7.00
	Fine sand	113	8	3.7	27	8.4	1.14	1.82	2.24	2.54	2.82	3.11	3.82	4.29	4.60	5.00
	Coarse sand	5	3	3.7	29	8.2	0.80	2.00	2	2	3	..	..	..	..	..
	All grades of soil	232	11	5.0	35	9.1	1.64	2.53	3.12	3.59	3.87	4.21	5.09	5.80	6.09	7.14
The rich area	Sandy clay	7	10	11.8	52	20.7	3.71	5.33	7.00	9	9	9	..	..	..	..
	Clayey sand	5	8	11.8	49	9.2	3.60	6.00	7	8	8	..	..	..	..	..
	Muddy sand	16	11	9.2	49	10.7	2.44	4.00	5.20	6.00	6.67	7.00	9	10	..	..
	Fine sand	6	8	9.7	31	11.7	2.83	4.33	5.50	6	8	8	..	..	..	..
	Coarse sand	22	9	8.1	39	12.6	1.95	3.17	4.43	5.40	5.75	6.33	7.50	9	9	..
	Clayey coarse sand	9	10	9.7	43	11.4	2.77	4.75	5.33	7.50	9	9	..	..	..	..
	All grades of soil	65	18	10.1	43	12.5	2.58	4.34	5.48	6.75	7.46	7.80	10.00	10.75	12.67	..

[1]) Taken from graph, Fig. 67.

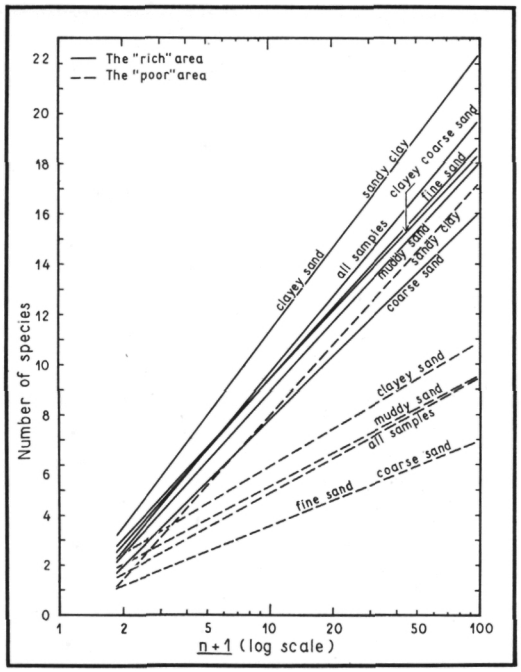

Fig. 67. Semi-cumulative curves (cf. Table 24) showing the number of species of echinoderms on various kinds of bottom deposit in the North Sea, plotted against log $(n+1)$ where, as in the preceding figures, n is the number of samples.

Fig. 67 shows semi-cumulative curves indicating the number of species in various kinds of bottom deposit in the rich area and the poor area. Again, the plotting is number of species against log $(n + 1)$. To prevent confusion, individual points are not shown in Fig. 67 which gives only the eye-fitted best straight line though each set of points. Table 24 may be consulted for further details. When sets of samples from the same grade of soil (clayey sand, fine sand, etc.) are compared the set from the rich area is always richer in species than the set from the poor area. The richest soil (sandy clay) has approximately the same number of species in the poor area as the poorest soil (coarse sand) has in the rich area. In both areas the finer grades of soil (sandy clay and clayey sand) are richest in species and the coarsest grade (coarse sand) poorest in species. In the poor area fine sand is as poor in species as coarse sand. Fine sand is not particularly poor in the rich area. The designation "fine sand" may have been given to a soil in the rich area other than that in the poor area.

There seems to be in the poor area a fairly close correlation between the number of species and the mean contents of bottom material in the grab (Table 24). However, it was shown above (p. 5) that in material from the poor area the number of species is not significantly dependent upon sample volume.

Evidently, the higher efficiency of the grab on soft grounds does not account for the difference in number of species on different grades of soil.

In both areas and particularly in the poor area there seems to exist a correlation between water depth and the grade of soil. The softer the grounds, the deeper the water (Table 24). The material does not show convincingly whether the water depth or the nature of the grounds, or both, determines the number of species of echinoderms per unit of area. Perhaps, the poorness of the coarse sand samples in both areas actually indicates that coarse sand is an unsuitable substratum in the North Sea to many species of echinoderms. The samples of coarse sand from the rich area originate from fairly deep water. Perhaps the richness of the fine sand in the rich area indicates that the poorness of the same soil in the poor area (i. e., on the Dogger Bank) is not so much caused by the grade of soil as by the nature of the overlying water. It has been suggested several time in the present paper that the poorness in species of the central North Sea is partly due to the predominance of *Sagitta setosa* water. If this hypothesis is adopted it may be expected that extremely poor conditions prevail on the Dogger Bank. The bank is the only part of the central North Sea shallow enough to be situated above the autumn discontinuity layer. Thus, the bank is during several months each year cut off from the more rich bottom water which is more or less influenced by *Sagitta elegans* water. This is in accordance with the increase in number of species in deeper water, particularly in the poor area. The deepest part of the poor area, with grounds of sandy clay, is probably as rich in species as the shallower part of the rich area.

In Fig. 68 the total number of species of echinoderms found in individual squares (Table 22) is plotted against log $(n + 1)$. The semi-cumulative curves from the rich area and the poor area are indicated. They were preferred to the estimated regression lines because the latter are

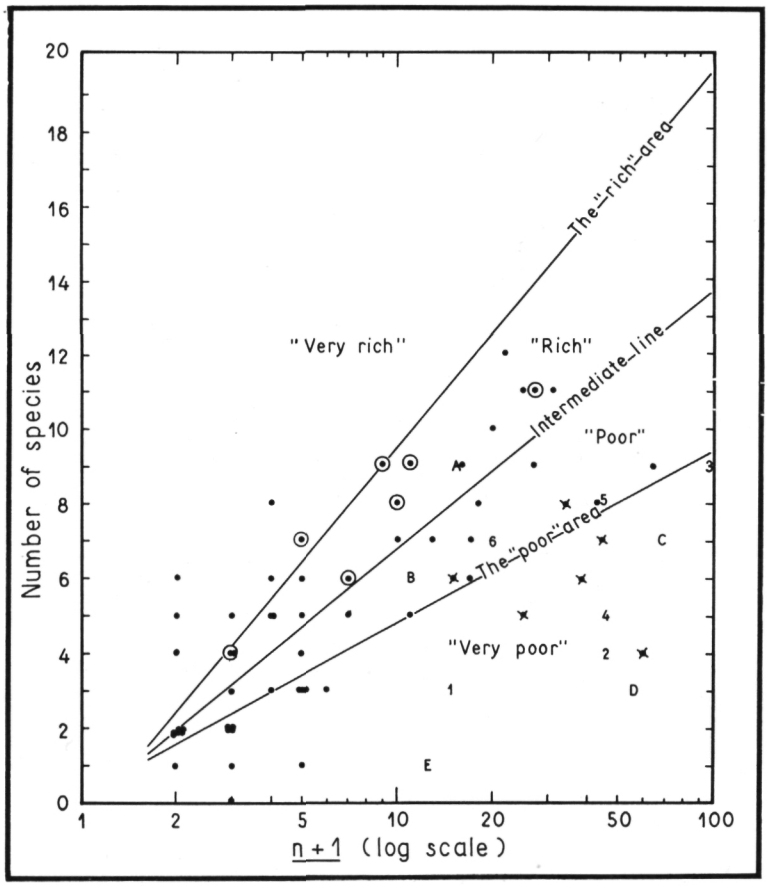

Fig. 68. Total number of species of echinoderms obtained in bottom samples in various North Sea localities, plotted against log $(n+1)$. The eye-fitted best straight lines indicating the species-area relationship in the poor area and the rich area (Fig. 65) are indicated. A line intermediate between these is also drawn. Dots indicate the results from individual statistical squares (Danish material from April and May 1950–55, Table 22). Encircled dots indicate squares included in the rich area. Crossed dots indicate squares included in the poor area. Other signatures are:

A. Caspers 1939. Helgoländer tiefe Rinne (25–60 m).
B. — 1950. — Austernbank (15–30 m).
C. Hagmeier 1925. German Bight (15–40 m).
D. — and Kändler 1927. German Waddensea (channels only).
E. Smidt 1951. Danish Waddensea (channels only).
1–6. Horn's Reef area 1932–39. Increasing depth (no. 1, shallowest, no. 6, deepest. Cf. text).

not so well identified for low values of n. A line intermediate between that for the rich area and that for the poor area is drawn, too. According to their situation above, between, or below the lines the squares are designated "very rich", "rich", "poor", or "very poor". Fig. 69 shows the horizontal variation in richness in species of echinoderms in the North Sea. "Very poor" squares are found in the German Bight, on the Dogger Bank, and in the northern North Sea. The poor

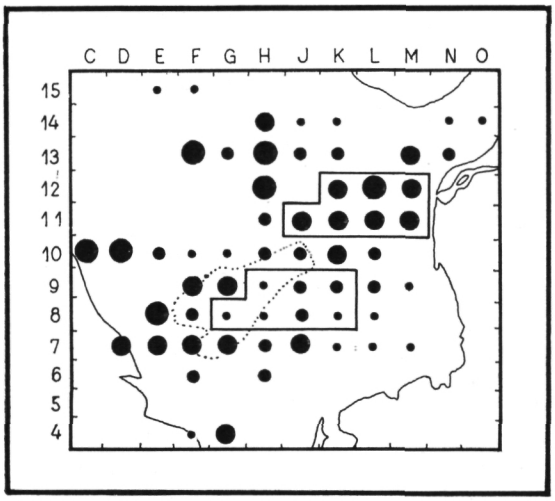

Fig. 69. The North Sea, with indication for each square of its richness in species of echinoderms. Based on Danish sampling in April and May 1950–55 (Fig. 68). The frames indicate the situation of "the rich area" and "the poor area". Symbols: ● very rich ● rich • poor • very poor.

character of northern North Sea squares is perhaps not reliable (cf. above, p. 105). "Rich" squares are found primarily in the transitional zone between the northern and the southern North Sea. "Very rich" squares are scattered in the western North Sea. No square from which a reasonably high number of samples is available is "very rich". Ordinary scatter of single observations may have caused squares from which few samples are available to be, erroneously, designated "very rich". However, six squares situated west of the Dogger Bank (C10, D7, D10, E7, E8, E10) remain "very rich" when the samples from these squares are pooled. They produce 16 species in 16 samples.

The echinoderm fauna of the Helgoländer tiefe Rinne is a "rich" one (CASPERS 1939; 9 species on 3.0 m², cf. Fig. 68). This might be expected because several charts of distribution in the present paper show local occurrence of northern North Sea forms in Helgoland waters. CASPERS (1939 p. 15) points to the temporary occurrence of northern North Sea water with a *Sagitta elegans* plankton in the deeper water layers of the Rinne. The Helgoländer Austernbank (CASPERS 1950) has fewer species of echinoderms (6 species on 1.9 m²). This fauna is "poor". In the German Bight HAGMEIER (1925) found a "very poor" fauna (7 species on 13.5 m², cf. Fig. 68). The intermediate position of the fauna of the Helgoländer Austernbank between the fauna of the tiefe Rinne and of the remaining part of the German Bight was observed by CASPERS (1950 p. 159). "Very poor" faunas were further found by HAGMEIER and KÄNDLER (1927) in the German Waddensea (3 species on 10.9 m²) by SMIDT (1951) in the Danish Waddensea (1 species on 2.3 m²), and by MISTAKIDIS (1951) in the estuaries of the rivers Crouch and Roach on the English south-east coast (3 species on 43 m²). Partly unpublished Danish investigations in the Nissum Broad in the Limfjord in 1914—55 produced 7 species on 185.9 m²: *Asterias rubens, Amphiura sp., Ophiura texturata, Ophiura albida, Psammechinus miliaris, Echinocyamus pusillus,* and *Echinocardium cordatum.* The depth range was 4—17 m. This fauna, too, is "very poor".

When the samples collected by Danish research vessels in the Horn's Reef area on the Jutland coast in 1932—39 are arranged according to water depth an increase in richness of the echinoderm fauna is observed from the shallower toward the deeper stations:—

Depth (m)	No. of samples (0.2 m²)	No. of species	Reference to Fig. 68	
6— 9	14	3	1	"very poor"
10—14	45	4	2	–
15—19	99	9	3	–
20—24	45	5	4	–
25—29	40	8	5	"poor"
30—34	19	7	6	–

These observations and the information available from literature quoted above are in accordance with the distribution of rich and poor squares as estimated by means of the material

from 1950—55. The decrease in number of species toward the coast in the southern North Sea is conspicuous.

The richness of individual stations operated by PETERSEN (1914) in the transitional area between the North Sea and the Baltic is shown in Fig. 70. Most stations cover 1—5 m², taken with the 0.1 m² PETERSEN grab. The number of species increases toward south until echinoderms gradually disappear in the southern Belt Sea, probably owing to the low salinity of the Baltic water. The few "rich" stations in the Kattegat are situated on the slope from the shallow western plateau toward the deep eastern channel. It appears from PETERSEN's lists that the "rich" stations in the Belt Sea are usually situated on similar slopes or in deep (40—50 m), narrow channels between the islands. Several are referred by PETERSEN to "the rich *Modiolus* epifauna". Apparently, the richest fauna is found in the transitional zone between two water masses. The surface water of Baltic origin is probably rich in organic and inorganic matter suplied from rivers and coasts. This water is brackish and perhaps also in other respects so different from oceanic water that few species of echinoderms thrive in it. The more saline bottom water seems to possess the qualities of oceanic water. It forms a suitable environment for echinoderms, but probably is more poor in nutriments than the Baltic (surface, coastal) water. The highest production of phytoplankton is found in shallow water of Baltic origin (STEEMANN NIELSEN 1940 p. 40, Fig. 17). When the two water masses are mixed with each other an enriched medium with important advantages of both water masses seems to be formed. The effect of the enrichment of the water is probably increased in localities in which the water movement is rapid, to the effect that a larger amount of useful substance is brought into contact with the animals.

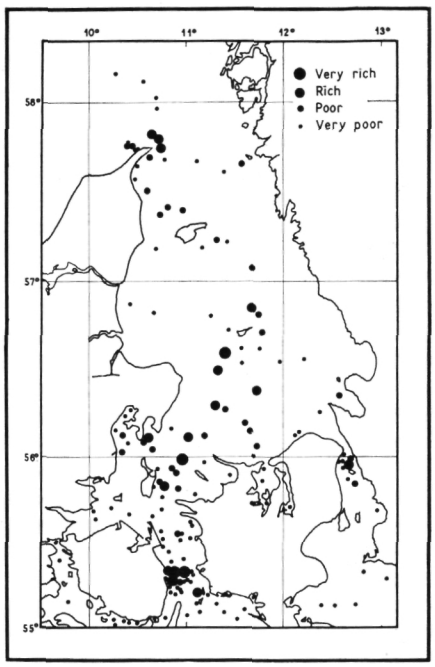

Fig. 70. The richness in echinoderm species in the Kattegat and the Belt Sea. Based on PETERSEN 1914. 1–5 m² sampled on most stations. See text and the corresponding chart for the North Sea, Fig. 69.

The echinoderm fauna of the North Sea may be compared with an arctic shallow water fauna by means of THORSON's (1934) grab samples from the Scoresby Sound fjord complex in East Greenland. PETERSEN grabs covering 0.2 m² and 0.1 m² were used. In order to make the material uniform the 0.1 m² samples were pooled two by two in the succession in which they appear in THORSON's tables. A set of 58 samples of 0.2 m² each was produced. The depth range is 9—72 m. The mean number of species of echinoderms on various units of area is as follows:—

1 sample,	1.34	species		5 samples,	2.91	species	
2 samples,	1.97	–		7	–	3.38	–
3	–	2.42	–	14	–	4.25	–
4	–	2.71	–	28	–	5.50	–

58 samples, 6 species.

A straight line relationship is approached when the number of species is plotted against log $(n + 1)$ in which n is the number of samples. The eye-fitted semi-cumulative curve is indicated on Fig. 65, p. 108. The arctic fauna seems to be at least as poor in species as the poor area in the North Sea.

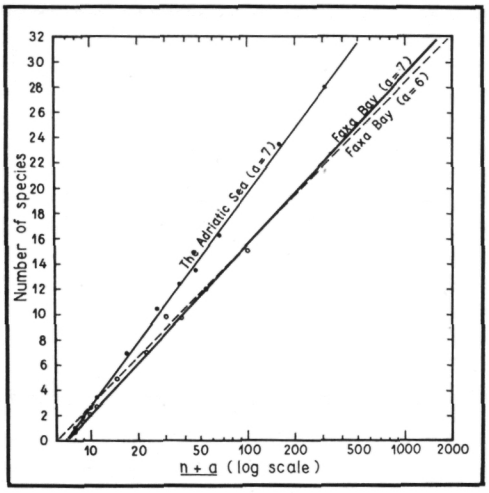

Fig. 71. The number of echinoderm species in the Adriatic Sea and Faxa Bay (Iceland), plotted against log $(n+7)$. The Faxa Bay observations are also plotted against log $(n+6)$ which may produce a better approach to a straight line. The log $(n+7)$ lines are directly comparable with each other.

The arctic samples originate from an area of approximately 300 km². On the assumption, that the line remains straight for high values of n it is found by extrapolation (Fig. 73) that 30 species of echinoderms should occur in the shallow water area of the Scoresby Sound fjord complex. Samples of the same size from the poor area and the rich area in the North Sea are supposed to produce 39 and 86 species, respectively.

VATOVA (1949) lists the contents of bottom samples from 390 stations in the Adriatic Sea. A single haul with the 0.2 m² PETERSEN sampler was taken on 306 stations in depths from 7 to 235 m. The mean number of species of echinoderms on various units of area is:—

1	sample,	0.96	species	20	samples,	10.40	species
2	samples,	1.82	–	30	–	12.40	–
3	–	2.58	–	40	–	13.43	–
4	–	3.32	–	60	–	16.20	–
10	–	6.83	–	153	–	23.50	–

306 samples, 28 species.

A straight line relationship is approached (Fig. 71) when the number of species is plotted against log $(n + 7)$. The necessity for the addition of 7 to the number of samples instead of 1 indicates

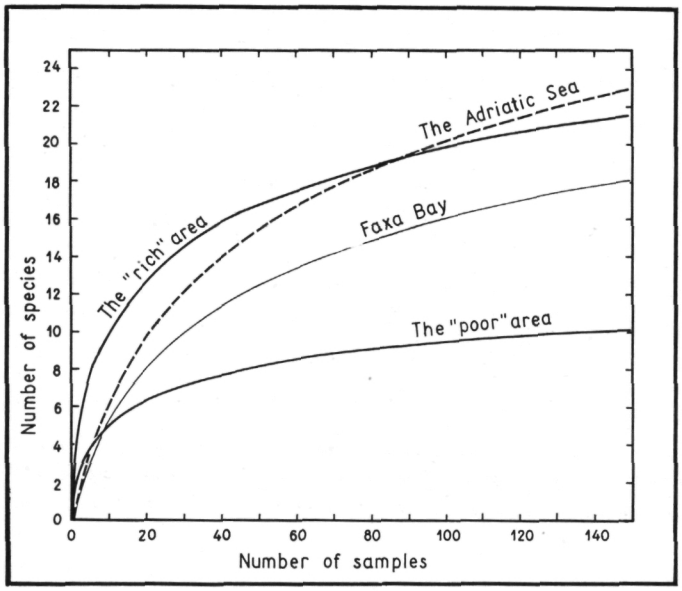

Fig. 72. Number of echinoderm species in four sea regions plotted against number of samples of 0.2 m² each. Note the intersection of the curves.

that the curve for the Adriatic rises slower for low values of n, but more rapidly for high values of n. As shown below (p. 135) the number of specimens per unit of area in the Adriatic is very

low as compared with the central North Sea. In the Adriatic the number of species in one sample is limited by the number of specimens in the sample. In the central North Sea there is often a large number of specimens in each sample.

Fig. 72 shows the number of species plotted against the number of samples (without the log transformation) for the Adriatic and for the rich area and the poor area in the North Sea. The curves are smoothed by transformation from the log scale straight lines on Figs. 65 and 71. When the number of samples from each of the three areas is below 4 sampling in the Adriatic Sea will produce fewer species than even the poor area in the North Sea. The number of species found in

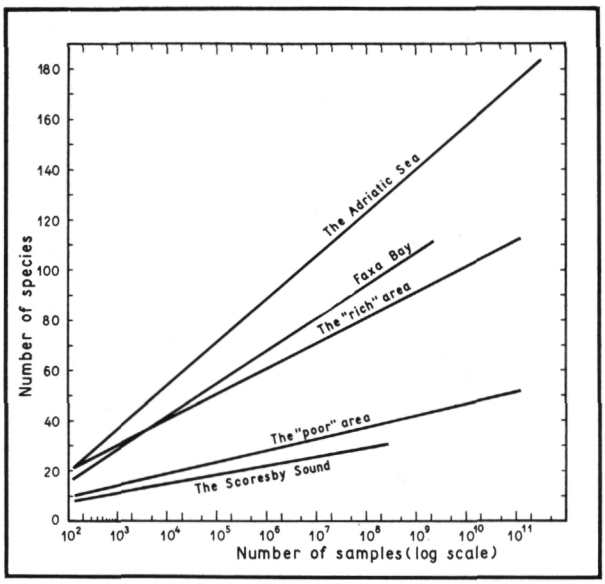

Fig. 73. Number of echinoderm species suggested to occur in various seas plotted against number of samples (log scale) of 0.2 m² each. Extrapolations from Figs. 65 and 71. See text.

the Adriatic remains lower than the number found in the rich area in the North Sea until 80 or 90 samples are obtained from each area. The area investigated by VATOVA covers approximately 63,000 km² or 315×10^9 samples. Extrapolation on the apparently straight line (Fig. 73) suggests the occurrence of 184 species of echinoderms in the Adriatic Sea. 125×10^9 samples correspond to the size of each of the selected areas in the North Sea. This number of samples should produce 177 species in the Adriatic, 112 species in the rich area in the North Sea and 52 species in the poor area in the North Sea.

SPÄRCK (1929) and EINARSSON (1941) give particulars for samples taken with the 0.2 m² PETERSEN grab in Faxa Bay, south-west Iceland. After omission of samples apparently not reasonably quantitative a set of 96 samples from depths between 6 and 166 m remains. The mean number of species of echinoderms on various units of area is:—

1 sample,	0.74	species		16 samples,	7.00	species	
2 samples,	1.46	–		24	–	9.75	–
3	–	2.03	–	32	–	9.67	–
4	–	2.71	–	48	–	12.00	–
8	–	4.83	–	96	–	15	–

A straight line relationship is approached when the number of species is plotted against log $(n + 7)$ or against log $(n + 6)$. Both lines are drawn on Fig. 71. The log $(n + 7)$ line is directly comparable with the corresponding line for the Adriatic Sea on the same figure. Faxa Bay seems to be rich in species although perhaps not as rich as the Adriatic Sea. Owing to a low density of specimens small collections will contain few species only. When less than 6 or perhaps 10 samples are available the number of species obtained in the Faxa Bay is lower than in the same number of samples from the central North Sea (cf. Fig. 72 which is based on the log $(n + 6)$ transformation). Until more than 2000—4000 samples become available from each area the number of species found in Faxa Bay probably remains below that found in the rich area in the North Sea (Fig. 73). Faxa Bay covers approximately 4600 km² or 23×10^9 samples. Extrapolation on the log $(n + 6)$ line (Fig. 73), which seems to be the better one, suggests the occurrence of 112 species of echinoderms in the bay.

Table 25.

No. of species of echinoderms suggested to occur within various regions of the sea. Cf. text.

	Area investigated (km²)	Suggested number of species		
		Within area investigated	On 4600 km²	On 300 km²
The Adriatic Sea	63,000	184	147	133
Faxa Bay	4,600	112	112	101
The rich area in the North Sea	24,300	112	95	86
The poor area in the North Sea	25,400	52	44	39
The Scoresby Sound fjord complex	300	30	—	30

Table 25 shows the number (taken from graph) of species occurring in the areas examined. The number supposed to occur within an area of the same size as Faxa Bay (4600 km²) and the shallow water region of the Scoresby Sound fjord complex (300 km²) is shown, too. Such calculations are valid only on the assumption that each region examined is uniform within its range. If it is not, the comparison should be based on random sampling within areas of the same size in each region. For instance, a comparison of the Scoresby Sound shallow water fauna with the fauna of other regions should preferably be based on random sampling within a selected area of 300 km² from each region. Fig. 68 (p. 111) discloses that the line representing the rich area in the North Sea probably rises too steeply owing to some heterogeneity of the area. The points indicating the total number of species obtained in the samples from each of the seven squares included in the rich area are, with a single exception, situated below the line. Lines representing individual squares would probably be situated below the line representing the seven squares together. If the lines representing other regions are biased in the same way the number of species in the smaller regions is under-estimated when, as in Table 25, the comparison is based on an area smaller than that from which the samples originated. The difference between the density of species in the Adriatic Sea and Faxa Bay may be due to such bias. The same is true for the difference between Scoresby Sound and the poor area in the North Sea.

Extrapolation beyond the size of the region investigated has no meaning. For instance, if the line representing the Adriatic is extrapolated to the size of the marine area of the world (approximately 10^{15} samples) 245 species in all are found. According to JENSENIUS MADSEN (1954

p. 31) the number of recent echinoderms known to science is about 6000. A line rising steeply enough to produce 6000 species in 10^{15} samples would require random sampling all over the marine area of the world or, more hypothetically, sampling within a limited area inhabited by a random selection of recent echinoderms.

Zoogeographical Analysis Based on Bottom Sampler Material.

Above (p. 96) was pointed to the subjectivity involved in the traditional method for zoogeographical analysis. It is difficult to distinguish objectively between species with a well-known distribution and species to be discarded as insufficiently known. The reference of individual species to zoogeographical zones like the Lusitanian-Boreal, Boreal, and Arctic-Boreal (cf. EKMAN 1953) may present difficulties, too. An attempt was made to develop a method which is not from the very beginning biased by the investigator's personal interpretation. Such a method may be based on comparison of fauna lists obtained in similar way in several localities.

For instance, in "the poor area" (cf. p. 106) in the southern North Sea 11 species of echinoderms were taken in the bottom samples available. A corresponding list of 11 species representing "the rich area" in the north-eastern North Sea is obtained when the species are listed as they appear in bottom samples arranged in random order. More than 11 species were taken in the samples from the rich area, but for the present purpose the list must be finished when 11 species are listed; the remaining samples are discarded. Similar lists of 11 species each may be obtained from the Adriatic Sea (VATOVA 1949) and from Faxa Bay in Iceland (EINARSSON 1948). The lists are given below. Names of species not listed from the poor area in the North Sea are printed in heavy type. The number of species in each list which are not listed from the poor area is indicated. Specific names are abbreviated, to save space; the full names are found in Table 20 (p. 96) or pp. 125—26.

The poor area	The rich area	The Adriatic Sea	Faxa Bay
A. fil.	*A. fil.*	***O. aran.***	*O. aff.*
O. alb.	*E. cord.*	***O. quin.***	*E. flav.*
E. cord.	*O. alb.*	***A. chi.***	*A. fil.*
E. pus.	*E. pus.*	*O. alb.*	*A. rub.*
A. rub.	*A. irr.*	***H. forsk.***	*O. alb.*
A. irr.	*A. brach.*	***L. dig.***	***S. droe.***
S. pur.	*E. flav.*	***A. aur.***	***A. sq.***
E. flav.	*O. frag.*	*O. frag.*	***O. acul.***
O. frag.	*S. pur.*	*A. fil.*	***B. lyr.***
O. aff.	*O. aff.*	***C. terg.***	***O. rob.***
A. brach.	***O. rob.***	***P. mem.***	***O. text.***
Not in the poor area:	1 species	8 species	6 species

A comparison shows that in the two North Sea areas the dominating species are essentially the same. The Adriatic and the Icelandic echinoderm fauna differ appreciably from the North Sea fauna. The method is seriously biased in one way, at least: it is necessary that the same species be given the same name in all lists. The deficiency of systematics affects the result. If, for instance, *Ophiocten sericeum* had been included in several of the lists above the result of the comparison depends upon the specific identity of forms referred to that species (cf. p. 66). Any zoogeographical method will be so biased.

Table 26.

Number of species represented in only one out of two sets of bottom samples containing 11 species each. Lists of species from various localities tested on series from four localities for which the species-area relationship is known (cf. text p. 120).

The fauna lists are found in Appendix 2.

Reference	Depth (m)	Locality	Test series																					
			The North Sea						Faxa Bay			The Adriatic Sea												
			The poor area	The rich area																				
				1	2	3	4	Av.	1	2	Av.	1	2	3	4	5	6	7	8	9	10	11	12	Av.
THORSON 1934	3–530	Scoresby Sound, E. Greenl.	11	10	11	11	11	10.8	10	10	10.0	11	11	11	11	11	11	11	11	11	11	11	11	11.0
IDELSON1930, BROTSKY1930	36–160	Spitsbergen	11	10	11	11	11	10.8	8	9	8.5	11	11	11	11	11	11	11	11	11	11	11	11	11.0
SPÄRCK 1929, EINARSSON 1941.	6–166	Faxa Bay, S.W. Iceland 1	6	6	6	7	6	6.2	—	3	—	9	9	9	9	8	9	9	9	9	9	9	10	9.0
— —	6–166	— — 2	8	7	7	8	8	7.5	3	—	—	9	9	9	9	9	9	9	9	9	10	9	10	9.2
SPÄRCK 1929	10–118	Faroe waters 1	6	7	7	7	6	6.8	5	7	6.0	8	9	9	8	8	8	9	9	8	9	9	9	8.6
—	115–270	— 2	7	7	7	7	7	7.0	7	8	7.5	10	10	10	10	10	10	10	10	10	11	10	11	10.2
STEPHEN 1923	42–190	Northern North Sea	3	3	4	3	4	3.5	6	8	7.0	9	9	9	9	8	9	9	9	9	9	9	10	9.0
The "Dana" 1950–55	58–125	F-K 13, H-K 14	4	4	3	4	4	3.8	6	6	6.0	9	9	8	9	9	9	9	9	9	10	9	10	9.1
—	45–82	C-D 10	4	3	6	4	6	4.8	5	6	5.5	8	9	9	8	9	8	9	9	8	10	9	9	8.8
—	54–81	D-E 7, E 8	4	4	6	5	6	5.2	7	8	7.5	9	10	10	9	10	9	10	10	9	10	10	9	9.6
—	25–49	H-M 7, L 8, L-M 9	1	2	3	2	3	2.5	6	8	7.0	9	9	8	7	8	7	9	8	7	10	9	9	8.3
—	31–48	L 10—11	2	—	—	—	—	—	7	8	7.5	9	9	8	7	8	7	9	8	7	10	9	9	8.3
—	24–40	L-M 12	3	—	—	—	—	—	7	8	7.5	8	8	8	7	9	7	8	9	7	9	9	8	8.1
—	27–68	J 10—11	1	—	—	—	—	—	5	8	6.5	8	9	8	8	8	8	9	9	8	9	9	9	8.5
—	30–79	F-H 10, F 9	2	2	3	2	3	2.5	6	7	6.5	8	9	8	8	9	8	9	9	8	10	9	9	8.7
—	17–79	F 7	2	2	2	3	3	2.5	7	8	7.5	9	9	8	7	8	7	9	8	7	10	9	9	8.3
—	32–54	K 10	2	3	2	3	3	2.8	5	7	6.0	9	9	8	7	8	7	9	8	7	10	9	9	8.3
—	31–57	K 11	3	—	—	—	—	—	5	6	5.5	9	9	8	7	8	7	9	8	7	10	9	9	8.3
—	24–66	G 9	2	3	4	4	3	3.5	5	7	6.0	8	9	9	8	9	8	9	9	8	10	9	9	8.8
—	17–49	The poor area	—	1	3	2	2	2.0	6	8	7.0	8	9	8	8	9	8	9	8	8	10	9	9	8.6

Danish res. ships, 1932–39	6–34	Horn's Reef	2	3	3	4	2	3.0	6	9	7.5	8	9	8	8	8	8	9	9	8	9	9	9	*8.5*
Petersen 1914	20–53	N.E. North Sea	2	3	3	3	2	2.8	5	8	6.5	9	9	8	9	8	9	9	9	9	9	9	10	8.9
Caspers 1939	30–60	Helgoländer tiefe Rinne	3	4	5	3	5	4.2	8	9	8.5	8	8	7	6	8	6	8	8	6	9	9	8	7.6
Petersen 1915	14–24	Kristiania (Oslo Fjord 1	5	5	3	5	5	4.5	7	8	7.5	8	8	7	7	7	7	8	7	7	9	8	9	7.7
—	24–150	— 2	5	5	4	5	6	5.0	7	8	7.5	8	9	8	8	9	8	8	9	9	8	9	8	8.4[1]
—	15–150	Skagerrak	6	6	4	6	6	5.5	5	7	6.0	8	8	8	7	6	7	8	7	7	8	8	9	7.6
Petersen 1914	24–75	E. Kattegat	6	5	4	6	6	5.2	5	5	5.0	8	8	7	7	7	7	8	7	7	9	8	9	7.7
—	5–53	Samsø Belt 1	5	5	6	6	5	5.5	2	5	3.5	9	9	9	9	8	9	9	9	9	9	9	10	9.0
—	18–40	— 2	6	6	7	7	6	6.5	3	5	4.0	9	9	9	9	8	9	9	9	9	9	9	10	9.0
—	20–42	Great Belt	7	7	8	8	7	7.5	5	6	5.5	10	10	10	10	10	10	10	10	10	11	10	11	10.2
—	14–31	The Sound 1	6	5	6	6	5	5.5	4	7	5.5	8	8	7	8	7	8	8	8	8	8	8	9	7.9
Danish Biol. St. 1920–38	4–41	— 2	5	5	6	6	5	5.5	4	7	5.5	8	8	8	8	7	8	8	8	8	8	8	9	8.0
Jones 1956	60–80	Irish Sea	5	5	4	5	5	4.8	5	6	5.5	8	8	8	8	8	8	8	8	8	9	8	9	8.2
Holme 1953	15–70	Plymouth outside waters 1	5	5	5	6	7	5.8	8	9	8.5	9	8	9	7	9	7	9	8	7	9	10	8	8.3
Ford 1923	15–70	— 2	3	4	6	4	5	4.8	7	9	8.0	8	9	8	8	8	8	9	9	8	8	9	8	8.3[2]
—	15–70	— 3	6	7	7	6	7	6.8	8	10	9.0	8	9	9	7	7	7	9	8	7	8	9	8	8.0[2]
Spärck 1931	9–150	Mediterranean Sea	9	9	7	8	9	8.2	9	9	9.0	7	5	5	4	5	5	5	5	4	5	7	6	5.2
Vatova 1949	7–235	Adriatic Sea 1	8	8	9	8	9	8.5	9	9	9.0	—	5	5	3	4	3	4	6	4	5	3	4	4.2
—		— 2	9	9	9	8	9	8.8	9	9	9.0	5	—	3	3	3	3	4	4	3	3	4	4	3.5
—		— 3	8	8	8	7	8	7.8	9	9	9.0	5	3	—	3	3	2	2	5	2	5	4	5	3.5
—		— 4	8	8	8	7	9	8.0	9	9	9.0	3	3	3	—	3	1	3	4	1	5	5	4	3.2
—		— 5	9	9	8	9	9	8.8	8	9	8.5	4	3	3	3	—	2	4	4	3	4	3	5	3.5
—		— 6	8	8	8	7	9	8.0	9	9	9.0	3	3	2	1	2	—	3	4	1	5	4	4	2.9
—		— 7	9	9	9	8	9	8.8	9	9	9.0	4	4	2	3	4	3	—	5	3	4	4	4	3.6
—		— 8	8	9	8	9	9	8.8	9	9	9.0	6	4	5	4	4	4	5	—	3	6	6	7	4.9
—		— 9	8	8	8	7	9	8.0	9	9	9.0	4	3	2	1	3	1	3	3	—	5	5	4	3.1
—		— 10	10	10	10	9	10	9.8	9	10	9.5	5	3	5	5	4	5	4	6	5	—	5	5	4.7
—		— 11	9	9	9	9	9	9.0	9	9	9.0	3	4	4	5	3	4	4	6	5	5	—	5	4.4
—		— 12	9	9	10	8	10	9.2	10	10	10.0	4	4	5	4	5	4	4	7	4	5	5	—	4.6

[1]) On the assumption that *"Cucumaria sp."* is not *C. elongata.*

[2]) On the assumption that Ford's unidentified *Synaptidae* are *Labidoplax digitata.*

Naturally, it is partly accidental which species will be among the first 11 species taken in bottom samples from a given area. Repeated sampling may produce another list of 11 species which is not identical with the first list. The method becomes more sensitive and gives more consistent results when several series from the same area are available. The mean number of samples necessary to produce 11 species of echinoderms can be seen on the graphs indicating the dependence of the number of species upon the area sampled (Fig. 65, p. 108 and Fig. 71, p. 114):—

The poor area:	212	samples	(0.2 m²	each)
The rich area:	14	–	-	-
The Adriatic Sea:	31	–	-	-
Faxa Bay:	44	–	-	-

The number of samples available from each area and the number of series of 11 species each which were, in practice, produced after randomization of the samples from each area are:—

The poor area:	232	samples,	1	series	of	11	species	
The rich area:	65	–	4	–	-	-	–	each
The Adriatic Sea:	306	–	12	–	-	-	–	-
Faxa Bay:	96	–	2	–	-	-	–	-

The fauna lists are given in Appendix 2. A test of all other series against the single series from the poor area gave the following result:—

The rich area (4 series):	a	mean	difference	of	2.0 species
The Adriatic Sea (12 series):	a	–	–	- 8.6	–
Faxa Bay (2 series):	a	–	–	- 7.0	–

For individual observations, see Table 26. Still, a good deal is left to accident because only one series is available from the poor area against which the other localities were tested. It is important, however, that not all series are equally reliable because they are not equally consistent. When the area investigated is very rich in species it cannot be expected that the same 11 species will appear first in successive investigations. When the area investigated is extremely poor in species there is a good chance that the more abundant forms will be represented in any fauna list from that area. The mean difference between two fauna lists of the same length from the same locality may be taken from the graphs on Figs. 65 and 71. In the poor area 11 species are produced in 212 samples, on an average. Two lists of 11 species each may be produced in $2 \times 212 = 424$ samples. The average number of different species expected to occur in 424 samples is 12.4 (Fig. 65). Thus, a second list of 11 species contains, on an average, $12.4–11.0 = 1.4$ species which did not enter the first list. The mean difference between fauna lists from the same area may be called the *basic difference*. The basic difference between lists of 11 species each from the rich area (still taken from graph) is 2.9 species. In the Adriatic it is 3.9 species and in Faxa Bay 3.5 species. The poor area in the central North Sea has the lowest basic difference of the areas examined. Fauna lists from the poor area will be more consistent and, therefore, more reliable than individual fauna lists from the other areas.

A difficulty in the interpretation of comparisons of fauna lists of the same length from two localities is that differences of the same order of magnitude as the basic difference in any of the two localities, or smaller, escape analysis. If, for instance, the difference between lists from two areas is, on an average, 4.0 species and it is known that the less consistent of the two lists (or sets of lists) has a basic difference of 4.5 species it is impossible to ascertain whether the species occur in essentially the same succession in the two localities. It is not known whether the species listed

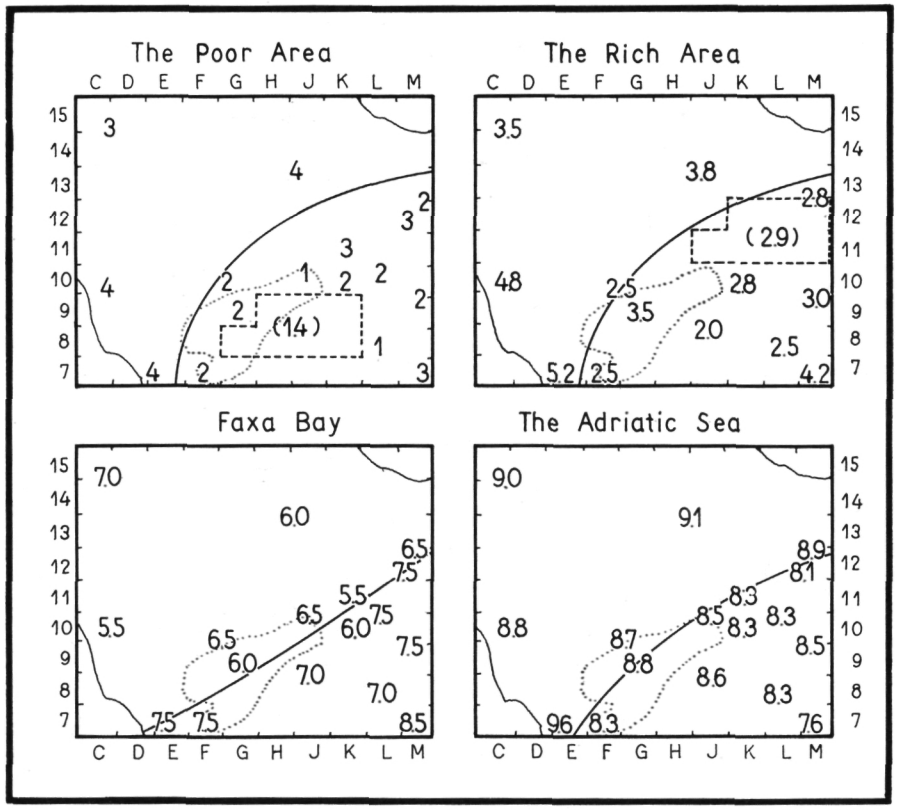

Fig. 74. The difference between the echinoderm fauna of various localities in the North Sea, and the fauna of the test localities. Based on comparison of lists of 11 species each. The numbers on the charts indicate the number of species that are not common to the test series and the local series tested. The test locality is indicated above each chart. Cf. Table 26.

from one locality only would be the next species to appear in samples from the other locality or whether it does not occur in that locality at all. The difficulty may be partly overcome by the use of test series from a locality so remote from other localities examined that the observed differences are well above the basic difference for any of the localities.

The practical application of the method described above is illustrated in Fig. 74. Lists of 11 species each, obtained by bottom sampling in various localities in the North Sea, are compared with the above mentioned test series: 1 from the poor area in the central North Sea (basic difference taken from graph, 1.4 species), 4 from the rich area in the north-eastern North Sea (bas. diff., 2.9 species), 2 from Faxa Bay in south-west Iceland (bas. diff., 3.5 species), and 12 from the Adriatic Sea (bas. diff., 3.9 species).

The comparison of other North Sea localities with the poor area shows small differences in the eastern and south-eastern North Sea and more conspicuous differences in the western and northern North Sea. On the chart, Fig. 74, upper left, a line roughly indicates the area within which small differences are observed. The mean difference within this area (12 observations), is 2.08 species. With 95 % confidence limits the range of the mean is 1.66—2.51 species. This is so little more than the basic difference (1.4 species) in the poor area that the observed differences may be accounted for by an only slightly higher basic difference in the localities tested. It should be remembered, namely, that the poor area was selected because of its scarcity in species which is indicated by the unusually low basic difference.

The comparison of North Sea localities with the rich area shows essentially the same features as the comparison with the poor area. The mean difference in the eastern and south-eastern North Sea (see Fig. 74) is 2.87 species which equals the basic difference in the rich area. Thus, the quantitative composition of the echinoderm fauna as indicated by the succession in which the species occur in bottom samples is much the same all over the southern and south-eastern North Sea. Minor differences, however, escape attention because they are covered by the basic difference. Again, the analysis fails to disclose whether the observed difference between the fauna in the south-eastern and the north-western North Sea is due to a difference in the quantitative composition of the fauna or to a particularly high basic difference in the north-western North Sea.

The comparison with the Faxa Bay series shows increasing difference from north-west to south-east in the North Sea. A decreasing difference from north-west to south-east is found in the comparison with test series from the Adriatic (Fig. 74), apparently to the effect that the echinoderm fauna of the inner (south-eastern) North Sea is of more southerly character than the fauna of the outer (north-western) North Sea. A similar result was arrived at in the non-quantitative zoogeographical analysis (p. 98).

Perhaps the richness in species is in the North Sea determined by the distribution of various water masses, particularly by the influence of *Sagitta elegans* water (the Helgoländer tiefe Rinne is rich in species, p. 112). Suppose, that the succession in which individual species appear is in the North Sea the same in samples from *elegans* water and *setosa* water. The more rare forms then must seem confined to localities influenced by *elegans* water because a reasonable number of samples from *setosa* water localities will produce few species except the most abundant ones. If southern species dominate the fauna quantitatively the northern forms will, in practice, be confined to *elegans* water localities, even if the temperature is exactly the same in the two water masses. The northern North Sea affinities of the Helgoländer tiefe Rinne may perhaps be accounted for in this way. They are, namely, indicated by the richness in species and by records of rare northern forms (p. 99).

There is no reason to believe that, as assumed above, the sequence in which the species of echinoderms appear in bottom samples is exactly the same all over the North Sea (see further next page). The true situation probably emerges from the comparison of the North Sea fauna with the Adriatic fauna and the Faxa Bay fauna (Fig. 74). The more south-easterly the locality sampled, the more prominent the position of the southern (Adriatic) fauna element. Accordingly, it becomes still more difficult to trace the northern forms so that there is but little chance that they are discovered except where *elegans* water, rich in species, occurs. Then we have the apparently contradictory situation that the Helgoländer tiefe Rinne has northern affinities because rare, northern forms are recorded, and southern affinities because the more abundant species are decidedly southern.

Another problem is why southern forms predominate in the southern North Sea. Perhaps they are favourably affected by the high summer temperatures, but are not too particular about the winter temperature that is low in most localities with high summer temperatures. Another possibility is that the Faxa Bay fauna is a selection of species adapted to life in the rich shore waters of the temperate Atlantic while the Adriatic fauna is a selection of species adapted to life in regions poor in nutriments. This would correspond to the distribution of rich and poor water in the North Sea except in the Helgoländer tiefe Rinne. The Rinne is supposed to be a rich locality, but the list of species from the Rinne is of decidedly Adriatic affinity. If the similarity of the single list from the Rinne and lists from the Adriatic is not due to accidents of sampling it indicates that temperature rather than food conditions produced the predominance of southern echinoderms in the southern North Sea.

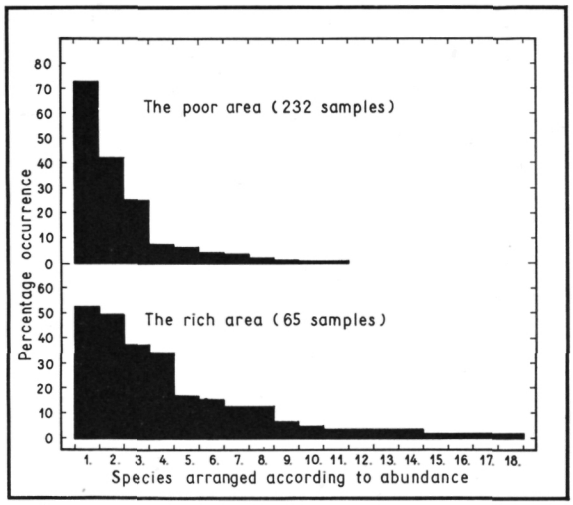

Fig. 75. Percentage of number of samples (0.2 m² each) in which each species of echinoderms occurred in the poor area in the southern North Sea and in the rich area in the northeastern North Sea. Species arranged and numbered according to abundance as in the lists below and on next page.

It is interesting to noce the negligible difference between the succession in which the species appear in the rich area in the north-eastern North Sea and in the poor area in the southern North Sea. Lists of, say, 20 species from each area would be almost identical. The point is, however, that while 20 species might be secured from the rich area by means of about 100 samples of 0.2 m² each there would be required about 20,000 samples from the poor area to secure a similar list (extrapolations on Fig. 65). In the poor area the abundant species are more abundant than in the rich area, and the rare species are more rare. This is illustrated in Fig. 75 and in the lists below which show the number of samples in which each species occurred:—

The poor area (232 samples)

Species no.	Name of species	No. of occurrences	Percentage occurrence observed	Percentage occurrence smoothed
1	*Echinocardium cordatum*	169	72.8	72
2	*Ophiura albida*	97	41.8	42
3	*Amphiura filiformis*	58	25.0	25
4	*Echinocyamus pusillus*	17	7.3	15
5	*Astropecten irregularis*	14	6.0	8.6
6	*Ophiura affinis*	9	3.9	5.0
7	*Echinocardium flavescens*	8	3.4	3.0
8	*Ophiothrix fragilis*	4	1.7	1.7
9	*Asterias rubens*	2	0.9	1.0
10	*Acrocnida brachiata*	1	0.4	0.6
11	*Spatangus purpureus*	1	0.4	0.4

The rich area (65 samples)

Species no.	Name of species	No. of occurrences	Percentage occurrence observed	Percentage occurrence smoothed
1	*Echinocardium cordatum*	34	52.3	59
2	*Amphiura filiformis*	32	49.2	47
3	*Ophiura albida*	24	36.9	36
4	*Echinocyamus pusillus*	22	33.8	28
5	*Echinocardium flavescens*	11	16.9	22
6	*Astropecten irregularis*	10	15.4	17
7	*Acrocnida brachiata*	8	12.3	14
8	*Ophiura affinis*	8	12.3	11
9	*Ophiothrix fragilis*	4	6.2	8.3
10	*Brissopsis lyrifera*	3	4.6	6.5
11	*Asterias rubens*	2	3.1	5.2
12	*Echinocardium pennatifidum*	2	3.1	4.0
13	*Cucumaria elongata*	2	3.1	3.1
14	*Spatangus purpureus*	2	3.1	2.5
15	*Ophiura robusta*	1	1.5	1.9
16	*Thyone fusus*	1	1.5	1.5
17	*Thyonidium commune*	1	1.5	1.2
18	*Luidia sarsi*	1	1.5	0.9

The smoothed percentages are graph readings on Fig. 76 in which the observed percentages are plotted on a log scale. The application of logarithms produced an approximately straight line relationship between the abundance of individual species.

Some rather queer effects of the relationship between "abundant" and "rare" species in the two areas may be mentioned. It is difficult to say which differences between the two lists are significant so far as the sequence of the species is concerned. It was found above that the difference is generally inconspicuous. On this assumption it is evident that, as mentioned above, any "rare" species (say, species no. 10) must appear as a northern North Sea form because the more rare species occur in a higher percentage of the hauls in the rich area than in the poor area. If, on the other hand, there is evidence that a "rare" species is more abundant in the southern North Sea than in the northern North Sea (e. g., *Psammechinus miliaris*, p. 66), that species must occupy a different position in the sequence of species in the two areas. Another implication of the observations on the relative abundance of species is that the most abundant echinoderm in both areas (*Echinocardium cordatum*) must appear as a southern North Sea form because the maximum abundance in the southern North Sea is higher than in the northern

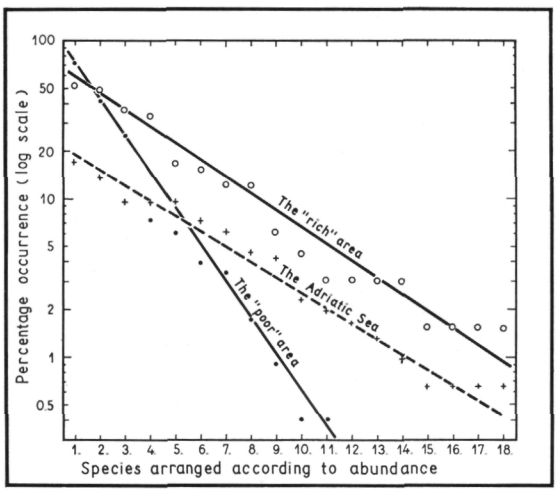

Fig. 76. Percentage of total number of samples in which each species of echinoderms occur. Percentages plotted on a log scale. Cf. Fig. 75. On the Adriatic Sea, see next page.

North Sea. Apparently, the quantitative distribution of a given species may be subject to analysis from two entirely different points of view. The analysis may concern the number (or weight) of specimens per unit of area. In that case few species of echinoderms are equally abundant in the north-eastern North Sea and the central North Sea. If the analysis concerns the position of the species in the fauna, i. e., which species it dominates quantitatively and which species it is dominated by, the distribution in the two areas usually will be the same. The method for zoogeographical analysis outlined above was described as quantitative. It is necessary to point out, that the method is quantitative only so far as the sequence of species is concerned.

When (p. 102) the changes in the distribution of echinoderms in the North Sea in the present century was discussed it was found difficult to correlate the observed changes with the simultaneous temperature increase. There was rather a tendency that the most abundant species in the central and southern North Sea became still more abundant while the more rare species became still more rare. The observation points to a decrease in the number of species occurring in the central and southern North Sea rather than to a significant change in the sequence in which the species occur when arranged according to abundance. In the present paper it is suggested repeatedly that the richness in species in the North Sea is determined particularly by the influence of *Sagitta elegans* water, whatever that influence may be. Localities rich in species are those strongly influenced by *Sagitta elegans* waters. Localities poor in species are those influenced by *Sagitta setosa* water. If this is true the changes in the distribution of echinoderms indicate a decrease in the influence of *Sagitta elegans* water in the central and southern North Sea in the present century. Such decrease in the *elegans* influence in the English Channel was observed by previous authors (cf. p. 18 in the present paper).

On Fig. 76 is plotted not only the percentage occurrence of each species in the two parts of the North Sea, but also the percentage occurrence in the Adriatic, based on 306 samples of 0.2 m² each, published by VATOVA (1949). These samples contained 28 species:—

Species no.	Name of species	Occurrences	
		No.	pCt. (obs.)
1	*Labidoplax digitata*	52	17.0
2	*Amphiura chiajei*	42	13.7
3	*Ophiopsila aranea*	29	9.5
4	*Amphiura filiformis*	29	9.5
5	*Schizaster canaliferus*	29	9.5
6	*Ophiura albida*	22	7.2
7	*Ophiothrix quinquemaculata*	19	6.2
8	*Thyone fusus*	14	4.6
9	*Cucumaria elongata*	13	4.2
10	*Echinocardium mediterraneum*	7	2.3
11	*Holothuria forskåli*	6	2.0
12	*Ophiothrix fragilis*	5	1.6
13	*Cucumaria tergestina*	4	1.3
14	*Astropecten aurantiacus*	3	1.0
15	*Palmipes membranaceus*	2	0.7
16	*Astropecten irregularis*	2	0.7
17	*Ophiura texturata*	2	0.7
18	*Psammechinus microtuberculatus*	2	0.7

(continued)

Species no.	Name of species	Occurrences	
		No.	pCt. (obs.)
19	*Thyone raphanus*	2	0.7
20	*Asterina gibbosa*	1	0.3
21	*Astropecten bispinosus*	1	0.3
22	*Ophiomyxa pentagona*	1	0.3
23	*Thyone inermis*	1	0.3
24	*Phyllophorus urna*	1	0.3
25	*Stichopus regalis*	1	0.3
26	*Leptosynapta galliennei*	1	0.3
27	*Antedon mediterranea*	1	0.3
28	*Leptometra phalangium*	1	0.3

The most characteristic feature of the echinoderm fauna of the Adriatic as compared with that of the North Sea is the absence of strongly dominating forms. The tendency was evident already when the rich area and the poor area in the North Sea were compared with each other: the richer in species, the less dominating are the most abundant forms. The complications involved when samples of faunas rich in species are referred to animal communities like PETERSEN's (1918, etc.) are discussed below, p. 141.

Above, no attention was paid to differences in the composition of the fauna of various grades of soil. The number of species found in each grade of soil in the rich area in the north-eastern North Sea and in the poor area in the southern North Sea is so small that comparisons must be based on few species only. The material from the rich area (65 samples) was divided into 9 lists of 8 species each, namely, one from clayey coarse sand (clcos), two from coarse sand (cos 1 and cos 2), 1 from fine sand (fs), two from muddy sand (ms 1 and ms 2), one from clayey sand (cls) and two from sandy clay (scl 1 and scl 2). ms 1 and ms 2 served for test series. The basic difference for each grade of soil was taken from graph (Fig. 67, p. 110) as described above, p. 120. In individual comparisons the following differences (no. of species) were found:—

List	clcos	cos 1	cos 2	fs	ms 1	ms 2	cls	scl 1	scl 2
ms 1	2	3	3	2	–	3	2	4	3
ms 2	1	3	2	1	3	–	2	5	5
Mean difference	1.5	3.0	2.5	1.5	–	–	2.0	4.5	4.0
Basic difference	2.4	2.3	2.3	2.5	2.5	2.5	2.8	2.8	2.8

The significance of the rather conspicuous difference between series from muddy sand and sandy clay cannot be proved. By random selection of one series from each kind of bottom deposit six independent observations of the difference between different grades of soil are obtained. By the ms 1 test (in which scl 2 and cos 1 were omitted) the mean difference is 2.5 species. The test on ms 2 (omitting scl 1 and cos 2) produced a mean difference of 2.3 species. Both values are of the same order of magnitude as the basic difference and, therefore, escape analysis. Tests based on longer fauna lists would be more sensitive because the basic difference increases only slightly with the number of species listed. For instance, on clayey sand in the rich area the basic difference (taken from graph) corresponding to fauna lists of various length is as follows:—

No. of species listed	Mean no. of samples involved	Basic difference	Bas. diff. in % of no. of species listed
4	1.2	2.1	52
8	4.1	2.8	35
15	20.5	3.1	21
25	168	3.4	14

In the poor area the number of species found on each grade of soil is so small that comparisons must based on lists of six species only. The disadvantage is compensated for by a low basic difference. For clayey sand the basic difference is 1.4 species or 23 % of the number of species listed. A comparison of lists of 6 species each from the poor area is as efficient as a comparison of lists of about 15 species from the rich area. Each list from the poor area was tested on five lists from muddy sand in that area:—

List:	fs 1	fs 2	cls	scl	ms 1	ms 2	ms 3	ms 4	ms 5
ms 1	1	2	1	2	–	1	1	1	1
ms 2	2	2	1	3	1	–	2	0	1
ms 3	1	2	1	1	1	2	–	2	2
ms 4	2	2	1	3	1	0	2	–	1
ms 5	2	1	2	3	1	1	2	1	–
Mean difference . . .	1.6	1.8	1.2	2.4	1.0	0.8	1.8	1.0	1.2
Basic difference	1.0	1.0	1.4	2.4	1.3	1.3	1.3	1.3	1.3

The comparison of muddy sand lists with each other produces another estimate of the basic difference for muddy sand. The comparison with other grades of soil did not reveal differences significantly above the respective basic differences. With 95 % confidence limits of the mean the difference between muddy sand lists and fine sand lists is 1.60 ± 0.72 (the fs 1 comparison) or 1.80 ± 0.57 (the fs 2 comparison). A larger material might disclose differences significantly above the basic difference for both grades of soil.

Apparently, the composition of the echinoderm fauna on various grades of soil is uniform to such an extent that no great harm is done when samples from all grades of soil are pooled before fauna lists are prepared. Even conspicuous differences as, for instance, between PETERSEN's animal communities in Danish waters may escape attention when the present method of analysis is used. When the species are few, as in the southern North Sea where very few species are abundant, there will be an obvious difference to the observer between two localities when a species which is the most abundant in one locality is no. 3 or no. 4 in the other locality. The fauna lists, however, may be almost identical in the two localities.

The difference between the North Sea fauna and the fauna of the transitional area between the North Sea and the Baltic is shown in Fig. 77. The comparison is based on fauna lists derived from PETERSEN's publications and from unpublished material collected by the Danish Biological Station in the years 1920—1938. The lists are reproduced in Appendix 2. The comparisons are summarized in Table 26, p. 118. The basic difference is not known.

A comparison of transitional area lists with the list from the poor area in the North Sea and with the four lists from the rich area in the North Sea indicates a considerable difference between the echinoderm fauna of the North Sea and the transitional area. The difference increases as the Baltic is approached. A test of the transitional area lists against two lists from Faxa Bay in Iceland reveals a marked similarity in the sequence of species in the two areas. In the

Belt Sea the basic difference for Faxa Bay is even approached. Previously PETERSEN (1893 p. 52) pointed to the predominance of northern species of echinoderms in the south-western Kattegat. He ascribed this occurrence to temperature conditions. BRATTSTRÖM (1941 p. 293) found it difficult to prove the hydrographical background for the predominance of a northern fauna element in the deeper, more saline, water layers in the transitional area. Nevertheless

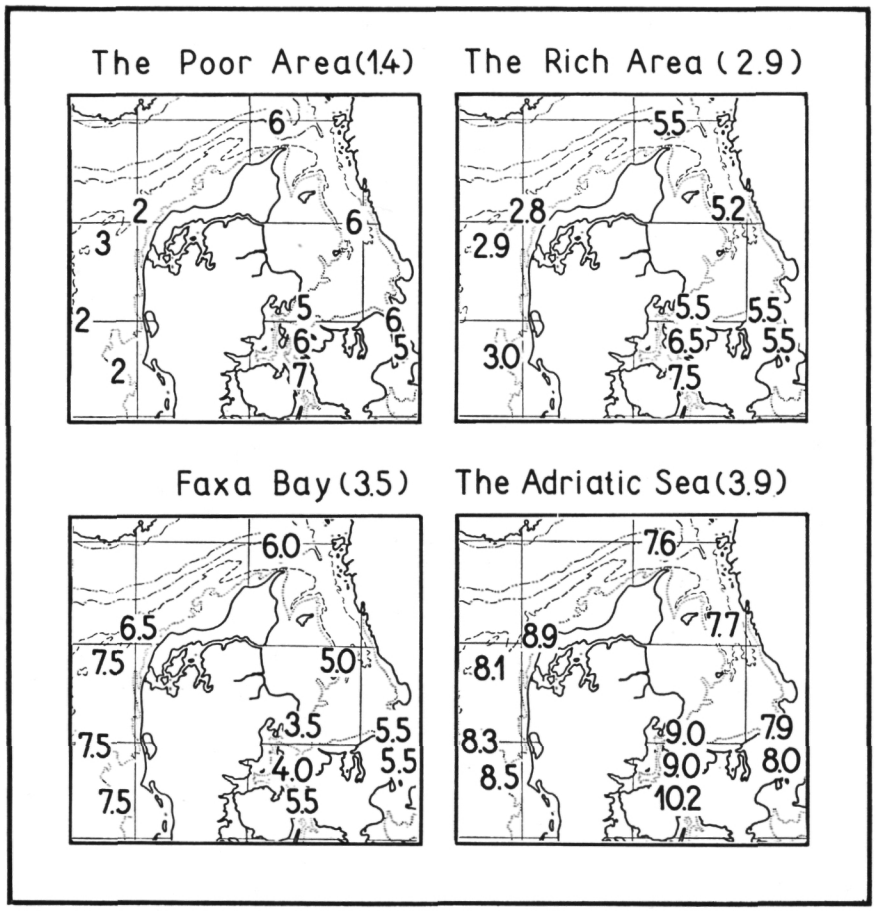

Fig. 77. Test of the difference between the composition of the echinoderm fauna of Danish waters and of other seas. The basic difference in the test series is indicated. From Table 26.

BRATTSTRÖM, too (l. c. p. 314), demonstrated an increase of northern forms in the direction toward the Baltic, particularly in the Great Belt. According to his opinion (l. c. p. 277) the high amount of detritus transported through the Sound and the Belt Sea from the Baltic produces extraordinarily good conditions of nourishment to many species, suspension feeders as well as deposit feeders. Detritus, i. e., particles in an early stage of decomposition, perhaps forms only a part of the extraordinary gathering of nutritive matter in the transitional area. Suspensed organic and inorganic matter may be important to the production of bacteria, phytoplankton, and bottom dwelling diatoms.

At present it is difficult to say which species of echinoderms flourish in the Belt Sea owing to the existence of temperature conditions favourable to northern forms, and which flourish owing to the specialized conditions of nourishment. Perhaps a higher proportion of rheophile,

comparatively euryhaline species with a high metabolic rate occurs in the shelf reegion of the North Atlantic than in more southern Seas. This might be due to the high production of phytoplankton in boreal seas and, so far as euryhalinity is concerned, to the large outflow of fresh water. Species occurring in the Mediterranean are more likely to be adapted to poor conditions of nourishment and to consistently high salinity. Similar reasons for the greater similarity of the Faxa Bay fauna to the northern North Sea fauna than to the southern North Sea fauna were suggested above (p. 123). The hypothesis was rejected, however, because available evidence (which may or may not be satisfactory) rather points to summer temperature as the factor determining the balance between northern and southern forms among the abundant species. As to the transitional area it seems more reasonable to retain the hypothesis owing to the evidence gathered by BRATTSTRÖM (quoted above) to the effect that it is more difficult to prove a correlation between temperature and predominance of northern (temperate Atlantic) fauna elements than between conditions of nourishment and such predominance.

Below is summarized the result of a comparison of the North Sea with more remote waters (based on Appendix 2 and Table 26). As usual, the numbers indicate the difference between lists of 11 species each:—

Area tested	No. of lists tested	No. of species different: Test against 1 list from the poor area in the North Sea:	No. of species different: Test against 4 lists from the rich area in the North Sea:
East Greenland—Spitsbergen	2	11.0	10.8
Faxa Bay—the Faroes	4	6.8	6.9
The North Sea	16—13	2.5	3.3
The Kattegat and the Belt Sea	9	5.7	5.6
The Irish Sea	1	5	4.8
Plymouth	3	4.7	5.8
The Mediterranean-Adriatic	13	8.6	8.6

Area tested	No. of lists tested	Test against 2 lists from Faxa Bay, Iceland:
East Greenland—Spitsbergen	2	9.2
The Faroes	2	6.8
The North Sea	17	6.8
The Kattegat and the Belt Sea	9	5.6
The Irish Sea	1	5.5
Plymouth	3	8.5
The Mediterranean-Adriatic	13	9.1

Area tested	No. of lists tested	Test against 12 lists from the Adriatic Sea:
East Greenland—Spitsbergen	2	11.0
Faxa Bay—the Faroes	4	9.2
The North Sea	17	8.6
The Kattegat and the Belt Sea	9	8.4
The Irish Sea	1	8.2
Plymouth	3	8.2
The Mediterranean	1	5.2
The Adriatic	12	3.8

As in previous cases the result is approximately the same when the comparison is based on the list from the poor area in the southern North Sea as when it is based on the four lists from the rich area in the north-eastern North Sea. The echinoderm fauna of the southern and north-eastern North Sea seems to be fairly specialized and uniform. The differences rapidly increases as soon as the comparison is based on lists from localities outside the North Sea. The affinity of the North Sea fauna with the Mediterranean (Adriatic) fauna is greater than with the arctic fauna. The same was found in the non-quantitative analysis (Table 21, p. 99). A fauna almost intermediate between the Mediterranean and the arctic apparently is found in Faxa Bay;

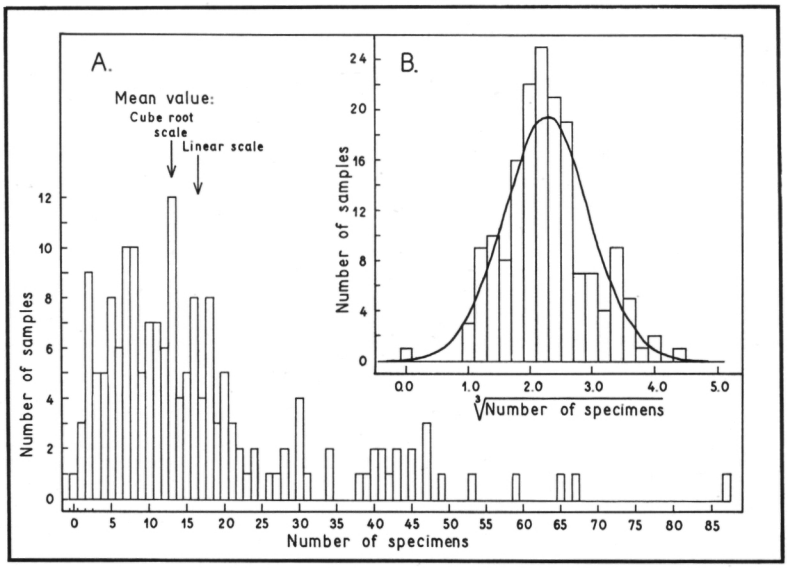

Fig. 78. Number of specimens (echinoderms) plotted against number of samples (0.2 m² each) on a linear scale (A) and on a cube root scale (B). The displacement of the cube root mean as compared with the arithmetic mean is indicated.

differences of 9.1 species and 9.2 species, respectively, were found in the tests based on Faxa Bay series. The similarity of the Faxa Bay lists with the list from the Irish Sea is striking although its significance cannot be proved. Again, the predominance of a temperate Atlantic element rather than of a decidedly northern element seems to be the more likely interpretation. The list from the Irish Sea and the two lists from the arctic have no species in common (Appendix 2).

Number of Specimens per Unit of Area.

It was shown on page 5 that when all species of echinoderms are pooled the dependence of the number of specimens caught upon the volume of the bottom sample is negligible. The skew distribution of the observations already referred to (p. 7) is illustrated diagrammatically in Fig. 78 A. The diagram is based on the same 170 samples from soft bottom in the eastern and southern North Sea which were used in Figs. 4 and 5. The majority of the observations are concentrated within the range of 2—20 specimens per sample, but samples with up to 87 specimens occur. Under such conditions it is difficult to compare in a sound way the results of various investigations or of parts of the same investigation. In the present case, however, the original function is almost normalized when the number of specimens is plotted on a cube root scale

instead of the linear scale used in Fig. 78 A. The transformed distribution is shown in Fig. 78 B. The smooth curve indicates the true normal distribution with the same mean and the same standard deviation as the observed approach. The mean number per sample estimated from the linear function is 16.55 specimens. The mean of the transformed function is 2.356, the cube of which gives 13.07 specimens per sample. The mean in the transformed distribution corresponds to the median in the original distribution. The mean and mode in the original distribution may be derived from the mean and mode of the transformed distribution. The same methods as employed by HALD (1952 p. 165) in the analogous derivation of mean and mode in the logarithmic normal distribution give:—

$$\text{the mean} = m^3 + 3\,s^2 m$$

$$\text{the mode} = \left(\frac{m}{2} + \sqrt{\frac{m^2}{4} - 2\,s^2}\right)^3$$

Where m and s are the mean and variance in the cube root transformation. The mode is not real when $m^2 \geq 8\,s^2$. The computations relating to the material considered show as follows:—

	Original distribution (raw data)	Transformed distribution
Mean	16.553	2.3557
Variance . . .	20.851	0.4859

Information on the original distribution, estimated from the parameters of the transformed distribution is so derived:—

$$\text{the mode} = \left(\frac{2.3557}{2} + \sqrt{\frac{2.3557^2}{4} - 2 \times 0.4859}\right)^3 = 6.05$$

$$\text{the median} = 2.3557^3 = 13.07$$

$$\text{the mean} = 2.3557^3 + 3 \times 0.4859 \times 2.3557 = 17.50.$$

The two estimates of the mean number per sample (16.55 and 17.50) differ from each other. Perhaps the higher estimate should be preferred because it is based on the parameters of an approximately normal distribution.

By means of the transformation it has been possible to obtain three valuable pieces of information on the number of specimens per unit of area: the most frequent observation (the mode), the observation with 50 % prohability in the cumulative distribution (the median) and the mean. Another advantage of the transformation is the resulting reduction of the variance. The advantage to this effect of the transformed function over the original one is illustrated in the following example:—

Suppose that an estimate of the abundance of echinoderms in a given area is required for comparison with other areas. If an estimate with a standard deviation (s_m) of the mean (m) equal to 5 % of the mean is considered sufficient it is found in the case already referred to:—

$$s_m = 0.05\,m$$

Original function:

$m = 16.553 \qquad s = 14.44$

$s = 0.8723\,m$

$$n = \left(\frac{s}{s_m}\right)^2 = \left(\frac{0.8723\,m}{0.05\,m}\right)^2 = 304$$

Transformed function:

$m = 2.3557 \qquad s = 0.6971$

$s = 0.2959\,m$

$$n = \left(\frac{s}{s_m}\right)^2 = \left(\frac{0.2959\,m}{0.05\,m}\right)^2 = 35$$

The required reliability of the estimate of the abundance of echinoderms is obtained by means of 304 samples if the raw data are used. If the transformation is adopted 35 samples will suffice provided, that a cube root transformation normalizes the original function in all areas considered. This is difficult to ascertain when few samples are available. On the other hand, the comparison of the raw data is biased by the application of the usual t test (for normal distributions with significantly different variances (s^2)) to markedly skew distributions.

In the treatment of the present material it is important whether all bottom samples collected in April and May 1950—55 may safely be pooled or whether each year should be considered separately. An examination of stations operated at the same positions in two or several years in succession may elucidate the problem.

120 stations operated in 1951 were operated again in 1952 (cf. Fig. 1, p. 4). 1479 echinoderms were collected in 1951 and 1710 in 1952. The mean number per sample was 12.35 in 1951 and 14.25 in 1952. The difference is too small to be important, particularly, because in 1952 a single sample accounted for 135 specimens or more than half the difference between the two years. The stations compared were well distributed over the area investigated. It may be taken for granted that the density of echinoderms did not change appreciably from 1951 to 1952.

29 stations were operated at fixed positions on the eastern part of the Dogger Bank in each of the years 1950—54 (cf. Fig. 1). The total number of echinoderms was:—

1950	1951	1952	1953	1954
204	255	310	166	178

The raw data give little information about the significance of the observed differences, because the number of observations is small and the standard deviation of single observations high. The mean number of echinoderms per sample and the variance are:—

Year	m	s^2
1950	7.035	120.68
1951	8.793	77.814
1952	10.690	113.36
1953	5.724	26.278
1954	6.138	47.692

A cube root transformation gives:—

1950	1.452	0.9024
1951	1.656	0.9945
1952	1.848	0.9090
1953	1.602	0.3843
1954	1.556	0.5565

A χ^2 test indicated that the cube root transformation stabilized the variance sufficiently ($\chi^2 = 8.391$; $f = 4$). The difference between the mean values in the transformed function is not significant ($v^2 = \frac{s_1^2}{s_2^2} = 1.621$; $f_1 = 140$; $f_2 = 4$). Thus, the median in the original distribution did not differ significantly from one year to another. In other words, in each of the five years the observations were distributed with about 50 % above a fixed number, and 50 % below that number.

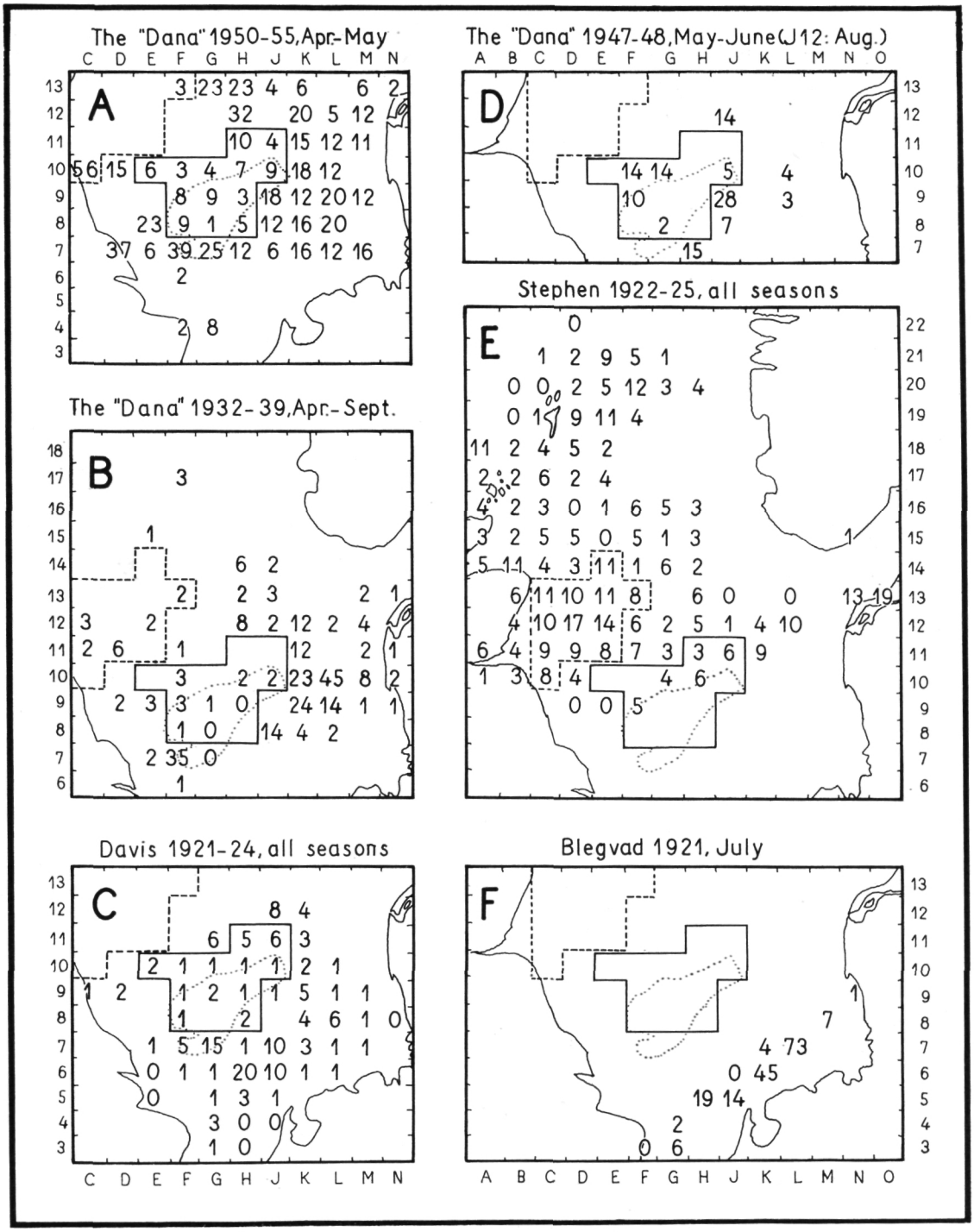

Fig. 79. Mean number of specimens (echinoderms) in each square as observed in various grab surveys. A full line frames the sparsely populated area mentioned next page. The area where STEPHEN observed a high abundance of echinoderms is framed by a broken line.

The combined evidence of the 120 stations scattered over a large area in 1951 and 1952 and the 29 stations operated on the eastern Dogger Bank in each of the years 1950—54 is that probably no appreciable change in the density of total echinoderms occurred within the area investigated in post-war years. All samples collected in April and May 1950—54 probably may safely be pooled. Without further evidence the few samples collected in 1955 are pooled with the rest of the material.

Local variation in the abundance of echinoderms in the North Sea is perhaps best illustrated by the average number per sample (0.2 m²) in each statistical square. The material from 1950—55 is presented in Fig. 79A. The cube root transformation is not adopted because its validity is proved for the central North Sea only. In many squares 10—20 specimens per sample were obtained. Densities of 10 per sample or less are found mainly on the Dogger Bank and in the somewhat deeper water off the northern edge of the Bank. This sparsely populated area is indicated on the chart.

A similar distribution is observed in the material from 1932—39, collected from April to September (Fig. 79B), and in Davis's material from 1921—24 (Fig. 79C). The Dogger Bank and the area immediately north of the bank seems to be consistently poor in echinoderms when these are counted by numbers.

Stephen (1934) in 1922—25 found a particularly high abundance of echinoderms within a large area off the Scottish coast (Fig. 79E). Scattered sampling in 1932—39 (Fig. 79B) did not reproduce Stephen's results. Stephen's sampling apparently was carried out in all seasons of the year. It is difficult to say to which extent local variation in abundance is overshadowed by seasonal variation.

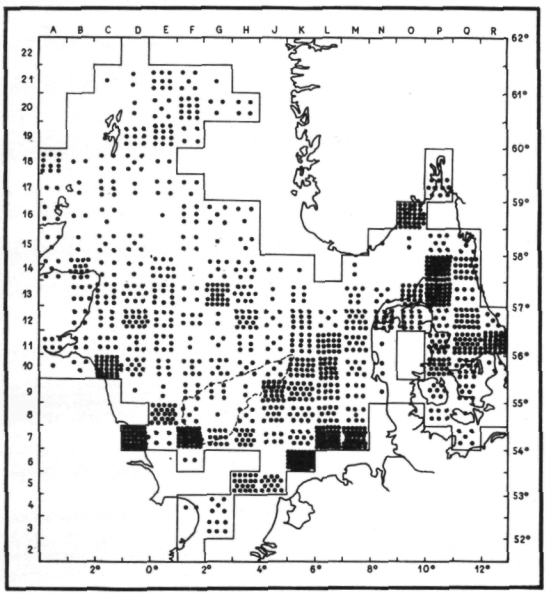

Fig. 80. The number of specimens (echinoderms) per 0.2 m², calculated for each statistical square in the North Sea and the transitional area between the North Sea and the Baltic. Based on the present grab material and on previous investigations exept Davis (1923, 1925). Each dot stands for one specimen per 0.2 m² in the square. Squares from which no material is avaiable are framed.

The German Bight seems particularly rich in echinoderms. This is apparent from the results obtained by Davis in 1921—24 (Fig. 79C), by Blegvad in 1921 (Fig. 79F), and by the "Dana" in 1932—39 (Fig. 79B) and 1950—55 (Fig. 79A). Also Caspers (1939, 1950) found high densities of echinoderms in the German Bight, namely (per 0.2 m²), 28 on the Helgoländer Austernbank in August—October 1938 and 99 in the Helgoländer tiefe Rinne in April 1937. In the tiefe Rinne the average for the year was 94 in 1936—37. Hagmeier (1925) found 14 per 0.2 m² as an average for the whole area investigated (LMN 8—9, KLMN 6—7). The density apparently decreased from about 60 to about 5 as the shore was approached.

The tidal zone and the first few metres below low water mark seem to be extremely poor in echinoderms in the southern North Sea (Hagmeier and Kändler 1927, Smidt 1951, Mistakidis 1951). The density apparently not exceeds 1 per 0.2 m².

For comparison with the density of echinoderm larvae Marshall (1948) and Rees (1954)

charted the density of echinoderms on the sea bottom. The charts were based primarily on STEPHEN's and DAVIS's investigations. It was suggested above (p. 20) that DAVIS's results are not entirely reliable. Therefore, a new issue of the chart is given in Fig. 80. It is based on Fig. 79 A, B, D, E, and F and on PETERSEN (1914, 1915), CASPERS (1939, 1950) and MISTAKIDIS (1951). On the whole, the highest densities are found in the Kattegat and in the south-eastern North Sea. The lowest densities were observed in the deepest part of the Skagerrak and the North Sea. The value of the chart is rather problematic, however, because the investigations are probably not equally reliable, and owing to seasonal variation of the abundance. It may also be suspected that the sieve mesh was not the same in all investigations. HOLME (1953 p. 20) and JÓNASSON (1955) pointed to the importance of the mesh to the number of specimens obtained.

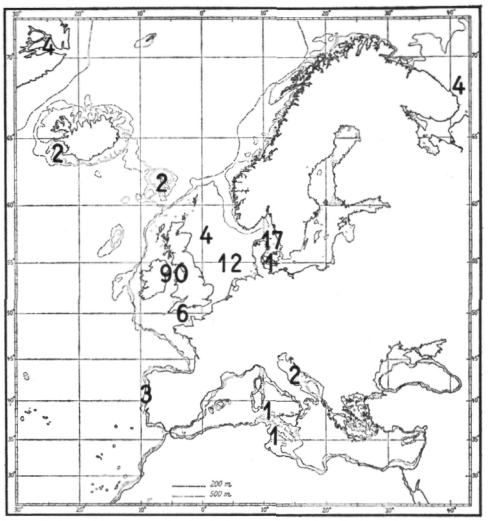

Fig. 81. Number of specimens (echinoderms) on 0.2 m² of sea bottom, as observed in various grab surveys. See also Table 27.

The samples from April and May 1950—55 produced 11.5 specimens (echinoderms) per sample, on an average. Table 27 and Fig. 81 show, for comparison, the densities found in grab surveys in other parts of Europe and in the arctic. In most places densities of 2—4 specimens per 0.2 m² were found. Outside the North Sea—Kattegat area high densities were obtained on the Spitsbergen Bank (IDELSON 1930) and in the Irish Sea (JONES 1952, 1956). The high value for the Irish Sea (90 per 0.2 m²) is perhaps not entirely reliable. The majority of the samples were taken within 35 square miles on the Cumberland coast where *Amphiura filiformis* occurred in enormous quantities.

Table 27.

No. of specimens (echinoderms only) per 0.2 m² in various localities outside the North Sea.

Reference	Locality	Depth (m)	Area sampled (m²)	No. per 0.2 m²
VIBE 1939	NW. Greenland	8–64	4.5	2.9
THORSON 1933	Franz Joseph Fjord, E. Greenland	2–60	15.1	5.6
— 1934	Scoresby Sound, E. Greenland	9–92	19.3	3.6
BERTELSEN 1937	SE. Greenland	5–235	0.8	1.2
ZENKEWITSCH 1927, 1930	Barents and White Seas	8–270	4.8	4.3
IDELSON 1930	Spitsbergen Bank	20–90	2.3	35.7
EINARSSON 1941	Faxa Bay, Iceland	27–165	14.2	2.5
SPÄRCK 1929	Faroe waters	10–115	12.4	2.3
JONES 1952, 1956	Irish Sea	10–80	22.7	90.0
FORD 1923, HOLME 1953	Off Plymouth	9–70	43.8	5.7
SPÄRCK 1931	Off Portugal	11–108	1.8	2.6
— —	Western Mediterranean	9–150	6.6	0.8
BRUUN 1940	Coast of Tunis	2–13	1.9	0.7
VATOVA 1949	Adriatic Sea	6–235	61.2	1.7
WIRSZUBSKI 1953	Coast of Israel	18–135	42.0	0.6–14.1[1]

[1]) Various grades of soil.

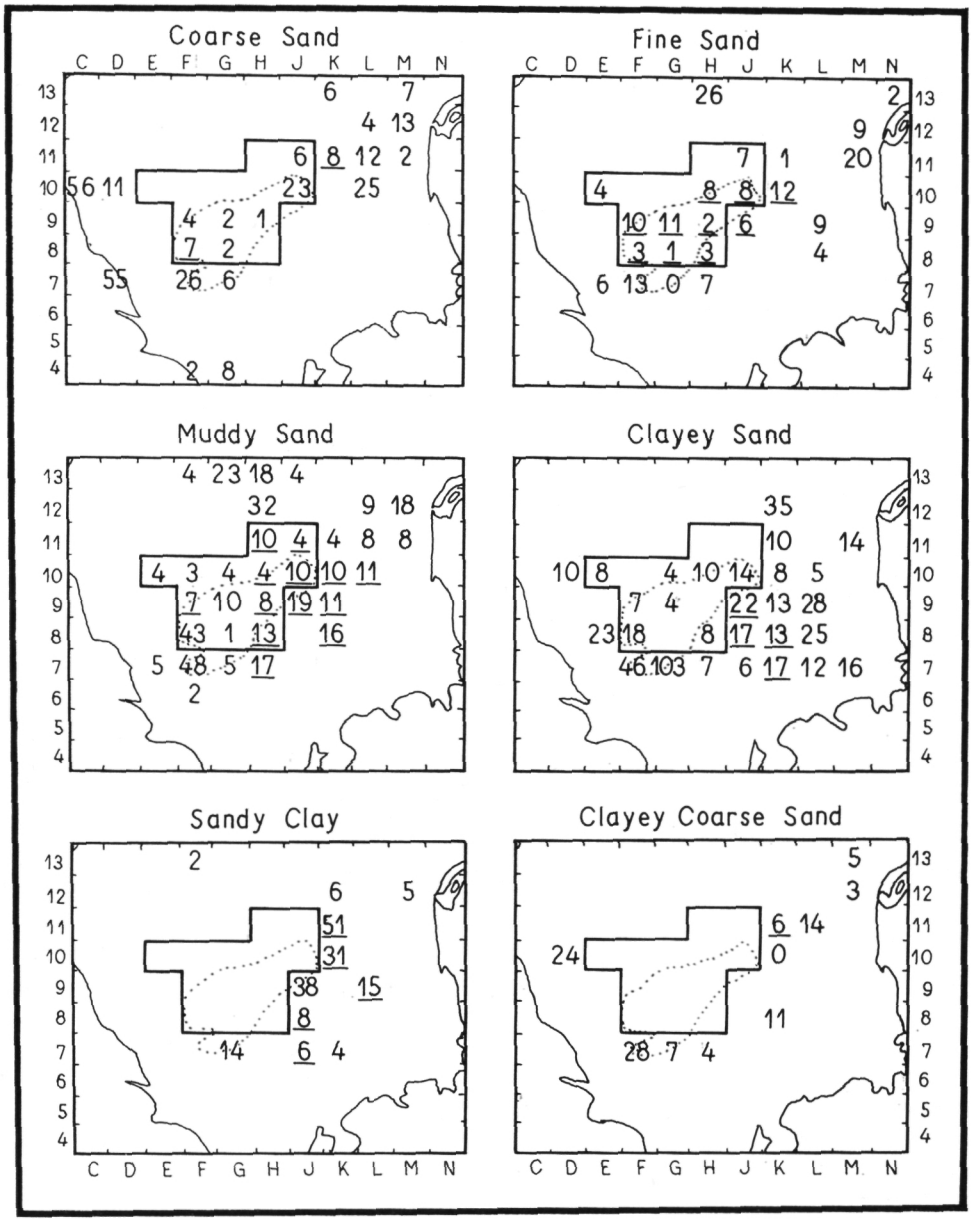

Fig. 82. Mean number of specimens (echinoderms) in each square on various bottom deposits. Averages based on five observations or more are underlined. The area with low abundances (Fig. 79, p. 133) is framed.

The densities given in Table 27 and Fig. 81 are biased by the arbitrary averaging of the result of a whole investigation, irrespective of differences occurring within each of the areas investigated. A breaking up of VATOVA's material from the Adriatic into statistical squares proves (Fig. 86 A, p. 142) that the Adriatic is generally poor as compared with the North Sea—Kattegat area (Fig. 80). In the Adriatic the deeper squares are poorer in echinoderms than the squares on the coast.

Fig. 82 shows for each square the average number of echinoderms per sample (0.2 m^2) on various kinds of bottom deposit. The area poor in echinoderms, indicated on Fig. 79, is

framed on each chart. Samples collected in April and May 1950—55 were used. Sandy clay and clayey coarse sand were not obtained within the framed area. Deposits obtained inside the frame as well as outside (coarse sand, fine sand, muddy sand, clayey sand) all show higher densities outside the frame. When for each deposit the mean values for individual squares are summed and averaged the following result is obtained:—

Deposit	No. of specimens per sample	
	inside the frame	outside the frame
Clayey coarse sand ..	–	9
Sandy clay.....	–	16
Clayey sand.....	9	22
Muddy sand.....	9	14
Fine sand.....	6	10
Coarse sand.....	6	18
All deposits (Fig.79A)	6	16

The result is biased by the different value of the numbers plotted on the charts. Some are mean values for scores of samples, others represent a single sample only (cf. Appendix 3). On Fig. 82 values based on five samples or more are underlined. Owing to the skewness of the distributional function of single observations (cf. Fig. 78 A) very high numbers may be expected particularly where a single observation or few observations are available. The bias is most pronounced on fine sand because in the frame 8 squares out of 10 are represented by averages of five samples or more. Outside the frame only 2 squares out of 13 are based on averages of at least five samples. The bias is eliminated by random selection of one sample of fine sand from each square:—

	E	F	G	H	J	K	L	M	N
13				26					2
12								9	
11					7	1		38	
10	4			8	11	32			
9		6	2	0	5		9		
8		2	1	2			4		
7	1	4	1	7					

Thus determined the mean number per sample per square is 4.3 in the frame and 10.7 outside it. Much stress should not be laid on these averages because they are based on only 10 and 13 samples, respectively. They point in the same direction as other evidence to the effect that the abundance of echinoderms within the framed area is on all deposits lower than in most other parts of the North Sea. The central North Sea (the *Sagitta setosa* water region) is poor, not only in species of echinoderms (p. 105), but also in specimens.

A very rough survey of the abundance of individual species in the North Sea is given in the list below. It is based on 652 samples (0.2 m² each) taken in April and May 1950—55 (cf. Fig. 1). Insufficient randomization of sampling is not accounted for.

Species no.	Name of species	Number in all	Number per sample
1	*Ophiura albida*	2109	3.235
2	*Amphiura filiformis*	2045	3.137
3	*Echinocardium cordatum*	1626	2.494
4	*Echinocyamus pusillus*	811	1.244
5	*Acrocnida brachiata*	304	0.466
6	*Ophiothrix fragilis*	184	0.282
7	*Echinocardium flavescens*	146	0.224
8	*Ophiura affinis*	81	0.124
9	*Astropecten irregularis*	57	0.087
10	*Cucumaria elongata*	36	0.055
11	*Spatangus purpureus*	13	0.020
12	*Ophiactis balli*	9	0.014
13	*Brissopsis lyrifera*	9	0.014
14	*Asterias rubens*	8	0.012
15	*Psammechinus miliaris*	6	0.009
16	*Ophiopholis aculeata*	5	0.008
17	*Ophiura robusta*	5	0.008
18	*Echinocardium pennatifidum*	4	0.006
19	*Ophiocomina nigra*	3	0.005
20	*Luidia sarsi*	2	0.003
21	*Strongylocentrotus droebachiensis*	2	0.003
22	*Cucumaria lactea (planci?)*	2	0.003
23	*Thyone fusus*	2	0.003
24	*Amphipholis squamatus*	1	0.002
25	*Ophiura texturata*	1	0.002
26	*Thyonidium commune*	1	0.002
	Echinocardium, not identified to species	26	0.040
	Total echinoderms	7498	11.500

Only species nos. 1—4 are widespread and abundant. *Acrocnida* and *Ophiothrix* (nos. 5 and 6) are locally abundant only. 158 out of 184 specimens of *Ophiothrix* listed were taken in three samples (squares C 10, D 7, F 7). *Asterias rubens*, inevitably represented in North Sea trawl catches, is not very abundant, actually. Perhaps it should be mentioned that the lowest density detectable in a grab survey like the present is one specimen in 652×0.2 m^2 = 130.4 m^2 of sea bottom. This density corresponds to 100,000,000 specimens on 13,000 km^2 which is the approximate area of the Dogger Bank.

Table 28 shows the mean number per sample on various kinds of bottom deposit. Included are only species which on one ground or another occur in a density of at least one specimen per sample. The density of the less abundant forms is shown in Appendix 3. *Echinocyamus pusillus* is the most abundant form on coarse sand. On fine sand it is *Ophiura albida* and on the softer deposits (muddy sand, clayey sand, sandy clay) *Amphiura filiformis*. The density of both *O. albida* and *A. filiformis* increases with the softness of the ground while *E. pusillus* is less abundant on the softer grounds. *Echinocardium cordatum* abounds in all grades of soil.

Table 28.

Density of abundant species of echinoderms on various kinds of bottom deposit. Number per sample in 652 samples taken in April and May 1950—55. 0.2 m² grab.

Bottom deposit	No. of samples	*Ophiothrix fragilis*	*Amphiura filiformis*	*Acronida brachiata*	*Ophiura albida*	*Echinocyamus pusillus*	*Echinocardium cordatum*	Total echinoderms
Coarse sand	66	2.1	0.3	0.2	0.8	**5.8**	0.9	11.1
Fine sand	248	0.0	0.3	0.3	**1.8**	1.3	1.3	5.5
Muddy sand	190	0.2	**4.5**	1.1	4.2	0.3	3.5	14.5
Clayey sand	84	0.1	**7.7**	0.2	4.9	0.1	5.1	18.6
Sandy clay	43	0.1	**8.9**	0	8.1	0.1	2.0	20.7
Clayey coarse sand	20	0.2	**2.5**	0.2	1.0	1.4	2.0	8.6
All grades of soil	652	0.3	3.1	0.5	**3.2**	1.2	2.5	11.5

The samples pooled in the group of "coarse sand" probably are of two kinds. The majority are extremely poor, without epifauna, while some few are rich, with many epifaunal forms. The rich ones (with *Ophiothrix*) were found particularly in British coastal waters, within reach of the rich *Sagitta elegans* plankton assemblage. The same area seems characterized by rapid water renewal, probably owing to tidal activity. The dominance of epifaunal suspension feeders (*Ophiothrix, Ophiocomina,* etc.) points to a dependence of the rich coarse sand fauna upon continuous food supply directly from the water. The poor coarse sand fauna, dominated by *Echinocyamus,* is found in the region poor in species and poor in specimens.

Local difference in the dominance of individual species in 1950—55 is illustrated in Fig. 83. Most squares are dominated by either *Ophiura albida* or *Amphiura filiformis. O. albida* dominates a large area east and south-east of the Dogger Bank; the dominance is probably temporary. Previous surveys produced quantities of *A. filiformis* from this area. There is evidence that *A. filiformis* was slowly gaining ground toward the end of the period of investigation (cf. p. 47). Fig. 84 in a similar way illustrates local dominance on various kinds of bottom deposit. Scattered dominance of *Echinocardium cordatum* is noticed on all deposits. Coarse sand is strongly dominated by *Echinocyamus*; an important deviation is probably the dominance of *Ophiothrix* in squares on the British coast, referred to above. Muddy sand and the more clayey grounds are dominated by *A. filiformis* or, south-east and east of the Dogger Bank, by *Ophiura albida.* The latter species penetrates more on to the fine sand than *A. filiformis.* The fauna of fine sand

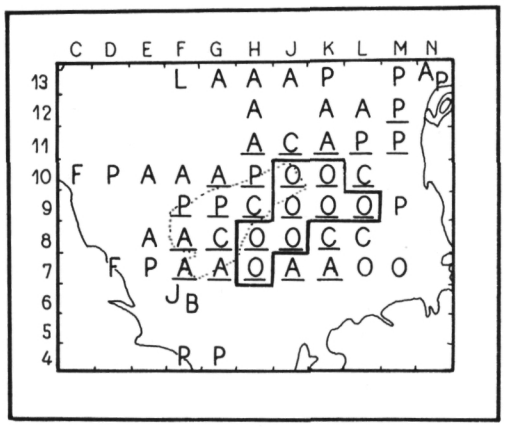

Fig. 83. The dominating species of echinoderms in each square. 652 samples taken in April and May 1950–55. Underlining of letters indicates that at least five samples were available. The area dominated by *Ophiura albida* is framed. Lettering (common to Figs. 83 and 84): A. *Amphiura filiformis,* B. *Acrocnida brachiata,* C. *Echinocardium cordatum,* F. *Ophiothrix fragilis,* J. *Astropecten irregularis,* L. *Brissopsis lyrifera,* N. *Ophiura affinis,* O. *Ophiura albida,* P. *Echinocyamus pusillus,* R. *Asterias rubens,* V. *Echinocardium flavescens.* Two letters in the same square indicate equal abundance of two species.

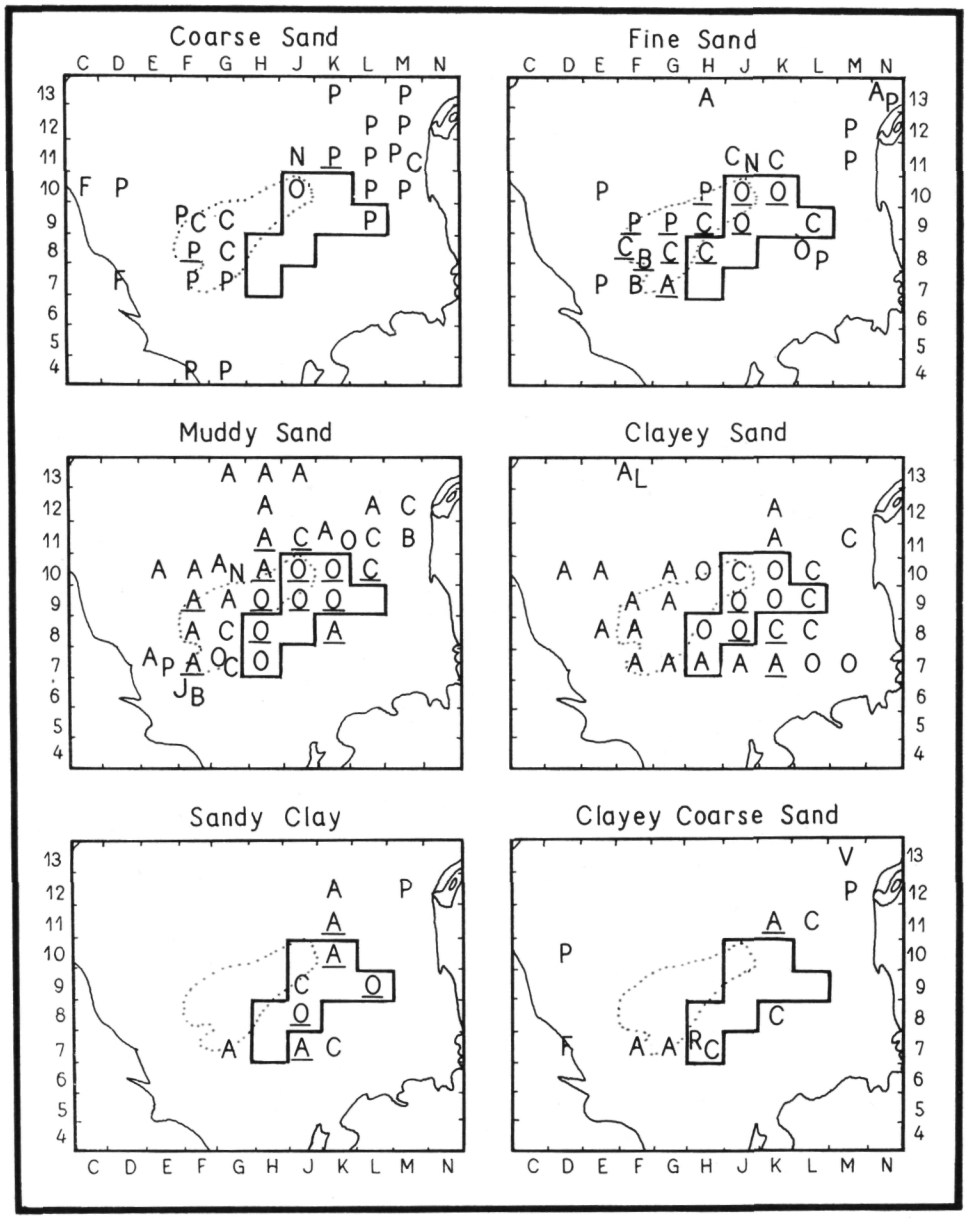

Fig. 84. The dominating species in each square on different types of bottom deposit. April and May 1950–55. The framed area is that dominated by *Ophiura albida* in Fig. 83. Lettering as in Fig. 83.

seems to be intermediate between the fauna of coarse sand and of muddy sand. *E. pusillus* and *O. albida*, besides *E. cordatum*, are the dominating forms. Clayey coarse sand apparently does not possess any characteristic fauna. This deposit is perhaps less stable than other deposits.

On the whole, there seems to exist a hard bottom fauna on coarse sand and fine sand and a soft bottom fauna on muddy sand, clayey sand, and sandy clay. The hard bottom fauna seems to correspond to PETERSEN's *Venus* community, the soft bottom fauna to his *Amphiura filiformis* community (cf. PETERSEN 1918, DAVIS 1923 p. 43). The more or less rheophile fauna with

suspension-feeding ophiuroids, known from a small number of samples taken on the British coast in 40—60 m, seems to correspond to PETERSEN's *Modiolus* epifauna. One species, *Echinocardium cordatum*, actually characterizes the whole area investigated except, perhaps, the British coast.

As mentioned above, only few species of echinoderms are really abundant in the North Sea. The percentage contribution of individual species to the catch of echinoderms is shown in Fig. 85. Again, the 652 samples from April and May 1950—55 were used. For comparison is

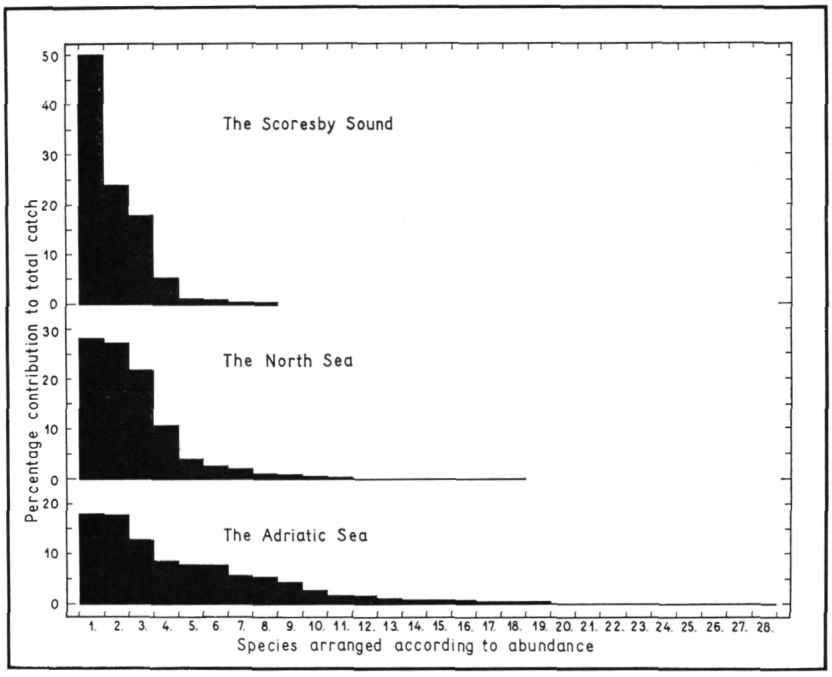

Fig. 85. Percentage contribution of individual species of echinoderms to the catch. Species arranged according to abundance. Material from bottom samples.

shown the percentage contribution to the catch of each species of echinoderms in Greenland waters and in the Adriatic Sea. The material from Greenland is derived from THORSON (1934) who in the Scoresby Sound fjord complex in East Greenland obtained 348 specimens on 19.3 m^2 of sampling. VATOVA's (1949) sampling in the Adriatic was used so far as 306 samples of 0.2 m^2 each (61.2 m^2 in all) are concerned; they produced 517 specimens. The difference between the three areas is evident. In the Scoresby Sound 50 % of the catch of echinoderms is accounted for by a single species. In the North Sea and the Adriatic the most abundant species accounts for 28 % and 18 % of the catch, respectively. Similar observations were made (p. 123) when the number of occurrences (i. e., the consistency) of each species in grab samples was compared. However, the most consistent species is not always the most abundant. The subject is discussed below (p. 150).

For systematizing ecological work like the erection of "animal communities", "faunistic zones", etc., it is necessary to know which species are the most abundant. For that purpose fauna lists must be available in which the sequence of species—when these are arranged according to numerical abundance—is reasonably consistent. The fewer species the samples contain

and the more specimens they contain, the more consistent the fauna list obtained. The example below is arbitrary. It illustrates the most likely result of an investigation of the echinoderm fauna in three sea regions by means of an 0.2 m² grab. It is supposed that within each area one sample is taken in each of 10 positions selected at random. Estimates of the number of species are taken from graph (Figs. 65 and 71):—

	No. of samples	No. of specimens	No. of species
The Scoresby Sound	10	40	4
The southern North Sea	10	100	5
The Adriatic Sea.....	10	20	6

It is fairly obvious that the Scoresby Sound and the North Sea samplings produced more reliable information on which species dominates than did the sampling in the Adriatic. Nevertheless, 10—15 samples from the Adriatic seem sufficient to reveal the most abundant species: When VATOVA's 306 samples of 0.2 m² each are referred to statistical square and pooled within each

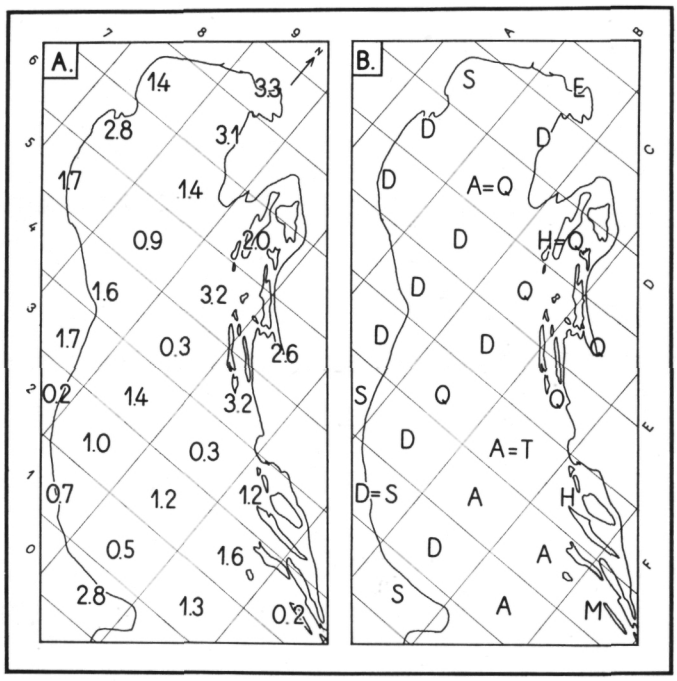

Fig. 86. The Adriatic Sea. Mean numbers of specimens of echinoderms per 0.2 m² in each statistical square (A) and the dominating species of echinoderms (B). Based on material published by VATOVA (1949). Cf. corresponding charts for the North Sea (Figs. 80 and 83). Lettering in chart B: A. *Amphiura filiformis*, D. *Leptosynapta digitata*, E. *Cucumaria elongata*, H. *Amphiura chiajei*, M. *Palmipes membranaceus*, Q. *Ophiothrix quinquemaculata*, S. *Schizaster canaliferus*, T. *Thyone fusus*.

square it is apparently not quite accidental which species dominates in number in individual squares (Fig. 86 B). There are 26 squares which leaves 12 samples, on an average, for each square. *Leptosynapta digitata* dominates on the Italian side, *Ophiothrix quinquemaculata* on the Yugoslavian side. The deeper central part of the area is dominated by *Amphiura filiformis* which dominates large parts of the North Sea, too.

The stabilizing effect of the pooling of samples may be illustrated by random pooling of samples from one statistical square in the North Sea and from one in the Adriatic Sea. In VATOVA's material the highest number of samples from a single square is 35 (square A 7, Fig. 86). For comparison was selected square J 9 in the North Sea (Fig. 83) from which a similar number of samples (33) is available. The total stock of echinoderms in the two sets of samples is as follows:—

The Adriatic Sea, A 7, 35 samples		The North Sea, J 9, 33 samples	
13	*Schizaster canaliferus*	465	*Ophiura albida*
11	*Amphiura chiajei*	109	*Echinocardium cordatum*
6	*Ophiopsila aranea*	8	*Echinocyamus pusillus*
6	*Echinocardium mediterraneum*	6	*Amphiura filiformis*
5	*Labidoplax digitata*	6	*Ophiura affinis*
5	*Thyone fusus*	2	*Astropecten irregularis*
2	*Amphiura filiformis*	2	*Echinocardium flavescens*
1	*Cucumaria elongata*	1	*Ophiothrix fragilis*
1	*Astropecten aurantiacus*		
1	*Thyone raphanus*		
51		599	

An indication of the dominance in individual samples and in groups of samples selected at random among the lot shows for square J 9 in the North Sea:—

	No. of sets dominated by				
	O. alb.	*E. cord.*	*E. pus.*	2 species	Total no. of sets
Individual samples	27	4	1	1	33
Pairs of samples	14	1	1	..	16
3 samples pooled	10	1	..	..	11
4 – –	8	..	..	..	8
5 – –	6	..	..	..	6

There is a fair chance that the dominating species is revealed already in the first sample and it most probably will be when five samples are available. In the Adriatic the situation is different:—

	No. of sets dominated by								
	S. can.	*A. chi.*	*O. aran.*	*E. med.*	*L. dig.*	*A. fil.*	2—5 species	Zero obs.	Total no. of sets
Individual samples ...	4	3	2	4	1	1	7	13	35
Pairs of samples	4	3	1	1	1	..	3	4	17
3 samples pooled ...	4	2	1	1	..	..	3	..	11
5 – – ...	2	2	1	..	..	..	2	..	7
8 – – ...	1	1	..	..	..	..	2	..	4
11 – – ...	1	1	..	..	..	..	1	..	3
17 – – ...	1	1	..	..	..	..	..	..	2

It is noted that among 17 pairs of samples, paired at random, 4 pairs did not contain echinoderms at all and in 3 pairs no single species dominated. When 8—17 samples are pooled it seems as if

either *Schizaster canaliferus* or *Amphiura chiajei* dominate if they are not, after all, equally abundant. The two sets of 17 samples each contained the following echinoderms:—

1.	2.
7 *Amphiura chiajei*	8 *Schizaster canaliferus*
6 *Ophiopsila aranea*	4 *Amphiura chiajei*
5 *Schizaster canaliferus*	2 *Echinocardium mediterraneum*
4 *Thyone fusus*	2 *Amphiura filiformis*
4 *Labidoplax digitata*	1 *Thyone raphanus*
4 *Echinocardium mediterraneum*	1 *Astropecten aurantiacus*
	1 *Cucumaria elongata*
	1 *Thyone fusus*
	1 *Labidoplax digitata*
30	21

The two lists are considerably different from each other and from the list based on all 35 samples (see above). Apparently, a set of 17 samples is not sufficient for the determination of which species dominates. It is even problematic whether the whole set of 35 samples is sufficient for that purpose. Usually, however, a set of 10—15 samples is sufficient (Fig. 86 B) provided, that it is not quite accidental that *L. digitata* was found to dominate the squares in the western Adriatic and *O. quinquemaculata* to dominate the eastern squares.

Perhaps it may be generalized from the evidence presented above that in the North Sea a single sample provides as much information about the probable name of the dominating species as in the Adriatic is produced by at least 10 samples.

The community concept, as introduced by PETERSEN, seems more easily applicable to faunas of the Scoresby Sound or North Sea type than to faunas of the Adriatic type. In the North Sea each of the more abundant species of echinoderms occur in 50 % of the samples (cf. p. 123). In the Adriatic (VATOVA 1949 p. 34) the most widespread echinoderm (*L. digitata*) occurs in 16 % of the samples and the species most widespread of all (the polychaete *Glycera rouxii*) occurs in 20 % of the samples. The occurrence of a large number of species probably advances the establishment of local fauna complexes in localities with ecological conditions slightly different from those prevailing in the surroundings. For the proper pooling of local facies into higher units, such as PETERSEN's communities, a still higher number of samples is required.

Aggregation.

In recent years several authors have paid attention to the more or less aggregated occurrence of the species obtained in grab samples. The deviation from the expected POISSON distribution for items distributed at random was investigated by a. o. HOLME (1950, 1953) and CLARK and MILNE (1955). In the POISSON distribution the mean (m) equals the variance (s^2):—

$$\frac{s^2}{m} = 1 .$$

Significant deviation from the POISSON distribution is observed in aggregated $\left(\frac{s^2}{m} > 1\right)$ and overdispersed $\left(\frac{s^2}{m} < 1\right)$ populations. HOLME (1950) observed overdispersion in a population of the lamellibranch *Tellina tenuis*. In this population individuals tended to maintain a certain territory, obviously in order to secure the undisturbed function of the sweeping siphons. Aggregation

(underdispersion) was observed by HOLME (1953) off Plymouth and by CLARK and MILNE (1955) in the Clyde. Difficulties arise, however, because the observed deviation from random (POISSON) distribution is dependent upon the mean. The higher the mean, the more evident the aggregation. This phenomenon usually leads to the observation that abundant species are aggregated while the rarer ones are distributed at random. As pointed out by CLARK and MILNE (1955 p. 173) a small grab will disclose fewer aggregations than a larger grab used on the same ground because the smaller grab produces smaller mean values.

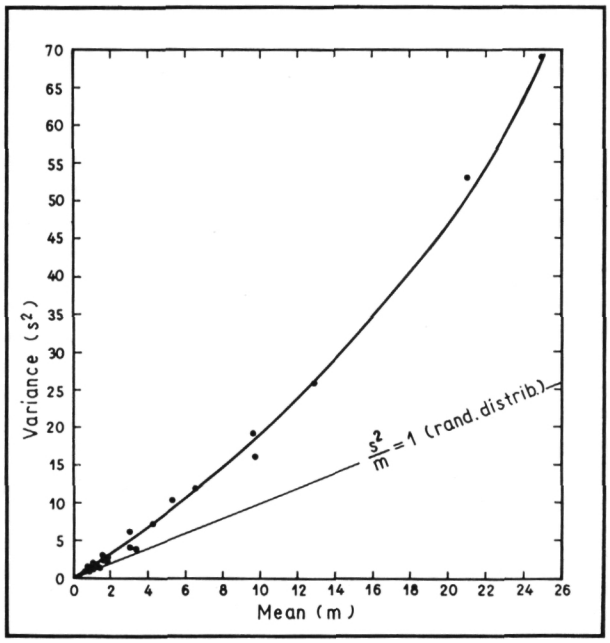

Fig. 87. Dependence of the variance upon the mean (number of specimens per sample). Various species and groups of species of bottom invertebrates. Three stations off Plymouth (HOLME 1953).

The condition may be examplified by means of the material presented by HOLME (1953) from Plymouth grounds. Available are two stations with 15 and 20 single hauls each (Bigbury Bay and Whitsand Bay, HOLME's Tables IV and V) and one with 40 samples (offshore, station B 5, HOLME's Table VI) taken in pairs with the double-scoop sampler. The dependence of the variance upon the mean in these series is shown in Fig. 87, for individual species and for whole animal groups (polychaetes, echinoderms, etc.). Species occurring in densities below 0.5 per sample were discarded. At densities below 2 per sample or so, the deviation from random distribution is inconspicuous. At higher densities the variance rapidly increases beyond the expected (POISSON) value. This is true for individual species as well as for groups of species. Obviously, the dependence of the variance upon the mean is not straight-lined as in the POISSON distribution. It may be described by an upwards curved line. It will be shown below (p. 149) that with increasing aggregation the variance rapidly increases so that it equals the square of the mean ($m^2 = s^2$; $m = s$). This suggests that in the distributional function here dealt with (perhaps a compound POISSON distribution) the mean equals some exponential function of s, the exponent of s indicating the extent of the deviation from random distribution. A constant (C) may account for possible deviations from the exponential function:

$$m = C \times s^a$$
$$\log m = \log C + a \times \log s$$

If so, a straight line relationship should in all cases be obtained when m and s are plotted against each other on a log scale. Fig. 88 shows the log scale relationship of m and s in HOLME's material. Aggregation (?, see below) becomes evident at densities of 2 per sample. This is true for single species and for groups of species. When the two scoopfuls from each haul on station B 5 are pooled so that the sample unit is doubled the new mean and variance fit with the single-scoop observations. Even the pooling of two successive hauls does not change the picture.

Aggregation is undetectable when one specimen only is available in the set of samples examined. On station B 5 (40 samples) 1 specimen corresponds to a density of 0.025 specimens per sample. Intersection of the line indicating random distribution (cf. Fig. 88) and the line through the plots occurs at $m = 0.025$. The Bigbury Bay station comprises 20 hauls. Correspondingly, the lines intersect at $m = 0.05$. Densities down to 0.5 per sample are plotted for the two bay stations. For station B 5 densities down to 0.1 specimen per sample are plotted. The heavy line on Fig. 88 is approximately intermediate between the lines for each of the three stations. A slight overdispersion seems to occur at low densities. The overdispersion may be due to the traditional procedure of counting an isolated fragment of a species, not otherwise represented in the sample, as one specimen. The apparent overdispersion probably would vanish if fragments comprising less than half part of a specimen were discarded.

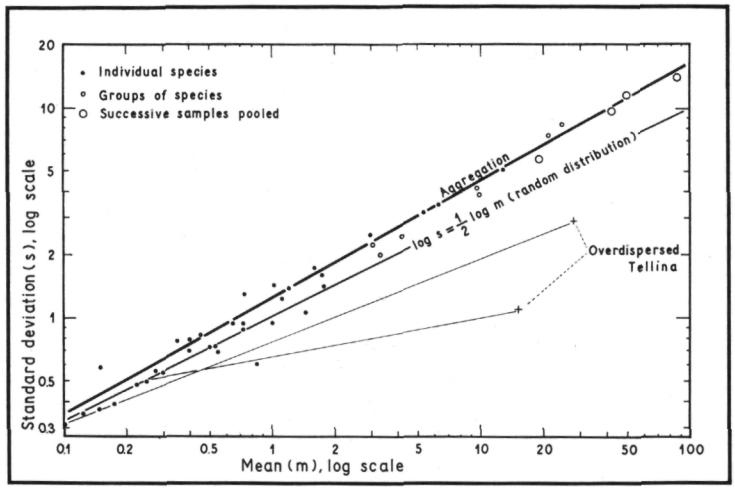

Fig. 88. Dependence of log mean upon log standard deviation at random distribution, in one case of aggregation and in one case of overdispersion (HOLME).

The deviation from random distribution, toward aggregation, observed for higher values of m perhaps has as little to do with true aggregation as the deviation, toward overdispersion, for small values of m has to do with true overdispersion. Both may be due to technical deficiency so that the animals were, actually, nicely distributed at random (see below, p. 150). The overdispersion in *Tellina tenuis* (HOLME 1950), illustrated in Fig. 88, was observed on high mean values. It seems to be a truly biological phenomenon.

Other interesting material for the study of animal aggregations was published by MENZIES and WIDRIG (1955). They investigated the aggregation of the marine wood-boring isopod *Lim-*

noria tripunctata on wooden blocks. They divided areas of 40 square inches into areas of 1 inch each. The mean number of burrows per square inch and the variance was computed in each experiment. The authors examined the deviation from random (POISSON) distribution and found aggregation except on some blocks with low burrow density. Another test based on the relation

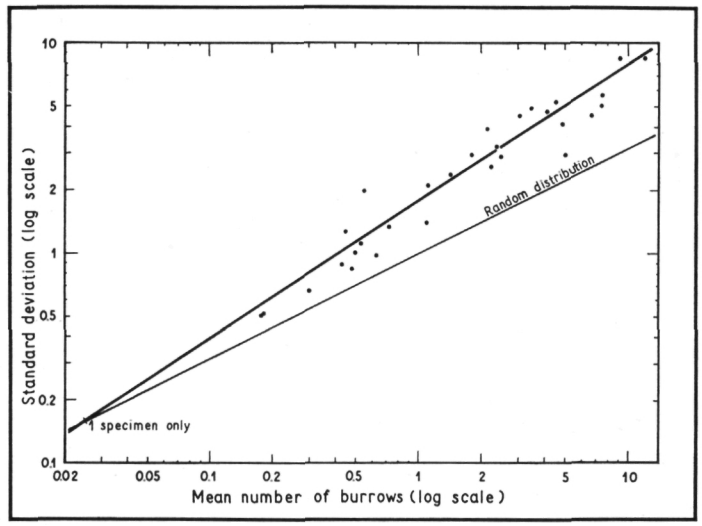

Fig. 89. Aggregation of *Limnoria* on wooden blocks (MENZIES and WIDRIG 1955). Mean number of burrows plotted against standard deviation of single observations (log scale). The heavy line (eye-fitted) indicates the aggregation.

between mean and variance in negative binomial frequency distributions (a test the present author is not acquainted with) indicated, that the aggregation decreased for the highest burrow densities. Fig. 89 shows a log scale plotting of means against standard deviations of single obser-

Table 29.

13 sets of 5 samples each from the North Sea. April and May 1952—55. Mean number (m) per sample (0.2 m²) and standard deviation of single observations (s) for some species of echinoderms and for total echinoderms.

Square	Station number	Haul number	*A. filiformis*		*O. albida*		*E. pusillus*		*E. cordatum*		Total echinoderms	
			m	s	m	s	m	s	m	s	m	s
F 8	8508	II-V, XI	..	..	..	..	..	..	1.200	1.643	1.200	1.643
F 8	8508	VI-X	..	..	..	..	..	..	1.000	1.414	1.000	1.414
F 8	8904	I-V	..	..	..	..	..	..	1.400	0.548	1.400	0.548
F 8	8904	VI-XI	..	..	..	..	..	..	1.000	1.225	1.000	1.225
G 8	8018	I-V	..	..	..	..	..	..	2.600	1.342	2.600	1.342
H 8	8512	I-V	..	..	..	..	..	..	2.600	1.140	2.800	1.483
H 8	8512	VI-X	..	..	..	..	..	..	2.200	0.837	2.400	0.894
J 10	8481	I-V	..	..	7.800	2.168	1.400	1.140	1.200	0.837	10.600	2.966
J 10	9506	I-V	..	..	3.000	3.240	..	..	6.800	2.049	10.000	3.937
K 8	8080	II-VI	0.800	0.447	..	..	..	..	12.600	2.881	13.600	2.510
K 8	8432	II-VI	1.400	0.894	..	..	..	..	10.600	3.507	12.600	4.506
K 8	8909	II-VI	5.800	4.207	..	..	..	..	6.000	3.391	12.600	1.517
K 8	9461	II-VI	30.400	13.01	..	..	..	..	8.200	1.924	39.000	13.58

vations. It seems as if the aggregation is the same on all blocks or, rather, that differences which may occur are independent of burrow density.

The accuracy of navigation of the "Dana" during the North Sea cruises was discussed p. 10. It was concluded that two stations given the same position in the station list should be considered identical only within the range of a nautical mile. The method developed above makes it

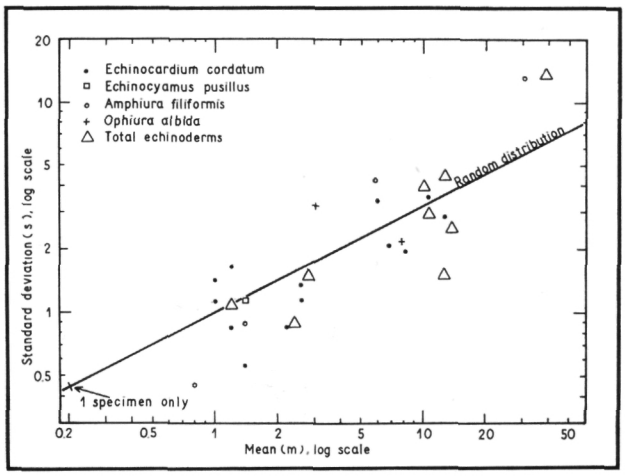

Fig. 90. Mean number per sample plotted against standard deviation (log scale). Individual species of echinoderms and total echinoderms in 13 sets of 5 samples each. The North Sea, April and May 1952–55. See Table 29.

possible to investigate the effect of navigational errors upon the echinoderm material. Sometimes several hauls were made on the same station. In the material collected in the years 1952—55 it is possible to select 13 sets of 5 hauls each. Table 29 shows the mean number of specimens (m) and the standard deviation of single observations (s) for the more abundant species of echinoderms and for total echinoderms. Fig. 90 shows m plotted against s on a log scale. There is no

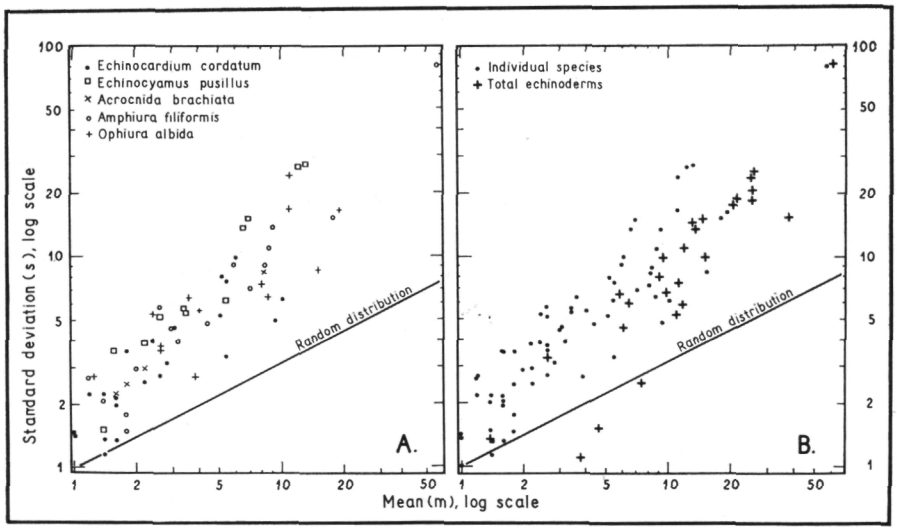

Fig. 91. Aggregation within statistical squares in the North Sea. Plotting as in preceding figures. See Table 30.

Table 30.

Mean number per sample (m) and standard deviation of single observations (s) for abundant species of echinoderms and for total echinoderms in one set of 5 samples from each of 27 statistical squares in the North Sea. Sets selected at random among the samples taken with 0.2 m² grabs in April and May 1950—54. Cf. Fig. 91.

Square	*A. filiformis*		*A. brachiata*		*O. albida*		*E. pusillus*		*E. cordatum*		Total echinoderms	
	s	*m*	*s*	*m*	*s*	*m*	*s*	*m*	*s*	*m*	*s*	*m*
F 9	4.58	3.0	..	..	..	..	1.52	1.4	..	..	2.51	7.4
F 8	9.25	6.0	3.03	2.2	..	..	5.50	3.4	1.41	1.0	13.75	13.2
F 7	15.44	18.0	8.56	8.2	6.43	3.6	3.58	1.6	3.36	5.4	15.78	37.4
G 10	1.48	1.8	..	..	..	..	..	..	0.45	0.2	1.10	3.8
G 9	2.92	2.0	..	..	5.37	2.4	3.90	2.2	3.49	1.8	7.97	9.0
G 8	..	..	..	..	..	..	..	..	1.34	1.4	1.34	1.4
G 7	80.44	57.0	..	..	..	..	..	..	3.91	2.4	82.49	61.0
H 11	8.99	8.4	..	..	..	..	..	..	..	..	11.10	11.8
H 10	2.68	1.2	..	..	3.78	2.6	5.64	3.4	2.19	1.4	9.76	9.4
H 9	..	..	..	..	..	..	..	..	2.07	1.6	3.29	2.6
H 8	..	..	..	..	5.52	4.0	..	..	1.41	1.0	6.61	5.8
H 7	7.05	7.2	..	..	23.59	10.8	..	..	2.49	2.2	19.33	21.2
J 11	..	..	..	..	1.00	1.0	..	..	1.95	1.6	1.52	4.6
J 10	..	..	..	..	6.54	8.8	..	..	1.34	1.6	7.40	11.2
J 9	..	..	..	..	16.54	19.2	..	..	7.92	5.2	21.08	25.0
J 8	..	..	..	..	2.68	3.8	..	..	..	..	4.53	6.0
J 7	4.83	4.4	..	..	..	..	..	..	1.14	1.4	5.60	6.4
K 11	13.75	9.2	..	..	3.58	2.6	15.21	6.8	..	..	18.52	20.4
K 10	3.96	3.2	..	..	8.60	15.0	..	..	9.72	6.0	19.30	25.0
K 9	..	..	..	..	7.38	8.0	..	..	4.53	3.0	5.94	11.6
K 8	2.07	1.4	..	..	..	..	..	..	4.92	9.2	5.17	10.8
K 7	11.94	8.8	..	..	..	..	..	..	5.24	5.0	15.39	14.6
L 11	1.79	1.8	2.49	1.8	..	..	5.27	2.6	3.11	2.8	6.80	9.6
L 10	..	..	..	..	3.58	1.6	27.34	13.2	6.20	10.0	25.11	25.4
L 9	..	..	..	..	16.89	11.0	26.83	12.0	2.19	1.4	24.60	25.6
M 12	5.81	2.6	..	..	..	..	6.19	5.4	7.47	5.4	10.00	15.0
M 11	..	..	2.19	1.6	2.68	1.2	13.65	6.6	2.70	2.6	14.87	13.0

conspicuous tendency to aggregation. Again, an apparent overdispersion for low values of m is probably due to the counting of isolated fragments as one specimen each, even when the fragment represented less than 50 % of the area covered by the individual. Unfortunately, the area or distance covered by each set of samples is not the same. Sometimes the five hauls were made on a line about half a mile long. In other cases it was attempted to cover 2—3 square miles. On the whole, however, it may be concluded that the echinoderms were distributed approximately at random within the range of errors of navigation, so that these may safely be neglected. This is true, naturally, only for the size of grab used in the present investigation. A bigger grab would produce higher mean values which might or might not reveal conspicuous aggregation. A higher number of hauls in each set also would improve the possibility for the detection of aggregation.

Table 30 and Fig. 91 illustrate the aggregation of echinoderms within statistical squares in the North Sea. From each of 27 squares a set comprising five samples from April—May

1950—54 were selected at random. The mean number per sample and the standard deviation were computed for the more abundant species and for total echinoderms. Abundances below one per sample were not considered. The deviation from random distribution is clear because not the variance (s^2) but the standard deviation (s) roughly equals the mean. Differences between individual species (Fig. 91 A) are not too conspicuous. *Echinocyamus pusillus* seems more aggregated than other species. *Amphiura filiformis* perhaps is slightly more aggregated than *Acrocnida brachiata, Ophiura albida,* and *Echinocardium cordatum.* The degree of aggregation of *E. cordatum* varies rather much from one square to another, but on the whole this species seems to be the most uniformly distributed of North Sea echinoderms. Accordingly, it was shown above that although in 1950—55 *Ophiura albida* was the most abundant echinoderm in the central and southern North Sea, *Echinocardium cordatum* was more consistent in bottom samples (cf. pp. 123 and 138). The method for zoogeographical analysis of bottom sampler material developed above (p. 117) is based rather on the more consistent species than on the more abundant species. That will not be very important, however, because any consistent species will be reasonably abundant. The contrast between consistence and abundance is probably more pronounced in samples taken with a small grab than in samples taken with a big grab. Perhaps the comparison of fauna lists for zoogeographical purposes ought to be based on material collected with the same size of grab.

Echinoderms as a group are less aggregated than individual species (Fig. 91 B). This indicates that the aggregation of individual species tends to be leveled off when several species are pooled. Thus, all species are not distributed in the same way within the square. A similar phenomenon was not observed in HOLME's material from Plymouth waters referred to above (p. 146). The distributional function did not change appreciably even when all species were pooled (Fig. 88). On the Plymouth grounds the proportionate abundance of each species remained constant from one sample to another. The sampler may have taken samples of not exactly the same size out of a randomly distributed population. If so, the "aggregation" illustrated in Fig. 88 is arbitrary.

Wet Weight per Unit of Area.

The presence on any ground of small and large species and of young and old specimens of individual species renders it probable that the distributional function of the weight of the animals is more complicated than that of the numbers.

The condition is visualized in Fig. 92, based on 120 samples taken in the North Sea in April and May 1951. The weights are plotted against the volume of the sample on a linear scale (left) and on a cube root scale (right). The cube root transformation tends to normalize the function. The dependence of the wet weight of echinoderms upon volume of sample is slight, if any. The diagrams Fig. 92 C show a conspicuous bimodality of the weight distribution of total echinoderms. There are few observations of weights of 20—30 grammes. The omission of the genus *Echinocardium* removes the bimodality and leaves observations of low weights (Fig. 92 B). Plotting of *Echinocardium* (Fig. 92 A) shows that the weight of small specimens of that genus fits with the weight distribution of other echinoderms. There is also a stock of large *Echinocardium* that heavily outweighs all other echinoderms.

E. cordatum is probably the only species of the genus responsible for the bimodality of the weight distribution. Several specimens, however, were so damaged that they could not with certainty be identified to species. *E. cordatum* was therefore pooled with *E. flavescens* and with unidentified *Echinocardium. E. pennatifidum* was not represented in the identified material from

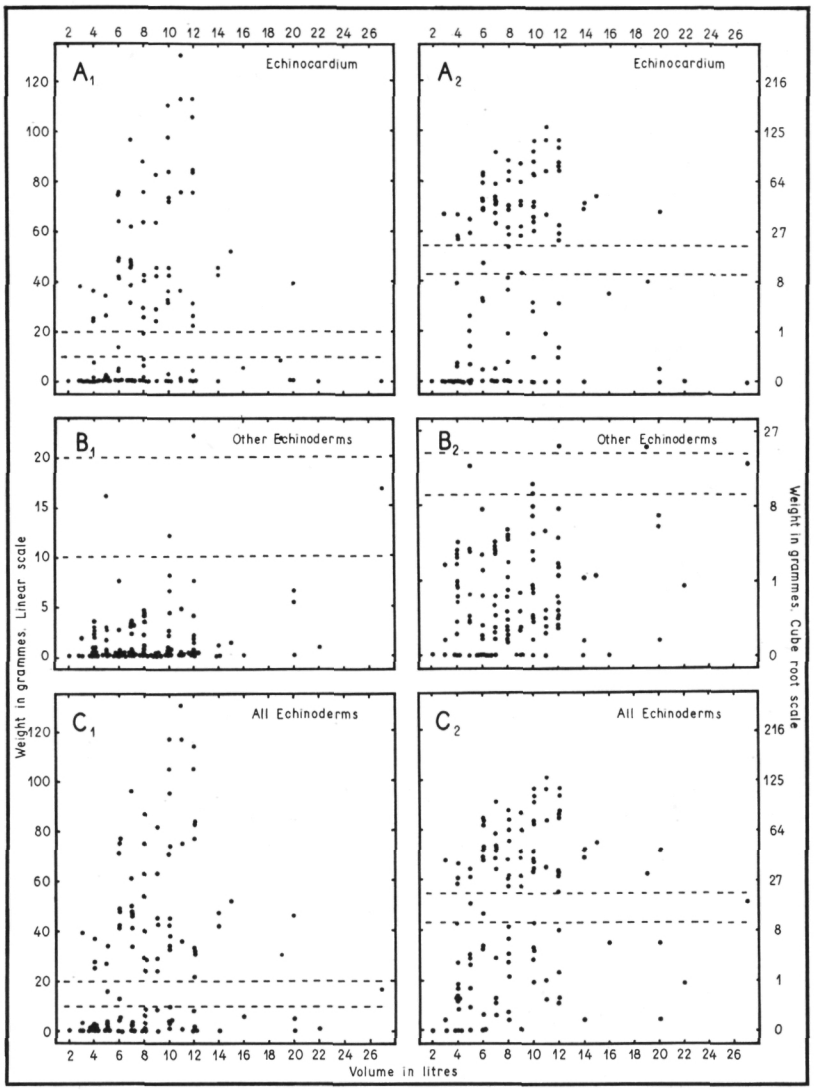

Fig. 92. Dependence of wet weight upon volume of sample. 120 samples (0.2 m² each) from the North Sea, April and May 1951. Left: Weight plotted on a linear scale. Right: Weight plotted on a cube root scale. The broken line indicates the bimodality of the weight distribution owing to the occurrence of a stock of large *Echinocardium* that outweighs all other echinoderm species.

these stations. Obviously, the wet weight of echinoderms in the North Sea largely depends upon the density of adult *E. cordatum*. In a previous section (p. 79)[1]) it was pointed out that *E. cordatum* is usually abundant in the North Sea but that, sometimes, the occurrence is more patchy than in recent years. The stock of adults in 1950—55 was referred to at least two spat-falls both of which occurred prior to the start of more extensive grab surveying in 1950. In 1950—55 the stock remained almost unchanged. Dying-off and growth were slow. The total weight of *Echinocardium* on 120 stations (one 0.2 m² haul on each station) operated in April and May 1951 (cf. Fig. 92) was 2644 grammes. The same stations were operated in April—May 1952 (see chart, Fig. 1) and then produced a total of 2854 grammes of *Echinocardium*. The difference is negligible.

[1]) See also footnote p. 82.

Table 31.

Mean wet weight in grammes per sample (0.2 m²) of the more abundant species of echinoderms. 654 samples from the North Sea, collected in April and May 1950—55. Included are species which on any one bottom deposit occur in a quantity of more than 500 mg per sample and species which occur in an average quantity of more than 100 mg per sample. For further details, see Appendix 4.

Bottom deposit	No. of samples	*Astropecten irregularis*	*Ophiothrix fragilis*	*Amphiura filiformis*	*Ophiura albida*	*Spatangus purpureus*	*Echinocardium cordatum*	*Echinocardium flavescens*	*Echinocardium pennatifidum*	*Brissopsis lyrifera*	Total *Spatangidae*	Total echinoderms
Coarse sand	65	0.3	1.2	0.0	0.0	2.4	17.5	1.2	0.7	..	21.9	23.9
Fine sand	248	0.1	0.0	0.0	0.3	..	31.7	0.6	..	..	34.2	34.8
Muddy sand	194	0.2	0.1	0.5	0.6	..	38.1	1.2	..	0.1	40.1	41.9
Clayey sand	85	0.3	0.0	1.0	0.8	..	37.0	1.1	..	..	38.5	40.9
Sandy clay	43	0.4	0.1	1.2	0.8	..	7.0	1.2	..	1.3	9.5	12.7
Clayey coarse sand.	19	0.2	0.2	0.1	0.3	7.5	17.7	4.0	..	..	23.5	30.6
All deposits	654	0.2	0.2	0.4	0.5	0.5	30.8	1.0	0.1	0.1	33.5	35.0
– – , pCt...	..	0.5	0.4	1.1	1.3	1.3	88.0	3.0	0.2	0.3	95.7	100.0

A limited interest only may be paid to the quantity of echinoderms (measured by wet weight) observed during the grab surveys of the North Sea in 1950—55. Little is known about the consistence of the fauna as far as the wet weight is concerned. Details from each square and from each type of bottom deposit are given in Appendix 4. A survey is given in Table 31. The dominance of the family of *Spatangidae* and, particularly, of *Echinocardium cordatum* is striking.

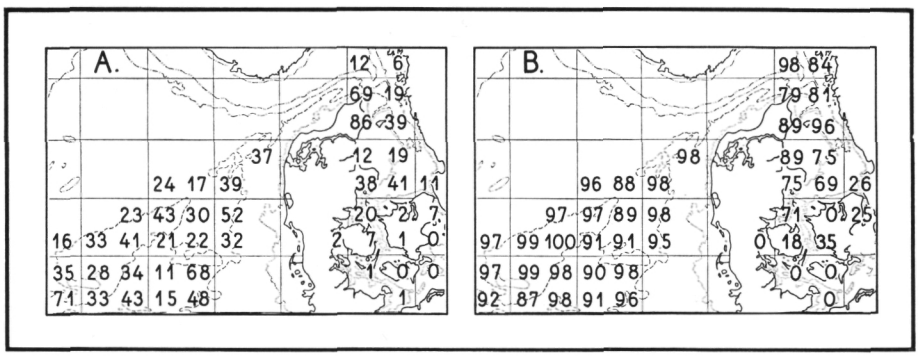

Fig. 93. *A:* Wet weight (in grammes per 0.2 m²) of echinoderms in the central North Sea (April and May 1950–55) and in the transitional area between the North Sea and the Baltic (PETERSEN 1914, 1915). Squares with less than 1.6 m² of sampling are omitted. *B:* Wet weight of *Spatangidae* as percentage of total echinoderms. Material as in *A*.

E. cordatum produced 88 % of the wet weight of echinoderms. Other spatangids produced 8 % out of the remaining 12 %. As large spatangids of several species were obtained in quantity by most investigators of the North Sea bottom fauna it is rather obvious that this family will usually dominate by weight, even if the present abundance of *E. cordatum* turns out to be temporary.

Fig. 93 A shows for each square from which at least 8 samples are available the wet weight in grammes per 0.2 m² of total echinoderms, compiled from Appendix 4. Inter-square differ-

ences, if any, are of local importance only. The wet weight is the same in the Dogger Bank squares as in eastern and south-eastern North Sea squares. For comparison is shown the wet weight of echinoderms in grammes per 0.2 m² in the transitional area between the North Sea and the Baltic (PETERSEN 1914, 1915). The quantities of echinoderms found by PETERSEN in the Kattegat are similar to those obtained in the North Sea in 1950—55. Echinoderms are of little importance in the Belt Sea and the western Baltic.

Fig. 93 B shows for each square the percentage contribution of spatangids to the wet weight of echinoderms. The dominance of spatangids is conspicuous both in the North Sea and

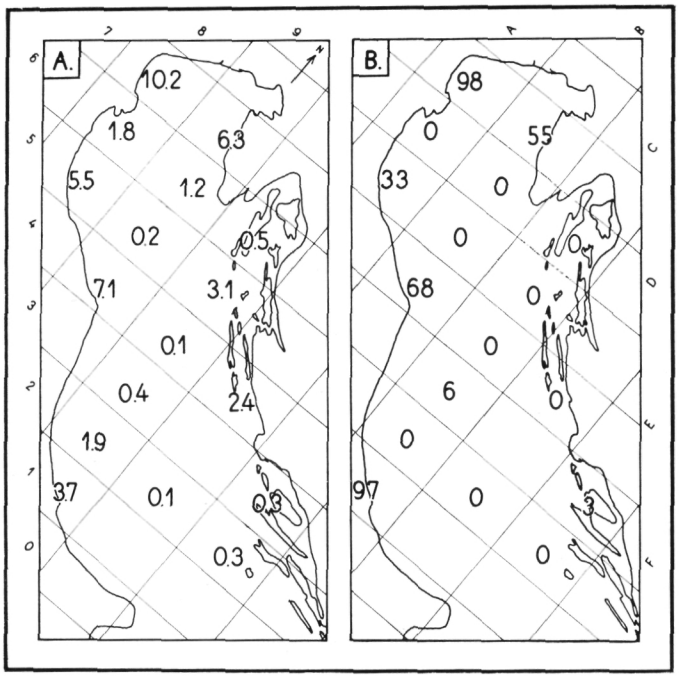

Fig. 94. The Adriatic Sea (VATOVA 1949). Wet weight of echinoderms per 0.2 m² of sea bottom (A) and percentage (by weight) af *Spatangoidea* (B). Cf. corresponding charts for the North Sea, Fig. 93.

the Kattegat. Spatangids are less important in the Belt Sea and the Sound between Denmark and Sweden. The decrease in salinity toward the Baltic is probably one reason for this. Again, the rapidly streaming water in the belts and sounds probably promotes the development of a suspension feeding ophiuroid and holothurian fauna element to the effect of a suppression of the spatangid element (cf. p. 101).

The echinoderm fauna of the Adriatic Sea, so well known from VATOVA's extensive sampling, forms a striking contrast to the fauna of the North Sea and the Kattegat. Fig. 94 A shows the mean wet weight of echinoderms per sample (0.2 m²) for each statistical square. On the coast, particularly on the Italian side, the weight is about one tenth of what was observed in the North Sea and the Kattegat. Farther offshore there is scarcely more than one hundredth of the North Sea quantities. *Spatangidae* are almost absent. On the Italian coast, however, a representative of another family (*Schizasteridae*) of the *Spatangoidea*, namely, *Schizaster canaliferus*, dominates almost as effectively as do the *Spatangidae* proper in the Kattegat (Fig. 94 B). An isolated dominance of spatangoids such as *Echinocardium cordatum*, *Brissopsis lyrifera*, and *Schizaster canali-*

Table 32.

Wet weight of echinoderms per 0.2 m² in various parts of the North Atlantic and the arctic. Percentage contribution to the catch by each class of echinoderms is indicated.

Reference	Locality	Depth (m)	Area sampled (m²)	Grammes per 0.2 m²	Percentage contribution to total weight of echinoderms						Zoogeographical zone
					Asteroidea	*Ophiuroidea*	*Spatangoidea*	Other *Echinoidea*	*Holothurioidea*	*Crinoidea*	
Thorson 1933.....	Franz Joseph Fjord, E. Greenl.	2–60	15.1	0.9	0	40	0	42	17	0	
Spärck 1933	– – – —	27–430	4.6	1.8	0	33	0	66	0	0	
Thorson 1934.....	Scoresby Sound, E. Greenland	9–92	16.9	0.7	2	29	0	0	69	0	Arctic
—	— , deep water communities	51–550	ca. 15.7	1.1	8	91	0	0	1	0	zone
Vibe 1939	N.W. Greenland waters	8–64	4.5	2.1	2	69	0	4	25	0	
Zenkewitsch 1927 ..	Barents and White Seas	8–270	ca. 4.8	0.7	..	..	..	..	..	..	
Idelson 1930	Spitsbergen Bank	20–90	2.3	67.3	0	4	0	13	84	0	
Einarsson 1941	Faxa Bay, S.W. Iceland	27–165	14.2	5.0	8	4	74	4	10	0	
Spärck 1929	Faroe waters	10–115	12.2	5.3	2	68	27	2	0	0	
Petersen 1915.....	Kristiania (Oslo) Fjord (squares P 17, P 18)	0–328	23.7	5.2	3	17	76	4	0	0	
— 1914, 1915	Kattegat (squares P-R 11–14)	4–170	88.6	38.0	0	16	80	1	2	0	
— 1914.....	Belt Sea (squares P-R 8–10)	4–42	218.9	5.9	11	21	47	9	11	0	
The "Dana" 1950–55, April-May.....	Central North Sea	17–150	131.0	35.0	1	3	96	0	0	0	Boreo-Lusitanian zone
Hagmeier 1925	German Bight	9–41	13.5	11.5	0	22	75	1	0	0	
Caspers 1939	Helgoländer tiefe Rinne	20–60	3.0	11.2	5	19	62	13	1	0	
— 1950	Helgoländer Austernbank	15–35	1.9	5.8	3	22	74	1	0	0	
Spärck 1931	Coast of Portugal	11–108	1.8	2.4	0	31	64	0	5	0	
Spärck 1931	Western Mediterranean .	9–150	6.6	0.3	24	16	20	3	36	0	
Bruun 1940	Coast of Tunis	2–13	1.9	0.7	27	38	0	34	0	0	Mediter-
Vatova 1949.....	Adriatic Sea, west coast	6–235	26.2	5.8	3	3	74	0	20	0	ranean
—	— offshore and east coast		35.0	1.6	0	30	1	12	54	2	zone
Wirszubski 1953 ...	Coast of Israel	18–135	42.0	3.1	0	3	97	0	0	0	

ferus is found on the coast of Israel in the eastern Mediterranean. The similarity of the echinoderm fauna of Israelian waters and of boreal seas is rather astonishing. The temperature is extremely high in Israelian waters: 16° in winter and 25° in summer in a depth of 55 m (Wirszubski 1953).

A survey of the wet weight of echinoderms in various parts of the North Atlantic and the arctic (Table 32) shows that the Arctic zone and the Mediterranean zone are more poor than the Boreo-Lusitanian zone. The remarkable richness of the Spitsbergen Bank (67 grammes per 0.2 m²) is probably not valid. It was produced by a few very large *Cucumaria frondosa* found in a single sample. The Boreo-Lusitanian zone is further characterized by the dominance of various representatives of the *Spatangoidea*. Less than 50 % contribution by this group to the total wet weight of echinoderms was observed in only two places within the Boreo-Lusitanian zone: the Belt Sea and Faroe waters. Both places are characterized by a rich development of the rheophile fauna element which, as mentioned above, tends to suppress the spatangoids.

When local peculiarities are left out of consideration it may be concluded that the echinoderm fauna of the continental shelf in the Boreo-Lusitanian zone is characterized by the dom-

inance (by wet weight) of the *Spatangoidea*, represented by such genera as *Spatangus*, *Brissopsis*, and *Echinocardium*. Within this spatangoid region lower units may be recognized, each unit being an area, or zone, dominated by one or a few species or genera of spatangoids. In the central North Sea, for instance, the spatangoid dominance is produced by *Echinocardium cordatum* which also dominates in moderate depths in the Kattegat. In the northern North Sea *E. flavescens* probably dominates, and it certainly does in Faxa Bay, S. W. Iceland (EINARSSON 1941). *Brissopsis lyrifera* dominates the echinoderm fauna of the Skagerrak in moderate depths and of the deep channel in the Kattegat (the *Brissopsis* community, PETERSEN). Unfortunately, a charting of the subdivisions of the spatangoid zone is beyond reach because several investigators of the quantitative distribution of the bottom fauna have not published the wet weight of individual species.

A Rough Estimate of Productivity.

Few attempts have been made to estimate the rate of production of animal tissue by bottom animals. BOYSEN JENSEN (1919) estimated the annual production of several species in the Limfjord, based on samples taken twice each year. He was able to follow the growth and decrease of individual year-classes of the more abundant species. BIRKETT (1954), in a paper read at the annual meeting of the International Council for the Exploration of the Sea, developed more satisfactory methods based on the patch studies introduced by DAVIS (1923). Unfortunately, the present material from the North Sea is not satisfactory for the application of either of these methods.

In the systematical part of the present paper evidence was gathered, that the stock of some species (e. g., *Ophiura albida*, *Echinocardium cordatum*) survived year after year without considerable decrease in numbers. Populations of other species (e. g., *Amphiura filiformis*, *Echinocyamus pusillus*) showed a rapid replenishment of the stock so that the same year class could not be sampled in more than one or a few successive years. Obviously, the productivity of each species is relative to the rate of stock replenishment. Thus a very rough idea of the proportionate productivity of each species and, consequently, of the whole echinoderm population may be obtained by weighting the quantity of each species by the life-span of the species. Life-span, however, in the present case is a vaguely defined term. Much is left to mere guess and much to the personal opinion of the observer. An estimate of the mean living age probably would be more relevant but, again, the material available is insufficient.

The life-span, expressed as the number of years in which a given year class probably will remain conspicuous in the samples may be so estimated for some of the more abundant species:

Amphiura filiformis (cf. p. 44). In the south-eastern North Sea most specimens collected in 1950—54 were small, predominantly belonging to the O-group. A life-span estimate of one year may be a good guess. In other parts of the area investigated patches were found, dominated by the I—III-group. A life-span of four years may be suggested. In practice, it is not necessary to keep the south-eastern North Sea stock separate because the occurrence of *A. filiformis* in that area was negligible.

Ophiura albida (cf. p. 56). In 1950—54 an almost unchanged stock was sampled, probably originating from a spat-fall in 1947 or 1948. The mean size of the animals increased slowly from 1950 to 1954. In 1932—34 a stock of very large *O. albida* was observed. If it may be assumed that the growth rate was approximately the same in the two periods the large specimens must be several years older than the recent stock of medium-sized animals. The recent stock, settled in 1947 or 1948, might still have some years to live at the end of the investigation in 1955. A life-span of 10 years may be suggested.

Echinocyamus pusillus (cf. p. 72). In 1950—54 the situation of patches of this species changed rapidly. This indicates a short life. There was evidence, however, that the same year class was sometimes sampled in two successive years. A life-span of two years may be a reasonably good estimate for the sampling period 1950—55. Locally, or sometimes, *E. pusillus* may grow very old in the North Sea. Persistent populations of old animals were observed off Helgoland in 1936—38 (CASPERS).

Echinocardium cordatum (cf. p. 79). As in the case of *Ophiura albida* a large and persistent stock was sampled in 1950—55. Apparently, there was a population of big animals, most conspicuous in the Dogger Bank region. Another population consisted of medium-sized animals and was most abundant in the south-eastern North Sea. There is evidence that the medium-sized animals originated from one or several spat-falls in the years 1946—48.[1]) The age of the big specimens could not be estimated. A life-span of 15 years may or may not be a good guess.

The life-span estimation for other, less abundant, species is rather hopeless. In some cases (*Strongylocentrotus droebachiensis, Ophiura robusta*) grab-caught specimens are obviously juvenile. Such species are allowed a life-span of two years, as *Echinocyamus*. Others, like *Astropecten* and *Ophiothrix*, seem to occur in several age groups without dominance of old adults. Such species and some rare forms are allowed five years. All spatangids are allowed 15 years, as *Echinocardium cordatum*.

Anybody who compares the above conclusions as to the life-span of individual species with the data on which the conclusions are based (cf. the systematical part of the paper) probably will disagree with the author in several cases. There is no doubt, however, that in one way or another there should be allowed for the long life of species like *O. albida* and *E. cordatum* as compared with the much shorter life of *A. filiformis* and *E. pusillus*.

As realized by PETERSEN and BOYSEN JENSEN (1911 p. 50) the wet weight of the animals brought up by the grab does not provide satisfactory knowledge of the quantity of organic matter present, primarily because the content of water and calcareous structures varies from one species to another. They decided to remove the calcareous skeletons by treatment with acid and to evaporate the water at 100° C. The remaining mixture of sodium chloride and other salts, organic dry matter, and inorganic intestinal contents was weighed and expressed as percentage of the wet weight. The wet weight sometimes was the weight of alcohol-stored specimens and sometimes the weight of unpreserved specimens. The percentage of dry matter in unpreserved specimens roughly corresponded to 90 % of the percentage for alcohol-stored specimens. The following echinoderms were analysed by PETERSEN and BOYSEN JENSEN. The percentages are based on the alcohol-weight:—

Psolus	19.7 % dry matter
Asterias	4.9 - - —
Ophiura	3.4 - - —
Echinus	1.8 - - —
Echinocardium	0.9 - - —

The low content of dry matter of echinoids, particularly of *Echinocardium*, is striking.

Several authors have carried out similar analyses. HOLME (1953 p. 23) found the following percentages of dry matter in alcohol-stored specimens. The probable percentages of dry matter in unpreserved specimens (90 % of alcohol-weight percentages) are added by the present author:—

[1]) See footnote p. 82.

	Alcohol	Unpreserved
Leptosynapta	24.2	21.8
Cucumaria	14.7	13.2
Ophiothrix fragilis	14.6	13.1
Amphiura	5.5	5.0
Echinocardium	2.3	2.1

HOLME's percentages seem rather higher than those found by PETERSEN and BOYSEN JENSEN. Again, holothurians show a high content of non-calcareous dry matter and *Echinocardium* a very low content.

STRUVE and KAIRIES (1930 pp. 13—14) weighed unpreserved specimens from the southern North Sea, evaporated the water and removed organic dry matter by ignition. Weighing before and after ignition produced the percentage of organic dry matter:—

Ophiura albida	6.9 %
Echinocyamus pusillus	6.8 -

A similar method was adopted by LEE (1951):—

Asterias forbesi	15.5 %

PETERSEN and BOYSEN JENSEN found lower percentages than more recent authors. The present author is not competent to judge whether the difference is due to local variation in dry matter percentage or to deficiency of the technique adopted by one or several authors. For the present purpose the important point is that the authors agree so far as the proportionate contents of dry matter of individual species or orders are concerned. On the assumption that the more recent authors are the more reliable, a list of dry weight percentages may be computed which covers fairly satisfactorily the groups of echinoderms in the North Sea:—

Genus analysed	Reference	%	Same percentage adopted for
Asterias	LEE	16	Other *Asteroidea*
Ophiothrix	HOLME	13	*Ophiocomidae, Ophiactidae*
Amphiura	HOLME	5	Other *Amphiuridae*
Ophiura	STRUVE and KAIRIES	7	Other *Ophiolepidae*
Echinocyamus	STRUVE and KAIRIES	7	
Echinocardium	HOLME	2	*Echinoidea* other than *Echinocyamus*
Cucumaria	HOLME	13	Other *Holothurioidea* (*Apoda* not present)

It is now possible to give a very rough idea of the proportionate contribution to the production made by each species in each statistical square. The basic material is the wet weight computations in Appendix 4. The conversion into terms of relative productivity is brought about by multiplication of the wet weight in grammes by the dry weight percentage and by the reciprocal of the life-span in years. An example illustrates the procedure and its effect:—

	Echinocyamus (a)	*Echinocardium* (b)	Ratio $\frac{a}{b}$
A Wet weight per sample	0.020 g	32.908 g	1 : 1646
B Dry weight percentage	7	2	
A × B	0.140	65.816	1 : 470
C Length of life	2 years	15 years	
$\frac{A \times B}{C}$	0.070	4.377	1 : 63

Table 33.

An estimate of the importance of individual species of echinoderms as producers and consumers in the North Sea. Based on 652 bottom samples from April and May 1950—55 (App. 3 and 4).

Species	No. per sample	Wet weight (g) per sample A	% organic dry matter B	Length of life (years) C	Index $\frac{B}{C}$	Relative productivity $D = \frac{AB}{C}$	Mean wet weight of specimens	Relative metabolic rate: Mean for av.-sized specimens E	Relative metabolic rate: The whole population AE
Astropecten irregularis	0.087	0.184	16	5	3.2	0.59	2.11	1.0	0.18
Luidia sarsi	0.003	0.026	16	5	3.2	0.08	8.67	0.7	0.02
Asterias rubens	0.012	0.075	16	2	8.0	0.60	6.25	0.8	0.06
Ophiothrix fragilis	0.282	0.154	13	5	2.6	0.40	0.55	1.5	0.23
Ophiocomina nigra	0.005	0.007	13	5	2.6	0.02	1.40	1.1	0.01
Ophiactis balli	0.014	0.000	13	5	2.6	0.00	0.021	4.0	0.00
Ophiopholis aculeata	0.008	0.003	13	2	6.5	0.02	0.38	1.7	0.01
Amphiura filiformis	3.137	0.382	5	4	1.25	0.48	0.12	2.4	0.16
Acrocnida brachiata	0.466	0.087	5	5	1.0	0.09	0.19	2.1	0.18
Amphipholis squamata	0.002	0.000	5	5	1.0	0.00	0.005	6.3	0.00
Ophiura texturata	0.002	0.000	7	2	3.5	0.00	0.083	2.6	0.00
— *affinis*	0.124	0.002	7	10	0.7	0.00	0.016	4.3	0.01
— *robusta*	0.008	0.000	7	2	3.5	0.00	0.007	5.7	0.00
— *albida*	3.235	0.472	7	10	0.7	0.33	0.15	2.2	1.04
Psammechinus miliaris	0.009	0.020	2	5	0.4	0.01	2.20	1.0	0.02
Strongylocentrotus droebachiensis	0.003	0.001	2	2	1.0	0.00	0.17	2.2	0.00
Echinocyamus pusillus	1.244	0.020	7	2	3.5	0.07	0.016	4.3	0.09
Spatangus purpureus	0.020	0.458	2	15	0.13	0.06	22.9	0.5	0.23
Echinocardium (3 species pooled)	2.764	32.908	2	15	0.13	4.39	12.0	0.6	19.74
Brissopsis lyrifera	0.014	0.119	2	15	0.13	0.02	8.50	0.7	0.08
Cucumaria elongata	0.055	0.034	13	5	2.6	0.09	0.62	1.5	0.05
— *lactea (planci?)*	0.003	0.000	13	2	6.5	0.00	0.057	2.9	0.00
Thyone fusus	0.003	0.008	13	5	2.6	0.02	2.54	1.0	0.01
Thyonidium commune	0.002	0.015	13	5	2.6	0.04	10.0	0.6	0.09
Total *Asteroidea*	0.10	0.29	..	..	4.4[1]	1.27	..	..	0.26[2]
— *Ophiuroidea*	7.27	1.10	..	..	1.1[1]	1.34	..	..	1.64[2]
— *Echinoidea* other than *Spatangidae*	1.25	0.04	..	..	2.0[1]	0.08	..	..	0.11[2]
— *Spatangidae*	2.79	33.49	..	..	0.13[1]	4.47	..	..	20.05[2]
— *Holothurioidea*	0.06	0.06	..	..	2.5[1]	0.15	..	..	0.15[2]
Total echinoderms	11.47	34.98	..	..	2.1[1]	7.30	..	..	22.21[2]
Percentage *Asteroidea*	1	1	..	..	..	17	..	..	1
— *Ophiuroidea*	63	3	..	..	..	18	..	..	7
— *Echinoidea* other than *Spatangidae*	11	0	..	..	..	1	..	..	0
— *Spatangidae*	24	96	..	..	..	61	..	..	90
— *Holothurioidea*	1	0	..	..	..	3	..	..	1

[1]) $\frac{D}{A}$. [2]) Summation.

Already the weighting of wet weights by dry weight percentages reveals a considerable overestimate of the importance of *Echinocardium*. Weighting by the length of life further diminishes the difference between the two species.

Similar computations for other echinoderms are given in Table 33. The higher the dry weight percentage and the shorter the life, the more productive the species. The index $\frac{\text{dry weight } \%}{\text{length of life}}$ is highest in *Asteroidea*, lowest in *Spatangidae*. Accordingly, the wet weight computations probably overestimate the importance of spatangids and underestimate the importance of all other groups, particularly the asteroids. This is clearly expressed in the percentage contribution of individual systematic groups to the total wet weight of echinoderms and to the total "productivity" of echinoderms (Table 33). While spatangids occupy 96 % of the total wet weight and asteroids 1 % only, spatangids contribute to the production by 61 % and asteroids by 17 %. Nevertheless, the spatangids maintain their prominent position in the echinoderm fauna of the

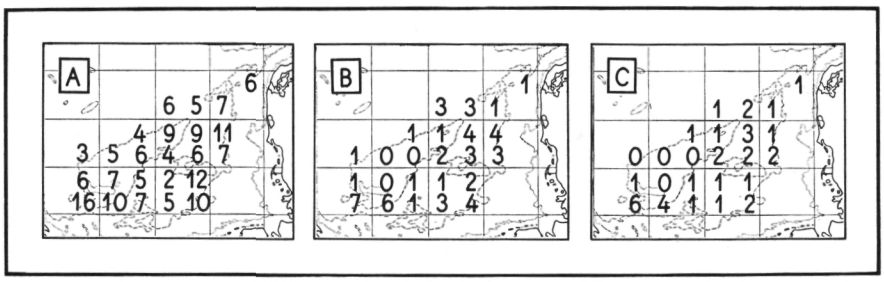

Fig. 95. *A:* An estimate of the productivity of the echinoderm fauna of the central North Sea. For explanation see p. 157. *B:* A similar estimate of the productivity of echinoderms suitable as food for fishes (i. e., *Asterias rubens* and *Spatangidae* omitted). *C:* Wet weight in grammes per 0.2 m² of echinoderms suitable as food for fishes. All three charts are based on bottom samples collected in April and May 1950–55. Squares from which less than 8 samples are available are omitted.

North Sea. It should be borne in mind, however, that the weighting of wet weight computations by dry matter contents and by life-span is a very subjective one and perhaps rather more expresses the author's personal opinion about the relative importance of individual species than it indicates the true condition in the North Sea.

Estimates of the relative productivity were made for each species in each statistical square so that the relative production in each square could be determined in the same way as the relative productivity of individual species. Fig. 95 A illustrates the result for squares with more than 8 samples from each (April and May 1950—55). Regular inter-square variation is not obvious although the Dogger Bank may be slightly less productive than the area east and south of the bank. An estimate of the production of echinoderms suitable as food for fishes may be obtained by the omission of *Asterias rubens* and *Spatangidae*. Young spatangids are suitable as food for fishes (Blegvad 1925 p. 30). In the present investigations juveniles were so scarce that their presence may be neglected. Fig. 95 B shows the relative production of fish food, due to echinoderms, in each square. The productivity of the Dogger Bank region is remarkably low. The same is found when the mere wet weight of echinoderms suitable as fish food is considered indicative for the production (Fig. 95 C).

These observations may have some bearing upon the well-established fact (Borley 1916 p. 26, and others) that the growth of plaice (*Pleuronectes platessa*) is more rapid on the Dogger Bank than elsewhere in the North Sea. Echinoderms are either not plaice food at all or they are second class food (Blegvad 1925 p. 30). There is evidence (Davis 1923, 1925, Ursin

1952) that first class food for plaice, such as polychaetes and small lamellibranchs, usually occurs in considerable quantities on the Dogger Bank. The small production of second class food (i. e., echinoderms) may improve the conditions of living for first class food animals and, thus, for the plaice.

As shown above the importance of spatangids as producers in the North Sea is not quite so great as indicated by the wet weight. An interesting point is the rôle played by individual species as consumers. Not very much is known, however, about the metabolic rate of individual species. It is probably higher in epifaunistic forms than in species belonging to the infauna

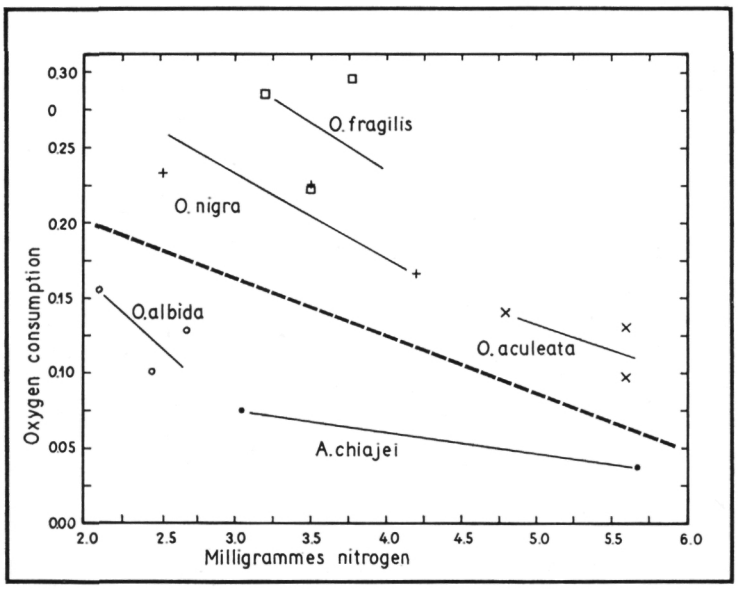

Fig. 96. Oxygen consumption (millilitres per day per milligramme nitrogen) plotted against nitrogen content of single specimens (WINTZELL 1918). The straight lines representing individual species are drawn on the assumption that there exists an approximately straight line relationship between oxygen consumption and nitrogen content, and that the oxygen consumption decreases with increasing nitrogen content. The broken line distinguishes observations made on supposed rheophile forms from observations made on other species of echinoderms.

(cf. SPÄRCK 1936). It may be expected that rheophile forms like *Ophiothrix fragilis* have a higher metabolic rate and, consequently, a higher demand for food than other species. WINTZELL (1918 p. 64) investigated the metabolic rate of several ophiuroids. The wet weight of the animals is not stated. The nitrogen content is stated, however, and gives some information on the size of the specimens. In Fig. 96 the oxygen consumption (millilitres per day per milligramme nitrogen) is plotted against the nitrogen content (milligrammes) of each specimen. Species supposed to be rheophile (*Ophiothrix fragilis, Ophiocomina nigra, Ophiopholis aculeata*) seem to have a higher metabolic rate than species that are not rheophile (*Ophiura albida, Amphiura chiajei*). However, until more up to date records become available it may be advisable to leave specific differences unaccounted for.

The effect of differences in the metabolic rate of small and big specimens, due to different heat loss to the surroundings, is more open to analysis. ZEUTHEN (1947 p. 133) points to the fact that the heat loss per unit of weight decreases by 52 % by a 10 times increase of the weight of the specimen. Experiments showed that the rate of decrease of the metabolic rate differs slightly

from the expected value. The observed value is usually about 40 %. Recent experiments (unpublished) by Mr. JAN BOËTIUS, M. Sc., indicated a rate of decrease of 50 % in echinoderms (several species from Faroe waters). By the adoption of a 50 % decrease of the metabolic rate by a 10 times increase in weight it is possible to weight the wet weight estimates by the oxygen consumption. In Table 33 is computed the mean wet weight per specimen of each species of echinoderms and the corresponding metabolic rate (volume O_2 consumed per unit of time and weight) on the assumption that specimens weighing 1 mg have an oxygen consumption of 10. The relative metabolic rate, so computed, varies from 6.3 in *Amphipholis squamata* (mean wet weight, 5 mg) to 0.5 in *Spatangus purpureus* (mean wet weight, 22.9 g). The bias originating from difference in weight of specimens belonging to the same species probably may be neglected in a rough estimate like the present. The last column in Table 33 shows the wet weight weighted by the relative metabolic rate of each species. A comparison of the percentage contribution of various systematic groups of echinoderms to the wet weight per sample and to production and consumption (Table 33, at the bottom) shows that wet weight figures tend to overestimate the indisputable importance of *Spatangidae* as producers as well as consumers. The importance of *Ophiuroidea* is underestimated in wet weight computations. *Asteroidea* seem to be highly productive animals with a low consumption. *Asteroidea*, however, are voracious animals which more than most other species exert a toll upon the initial production of organic matter by plants, because the assimilated carbon has to pass several links before it becomes suitable as food for asteroids. An attempt to weight the quantity of each species of echinoderms by the "expensiveness" of its food is probably premature because too little is known about the food preferences of most species. Many ophiuroids, for instance, probably are optional predators feeding on detritus in lack of suitable prey.

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Summary.

The investigation is restricted to species recorded from the North Sea in depths of 100 metres or less. The echinoderms from about 700 bottom samples taken with a 0.2 m² modified VAN VEEN grab in 1950—55 were identified, counted, measured and, partly, weighed. Supporting evidence was gathered from about 500 bottom samples taken in 1932—48 and from several hundred trawl, seine, and dredge hauls made in 1922—55. The material was collected by Danish research vessels, primarily the "Dana". The mean contents of bottom material in the grab in 1950—54 was 8—16 litres, depending on the grade of soil. Neither the number of species, nor the number of specimens, nor the wet weight was significantly dependent upon sample volume.

Short accounts of the distribution and, when possible, population dynamics of individual species in the North Sea are given. The influence of bottom temperature, grade of soil, etc., upon the distribution is discussed. Few species are recorded from the central and south-eastern North Sea (the Dogger Bank and the area south and east of the bank). Several species are confined to the north British coast, the western edge of the Dogger Bank, and the area between the north-eastern end of the Dogger Bank and the Danish coast. Many species—particularly among the less abundant ones—are recorded from the whole northern North Sea but not, or not very often, from the southern North Sea. Some species are restricted to the British coast and, partly, to the

edge of the Norwegian Channel. A good many species have a more or less bimodal distribution in the North Sea-Baltic area. An example is *Amphiura chiajei* which abounds in Scottish waters of the North Sea and in the Skagerrak-Kattegat region, but is rare or even undetectable in most parts of the North Sea.

The distribution of individual species is only slightly tied up with temperature, salinity, and grade of soil. It seems more dependent upon the distribution of plankton assemblages which, again, are indicators of distinct water masses. For instance, the distribution of many species of echinoderms resembles the distribution of water of recent Atlantic origin, particularly characterized by *Sagitta elegans*. Few species of echinoderms were found in the central North Sea water, known as the *Sagitta setosa* water.

The sequence of the species when arranged according to abundance is approximately the same all over the North Sea except, perhaps, on the British coast. The abundant species are less abundant in the northern North Sea (i. e., in localities influenced by *Sagitta elegans* water) than in the central and southern North Sea (i. e., in water influenced by *Sagitta setosa* water or local coastal water masses). The rare species are more abundant in the northern North Sea than in the central and southern North Sea. The situation may be examplified by the comparison of the expected result of bottom sampling in a northern North Sea locality and in a central North Sea locality. 20 species of echinoderms may be obtained in about 100 samples from the northern North Sea, but in no less than 20,000 samples from the southern North Sea. The point is that there will be no appreciable difference between the two fauna lists gathered with so different an effort. This implies that any abundant species as, for instance, *Echinocardium cordatum*, will appear as a southern and central North Sea form, because the highest percentage occurrence of a single species in the hauls is obtained in the central and southern North Sea. A rare form listed as, say, number 20 in both fauna lists will appear as a northern North Sea form because it is practically impossible to collect species number 20 in the southern North Sea, which is so poor in species. The general geographical distribution of the abundant species is predominantly southern. The northern forms are on the whole less abundant. The implication is that northern forms are detactable only in localities rich in species, i. e., in *Sagitta elegans* water. The temperature conditions in such localities are not necessarily more favourable to northern species than to southern species.

A comparison of fauna lists (echinoderms only) based on bottom sampler material from various localities in the North Sea with lists of the same length from a southern sea area (the Adriatic) and a northern sea area (Faxa Bay in Iceland) showed that the dominance of the southern fauna element in the North Sea increased from north-west toward south-east. For instance, fauna lists of 11 species each from the Adriatic Sea had, on an average, 3 species in common with similar lists from the German Bight but only 2 species in common with lists from the north-western North Sea. A striking similarity between such fauna lists from Faxa Bay and the Belt Sea in the transitional area between the North Sea and the Baltic was ascribed to the predominance in both areas of rheophile forms with a high demand for food. Rheophile forms are more scarce in the North Sea. They are partly commensal with colonial animals (sponges, corals) which maintain a water flow in their immediate neighbourhood.

Changes in the distribution of individual species in the central and southern North Sea in the present century could not be tied up with the recent temperature increase. If there is any tendency in these changes at all it is rather so that the abundant species became still more abundant and the rare species still more rare. An accentuation of the borderline between the *Sagitta elegans* water region and southern North Sea water masses, particularly the *Sagitta*

setosa region, is suggested. A few species suffered reduction during the cold winter of 1947 but recovered afterwards.

The number of specimens (echinoderms) per unit of area is particularly low, 5—10 per sample, in the Dogger Bank region. There were 10—20 specimens per sample in most other parts of the North Sea. The higher densities were found in the finer grades of soil, both in the Dogger Bank region and elsewhere. The densities of echinoderms observed in the North Sea are higher than in most other sea areas in the North Atlantic and Mediterranean region although not higher than in the Kattegat. *Echinocyamus* was the most abundant form in coarse sand. *Ophiura albida* was the most abundant in fine sand and in company with *Amphiura filiformis* dominated the softer deposits, too. *Echinocardium cordatum* abounded in all grades of soil.

Echinocardium cordatum occurred in more hauls than other species. *Ophiura albida* was found in higher numbers than other species. *O. albida* must have been more aggregated than *E. cordatum*. It was found difficult to compare the aggregation of individual species because the conspicuousness of aggregation depends upon the mean number of specimens per sample. The bigger the grab or the more abundant the species, the more evident the deviation from random distribution. Log scale plotting of the mean against standard deviation of single observations gives a rough survey, almost independent of the mean, of the aggregation. Appreciable aggregation could not be detected within area units of 2—3 square miles. Within area units of about 1000 square miles (statistical squares) *Echinocardium* seemed to be less aggregated (more evenly distributed) than other species; *Echinocyamus pusillus* was the most aggregated species.

The wet weight per unit of area was approximately the same all over the area investigated. About 90 % of the wet weight was accounted for by spatangid species, particularly *Echinocardium cordatum*. A similar dominance of spatangids is observed all over the Boreal-Lusitanian region except, perhaps, where the rheophile fauna element with suspension feeding ophiuroids and holothurians dominates. Quantities of echinoderms similar to those found in the North Sea in the present investigation (30 g per 0.2 m^2) have been found in the Kattegat, but scarcely anywhere else in the north-west Atlantic and Mediterranean region.

Weighting of the wet weight by approximate life-span and dry weight of individual species showed that the importance of *Spatangidae* is over-estimated when the wet weight (the standing crop) is considered proportionate to production. Spatangids maintain a prominent position as producers, all the same. The production of echinoderms suitable as food for fishes seems to be lower on the Dogger Bank than in the surrounding waters.

The importance of spatangids as consumers is considerable although, like their rôle as producers, somewhat over-estimated in wet weight computations. They are big animals with a comparatively small heat loss to the surroundings and, probably, with a correspondingly low oxygen consumption.

Appendix 1.

List of grab stations with total number caught of each of the more abundant species of echinoderms. Occurrences of less abundant species are listed in the systematical section (p. 25 ff).

Abbreviations:

Samplers:
01 P: PETERSEN grab, 0.1 m²
02 P: – – , 0.2 m²
01 V: VAN VEEN – , modified, 0.1 m²
02 V: – – , – 0.2 m²
01 K: KNUDSEN bottom sampler, 0.1 m²

Bottom deposits:

cl	clay	(st)	few stones
mcl	muddy clay	st	stones
scl	sandy clay	*st*	many stones
cls	clayey sand		
ms	muddy sand	(sh)	few shells
fs	fine sand	sh	shells
s	sand	*sh*	many shells
cos	coarse sand		

Species:

A. irr.	*Astropecten irregularis*
O. frag.	*Ophiothrix fragilis*
A. fil.	*Amphiura filiformis*
A. brach.	*Acrocnida brachiata*
O. text.	*Ophiura texturata*
O. aff.	*Ophiura affinis*
O. alb.	*Ophiura albida*
E. pus.	*Echinocyamus pusillus*
E. cord.	*Echinocardium cordatum*
E. flav.	*Echinocardium flavescens*
E. indet.	*Echinocardium*, not identified to species

1932 — "Dana".

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E.* indet.
4314...	10-5	54°43	2°20	G 8	22	c. 5	fs *sh* st	2	02 P	..	..	..	..	..	..	..	..	1	..	..
4315...	11-5	54°47′	4°06′	J 8	48	c. 15	scl	2	—	..	..	5	..	..	..	1	..	1	6	..
4316...	12-5	54°54′	5°18′	K 8	40	c. 15	scl	2	—	..	..	6	..	..	..	..	..	..	..	..
4317...	—	55°05′	6°12′	L 9	46	c. 25	cl	2	—	..	..	41	..	..	..	..	..	..	..	3
4318...	13-5	55°11′	7°5′	M 9	29	c. 5	s	2	—	1	..	..	..	..	..	..	..	1	..	..
4321...	14-5	56°13	8°03′	N 11	18	c. 10	cls	2	—	..	..	..	..	..	..	..	..	..	..	..
4322...	—	55°59′	7°32′	M 10	26	c. 20	fs	2	—	..	..	..	..	..	..	..	..	1	..	..
4323...	15-5	55°53′	6°24′	L 10	43	c. 20	fs	2	—	..	..	1	..	..	..	..	..	1	1	..
4324...	—	55°47′	5°27′	K 10	50	c. 25	scl	2	—	..	..	8	..	..	..	6	..	1	..	..
4325...	16-5	55°42′	3°52′	H 10	40	c. 15	fs	2	—	..	1	..	1	..	..	..	..	..	1	..
4328...	17-5	55°01′	2°27′	G 9	35	c. 10	s *sh*	2	—	..	..	.	1	..	..	..	..	1	..	..
4329...	—	56°12′	1°42′	F 11	95	c. 2	scl	?	01 P	..	..	3	..	1	1	..	..	3	5	1
4329...	18-5	—	—	F 11	90	c. 2	scl	?	—											
4330...	—	56°12′	0°43′W	D 11	74	c. 8	cls	2	02 P	..	..	5	..	..	..	4	..	..	2	..
4331...	23-5	55°28′	0°23′W	D 9	70	c. 1	cos sh	2	—	..	..	1	..	..	..	1	..	..	..	..
4332...	—	55°01′	0°31′E	E 9	86	c. 25	cl	2	—	..	..	7	..	..	..	..	..	..	..	..
4333...	24-5	55°00′	0°43′	E 9	72	c. 15	s	2	—	..	..	2	..	..	..	..	..	4	1	..

1932 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E. indet.*
4335...	24-5	54°50′	2°00′	G 8	24	c. 15	cos *sh*	2	02 P	..	..	..	..	..	..	..	..	..	..	..
4336...	25-5	54°20′	0°45′	E 7	50	c. 10	s (sh)	2	—	..	..	1	9	..	..	..	..	..	..	..
4337...	—	54°10′	0°50′	E 7	42	c. 20	cos st sh	2	—	..	..	..	..	..	..	2	18	..	..	..
4339...	28-5	53°55′	1°13′	F 6	35	c. 20	fs (sh)	2	—	..	..	..	1	..	..	..	..	1	..	..
4340...	—	54°03′	1°53′	F 7	80	c. 25	cls sh	2	—	..	..	55	..	..	..	16	..	..	3	..
4341...	29-5	54°30′	2°20′	G 8	17	c. 5	s *sh*	2	—	..	..	..	..	..	..	..	..	1	..	..
4344...	30-5	55°09′	2°50′	G 9	27	c. 4	fs (sh)	2	01 P	..	..	..	..	..	..	..	..	1	..	..
4350...	2-6	56°21′	5°37′	K 11	56	c. 35	scl	2	02 P	..	..	..	..	..	..	17	..	..	..	1
4351...	—	56°40′	6°02′	L 12	51	c. 2	s	2	01 P	..	..	..	..	..	1	..	3	..	..	..
4355...	4-6	56°16′	1°54′	F 11	84	c. 2[1])	fs	2	—	..	..	..	..	..	..	..	..	..	..	..

[1]) Deficient sample.

1933 — "Dana".

4521 I..	27-6	57°19′	8°45′	N 13	27	c. 5	s st	1	02 P	..	..	..	..	..	..	..	..	..	..	..
— II..	—	—	—	—	26	c. 8	s st	1	—	..	..	..	..	..	..	..	..	..	..	..
4522 I..	—	57°19′	8°45′	N 13	62	8–10	s	1	—	..	..	..	..	..	..	..	..	..	1	..
— II..	—	—	—	—	62	c. 10	s	1	—	..	..	..	..	..	..	..	..	..	..	..
4523 I..	28-6	56°55′	5°07′	K 12	63	c. 2	s	1	—	..	..	17	..	..	..	..	..	..	1	..
— II..	—	—	—	—	63	c. 3	s	1	—	..	..	26	..	1	..	..	..	..	1	..
4524 I..	29-6	56°38′	4°09′	J 12	64	c. 6	ms	1	—	..	..	2	..	..	..	..	..	..	..	1
— II..	—	—	—	—	64	c. 6	ms	1	—	..	..	4	..	..	..	..	..	..	..	..
4525 I..	—	56°00′	4°06′	J 11	56	c. 3	s	1	—	..	..	1	..	..	..	..	..	..	..	..
— II..	—	—	—	—	56	c. 3	s	1	—	..	..	..	..	..	..	..	..	1	..	..
4526 I..	—	55°36′	4°04′	J 10	30	c. 2	cls	1	—	..	..	..	..	..	..	..	..	..	..	..
— II..	—	—	—	—	30	c. 2	cls	1	—	..	..	1	..	..	..	..	..	..	..	..
4527 I..	30-6	55°00′	2°38′	G 9	25	c. 1.5	s	1	—	..	..	..	..	..	..	..	..	1	..	..
— II..	—	—	—	—	25	c. 3	s	1	—	..	..	..	1	..	..	..	..	1	..	..
4528 I..	—	54°35′	1°30′	F 8	30	c. 2	st	1	—	..	..	..	..	..	..	..	..	..	..	..
— II..	—	—	—	—	30	c. 3	cos	1	—	..	..	..	1	..	..	..	..	..	..	..
4529...	—	54°41′	1°45′	F 8	30	7–8	s	1	—	..	..	..	..	..	..	..	..	1	..	..
4530 I..	1-7	55°17′	1°40′	F 9	38	c. 2	fs	1	—	..	..	..	3	..	..	..	..	..	..	..
— II..	—	—	—	—	38	c. 3	fs	1	—	..	..	1	1	..	..	..	..	1	..	..
4531 I..	—	55°50′	1°30′	F 10	81	c. 4	ms	1	—	..	..	..	..	..	..	..	..	..	..	..
— II..	—	—	—	—	81	c. 3	ms	1	—	..	..	1	..	..	..	..	..	..	..	1
4532 I..	2-7	56°40′	0°00′	E 12	80	c. 3	fs	1	—	..	..	1	..	..	..	..	..	..	..	..
— II..	—	—	—	—	80	c. 1.5	fs	1	—	..	..	2	..	..	..	..	..	..	..	..
4533 I..	—	56°30′	1°20′W	E 12	68	c. 4	fs	1	—	..	..	4	..	..	..	..	..	..	..	..
— II..	—	—	—	—	68	c. 8	fs	1	—	..	..	2	..	..	..	..	..	..	..	..
4536 I..	5-7	55°28′	0°25′W	D 9	?	c. 2	s	1	—	..	..	4	..	..	..	..	..	..	..	..
— II..	—	—	—	—	79	c. 2	fs sh	1	—	..	..	2	..	..	..	..	..	1	..	..
4537 I..	—	55°00′	0°42′E	E 9	77	c. 4	ms	1	—	..	..	1	..	..	..	..	..	..	..	..
— II..	—	—	—	—	77	c. 6	ms	1	—	..	..	1	..	..	..	..	..	..	..	1
4538 I..	6-7	54°43′	2°20′	G 8	26	c. 3	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
— II..	—	—	—	—	26	c. 4	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
4542 I..	8-7	55°37′	7°50′	M 10	15	c. 4	fs sh	1	—	..	..	..	..	1	..	..	..	3	..	..
— II..	—	—	—	—	15	c. 4	fs sh	1	—	..	..	..	..	..	..	..	..	6	..	..
4543 I..	—	55°28′	8°04′	N 9	11	c. 5	ms	1	—	..	..	..	..	..	..	..	..	..	..	..
— II..	—	—	—	—	11	c. 5	ms	1	—	..	..	..	..	..	..	..	..	..	..	..
4544 I..	—	55°25′	8°13′	N 9	13	c. 2	ms	1	—	..	..	..	..	..	..	..	..	..	..	..
— II..	—	—	—	—	13	c. 3	ms	1	—	..	..	..	..	1	..	..	..	..	..	..
4551 I..	12-7	55°17′	8°09′	N 9	17	c. 4	ms sh	1	—	..	..	..	..	1	..	..	..	..	..	..
— II..	—	—	—	—	17	c. 2	ms sh	1	—	..	..	..	..	..	..	..	..	..	..	..
4552 I..	—	55°18′	7°45′	M 9	21	c. 3	ms sh	1	—	..	..	..	..	..	..	..	..	..	..	..
— II..	—	—	—	—	21	c. 4	ms sh	1	—	..	..	..	..	..	..	1	1	..	..	..
4558 I..	17-7	54°47′	4°05′	J 8	50	c. 3	ms	1	—	..	..	36	..	..	1	1	..	..	4	..
— II..	—	—	—	—	50	c. 4	ms	1	—	..	..	28	..	..	..	1	..	..	3	..
4559 I..	—	55°03′	5°55′	K 9	43	c. 8	ms	1	—	..	..	30	..	..	..	..	..	1	..	..
— II..	—	—	—	—	43	c. 5	ms	1	—	..	..	20	..	..	..	..	..	..	..	..
4561 I..	19-7	55°47′	5°27′	K 10	52	c. 7	s	1	—	..	1	1	..	..	..	1	..	1	..	..
— II..	—	—	—	—	52	c. 4	s	1	—	1	..	2	..	..	1	..	..	1	..	..

1933 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E. indet.*
4565 I	20-7	56°08′	0°30′W	D 11	79	c. 4	cos sh	1	02 P			4						1		
— II	—	—	—	—	79	c. 4	cos sh	1	—			8								
4566 I	—	56°08′	1°20′W	C 11	47	c. 5	cos	1	—											
— II	—	—	—	—	47	c. 5	sh	1	—								3			
4733	6-9	55°27′	8°11′	N 9	10	c. 3 + c. 3	cls	2	—					3				3		
4735	—	55°27′	7°37′	M 9	29	c. 3 + c. 4	cos	2	—											
4737	—	55°27′	6°50′	L 9	29	c. 3 + 3-4	fs	2	—											
4739	7-9	55°20′	6°25′	L 9	42	c. 2 + c. 3	ms	2	—			21								
4740	—	55°20′	6°50′	L 9	29	c. 3 + c. 3	ms	2	—							10		1		
4742	—	55°20′	7°37′	M 9	25	c. 3 + c. 4	fs	2	—									1		
4744	—	55°20′	8°11′	N 9	14	2-3 + 2-3	fs sh	2	—					1						
4745	—	55°10′	8°11′	N 9	10	3 + 3	fs	2	—					1						
4747	—	55°10′	7°37′	M 9	22	1.5 + 2.5	fs	2	—							1				
4749	8-9	55°10′	6°50′	L 9	35	5 + 5	cos	2	—							2	7	2		
4752	—	55°39′	7°48′	M 10	18	5 + 5	fs	2	—									1		

1934 — "Dana".

5194	15-6	55°27′	8°11′	N 9	11	4	fs	2	02 P					9						
5195	—	55°18′	8°20′	N 9	7	5	fs	2	—					2						
5196	—	55°18′	8°17′	N 9	12	3	cls sh	2	—					2						
5197	16-6	55°05′	8°18′	N 9	9	3	fs	2	—					1						
5198	—	55°05′	8°15′	N 9	13	4	s	2	—											1
5199 K	—	55°05′	8°00′	N 9	18	(22)	s	1	01 K											6
— a	—	55°05′	8°00′	N 9	18	(30)	s	1	—											
— P	—	55°05′	8°00′	N 9	18	6	s	2	02 P											3
5200 P	—	55°14′	8°04′	N 9	16	c. 25	cos	2	—											
— K	—	55°14′	8°04′	N 9	16	(30)	cos	1	01 K											
5201 K	—	55°22′	7°54′	M 9	16	(30)	s	1	—											1
— P	—	55°22′	7°54′	M 9	16	3	s	2	02 P											1
5202	—	55°27′	8°00′	N 9	15	6	s	2	—							1				4
5203 P	—	55°27′	7°45′	M 9	25	10	s	2	—											
— K	—	55°27′	7°45′	M 9	25	(30)	s	1	01 K											
5204 P	—	55°18′	7°43′	M 9	21	5	s	2	02 P							1				4
— K	—	55°18′	7°43′	M 9	21	(22)	s	1	01 K											3
5205	17-6	55°05′	7°40′	M 9	21	10	s	2	02 P							1				12
5206 P	—	55°05′	7°20′	M 9	21	10	cos	2	—								1			1
— K	—	55°05′	7°20′	M 9	21	(30)	cos	1	01 K								1			
5207 P	—	55°18′	7°13′	M 9	26	5	s	2	02 P											4
— K	—	55°18′	7°13′	M 9	26	(22)	s	1	01 K											9
5208 P	—	55°30′	7°07′	M 10	28	5	fs	2	02 P				3							
— K	—	55°30′	7°07′	M 10	28	(22)	s above / scl below	1	01 K											
5209 P	—	55°18′	6°59	L 9	37	10	cos	2	02 P							2	7			6
— K	—	55°18	6°59	L 9	37	(15)	cos	1	01 K								2			
5210 K	—	55°05	6°50′	L 9	38	(30)	cls	1	—			11								1
— P	—	55°05′	6°50′	L 9	38	8	cls	2	02 P			55				3				11
5211 P	—	55°18′	6°40′	L 9	40	10	cls	2	—			25				1				3
— K	—	55°18′	6°40′	L 9	40	(30)	cls	1	01 K											1
5212 P	18-6	55°30′	6°47′	L 10	33	8	cos	2	02 P								13			1
— K	—	55°30′	6°47′	L 10	33	(30)	cos	1	01 K											
5213 K	—	55°37′	7°30′	M 10	15	(30)	cos	1	—											
— P	—	55°37′	7°30′	M 10	15	12	cos	2	02 P											
5214 K	—	55°37′	7°45′	M 10	19	(22)	cos	1	01 K											8
— P	—	55°37′	7°45′	M 10	19	9	cos	2	02 P											4
5215	—	55°37′	8°00′	N 10	14	5	fs	2	—											
5216 P	—	55°45′	8°00′	N 10	18	8	s	2	—					2		1				5
— K	—	55°45′	8°00′	N 10	18	(30)	s above / scl below	1	01 K											1
5217	—	55°45′	7°45′	M 10	22	8	s	2	02 P											5

1934 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E. indet.*
5218P	18-6	55°45′	7°30′	M 10	26	8	s	2	02 P	..	..	..	..	..	..	2	1	1	..	..
— K	—	55°45′	7°30′	M 10	26	(30)	s	1	01 K	..	..	..	..	..	..	..	..	..	..	1
5219P	19-6	55°39′	7°19′	M 10	24	10	cos	2	02 P	..	..	..	..	..	..	..	..	..	..	..
— K	—	55°39′	7°19′	M 10	24	(30)	cos	1	01 K	..	..	..	..	..	..	..	..	..	..	..
5220K	—	55°30′	7°28′	M 10	29	(30)	cos	1	—	..	..	..	..	..	..	1	1	..	..	..
— P	—	55°30′	7°28′	M 10	29	10	cos	2	02 P	..	..	..	..	..	..	..	..	..	..	..
5221P	—	55°30′	8°01′5	N 10	25	15	s above scl below	2	—	..	..	..	..	..	..	..	..	..	..	..
— K	—	55°30′	8°01′5	N 10	25	(30)	s above scl below	1	01 K	..	..	..	..	..	..	..	..	..	..	..
5222K	—	55°28′	8°11′	N 9	9	(30)	cls	1	—	..	..	..	..	..	..	..	..	..	..	5
— P	—	55°28′	8°11′	N 9	9	4	s	2	02 P	..	..	..	..	..	..	..	..	..	..	..
5227	22-6	55°03′	5°55′	K 9	40	?	fs	2	—	1	..	42	..	..	..	..	..	3	..	..
5228	23-6	54°51′	4°40′	J 8	41	?	fs	2	—	..	..	12	..	..	..	..	..	2	2	..
5229	—	54°47′	4°05′	J 8	47	c. 5	ms	2	—	..	..	3	..	..	..	..	..	2	2	..
5230	24-6	54°43′	2°20′	G 8	26	c. 4	fs	2	—	..	..	..	..	..	..	..	..	1	..	..
5231	—	55°00′	2°38′	G 9	31	c. 4	fs sh	2	—	..	..	..	..	..	..	..	..	1	..	..
5232	—	55°18′	3°21′	H 9	30	c. 3	fs	2	—	..	..	..	..	..	..	..	..	..	..	..
5233K	25-6	55°36′	4°04′	J 10	35	(30)	fs	1	01 K	..	..	..	..	2	..	..	..	3	..	..
— P	—	55°36′	4°04′	J 10	35	c. 3	fs	2	02 P	..	..	..	1	..	..	1	..	1	..	..
5234	—	55°33′	4°20′	J 10	47	c. 3	?	2	—	..	..	1	..	1	..	1	..	1	..	..
5235	26-6	55°47′	5°27′	K 10	52	c. 10	cl	2	—	..	..	100	..	1	..	5	..	3	..	..
5236	—	55°53′	6°24′	L 10	41	c. 6	s	2	—	..	..	80	..	..	..	2	..	3	..	..
5237	—	55°53′	7°20′	M 10	25	c. 5	cos	2	—	..	..	..	..	1	..	..	..	..	..	..
5238	27-6	55°53′	8°00′	N 10	20	c. 10	s	2	—	..	..	..	..	1	..	1	..	10	..	..
5239	—	56°26′	8°00′	N 11	21	3	cos	3	—	..	..	1	..	..	..	..	1	..	..	..
5240	—	56°29′	7°54′	M 11	23	4	cos	2	—	..	..	1	..	..	..	..	9	..	..	..
5241	—	56°33′	7°54′	M 12	23	16	cos	1	—	..	..	..	..	..	..	..	..	..	..	..
5242	28-6	56°32′	6°54′	L 12	38	c. 10	cos	2	—	..	..	..	..	..	1	2	1	..	2	..
5244	—	56°40′	5°55′	K 12	55	8	cl cos	2	—	1	..	1	..	..	..	..	..	2	4	..
5245	—	56°55′	5°07′	K 12	64	c. 7	s	2	—	1	..	5	..	..	2	..	..	5	..	..
5246	29-6	56°38′	4°07′	J 12	61	?	fs	2	—	..	..	1	..	..	1	..	..	1	..	..
5247	—	57°38′	4°20′	J 14	78	c. 10	fs	2	—	..	..	1	..	..	..	..	..	..	2	..
5248	30-6	57°23′	3°26′	H 13	63	c. 10	s	2	—	..	..	1	..	..	1	..	..	1	..	..
5249	—	57°23′	1°40′	F 13	93	c. 10	ms?	2	—	..	..	2	..	..	..	..	..	..	1	..
5250 I	1-7	58°15′	0°40′	E 15	150	"full"	ms?	1	—	..	..	..	..	..	..	..	..	..	..	..
— II	—	58°15′	0°40′	E 15	150	(30)	ms?	1	01 K	..	..	..	..	..	..	..	..	..	..	..

1936 — "Biologen".

4877	12-6	55°27′	8°12′	N 9	10	3.5	cls	2	02 P	..	..	..	..	..	..	..	..	..	..	..
4878	—	55°27	8°00	N 9	14	5	cls	4	—	..	..	..	..	..	..	..	..	..	..	..
4879	—	55°18′	8°05′	N 9	15	4	cls (sh)	2	—	..	..	..	..	..	..	..	..	..	..	..
4881	13-6	55°27′	7°20′	M 9	28	10	cos	2	—	..	..	..	..	..	..	..	2	..	..	..
4882	—	55°18′	7°15′	M 9	26	8	s	2	—	..	..	..	..	..	..	..	..	..	..	..
4883	—	55°21′	7°26′	M 9	24	5	s	2	—	..	..	..	..	..	..	..	..	..	..	..
4884	14-6	55°18′	8°15′	N 9	15	4	cls sh	2	—	..	..	..	..	..	..	..	..	..	..	..
4885	—	55°18′	8°20′	N 9	8	5	cls	2	—	..	..	..	..	..	..	1	..	..	..	..
4886	—	55°07′	8°19′	N 9	9	5	cls	2	—	..	..	..	..	..	..	..	..	7	..	..
4887	—	55°07′	8°15′	N 9	12	5	cls	2	—	..	..	..	..	..	..	..	..	2	..	..
4888	17-6	55°21′	7°55′	M 9	19	4	cls (sh)	2	—	..	..	..	..	..	..	..	..	..	..	..
4889	—	55°17′	7°44′	M 9	23	5	s	2	—	..	..	..	..	..	..	..	..	..	..	..
4891	—	55°05′	7°41′	M 9	22	6	s	2	—	..	..	..	..	..	..	..	..	..	..	5
4892	18-6	55°23′	8°18′	N 9	16	10	cls (sh) ms?	2	—	..	..	..	..	1	..	..	..	1	..	1
4893	—	55°13′	8°08′	N 9	15	6	cls	2	—	..	..	..	..	..	..	..	..	..	..	1
4895	—	55°05′	7°50′	M 9	20	5	s	2	—	..	..	..	..	..	..	..	..	..	..	2
4896	19-6	55°43′	7°45′	M 10	18	6	s	2	—	..	..	..	..	..	..	..	..	..	..	1
4897	—	55°43′	7°30′	M 10	20	4	s	2	—	..	..	..	..	..	..	..	..	..	..	..
4898	—	55°37′	7°30′	M 10	17	5	s	2	—	..	..	..	..	..	..	..	..	..	..	2
4899	—	55°28′	8°08′	N 9	10	6	s	2	—	..	..	..	..	3	..	3	..	..	..	..

1936 — "Biologen" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume	Bottom	No. of samples	Sampler	*A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E.* indet.
4900...	20-6	55°38′	7°45′	M 10	14	8	cls	2	02 P	..	..	..	..	..	..	..	..	..	..	..
4901...	—	55°43′	8°00′	N 10	16	7	cls	2	—	..	..	..	..	..	..	..	..	..	..	..
4902...	—	55°38′	8°00′	N 10	14	5	s	2	—	..	..	..	..	..	..	..	..	..	..	..
4904...	21-6	55°57′	8°02′	N 10	22	10	cls? ms?	2	—	..	..	..	..	..	..	..	..	..	..	9
4905...	—	56°11′	8°00′	N 11	17	8	cos	2	—	..	..	..	..	..	..	..	..	..	..	..

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5295...	18-6	55°23′	8°10′	N 9	16	1.5	fs	2	02 P	..	..	..	..	..	..	..	..	..	..	..
5296...	—	55°21′	7°54′30″	M 9	19	1.5	fs	2	—	..	..	..	..	..	..	..	..	..	..	..
5297...	—	55°18′	8°05′	N 9	17	1.5	fs	2	—	..	..	..	..	..	..	..	..	..	..	..
5298...	—	55°14′	8°08′	N 9	15	1.5	fs	2	—	..	..	..	..	..	..	..	..	..	..	..
5299...	20-6	55°28′	8°12′	N 9	9	4	cls	2	—	..	..	..	..	11	..	1	..	..	..	..
5300...	—	55°28′	8°07′	N 9	13	2.5	cls	2	—	..	..	..	..	3	..	1	..	..	..	..
5301...	—	55°27′	8°00′	N 9	13	4	cls	2	—	..	..	..	..	1	..	..	..	..	..	..
5302...	—	55°26′	7°48′	M 9	22	4	fs	2	—	..	..	..	..	2	..	2	..	..	..	..
5305...	21-6	55°21′	8°18′	N 9	10	4	cls	2	—	..	..	..	..	..	..	..	..	..	..	..
5306?A	—	Grådyb lightbuoy		N 9	?	?	cls	3	01 V	..	..	..	..	2	..	1	..	..	..	..
5306...	—	55°25′	8°05′	N 9	15	7	cls	2	—	..	..	..	..	..	..	..	..	..	..	3
5307 I..	—	55°30′	8°08′	N 10	6	11	cls	3	—	..	..	..	..	..	..	..	..	..	..	..
— III..	—	55°30′	8°08′	N 10	6	3.5	cls	2	02 P	..	..	..	..	..	..	..	..	..	..	..
5308...	22-6	55°36′	7°43′	M 10	14	5	cos	2	01 V	..	..	..	..	..	..	..	..	..	..	3
5309...	24-6	55°38′	8°00′	N 10	15	4	fs	2	—	..	..	..	..	2	..	..	..	..	..	..
5310...	—	55°41′	7°46′	M 10	16	6	fs	2	—	..	..	..	..	..	..	..	..	..	..	..
5311...	—	55°41′	7°35′	M 10	14	11	fs	2	—	..	..	..	..	..	..	..	..	..	..	..
5312...	25-6	55°17′	7°44′	M 9	25	6	fs	2	—	..	..	..	..	..	..	..	..	..	..	1
5313...	—	55°14′	7°30′	M 9	23	5	fs	2	—	..	..	..	..	..	..	..	..	..	..	2
5314...	27-6	55°08′	7°55′	M 9	19	6	fs	2	—	..	..	..	..	..	..	..	..	..	..	13
5315...	—	55°08′	7°40′	M 9	21	8	fs	2	—	..	..	..	..	..	..	..	..	..	..	4
5316...	—	55°09′	7°26′	M 9	22	7	fs	2	—	..	..	..	..	..	..	..	..	..	..	4
5317...	28-6	55°11′	8°17′	N 9	9	5	fs	2	—	..	..	..	..	..	..	..	..	..	..	..
5318...	—	55°11′	8°14′	N 9	12	5	fs	2	—	..	..	..	..	2	..	1	..	2	..	..

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5741...	9-3	55°05′	6°05′	L 9	45	5	fs	1	02 P	..	..	1	..	..	..	..	..	..	1	..
5751...	15-3	55°24′	8°03′	N 9	17	?	s	1	—	..	..	1	..	1	..	..	..	..	..	..
5765...	21-4	57°19′	8°45′	N 13	26	0.5	fs	1	—	..	..	1	..	..	..	..	..	2	..	..
5768...	22-4	57°11′	7°45′	M 13	53	5	cos sh	1	—	..	..	..	..	..	2	1	2	..	..	..
5770...	—	56°33′	7°54′	M 12	26	6	cos sh	1	—	..	..	1	1	..	..	..	2	..	..	..
5771...	—	56°42′	6°57′	L 12	38	2.5	cos st.	1	—	..	..	..	..	..	..	..	..	..	..	..
5772...	23-4	55°53′	6°11′	L 10	47	2	scl	1	—	..	..	19	..	..	..	..	..	..	..	..
5773...	—	55°53′	7°20′	M 10	24	8	cos	1	—	..	..	..	..	..	..	..	1	..	..	..
5774...	—	55°53′	8°00′	N 10	20	4—5	scl sh	1	—	..	..	..	..	..	..	..	..	5	..	..
5775...	—	55°37′	8°00′	N 10	18	1	scl	1	—	..	..	..	..	1	..	..	..	3	..	..
5776...	—	55°37′	7°30′	M 10	19	2	fs	1	—	..	..	..	..	..	..	..	..	..	..	..
5777...	24-4	55°17′	7°20′	M 9	26	4	cls	1	—	..	..	..	1	..	..	..	..	1	..	..
5778...	—	55°17′	8°00′	N 9	19	1–1.5	s	1	—	..	..	..	..	..	..	..	..	..	..	..
5779...	26-4	55°37′	6°20′	L 10	45	5	scl	1	—	..	..	201	..	..	..	..	..	1	1	..
5783...	27-4	55°52′	4°58′	J 10	38	2	fs	2	—	..	..	..	..	..	..	..	..	2	..	..
5784 I..	—	55°53′	4°20′	J 10	50	2.75	s	1	—	..	..	1	..	..	..	3	..	1	..	..
— II..	—	55°53′	4°20′	J 10	50	?	s	1	01 P	..	..	1	..	..	..	1	..	..	..	..
— III..	—	55°53′	4°20′	J 10	50	3.5	s	1	01 V	..	..	1	..	..	..	1	..	1	1	..
5785...	—	55°36′	4°04′	J 10	35	1.35	s sh	1	02 P	..	..	..	2	..	..	..	..	..	..	..
5786...	28-4	55°18′	3°21′	H 9	29	1.3	s sh	1	—	..	..	..	..	..	..	..	..	..	..	..
5787...	—	55°00′	2°38′	G 9	28	3.9	fs sh	1	—	..	..	..	..	..	..	..	..	1	..	..
5788 I..	—	54°30′	2°20′	G 8	19	6.5	s sh	1	—	..	..	..	..	..	..	..	..	..	..	..
— II..	—	54°30′	2°20′	G 8	19	0.45	s sh	1	01 P	..	..	..	..	..	..	..	..	..	..	..
— IV..	—	54°30′	2°20′	G 8	19	2.5	s sh	1	01 V	..	..	..	..	..	..	..	..	2	..	..
— V..	—	54°30′	2°20′	G 8	19	2.0	s sh	1	—	..	..	..	..	..	..	..	..	..	..	..

1938 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	E. indet.
5789 I	28-4	54°03′	1°53′	F 7	76	1.45	scl	1	02 P	..	..	20	..	..	..	8	..	..	..	..
— II	—	54°03′	1°53′	F 7	76	7.5	scl	1	01 V	..	..	3	..	..	..	2	..	..	..	..
5790 I	29-4	54°50′	1°40′	F 8	26	0.5[1]	s	1	02 P	..	1	..	..	..	..	..	..	..	..	..
— II	—	54°50′	1°40′	F 8	26	2	s	1	01 P	..	..	1	..	..	..	..	..	..	..	..
— III	—	54°50′	1°40′	F 8	26	4.2	s	1	01 V	..	..	1	..	..	..	..	..	..	..	..
5791	30-4	55°50′	1°30′	F 10	80	4.7	cls	1	02 P	..	1	5	..	..	..	..	1	..	..	..
5792	—	56°22′	1°49′	F 11	92	4	cls (sh)	1	—	..	..	..	..	..	..	..	..	..	2	..
5794	1-5	56°45′	3°05′	H 12	66	3.5	cls	1	—	..	..	8	..	..	..	..	..	..	..	..
5795	—	57°05′	4°10′	J 13	64	3.9	cls	1	—	..	..	..	..	..	..	1	..	1	..	..
5796	—	57°35′	4°07′	J 14	74	3.4	mcl	1	—	..	..	3	..	..	..	..	..	..	..	..
5797	—	57°47′	3°37′	H 14	68	3	s sh	1	—	..	..	2	..	..	..	..	..	..	..	..
5798	—	59°00′	1°20′	F 17	120	6	scl (sh)	1	—	1	..	..	..	..	..	..	..	..	1	..
6036	9-8	55°20′	8°16′	N 9	13	5	cls *sh*	1	—											
6038	10-8	55°10′	6°12′	L 9	45	4	cls	1	—											
6039	—	55°23′	6°18′	L 9	42	4	cls	1	—											
6046	11-8	55°20′	7°51′	M 9	19	3	?	1	—	..	..	80	..	10	..	4	18	150	4	..
6048	—	55°27′	7°34′	—	26	?	?	1	—											
6049	—	55°30′	6°55′	L 10	29	4	s	1	—											
6045 1	—	55°20′	8°05′	N 9	17	5	ms (cls?) sh	1	—	..	..	..	..	..	..	1	..	..	..	..
— 2	—	—	—	—	17	6	ms (cls?) sh	1	—	..	1	..	..	1	..	..	..	..	..	..
— 3	—	—	—	—	17	4	ms (cls?) sh	1	—	..	..	..	..	..	..	..	..	..	..	1
— 4	—	—	—	—	17	7	ms (cls?) sh	1	—	..	..	..	..	..	..	1	..	..	..	..
— 5	—	—	—	—	17	6	ms (cls?) sh	1	—	..	..	..	..	..	..	..	..	..	..	..
— I	—	—	—	—	17	6	ms (cls?) sh	1	—	..	..	..	..	..	..	..	..	..	..	..
— 7	—	—	—	—	17	6	ms (cls?) sh	1	—	..	..	..	..	..	..	..	..	..	..	..
— 8	—	—	—	—	17	6	ms (cls?) sh	1	—	..	..	..	..	..	..	1	..	..	..	..
— 9	—	—	—	—	17	2	s sh	1	—	..	..	..	..	..	..	..	..	..	..	1
— 10	—	—	—	—	17	6	s sh	1	—	..	..	..	..	..	..	..	..	..	..	1
— 11	—	—	—	—	17	5	ms (cls?) sh	1	—	..	..	..	..	..	..	2	..	..	..	..
— 12	—	—	—	—	17	4	s sh	1	—	..	..	..	..	..	..	..	..	..	..	2
— 13	—	—	—	—	17	5	s sh	1	—	..	..	..	..	..	..	..	..	..	..	..
— 14	—	—	—	—	17	6	ms (cls?) sh	1	—	..	..	..	..	..	..	1	..	..	..	2
— 15	—	—	—	—	17	5	ms (cls?) sh	1	—	..	..	..	..	1	..	1	..	..	..	..
— 16	—	—	—	—	17	5	ms (cls?) sh	1	—	..	..	..	..	..	..	..	..	..	..	1
6047 1	—	55°22′	7°41′	M 9	19	4	s	1	—	..	..	..	..	..	..	1	..	..	..	
— 2	—	—	—	—	19	3	s	1	—	..	..	..	1	..	..	..	..	..	..	
— 3	—	—	—	—	19	5	s	1	—	..	..	..	..	..	..	..	..	..	..	
— 4	—	—	—	—	19	4	s	1	—	..	..	..	..	..	..	1	..	..	..	
— 5	—	—	—	—	19	2	s	1	—	..	..	..	..	..	..	..	..	..	..	
— 6	—	—	—	—	19	3	s	1	—	..	..	..	..	..	..	2	..	..	..	
— 7	—	—	—	—	19	2.5	s	1	—	..	..	..	..	..	..	..	..	..	..	
— 8	—	—	—	—	19	6	s	1	—	..	..	..	..	..	..	..	..	..	..	15
— 9	—	—	—	—	19	6	s	1	—	..	..	..	..	..	..	..	..	..	..	
— 10	—	—	—	—	19	2	s	1	—	..	..	..	..	..	..	..	..	..	..	
— 11	—	—	—	—	19	7	s	1	—	..	..	..	..	..	..	..	..	1	..	
— 12	—	—	—	—	19	7	s	1	—	..	..	..	..	..	..	1	..	1	..	
— 13	—	—	—	—	19	7	s	1	—	..	..	..	..	..	..	..	..	1	..	
— 14	—	—	—	—	19	6	s	1	—	..	..	..	..	..	..	..	1	6	..	
— 15	—	—	—	—	19	7	s	1	—	..	..	..	..	..	..	..	..	..	..	
— 16	—	—	—	—	19	7	s	1	—	..	..	..	..	..	..	..	..	1	..	
6050 1	—	55°34′	7°20′	M 10	33	1	cos st	1	—	..	..	..	..	..	1	1	..	..	..	..
— 2	—	—	—	—	33	10	cos	1	—	..	..	..	..	..	..	4	..	..	..	..
— 3	—	—	—	—	33	5	cos	1	—	..	..	..	..	..	2	19	21	14	..	..
— 4	—	—	—	—	33	12	mcos	1	—	..	..	..	..	..	1	3	..	..	..	..
— 5	—	—	—	—	33	12	cos	1	—	..	..	..	..	..	4	1	1	3	..	..
— 6	—	—	—	—	33	2	cos st	1	—	..	..	..	..	..	..	..	..	..	2	..
— 7	—	—	—	—	33	10	cos	1	—	..	..	..	..	..	1	20	14	..	..	20
— 8	—	—	—	—	33	12	cos st	1	—	..	..	..	..	..	..	2	4	3	3	..
— 9	—	—	—	—	33	10	cos st	1	—	..	..	..	..	..	3	1	..	4	2	..
— 10	—	—	—	—	33	12	cos st	1	—	..	..	..	..	..	..	3	13	10	..	..
— 11	—	—	—	—	33	8	cos	1	—	..	..	..	..	..	..	2	..	..	25	..

[1]) Deficient sample.

1938 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	E. indet.
6050[12]	11-8	55°34′	7°16′	M 10	33	10	cos	1	02 P	..	..	..	..	..	..	3	3	5	2	..
— [13]	—	—	—	—	33	10	cos	1	—	..	..	..	..	..	..	4	3	..	7	..
— [14]	—	—	—	—	33	8	cos	1	—	..	..	..	..	..	..	3	2	16	18	..
— [15]	—	—	—	—	33	8	cos	1	—	..	..	..	..	..	2	28	33	1	150	..
— [16]	—	—	—	—	33	6	s	1	—	..	..	..	1	..	..	6	1	80	..	..
6051...	—	55°41′	7°16′	M 10	29	8	cos	1	—	..	..	..	..	..	..	1	..	1	..	..
6052...	—	55°38′	7°32′	M 10	17	12	cos	1	—	..	..	..	..	..	..	..	..	..	..	..
6053...	—	55°45′	7°32′	M 10	19	8	cos	1	—	..	..	..	..	..	..	..	4	9	..	..
6054...	—	55°44′	7°48′	M 10	16	3	s	1	—	..	..	..	..	..	..	..	..	..	..	..
6055...	—	55°37′	7°46′	M 10	18	4	s	1	—	..	..	..	..	..	..	..	..	..	..	..
6056...	—	55°37′	8°00′	N 10	15	3	s	1	—	..	..	..	..	..	..	..	..	..	..	..
6057...	—	55°44′	8°00′	N 10	13	3	s	1	—	..	..	..	..	..	..	..	..	..	..	..
6058...	12-8	56°31′	7°56′	M 12	23	3	cos st	1	—	..	..	..	..	..	..	..	..	..	..	..

1939 — "Dana".

6062...	4-7	56°20′	7°50′	M 11	26	6	fs	2	02 P	..	..	..	2	..	..	2	..	..	..	..
6063...	—	55°58′	7°56′	M 10	22	6	fs (sh)	2	—	..	..	..	..	..	..	1	..	..	..	..
6064...	—	55°47′	8°00′	N 10	17	5	cls (sh)	2	—	..	..	..	1	2	..	1	..	..	..	..
6065...	—	55°37′	8°00′	N 10	12	7	fs (sh)	2	—	..	..	..	..	8	..	..	..	..	..	1
6066...	—	55°37′	7°45′	M 10	16	12	s	2	—	..	..	..	..	..	..	..	..	15	..	..
6067...	—	55°47′	7°45′	M 10	22	8	s	2	—	..	..	..	..	..	..	..	..	..	..	1
6068...	—	55°47′	7°25′	M 10	23	6	s	2	—	..	..	..	..	..	..	..	..	..	..	1
6069...	—	55°37′	7°30′	M 10	15.5	6	cos	2	—	..	..	..	..	..	..	..	..	..	..	..
6070...	—	55°40′	7°15′	M 10	27	15	cos	2	—	..	..	..	..	..	..	..	1	..	..	..
6071...	—	55°32′	7°23′	M 10	29	12	cos	2	—	..	..	..	..	..	..	9	6	..	..	..
6072...	—	55°27′	7°40′	M 9	23	10	cos	2	—	..	..	..	1	..	..	..	1	..	..	1
6073...	5-7	55°27′	8°11′	N 9	11	10	ms	2	—	..	..	..	..	2	..	..	..	..	..	..
6074...	—	55°22′	8°18′	N 9	10	10	ms? (sh)	2	—	..	..	..	..	6	..	..	..	..	..	..
6075...	—	55°18′	8°15′	N 9	15	12	ms? sh	2	—	..	..	..	..	1	..	..	..	..	..	3
6076...	—	55°13′	8°06′	N 9	16	10	s sh	2	—	..	..	..	..	..	..	..	..	..	..	2
6077...	—	55°05′	8°15′	N 9	14	10	s (sh)	2	—	..	..	..	..	..	..	..	..	..	..	..
6078...	—	55°05′	8°00′	N 9	19	8	s	2	—	..	..	..	..	..	..	..	..	..	..	1
6079...	—	55°05′	7°45′	M 9	21	10	s	2	—	..	..	..	..	..	..	..	..	..	..	7
6080...	—	55°05′	7°25′	M 9	25	12	s	2	—	..	..	..	..	..	..	..	..	..	..	1
6081...	6-7	55°05′	7°00′	M 9	35	12	cos	2	—	..	..	..	..	..	..	..	..	..	..	1
6082...	—	55°18′	7°13′	M 9	28	10	s (sh)	2	—	..	..	..	..	..	..	..	..	..	..	..
6083...	—	55°18′	7°35′	M 9	24	15	s	2	—	..	..	..	..	..	..	..	..	..	..	3
6084...	—	55°18′	7°53′	M 9	20	6	ms (sh)	2	—	..	..	..	..	1	..	2	..	..	..	1
6085...	—	55°25′	8°00′	N 9	16	6	s (sh)	2	—	..	..	..	..	1	..	1	..	..	..	..
6244...	27-8	57°47′	3°37′	H 14	84	1.5	s	1	—	..	..	4	..	..	2	..	..	..	4	..

1947 — "Dana".

6537...	14-5	54°22′	3°54′	H 7	45	3	fs	1	02 P	..	..	..	..	..	..	..	..	..	..	..
6539...	15-5	54°39′	2°12′	G 8	25	0.5[1]	s	1	—	..	..	1	..	..	..	..	..	..	..	..
6540...	—	55°15′	1°44′	F 9	51	2	s	1	—	..	..	..	..	..	3	2	2	..	..	..
6541...	16-5	55°15′	2°03′	G 9	36	4	cos sh	1	01 V	..	..	..	..	..	1	..	1	1	..	..
6542...	—	55°15′	2°05′	G 9	37	?	s	1	—	..	..	..	..	..	..	..	..	..	..	..
6543...	17-5	55°20′	3°12′	H 9	30	?	s sh	1	—	..	..	..	..	..	..	..	..	..	..	1
6544...	18-5	55°38′	4°46′	J 10	38	2.5	s sh	1	—	..	..	..	..	..	..	4	..	..	..	..

[1]) Deficient sample.

1948 — "Dana".

6834...	11-5	55°15′	4°34′	J 9	44	4	ms	1	02 V	..	..	..	..	..	..	28	..	..	..	..
6835...	12-5	55°38′	6°29′	L 10	37	4	ms	1	—	..	..	..	..	..	..	2	..	2	..	..
6838...	20-5	55°38′	4°50′	J 10	38	5	fs	1	—	..	..	..	..	..	..	..	..	..	..	..
6839...	—	54°47′	4°10′	J 8	47	3	cls	1	—	..	..	..	..	..	..	..	..	..	..	..
6841...	22-5	54°11′	3°50′	H 7	46	6 + 5	scl	2	—	..	..	..	..	..	43	1	..	..	..	..

1948 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E. indet.*
6843...	23-5	54°43′	2°28′	G 8	22	7	s sh	1	02 V	..	..	..	..	..	..	..	..	..	..	1
6844...	—	55°00′	1°11′	F 9	40	6	s (sh)	1	—	..	..	4	8	..	..	..	..	..	..	..
6847...	25-5	55°32′	2°26′	G 10	52	7	s sh	1	—	..	..	..	..	..	2	9	..	3	..	..
6849...	26-5	55°37′	4°56′	J 10	40	6	s (sh)	1	—	..	..	..	..	..	..	12	..	..	..	..
6851...	27-5	54°52′	4°42′	J 8	40	8	ms	1	—	..	..	..	..	..	3	8	..	3	..	..
6853...	3-6	55°24′	6°25′	L 9	41	4	s	1	—	..	..	..	..	..	2	1	..	..	..	..
6854...	4-6	55°38′	4°46′	J 10	37.5	6	cls	1	—	..	..	..	..	..	..	1	..	..	..	1
6856...	5-6	55°50′	1°32′	F 10	83	5	ms	1	—	..	..	4	..	..	10	..	..	..	..	..
7017...	15-8	56°38′	4°07′	J 12	51	8	s sh	1	—	..	..	..	..	..	8	4	..	..	..	1

1950 — "Dana".

7021P..	28-4	55°21′	3°38′	H 9	27.5	?	?	1	02 P	..	..	..	..	..	..	..	..	..	..	..
7021V..	2-5	55°21′	3°38′	H 9	27.5	4	fs *sh*	1	02 V	..	..	..	..	..	..	..	..	..	..	..
7022...	—	55°13′	3°40′	H 9	35	7–8	fs *sh*	1	—	..	..	..	..	..	..	2	..	..	..	1
7023...	—	55°06′	3°40′	H 9	42	7–8	fs *sh*	1	—	..	..	..	..	..	..	12	..	2	..	..
7024...	—	54°57′	3°40′	H 8	43	3–4	fs (sh)	1	—	..	..	..	..	..	..	12	..	..	..	1
7025...	—	54°54′	3°43′	H 8	44	4	ms	1	—	..	..	..	..	..	..	6	..	1	..	..
7026...	3-5	55°05′	4°00′	J 9	46.5	7–8	ms	1	—	..	..	..	..	..	1	13	..	3	..	..
7027...	—	55°13′	4°00′	J 9	43.5	6–8	ms	1	—	..	..	..	..	..	..	12	1	..	..	..
7028...	—	55°21′	4°00′	J 9	39	7–8	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	1
7029...	—	55°23′	4°00′	J 9	28	7–8	fs *sh*	1	—	..	..	..	..	..	..	..	..	..	..	1
7030...	4-5	55°30′	4°00′	J 10	30	4	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
7031...	—	55°38′	4°00′	J 10	35	8	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
7032...	—	55°45′	4°00′	J 10	39	3	fs sh	1	—	..	..	..	..	..	..	2	..	..	..	1
7033...	—	55°54′	4°20′	J 10	45.5	5	fs (sh)	1	—	..	..	..	..	..	..	..	..	1	..	1
7034...	—	55°46′	4°20′	J 10	38	8	fs sh	1	—	..	..	..	..	..	..	2	1	1	..	2
7035...	5-5	55°38′	4°20′	J 10	33	10	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	3
7036...	—	55°30′	4°20′	J 10	30	?	fs sh	1	—	..	..	..	..	..	..	1	..	..	..	2
7037...	—	55°22′	4°20′	J 9	45	10	ms sh	1	—	..	..	..	..	..	1	15	..	..	..	..
7038...	—	55°14′	4°20′	J 9	46	5	ms sh	1	—	..	..	..	..	..	..	12	..	..	..	..
7039...	—	55°20′	4°40′	J 9	47	4	ms	1	—	..	..	..	..	..	..	20	..	..	..	..
7040...	—	55°28′	4°40′	J 9	39	10	ms(sh)	1	—	..	..	..	..	..	..	7	..	1	..	..
7041...	—	55°36′	4°40′	J 10	34	8–9	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	4
7042I..	—	55°44′	4°40′	J 10	43.5	5–6	ms (sh)	1	—	..	..	..	..	..	..	8	..	..	..	..
— II..	—	55°44′	4°40′	J 10	43.5	3–4	ms (sh)	1	—	..	..	..	..	..	..	5	1	..	..	2
7043...	—	55°52′	4°40′	J 10	40	4–5	fs (sh)	1	—	..	..	..	..	..	..	3	..	..	..	..
7044...	6-5	55°34′	4°57′	J 10	41	9	ms (sh)	1	—	..	..	..	..	..	..	21	..	1	..	..
7045I..	—	55°40′	5°00′	K 10	43	1	ms (sh)	1	—	..	..	..	..	..	..	6	..	..	..	..
— II..	—	55°40′	5°00′	K 10	43	6–8	ms (sh)	1	—	..	..	..	..	..	..	12	..	..	..	2
7046...	—	55°48′	5°00′	K 10	36	10	ms (sh)	1	—	..	..	..	..	..	..	1	..	..	..	..
7047...	—	55°56′	5°00′	K 10	40	5	ms (sh)	1	—	..	..	..	..	..	..	1	..	..	..	1
7048...	—	56°04′	5°00′	K 11	43	7	cos (sh st)	1	—	1	..	..	..	..	..	..	..	..	..	..
7049...	—	56°08′	5°20′	K 11	46	9	cl cos(sh)	1	—	..	1	3	..	..	..	..	..	..	..	..
7050...	—	56°00′	5°20′	K 11	49	10	cl cos	1	—	..	..	2	..	..	..	1	..	..	..	2
7051...	—	55°52′	5°20′	K 10	54	15	scl	1	—	..	..	8	..	..	..	7	..	..	2	..
7052...	—	55°44′	5°20′	K 10	53	12	scl	1	—	1	..	2	..	..	..	..	..	..	..	..
7053...	7-5	55°25′	5°00′	K 9	46	4–5	ms	1	—	..	..	..	..	..	..	3	..	..	..	..
7054...	—	55°23′	3°08′	H 9	30	9	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
7055...	7/8-5	55°49′	3°40′	H 10	49	8	cls (sh)	1	—	..	..	..	..	..	..	9	..	..	..	1
7056...	8-5	55°37′	3°40′	H 10	40	4	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
7057...	—	55°29′	3°40′	H 9	30	8	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	1
7058...	—	54°44′	4°08′	J 8	48	10	scl	1	—	..	..	..	..	..	..	5	..	1	..	..
7059...	—	54°55′	5°28′	K 8	41	7	cl cos	1	—	..	..	..	..	..	..	2	..	9	..	..
7090...	15-5	55°24′	6°05′	L 9	48	15	scl	1	—	..	..	..	..	..	..	41	..	..	..	1
7091...	16-5	55°39′	6°29′	L 10	41	15	ms	1	—	..	..	..	..	..	..	..	..	..	..	7
7095...	24-5	55°44′	3°20′	H 8	42	4–5	ms	1	—	..	..	..	..	..	..	10	..	..	..	..
7096...	—	54°52′	3°20′	H 8	39	8	ms	1	—	..	..	..	..	..	..	2	..	2	..	..
7097...	—	55°00′	3°20′	H 9	34	8	cos sh	1	—	..	..	..	..	..	..	1	..	..	..	..
7098...	—	55°08′	3°20′	H 9	30	15	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	2

1950 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E.* indet.
7099...	24-5	55°16′	3°20′	H 9	28	10	fs *sh* (st)	1	02 V	..	..	..	..	..	..	..	..	..	..	1
7100...	—	55°24′	3°20′	H 9	32	12	fs *sh* (st)	1	—	..	..	..	..	..	..	1	..	..	..	..
7101...	—	55°32′	3°20′	H 10	38	10	fs sh (st)	1	—	..	..	..	..	..	..	1	..	..	..	..
7102...	—	55°40′	3°20′	H 10	43	7–8	fs sh	1	—	..	..	..	..	..	..	1	1	1	..	..
7103...	—	55°33′	3°00′	H 10	43	5	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
7104...	—	55°25′	3°00′	H 9	31	10	cos *sh*	1	—	..	..	..	..	..	..	..	1	..	..	..
7105...	25-5	55°17′	3°00′	H 9	28	8–10	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
7106...	—	55°09′	3°00′	H 9	26	8	fs sh	1	—	..	..	..	..	..	..	..	..	1	..	1
7107...	—	55°01′	3°00′	H 9	23	7	cos sh	1	—	..	..	..	..	..	..	..	..	..	..	1
7108...	—	54°53′	3°00′	H 8	27	7–8	fs (sh)	1	—	..	..	..	..	..	..	..	..	..	..	..
7109...	—	54°45′	3°00′	H 8	36	8	fs (sh)	1	—	..	..	..	..	..	..	..	..	..	..	1
7110...	—	54°37′	3°00′	H 8	35	4	fs (sh)	1	—	..	..	..	..	..	..	7	..	..	..	..
7111...	—	54°29′	3°00′	H 7	38	6	ms	1	—	..	..	..	..	..	..	53	..	..	..	1
7112...	—	54°21′	3°00′	H 7	40	8	ms	1	—	..	..	..	..	..	..	15	..	2	..	..
7113...	—	55°26′	2°37′	G 9	44	15	ms	1	—	..	..	1	..	..	..	..	..	1	..	7
7114...	26-5	58°15′	0°40′	E 15	150	20–25	scl	1	—	..	..	..	..	..	..	..	..	..	..	..
7379...	20-8	58°24′	0°37′	E 15	151	8	scl (sh)	1	—	2	..	..	..	..	..	..	..	..	..	..
7380...	—	58°15′	0°40′	E 15	153	40	fs (sh)	1	—	..	..	..	..	..	..	..	..	..	..	..
7381...	—	58°13′	1°04′	F 15	145	30	scl (sh)	1	—	..	..	..	..	..	..	..	..	..	..	..
7382...	—	57°47′	3°37′	H 14	68	6	cls	1	—	..	..	1	..	..	1	..	..	..	..	..
7383...	21-8	57°33′	5°30′	K 14	90	5	cos	1	—	..	..	..	..	..	..	..	..	..	..	..
7384...	—	57°11′	7°45′	M 13	53	8	fs sh st	1	—	..	..	..	..	..	..	..	..	..	..	..

1951 — "Jens Væver".

165 [1]) ..	9-6	55°05′	7°50′	M 9	?	1	fs	2	01 V	..	..	..	..	..	..	..	..	..	..	..
165 a[1]) .	—	55°05′	8°01′	N 9	?	1	fs	2	—	..	..	..	..	..	..	..	..	..	..	..
167....	10-6	55°07′	8°22′	N 9	?	1	fs	2	—	..	..	..	..	..	..	..	..	..	..	..
168....	—	55°06′	7°36′	M 9	?	1	fs	2	—	..	..	..	..	..	..	..	..	..	..	..
174....	12-6	55°28′	8°13′	N 9	?	1	?	2	—	..	..	..	..	..	..	..	..	..	..	..
175....	—	55°35′	7°51′	M 10	?	2	fs	2	—	..	..	..	..	1	..	..	..	..	..	..

[1]) Samples perhaps interchanged.

1951 — "Dana".

7385...	29-4	56°55′	6°50′	L 12	38	12	cos (sh)	1	02 V	..	..	..	..	..	..	..	3	..	..	..
7386...	—	56°39′	6°50′	L 12	39	10.5	cos (sh st)	1	—	..	..	1	..	..	1	2	..	..	..	..
7387...	—	56°23′	6°50′	L 11	38	10	cl cos (sh)	1	—	..	..	3	5	..	..	..	..	5	..	..
7388...	—	56°07′	6°50′	L 11	41	11	cl cos	1	—	..	..	1	..	..	..	..	1	..	..	..
7389...	—	55°51′	6°50′	L 10	35	12	cos (sh)	1	—	..	..	..	..	..	..	..	62	7	..	..
7390...	—	55°35′	6°50′	L 10	31	7.5	ms	1	—	..	..	..	..	..	..	8	4	8	..	..
7392...	1-5	55°36′	5°40′	K 10	47	8.5	scl	1	—	..	..	14	..	..	..	1	..	1	..	..
7393...	—	55°44′	5°40′	K 10	47	20	scl	1	—	..	..	28	..	..	..	5	..	1	..	..
7394...	2-5	55°52′	5°40′	K 10	47	12	scl	1	—	1	1	78	..	..	..	6	..	..	1	..
7395...	—	56°00′	5°40′	K 11	50	19	scl	1	—	..	..	33	..	..	..	7	..	..	1	..
7396...	—	56°08′	5°40′	K 11	52	27	scl	1	—	..	..	22	..	..	..	14	..	..	..	..
7397...	—	56°16′	5°40′	K 11	37	12	s	1	—	..	..	..	..	..	..	..	12	3	..	..
7398...	—	56°16′	5°20′	K 11	56	22	scl	1	—	..	1	2	..	..	..	60	..	1	1	..
7399 [1]..	—	56°08′	5°20′	K 11	40	8	cl cos (sh) st	1	—	..	..	..	..	..	1	8	..	..	2	..
— [II]..	—	56°08′	5°20′	K 11	40	13	cl cos (sh) st	1	02 P	..	..	..	..	..	..	2	1	2	..	..
7400...	—	56°00′	5°20′	K 11	45	8	cl cos	1	02 V	1	..	7	..	..	1	1	..	1	..	..
7401 [1]..	—	55°52′	5°20′	K 10	51	12	scl	1	—	..	..	9	..	..	2	15	..	1	..	..
— [II]..	—	55°52′	5°20′	K 10	51	8	scl	1	—	..	..	18	..	..	..	11	..	..	1	..
7402...	—	55°44′	5°20′	K 10	50	4.5	scl	1	—	..	..	1	..	..	..	15	..	..	..	..
7403...	—	55°36′	5°20′	K 10	46	6.5	scl	1	—	..	..	1	..	..	..	17	..	1	..	..
7404...	—	55°37′	4°56′	J 10	38	9	ms (sh)	1	—	..	..	..	..	..	..	4	..	1	..	..
7405...	—	55°32′	4°50′	J 10	37	4	ms (sh)	1	—	..	..	..	..	..	..	4	..	3	..	..
7406 [1]..	—	55°34′	4°57′	J 10	37	10	ms (sh)	1	—	..	..	..	..	..	..	2	..	4	..	..
— [II]..	—	55°34′	4°57′	J 10	37	8	ms (sh)	1	02 P	..	..	..	..	..	..	15	..	3	..	..
7407...	—	55°40′	5°00′	K 10	40	12	ms	1	02 V	..	..	..	..	..	..	9	..	2	..	..

1951 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E. indet.*
7408...	3-5	55°48′	5°00′	K 10	34	7	ms	1	02 V	..	..	..	..	..	1	15	1	1	..	..
7409...	—	55°56′	5°00′	K 10	37	4	cl cos	1	—	..	..	..	..	..	..	..	..	..	..	..
7410...	—	56°04′	5°00′	K 11	43	12	cl cos	1	—	..	..	1	..	..	..	..	..	1	..	..
7411...	—	56°12′	5°00′	K 11	52	9	cls	1	—	..	..	1	..	..	..	..	..	1	..	..
7412...	—	56°00′	4°40′	J 11	47	11	ms	1	—	..	..	1	..	..	..	..	..	5	..	..
7413...	—	55°52′	4°40′	J 10	37	6	fs sh	1	—	..	..	..	..	..	..	2	2	2	..	..
7414...	—	55°44′	4°40′	J 10	41	7	ms (sh)	1	—	..	..	..	..	..	..	7	1	1	..	..
7415...	—	55°36′	4°40′	J 10	35	11	fs sh	1	—	..	..	..	..	..	..	4	1	2	..	..
7416 [I]..	—	55°28′	4°40′	J 9	38	10	ms	1	—	..	..	..	..	..	..	25	..	3	..	..
— [II]..	—	55°28′	4°40′	J 9	38	6	ms (sh)	1	02 P	..	..	..	..	..	..	23	..	1	..	..
7417 [I]..	—	55°20′	4°40′	J 9	44	6	ms	1	—	..	..	..	..	..	..	44	1	4	..	..
— [II]..	—	55°20′	4°40′	J 9	44	?	?	1	02 V	..	..	..	..	..	1	21	..	4	..	..
7418...	—	55°12′	4°40′	J 9	45	8	cls	1	—	..	..	..	..	..	..	7	..	2	..	..
7419...	—	55°15′	4°34′	J 9	45	7	cls	1	—	1	..	..	..	..	..	11	..	..	..	..
7420...	—	55°08′	4°25′	J 9	46.5	7	cls	1	—	..	..	..	..	..	..	17	..	7	..	..
7421...	—	55°06′	4°20′	J 9	46	10	scl	1	—	..	..	..	..	..	..	12	2	23	1	..
7422...	—	55°14′	4°20′	J 9	43	5	ms (sh)	1	—	..	..	..	..	..	..	3	..	..	1	..
7423...	—	55°22′	4°20′	J 9	42	6	ms (sh)	1	—	..	..	..	..	..	..	22	1	4	..	..
7424...	—	55°30′	4°20′	J 10	30	6	fs sh	1	—	..	..	..	..	..	..	2	..	2	..	..
7425...	—	55°38′	4°20′	J 10	32	4	s sh	1	—	..	..	..	..	..	..	23	..	..	..	..
7426...	—	55°46′	4°20′	J 10	35	14	fs sh	1	—	..	..	..	..	..	..	11	1	1	..	..
7427 [I]..	—	55°54′	4°20′	J 10	43	6	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
— [II]..	—	55°54′	4°20′	J 10	43	3	fs sh	1	02 P	..	..	..	..	..	..	..	..	..	..	..
7428...	—	56°02′	4°20′	J 11	51	11	ms	1	02 V	1	..	..	..	..	..	1	..	1	..	..
7429...	4-5	55°54′	4°00′	J 10	52	10	ms	1	—	..	..	1	..	..	..	2	..	1	1	..
7430...	—	55°46′	4°00′	J 10	36	6	fs sh	1	—	..	..	..	..	..	..	4	2	..	3	..
7431...	—	55°38′	4°00′	J 10	33	7	fs sh	1	—	..	..	..	..	..	..	3	..	1	..	..
7432...	—	55°30′	4°00′	J 10	29	6	fs sh	1	—	..	..	..	..	..	..	1	2	2	..	..
7433...	—	55°22′	4°00′	J 9	35	7	fs sh	1	—	..	..	..	..	..	..	4	..	1	..	..
7434...	—	55°14′	4°00′	J 9	41	5	ms (sh)	1	—	..	1	2	..	..	2	35	..	7	..	..
7435...	—	55°06′	4°00′	J 9	44	8	cls	1	—	..	..	..	..	..	..	21	..	2	..	..
7436...	—	54°58′	4°00′	J 8	43	9	cls	1	—	..	..	..	..	..	..	32	..	9	..	..
7437...	—	55°05′	3°40′	H 9	40	6	ms (sh)	1	—	..	..	2	..	..	..	14	..	2	..	..
7438...	—	55°13′	3°40′	H 9	32	10	fs (sh)	1	—	..	..	..	..	..	..	2	..	2	..	..
7439...	—	55°21′	3°40′	H 9	26	6	fs sh	1	—	..	..	..	..	..	..	..	..	2	..	..
7440...	—	55°17′	3°30′	H 9	26	7	fs *sh*	1	—	..	..	..	..	..	..	2	..	2	..	..
7441...	—	55°29′	3°40′	H 9	31	5	fs *sh* (st)	1	—	..	..	..	..	..	..	6	1	..	..	..
7442...	—	55°37′	3°40′	H 10	36	12	fs sh	1	—	..	..	..	..	..	..	3	1	1	..	..
7443...	—	55°45′	3°40′	H 10	47	10	fs sh st	1	—	..	..	..	..	..	1	3	4	5	..	..
7444 [I]..	—	55°53′	3°40′	H 10	53	3	fs sh	1	—	..	..	..	..	..	..	..	..	..	3	..
— [II]..	—	55°53′	3°40′	H 10	53	6	fs sh	1	—	1	..	..	..	..	..	1	..	..	1	..
7445...	—	55°48′	3°20′	H 10	55	7	ms (sh)	1	—	..	..	1	..	..	2	1	..	..	..	..
7446...	—	55°40′	3°20′	H 10	42	6	fs sh (st)	1	—	..	..	..	..	..	..	1	..	..	..	..
7447 [I]..	—	55°32′	3°20′	H 10	37	6	fs *sh* (st)	1	—	..	..	..	..	..	..	3	3	2	..	..
— [II]..	—	55°32′	3°20′	H 10	37	2	fs *sh* (st)	1	02 P	..	..	..	..	..	..	1	1	..	..	..
7448...	—	55°24′	3°20′	H 9	30	5	fs *sh* (st)	1	02 V	..	..	..	..	..	..	1	2	1	..	..
7449...	5-5	55°16′	3°20′	H 9	26	8	fs *sh* (st)	1	02 V	..	..	..	..	..	..	..	2	3	..	..
7450 [I]..	—	55°08′	3°20′	H 9	31	6	fs sh	1	—	..	..	..	..	..	..	..	..	2	..	..
— [II]..	—	55°08′	3°20′	H 9	31	7	fs sh	1	02 P	..	..	..	..	..	..	1	..	2	..	..
7451 [I]..	—	55°09′	3°00′	H 9	26	5	fs *sh*	1	—	..	..	..	..	..	..	..	..	..	..	..
— [II]..	—	55°09′	3°00′	H 9	26	3	fs *sh*	1	02 V	..	..	..	..	..	..	1	..	..	..	..
7452...	—	55°17′	3°00′	H 9	29	7	fs *sh* (st)	1	—	..	..	..	..	..	..	..	1	3	..	..
7453...	—	55°25′	3°00′	H 9	33	9[1])	cos *sh*	1	—	..	..	..	..	..	..	..	..	..	..	..
7454...	—	55°33′	3°00′	H 10	40	5	s sh (st)	1	—	..	..	..	..	..	2	1	17	1	..	..
7455...	—	55°41′	3°00′	H 10	55	4	fs (sh st)	1	—	..	..	1	..	..	4	1	1	..	..	..
7456...	—	55°35′	2°40′	G 10	50	7	fs sh (st)	1	—	..	..	..	..	..	1	12	9	..	..	..
7457...	—	55°35′	2°20′	G 10	65	3	cls	1	—	..	..	2	..	..	..	1	1	..	..	..
7458...	—	55°27′	2°00′	G 9	50	4	fs sh	1	—	..	..	..	..	..	..	6	4	..	1	1
7459...	—	55°19′	1°40′	F 9	44	3	fs (sh st)	1	02 P	..	..	1	..	..	..	6	11	3	1	..
7460 [I]..	—	55°11′	1°20′	F 9	45	1.5	fs (sh)	1	—	..	..	..	1	..	..	..	7	1	..	..
— [II]..	—	55°11′	1°20′	F 9	45	3.5	fs (sh)	1	—	..	..	..	1	..	..	..	3	1	..	..

[1]) Animals from 2 l only.

1951 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E. indet.*
7461...	5-5	55°03′	1°00′	F 9	61	3	cls (sh)	1	02 P	..	..	11	..	..	..	..	..	..	..	..
7462...	—	54°55′	1°00′	F 8	50	4.5	s (sh)	1	—	..	..	9	5	..	..	..	1	..	..	..
7463...	—	54°47′	1°00′	F 8	50	7	cls	1	—	..	..	19	3	..	..	..	..	1	1	..
7464...	—	54°39′	1°00′	F 8	60	5	ms (sh)	1	—	..	..	16	32	..	..	..	..	..	..	..
7465...	—	54°31′	1°00′	F 8	55	4	cls	1	—	..	..	7	4	..	..	1	..	..	..	..
7466...	6-5	54°31′	1°20′	F 8	28	9.5	cos st	1	—	..	..	..	..	..	..	4	1	..	..	1
7467...	—	54°39′	1°20′	F 8	30	10.5	cos (sh)	1	02 V	..	..	..	..	..	..	..	..	..	..	..
7468...	—	54°47′	1°20′	F 8	23	6	fs (sh)	1	—	..	..	..	..	..	..	..	..	2	..	..
7469...	—	54°55′	1°20′	F 8	25	11	cos (sh)	1	—	..	..	..	..	..	..	..	..	..	1	..
7470...	—	55°03′	1°20′	F 9	39	3.5	ms sh	1	—	..	..	..	..	..	..	1	2	..	..	..
7471...	—	55°11′	1°40′	F 9	36	4	ms sh (st)	1	—	..	..	2	2	..	..	2	1	..	2	..
7472...	—	55°03′	1°40′	F 9	35	8	fs sh	1	—	..	..	..	..	..	..	..	4	2	1	..
7473...	—	54°55′	1°40′	F 8	26	2	fs *sh* (st)	1	—	..	..	..	..	..	..	..	..	2	..	..
7474...	—	54°47′	1°40′	F 8	23	14	cos sh	1	—	..	..	..	..	..	..	..	1	..	..	..
7475 [I]..	—	54°39′	1°40′	F 8	22	3	fs (sh)	1	—	..	..	..	..	..	..	..	..	1	..	..
— [II]..	—	54°39′	1°40′	F 8	22	6	fs (sh)	1	—	..	..	..	..	..	..	..	..	..	..	..
7476...	—	54°31′	1°40′	F 8	18	9	fs (sh st)	1	—	..	..	..	..	..	..	..	..	1	..	..
7477...	—	54°23′	1′40′	F 7	48	11	cls	1	—	..	..	41	4	..	..	..	..	10	2	..
7478...	—	54°15′	1°40′	F 7	48	10	ms	1	—	..	..	21	7	..	..	..	..	8	..	..
7479...	—	54°07′	1°40′	F 7	68	10	cls	1	—	..	..	42	..	..	..	1	..	6	..	..
7480...	7-5	54°07′	2°00′	G 7	60	12	cls	1	—	..	..	115	1	..	..	..	..	9	..	..
7481...	—	54°15′	2°00′	G 7	37	12	cos sh	1	—	..	..	2	1	..	..	..	2	..	3	..
7482...	—	54°23′	2°00′	G 7	36	1.5	fs (sh) st	1	—	..	..	1	..	..	..	..	..	..	..	..
7483...	—	54°31′	2°00′	G 8	18	8	fs sh	1	—	..	..	1	..	..	..	..	..	2	..	..
7484...	—	54°39′	2°00′	G 8	24	6	fs (sh st)	1	—	..	..	..	..	..	..	1	..	..	..	..
7486...	—	54°47′	2°20′	G 8	22	6	fs *sh* (st)	1	—	..	..	..	..	..	..	..	..	2	..	..
7488...	—	54°55′	2°20′	G 8	27	6	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
7489...	—	55°03′	2°20′	G 9	35	9	fs *sh*	1	—	..	..	..	..	..	..	..	..	7	..	..
7490...	—	55°11′	2°20′	G 9	32	8	fs *sh* (st)	1	—	..	..	..	..	..	..	..	9	3	..	..
7491...	—	55°19′	2°20′	G 9	37	8	fs *sh*	1	—	..	..	4	..	..	..	2	2	1	..	..
7492...	—	55°27′	2°20′	G 9	44	10	fs (sh)	1	—	..	..	..	..	..	1	1	3	1	5	..
7493...	—	55°19′	2°00′	G 9	41	4	fs sh	1	—	..	..	..	..	..	3	4	5	..	5	..
7494...	—	55°11′	2°00′	G 9	32	8	fs *sh*	1	—	..	..	..	1	..	2	3	2	2	1	..
7495...	—	55°03′	2°00′	G 9	34	2.5	cos st (sh)	1	—	..	1	..	..	..	..	..	..	..	..	..
7496...	—	54°55′	2°00′	G 8	24	12	fs sh	1	—	..	..	..	..	..	..	..	..	1	..	..
7497...	—	54°47′	2°00′	G 8	22	10	fs (sh)	1	—	..	..	..	..	..	..	..	..	..	..	..
7498...	—	54°39′	2°20′	G 8	18	3	fs (*sh*) (st)	1	—	..	..	..	..	..	..	..	..	..	..	..
7499...	8-5	54°31′	2°20′	G 8	20	8	fs sh	1	—	..	..	..	..	..	..	..	1	2	..	..
7500...	—	54°23′	2°20′	G 7	27	4	fs sh (st)	1	—	..	..	..	..	..	..	..	..	..	..	..
7501...	—	54°15′	2°20′	G 7	30	12	ms (st)	1	—	..	..	1	..	..	..	1	..	3	..	..
7502...	—	54°07′	2°20′	G 7	51	6	cls	1	—	..	..	170	..	..	..	..	..	3	..	..
7503...	—	54°07′	2°40′	G 7	60	17	scl	1	—	..	..	14	..	..	..	..	..	..	..	..
7504...	—	54°15′	2°40′	G 7	38	6	ms (sh)	1	—	..	..	..	..	..	..	6	..	4	..	..
7505...	—	54°23′	2°40′	G 7	26	4	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
7506...	—	54°31′	2°40′	G 8	23	4	fs sh	1	—	..	..	..	..	..	..	..	..	1	..	..
7507...	—	54°39′	2°40′	G 8	18	5.5	fs sh	1	—	..	..	..	..	..	..	..	..	1	..	..
7508...	—	54°47′	2°40′	G 8	19	2	fs sh (st)	1	—	..	..	..	..	..	..	..	..	..	..	..
7509...	—	54°55′	2°40′	G 8	21	6	ms *sh* (st)	1	—	..	..	..	..	..	..	..	..	..	..	..
7510...	—	55°03′	2°40′	G 9	25	6	fs *sh* (st)	1	—	..	..	..	..	..	..	..	2	1	..	..
7511...	—	55°11′	2°40′	G 9	29	4	fs *sh* (st)	1	—	..	..	..	..	..	..	2	8	1	..	..
7512...	—	55°19′	2°40′	G 9	34	8	fs sh st	1	—	..	..	..	..	..	..	9	6	1	..	..
7513...	—	55°27′	2°40′	G 9	39	6	fs sh	1	—	..	..	..	..	..	2	3	17	..	1	..
7514...	—	55°01′	3°00′	H 9	23	4	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
7515...	9-5	54°53′	3°00′	H 8	20	2	fs *sh*	1	—	..	..	..	..	..	..	..	..	..	..	..
7516...	—	54°45′	3°00′	H 8	30	7	fs (sh)	1	—	..	..	..	..	..	..	..	..	5	..	..
7517...	—	54°37′	3°00′	H 8	33	7	fs (sh)	1	—	..	..	..	..	..	..	1	..	2	..	..
7518...	—	54°29′	3°00′	H 7	33	4	ms	1	—	..	..	..	..	..	..	5	..	4	..	..
7519...	—	54°21′	3°00′	H 7	39	9	cls	1	—	..	..	2	..	..	..	5	..	2	..	..
7520...	—	54°13′	3°00′	H 7	43	5	cl cos st	1	—	..	..	..	1	..	..	..	..	2	..	..
7521...	—	54°36′	3°20′	H 8	39	3	fs (sh)	1	—	1	..	..	..	..	..	1	..	1	..	..
7522...	—	54°44′	3°20′	H 8	40	4.5	cls	1	—	..	..	..	..	..	..	5	..	4	..	..

1951 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E. indet.*
7523...	9-5	54°52′	3°20′	H 8	38	8.5	cls	1	02 V	1	..	2	..	..	1	9	..	..	..	..
7524...	—	55°00′	3°20′	H 9	31	6.5	fs sh	1	—	..	..	..	..	..	..	3	..	5	..	..
7525...	—	54°57′	3°40′	H 8	42	5	ms	1	—	..	..	..	..	..	..	26	..	5	..	..
7526...	—	54°49′	3°40′	H 8	42	3.5	ms	1	—	..	..	..	..	..	..	17	..	1	..	..
7527...	—	54°58′	4°20′	J 8	47	12	scl	1	—	2	..	..	..	..	..	6	..	..	4	..
7529...	—	54°50′	4°20′	J 8	48	8	scl	1	—	..	..	..	..	..	..	6	..	1	..	..
7530...	—	54°42′	4°20′	J 8	47	4	scl	1	—	..	..	..	..	..	..	2	..	..	..	..
7531...	—	54°34′	4°20′	J 8	47	16	scl	1	—	..	..	..	..	..	..	..	..	2	..	..
7532...	10-5	54°26′	4°20′	J 7	47	8	scl	1	—	..	..	..	..	..	..	1	..	1	..	..
7533...	—	54°36′	5°00′	K 8	41	6	ms	1	—	..	..	..	..	..	..	..	..	8	..	..
7534...	—	54°44′	5°00′	K 8	42	6	ms	1	—	..	..	..	..	..	..	..	..	5	..	..
7535...	—	54°52′	5°00′	K 8	40	6	ms	1	—	..	..	..	..	..	..	..	..	2	..	..
7536...	—	55°00′	5°00′	K 9	38	14	ms	1	—	..	..	..	..	..	..	1	..	5	..	..
7537...	—	55°08′	5°00′	K 9	39	6	ms (sh)	1	—	1	..	..	..	..	..	..	..	1	..	..
7538...	—	55°16′	5°00′	K 9	44	5	cls	1	—	..	..	..	..	..	..	9	..	3	1	..
7539 I..	—	55°24′	5°00′	K 9	43	2	ms	1	—	..	..	..	..	..	..	13	..	1	..	..
— II..	—	55°24′	5°00′	K 9	43	2	ms	1	—	1	..	..	..	..	..	12	..	..	..	..
—III..	—	55°24′	5°00′	K 9	43	7	ms	1	—	..	..	..	..	..	2	16	..	..	..	..
7540...	—	55°32′	5°00′	K 10	41	8	ms	1	—	3	..	..	..	..	..	17	..	1	..	..
7541...	—	55°38′	4°46′	J 10	36	10	fs sh	1	—	..	..	..	..	..	..	16	..	1	..	..
7542...	—	55°32′	4°48′	J 10	37	11	ms (sh)	1	—	..	..	..	..	..	..	15	..	..	..	..
7543...	11-5	55°37′	6°20′	L 10	39	9	cls	1	—	1	..	..	..	..	..	..	..	3	..	..
7544...	—	55°40′	6°30′	L 10	40	8	ms	1	—	1	..	..	..	..	..	..	..	6	..	..
7545...	16-5	55°24′	7°37′	M 9	25	6.5	cos (sh)	1	—	..	..	..	..	..	..	..	..	1	..	..
7546...	—	55°23′	7°17′	M 9	25	7	s (sh)	1	—	..	..	..	..	..	..	1	..	3	..	..
7547...	—	55°19′	6°42′	L 9	37	20[1])	cos (st)	1	—	..	..	..	..	..	..	..	1	..	..	..
7548...	—	55°03′	6°50′	L 9	35	3	cls	1	—	..	..	..	..	..	..	15	..	11	..	..
7549...	17-5	54°47′	6°50′	L 8	39	11.5	cls	1	—	..	..	..	..	..	..	10	..	35	..	..
7550...	—	54°31′	6°50′	L 8	35	9	cls	1	—	..	..	..	..	..	..	2	..	11	..	..
7551...	—	54°16′	7°29′	M 7	39	4	cls	1	—	..	..	..	..	..	..	15	..	4	..	..
7552...	—	54°16′	6°57′	L 7	36	7	cls	1	—	..	..	..	..	..	..	11	..	9	..	..
7553...	—	54°17′	6°23′	L 7	35	15	cls (sh)	1	—	..	..	..	..	..	..	2	..	3	..	..
7554...	—	54°17′	5°49′	K 7	38	12.5	cls (sh)	1	—	..	..	1	..	..	..	1	..	17	..	..
7555...	—	54°18′	5°15′	K 7	42	20	cls	1	—	1	..	..	..	..	..	..	..	7	..	..
7556...	—	54°18′	4°41′	J 7	44	12	scl	1	—	3	..	1	..	..	..	..	..	1	..	..
7557...	—	54°19′	4°07′	J 7	47	11	scl	1	—	..	..	2	..	..	..	..	..	2	..	..
7558...	—	54°21′	3°33′	H 7	43	8	ms	1	—	..	..	15	..	..	..	..	..	6	..	..
7561...	18-5	54°23′	2°00′	G 7	34	5.5	ms (sh)	1	—	..	..	..	..	..	..	2	..	..	..	..
7563...	—	54°15′	1°20′	F 7	41	8	ms (sh)	1	—	..	..	..	32	..	..	..	2	2	..	..
7564...	—	54°23′	1°20′	F 7	57	12	ms	1	—	..	..	42	16	..	..	1	..	6	..	..
7566...	—	54°23′	1°00′	F 7	42	10	fs sh	1	—	1	..	..	3	..	..	..	..	..	..	..
7567...	—	54°26′	0°42′	E 7	58	8.5	ms	1	—	..	..	1	1	..	1	..	2	..	..	..
7568...	—	54°27′	0°08′	E 7	66	8.5	fs	1	—	..	..	..	..	..	..	..	1	..	..	..
7569...	—	54°28′	0°25′W	D 7	51	8	cos (sh cl) *st*	1	—	..	3	..	..	..	..	..	3	..	..	..
7570...	19-5	55°38′	1°33′W	C 8	45	2	cos *st*	1	—	..	39	..	1	..	..	..	3	..	..	..
7571...	—	55°37′	0°58′W	D 8	82	13.5	cls	1	—	..	2	5	..	..	..	..	2	..	1	..
7572...	—	55°35′	0°22′W	D 8	64–66	7	s	1	—	..	..	..	..	..	4	1	5	..	1	..
7573...	—	55°34′	0°13′	E 8	64	12	fs	1	—	..	..	1	..	..	..	..	3	..	..	..
7574...	—	55°32′	0°49′	E 8	77–78	4.5	ms (sh)	1	—	..	..	4	..	..	..	..	..	..	..	..
7575...	—	55°03′	1°00′	F 9	62	7	ms (sh)	1	—	..	..	2	..	..	..	..	..	2	2	..
7577...	—	55°03′	1°20′	F 9	34	14[2])	cos (sh) *st*	1	—	..	..	..	..	..	..	..	1	..	..	..
7579...	—	55°11′	1°20′	F 9	54	10.5	s (sh st)	1	—	1	..	..	..	..	..	..	2	2	1	..
7580...	20-5	55°31′	1°24′	F 10	72	8	ms (st)	1	—	1	..	1	..	..	..	..	..	..	..	..
7589...	21-5	55°21′	5°32′	K 9	47	5	ms	1	—	..	1	1	..	..	..	13	..	6	..	..
7590...	—	55°19′	6°07′	L 9	47	22	scl	1	—	..	..	..	..	..	..	2	..	..	..	..
7591...	—	55°35′	6°24′	L 10	42	13	cls	1	—	..	..	1	..	..	..	..	..	3	..	..
7592...	—	55°25′	6°05′	L 9	47	15	scl	1	—	..	..	..	..	..	..	..	..	3	..	..
7593 I..	—	54°55′	5°28′	K 8	40	10	ms	1	—	..	..	..	..	..	..	..	..	14	..	..
— II..	22-5	54°55′	5°28′	K 8	40	8	ms	1	—	..	..	..	..	..	..	1	..	14	..	..
7594...	23-5	54°11′	3°50′	H 7	43	15	cls	1	—	..	..	1	..	..	..	..	..	1	..	..
7595...	—	54°03′	1°57′	F 7	79	15.5	cls	1	—	..	..	12	..	..	..	15	..	3	..	

[1]) Animals from 10 l only. [2]) Animals from 7 l only.

1951 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E. indet.*
7596 I	23-5	54°07′	1°42′	F 7	62	7	cl cos	1	02 V	.	.	15	.	.	.	2	.	9	2	.
— II	—	54°07′	1°39′	F 7	62	11	ms	1	—	.	.	14	7	.	.	2	.	8	2	.
— III	—	54°08′	1°37′	F 7	59	8	ms	1	—	.	23	17	11	.	.	1	1	11	1	.
— IV	24-5	54°06′	1°43′	F 7	69	14	ms	1	—	.	.	10	1	.	.	23	3	4	2	.
— V	—	54°10′	1°34′	F 7	61	10	ms	1	—	.	1	2	.	.	.	3	15	2	.	.
— VI	—	54°07′	1°39′	F 7	73	11	ms	1	—	.	1	43	.	.	.	15	.	10	.	.
— VII	—	54°08′	1°35′	F 7	58	18	s	1	—	.	.	1	.	.	.	3	20	1	1	.
7597 I	—	54°39′	1°40′	F 8	23	9	s (sh)	1	—	.	.	1	.	.	.	.	.	2	.	.
— II	—	54°39′	1°41′	F 8	22	6	s	1	—	.	.	.	1	.	.	.	.	.	.	.
7598	—	54°55′	1°40′	F 8	25	11	s (sh)	1	—	.	.	.	.	.	.	.	.	5	.	.
7599	—	55°19′	1°40′	F 9	40	9.5	fs (sh)	1	—	.	.	.	1	.	1	2	2	.	3	.
7600 I	—	55°19′	1°39′	F 9	40	15	cos (sh)	1	—	.	.	.	.	.	1	.	.	.	.	.
— II	—	55°20′	1°42′	F 9	41	7	fs sh	1	—	.	.	.	1	.	1	4	5	1	1	.
7603 I	25-5	55°00′	2°38′	G 9	24	6	s sh (st)	1	—	.	.	.	.	.	.	.	.	1	.	.
— II	—	55°00′	2°38′	G 9	24	7.5	s sh (st)	1	—	.	.	.	.	.	.	.	.	3	.	.
— III	—	54°58′	2°43′	G 10	23	7	fs sh (st)	1	—	.	.	.	.	.	.	.	.	2	.	.
7604 I	—	55°15′	4°34′	J 9	45	3	fs sh	1	—	.	.	.	.	.	.	2	.	1	.	.
— II	—	55°15′	4°34′	J 9	45	12.5	cls	1	—	.	.	.	.	.	.	9	.	.	.	.
7605	31-5	56°00′	3°00′	H 11	70	11	ms	1	—	.	.	4	.	.	1	1	.	.	1	.
7606	—	56°07′	3°02′	H 11	69	12.5	ms	1	—	.	.	2	.	.	.	1	.	.	.	.
7607	—	56°15′	3°00′	H 11	70	8.5	ms	1	—	.	.	11	.	.	.	.	.	.	.	.
7609	—	56°30′	3°00′	H 12	69	10.5	ms	1	—	.	.	23	.	.	.	1	.	.	4	.
7610	—	56°45′	3°00′	H 12	67	11.5	ms	1	—	.	.	28	.	.	.	1	2	.	1	.
7611	—	57°00′	3°00′	H 13	67	12	fs	1	—	1	.	21	.	.	1	1	.	1	1	.
7612	—	57°04′	1°40′	F 13	95	13	cls	1	—	.	.	1	.	.	.	.	.	.	.	.
7743	3-7	58°12′	0°37′	E 15	140	15	scl	1	—	.	.	.	.	.	.	.	.	.	.	.
7744	—	58°10′	1°06′	F 15	130	27.5	scl (sh)	1	—	.	.	.	.	.	.	.	.	.	.	.
7745	—	57°58′	3°03′	H 14	62	16	s (sh)	1	—	.	.	10	.	.	2	3	1	.	3	.
7746	—	57°54′	3°50′	H 14	80	20	s (sh)	1	—	.	.	10	.	.	2	2	4	.	.	.
7747	—	57°51′	4°47′	J 14	95	7	ms	1	—	.	.	3	.	.	.	.	.	.	.	.
7748	—	57°47′	5°31′	K 14	111	27	cls (st)	1	—	.	.	1	.	.	.	.	.	.	.	.
7749	4-7	57°43′	8°42′	N 14	165	21	?	1	—	.	.	.	.	.	.	.	.	.	.	.
7750	—	57°53′	9°23′	O 14	145	13.5	scl	1	02 P	.	.	.	.	.	.	.	.	1	.	.
7848	14-12	57°51′	4°47′	J 14	100	3.5	s sh	1	—	.	.	.	.	.	.	.	.	.	.	.
7849	—	57°47′	5°31′	K 14	125	15	scl	1	—	.	.	.	.	.	.	.	.	.	.	.
7850	15-12	57°43′	8°42′	N 14	192	12.5	scl	1	—	.	.	.	.	.	.	.	.	.	.	.
7851	—	57°53′	9°23′	O 14	158	16.5	cls	1	—	.	.	.	.	.	.	.	.	.	.	.

1952 — "Dana".

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E. indet.*
7868	26-4	56°42′	6°50′	L 12	38	7.5	cos *st*	1	02 V	.	.	1	.	.	.	.	.	.	.	.
7869	—	56°39′	6°50′	L 12	40	6	ms	1	—	.	.	6	.	.	.	.	2	1	.	.
7870	—	56°23′	6°50′	L 11	39	10	ms	1	—	.	.	4	4	.	.	.	.	7	.	.
7871	—	56°08′	6°49′	L 11	40	17[1])	cos	1	—	.	.	1	.	.	.	.	9	.	.	.
7872	—	55°51′	6°50′	L 10	38	15	s (sh)	1	—	1	.	.	.	.	.	.	1	2	.	.
7873	—	55°35′	6°50′	L 10	33	11	ms	1	—	.	.	.	.	.	.	.	.	21	.	.
7874	—	55°19′	6°07′	L 9	49	27	scl	1	—	.	.	1	.	.	.	4	.	.	.	.
7875	—	55°21′	5°32′	K 9	46	13	cls	1	—	.	.	.	.	.	.	10	.	2	.	.
7876	27-4	55°22′	4°57′	J 9	47	8	cls	1	—	.	.	.	.	.	.	21	.	1	.	.
7877	—	55°23′	4°21′	J 9	43	10	cls	1	—	.	.	1	.	.	1	33	.	8	.	.
7878	—	55°25′	3°46′	H 9	31	8	fs sh	1	—	.	.	.	.	.	.	.	.	3	.	.
7879	—	55°26′	3°10′	H 9	33	7	fs *sh*	1	—	.	.	.	.	.	.	.	.	2	.	.
7880	—	55°28′	2°35′	G 9	43	6	cos *st*	1	—	.	.	.	.	.	.	.	.	.	.	.
7881	—	55°29′	2°00′	G 9	66	14	ms	1	—	.	.	7	.	.	.	.	.	.	2	.
7882	—	55°31′	1°24′	F 10	79	6	cls	1	—	.	.	2	.	.	.	.	.	.	.	1
7883	—	55°32′	0°49′	E 10	82	10	cls	1	—	.	.	8	.	.	.	.	.	2	.	.
7884	28-4	55°34′	0°13′	E 10	68	11	cls	1	—	.	.	2	.	.	.	.	3	.	1	.
7885	—	55°35′	0°22′W	D 10	68	6	cl cos st	1	—	.	.	2	.	.	.	.	17	.	.	.
7886	—	54°45′	0°00′	E 8	81	14	cls	1	—	.	1	19	.	.	.	.	1	.	1	.
7887	—	54°27′	0°08′	E 7	67	13	ms	1	—	.	.	2	.	.	.	.	1	.	1	.

[1]) Animals from 6 l only.

1952 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E. indet.*
7888...	28-4	54°26′	0°42′	E 7	60	6	fs	1	02 V	..	..	1	1	..	..	..	5	..	2	2
7889...	—	54°25′	1°16′	F 7	58	12	fs	1	—	..	..	2	4	..	1	..	10	..	..	..
7890...	—	54°24′	1°50′	F 7	37	10	ms	1	—	..	..	1	4	..	..	1	..	5	1	..
7891...	—	54°23′	2°24′	G 7	31	10	ms	1	—	..	..	..	..	..	..	1	..	3	..	..
7892...	—	54°22′	2°58′	G 7	38	11	cls	1	—	..	..	4	..	..	..	..	..	5	..	..
7893...	—	54°21′	3°33′	H 7	45	9	fs	1	—	..	..	2	..	..	..	..	2	3	..	..
7894...	—	54°19′	4°07′	J 7	48	13	scl	1	—	..	..	11	..	..	..	..	..	3	1	..
7895...	—	54°18′	4°41′	J 7	47	25	scl	1	—	1	..	2	..	..	..	..	..	2	..	..
7896...	—	54°18′	5°15′	K 7	43	22	scl (sh)	1	—	..	..	..	..	..	..	..	..	4	..	..
7897...	—	54°17′	5°49′	K 7	39	12	cls	1	—	..	..	2	..	..	..	..	..	11	..	..
7898...	—	54°17′	6°23′	L 7	37	12	cls	1	—	..	..	1	..	..	..	3	..	3	..	..
7899...	—	54°16′	6°57′	L 7	36	6	cls	1	—	..	..	..	..	..	..	9	..	9	..	..
7900...	—	54°16′	7°29′	M 7	40	12	cls	1	—	..	..	..	..	..	..	4	..	8	..	..
7901...	—	54°31′	6°50′	L 8	37	12	cls	1	—	..	..	..	..	..	..	3	..	15	..	..
7902...	30-4	54°47′	6°50′	L 8	32	14	fs	1	—	..	..	..	..	..	..	2	2	..	..	..
9903...	—	55°03′	6°50′	L 9	38	20	cls	1	—	..	..	..	..	..	1	8	..	21	..	..
7904...	—	55°19′	6°50′	L 9	30	10	fs	1	—	..	..	..	..	..	..	..	2	7	..	..
7905...	—	55°19′	6°42′	L 9	37	10	cos st	1	—	1	..	..	..	..	..	..	60	..	..	..
7910...	—	55°36′	5°40′	K 10	51	16	scl	1	—	..	..	7	..	..	..	29	..	23	..	..
7911...	—	55°44′	5°40′	K 10	50	16	scl	1	—	..	..	8	..	..	..	12	..	..	..	..
7912...	—	55°52′	5°40′	K 10	50	28	scl	1	—	..	..	31	..	..	..	8	..	..	..	..
7913...	—	56°00′	5°40′	K 11	52	23	scl	1	—	..	..	48	..	..	..	17	..	..	..	..
7914...	—	56°08′	5°40′	K 11	53	27	scl	1	—	..	..	32	..	..	..	7	..	..	1	..
7915...	1-5	56°16′	5°40′	K 11	42	18	cos	1	—	1	..	..	..	..	..	..	..	1	..	..
7916...	—	56°12′	5°00′	K 11	52	6	ms	1	—	..	..	1	..	..	..	..	..	..	..	..
7917...	—	56°04′	5°00′	K 11	45	8	cos st (cl)	1	—	..	..	..	..	..	..	..	3	..	..	..
7918...	—	55°56′	5°00′	K 10	40	8	fs	1	—	..	..	..	..	..	..	12	..	3	..	..
7919...	—	55°48′	5°00′	K 10	35	17	fs (sh)	1	—	..	..	..	..	..	..	3	..	1	..	..
7920...	—	55°40′	5°00′	K 10	42	10	fs	1	—	..	..	..	..	..	..	31	..	1	..	..
7921...	—	55°35′	4°56′	J 10	38	10	fs sh	1	—	..	..	..	..	..	..	6	..	10	..	..
7922...	—	55°32′	4°51′	J 10	38	14	ms	1	—	..	..	..	..	..	..	1	..	13	..	..
7924...	—	55°32′	5°00′	K 10	42	14	ms	1	—	..	..	..	..	..	..	1	..	..	..	..
7925...	—	55°33′	4°53′	J 10	36	10	fs	1	—	..	..	..	..	..	..	7	..	3	..	..
7927...	—	55°24′	5°00′	K 9	44	14	ms	1	—	..	..	..	..	..	1	41	..	1	..	..
7928...	—	55°16′	5°00′	K 9	45	13	cls	1	—	..	..	..	..	..	1	15	..	2	..	..
7929...	—	55°08′	5°00′	K 9	39	13	ms (sh)	1	—	..	..	..	..	..	..	6	..	2	..	..
7930...	—	55°06′	4°20′	J 9	48	16	cls	1	—	..	..	..	..	..	..	28	..	19	..	..
7931...	—	55°14′	4°20′	J 9	45	14	ms sh	1	—	..	..	..	..	..	..	4	..	3	..	..
7932...	—	55°22′	4°20′	J 9	44	11	ms	1	—	..	..	1	..	..	..	3	..	5	..	1
7933...	—	55°30′	4°20′	J 10	30	5	fs *sh*	1	—	..	..	..	..	..	..	1	2	4	..	..
7934...	—	55°38′	4°20′	J 10	34	8	fs sh	1	—	..	..	..	..	..	..	..	4	2	..	..
7935...	2-5	55°46′	4°20′	J 10	38	7	fs	1	—	..	..	..	..	..	..	14	2	1	..	..
7936...	—	55°54′	4°20′	J 10	44	6	fs sh	1	—	..	..	..	..	..	..	3	..	2	1	..
7937...	—	55°45′	3°40′	H 10	44	7	fs sh (st)	1	—	..	..	..	..	..	..	1	1	1	1	..
7938...	—	55°37′	3°40′	H 10	39	10	fs *sh*	1	—	..	..	..	..	..	..	9	13	2	..	..
7939...	—	55°29′	3°40′	H 9	33	10	fs *sh*	1	—	..	..	1	..	..	..	..	2	..	..	..
7940...	—	55°21′	3°40′	H 9	29	9	fs *sh*	1	—	..	..	..	..	..	..	..	2	2	..	..
7941...	—	55°13′	3°40′	H 9	33	10	fs	1	—	..	..	5	..	..	..	6	..	3	..	..
7943...	—	55°05′	3°40′	H 9	41	8	ms	1	—	..	..	..	..	..	..	..	..	..	..	..
7944...	—	55°01′	3°00′	H 9	24	7	fs *sh*	1	—	..	..	..	..	..	..	..	..	..	..	..
7945...	—	55°09′	3°00′	H 9	29	8	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
7947[11] .	—	55°17′	3°00′	H 9	28	10	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
7948...	—	55°25′	3°00′	H 9	31	10	fs sh	1	—	..	..	..	..	..	..	..	3	3	..	..
7949...	—	55°33′	3°00′	H 10	43	6	fs *sh* st	1	—	..	..	..	..	..	1	7	17	3	..	..
7950...	—	55°27′	2°20′	G 9	44	6	fs	1	—	..	..	2	..	..	..	..	..	..	..	..
7951...	3-5	55°19′	2°20′	G 9	38	6	fs sh	1	—	..	..	..	..	..	..	..	13	5	..	..
7952...	—	55°11′	2°20′	G 9	32	5	fs *sh*	1	—	..	..	..	..	..	..	..	1	..	..	..
7953...	—	55°03′	2°20′	G 9	32	7	fs	1	—	..	..	..	..	..	..	..	..	1	..	..
7955...	—	55°03′	1°40′	F 9	30	18	fs	1	—	..	..	..	..	..	..	..	..	..	..	..
7956...	—	55°11′	1°40′	F 9	39	14	fs	1	—	..	..	..	1	..	..	..	3	1	1	..
7957...	—	55°03′	1°00′	F 9	64	10	ms	1	—	..	..	8	..	..	..	..	..	..	..	..

1952 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. ord.*	*E. flav.*	*E. indet.*
7958...	3-5	54°55′	1°00′	F 8	59	10	cos	1	02 V	..	..	3	1	..	..	..	24	..	3	..
7959...	—	54°47′	1°00′	F 8	57	14	ms	1	—	..	..	35	1	..	..	..	4	1	3	..
7960...	—	54°39′	1°00′	F 8	55	18	fs	1	—	..	..	3	34	..	3	..	3	..	..	..
7961...	—	54°31′	1°00′	F 8	60	12	ms	1	—	..	..	21	6	..	1	1	3	2	1	..
7962...	—	54°23′	1°00′	F 7	46	18	fs	1	—	..	..	..	18	..	..	..	8	1	..	1
7963...	—	53°59′	1°40′	F 6	34	7	ms	1	—	1	..	..	1	..	..	..	..	..	..	..
7964...	—	54°07′	1°40′	F 7	40	15	ms	1	—	..	..	2	26	..	..	..	6	1	..	..
7965...	—	54°15′	1°40′	F 7	48	19	ms	1	—	..	..	110	20	..	..	..	..	5	..	..
7966...	—	54°23′	1°40′	F 7	40	16	ms	1	—	..	..	5	16	..	..	1	..	2	1	..
7967...	4-5	54°26′	1°41′	F 7	17	13	fs sh	1	—	..	..	..	1	..	..	..	..	3	..	..
7968...	—	54°31′	1°40′	F 8	20	6	fs	1	—	..	..	..	..	..	..	..	..	1	..	..
7969...	—	54°39′	1°40′	F 8	23	10	fs	1	—	..	..	..	..	..	..	..	..	3	..	..
7970...	—	54°47′	1°40′	F 8	27	10	cos st	1	—	..	..	..	..	..	..	..	13	..	..	..
7971...	—	54°39′	1°35′	F 8	21	10	fs	1	—	..	..	..	..	..	..	..	..	1	..	..
7972...	—	54°39′	1°37′	F 8	22	2.5	cos sh *st*	1	—	..	..	..	..	..	..	..	2	..	..	..
7973...	—	54°55′	1°40′	F 8	28	8	fs	1	—	..	..	..	1	..	..	2	..	3	..	..
7974...	—	55°11′	1°20′	F 9	60	6	ms	1	—	..	..	1	1	..	1	2	..	2	1	..
7975...	—	55°19′	1°40′	F 9	43	5	fs sh	1	—	..	..	..	..	..	..	4	12	1	1	..
7976...	—	55°27′	2°00′	G 9	66	8	ms	1	—	..	..	6	..	..	..	6	..	1	..	..
7977...	—	55°35′	2°20′	G 10	75	11	ms	1	—	..	..	4	..	..	..	..	..	..	..	..
7978...	—	55°35′	2°40′	G 10	60	8	ms	1	—	..	..	1	..	..	3	..	..	1	..	..
7979...	—	55°41′	3°00′	H 10	60	10	ms	1	—	..	..	1	..	..	2	..	..	..	..	1
7980...	—	55°48′	3°20′	H 10	60	12	ms	1	—	..	..	1	..	..	..	..	..	..	..	1
7981...	5-5	55°53′	3°40′	H 10	56	6	ms	1	—	..	..	..	..	..	1	..	1	1	2	..
7982...	—	55°54′	4°00′	J 10	53	10	ms	1	—	..	..	3	..	..	1	8	..	1	5	..
7983...	—	56°02′	4°20′	J 11	50	6	fs (sh)	1	—	..	..	..	..	..	2	1	..	2	1	..
7984...	—	56°00′	4°40′	J 11	42	12	cos	1	—	1	..	..	..	..	3	..	1	1	..	..
7985...	—	56°00′	5°00′	K 11	42	13	cos	1	—	..	..	..	..	..	..	..	2	2	..	..
7986...	—	56°00′	5°20′	K 11	52	9	cls	1	—	1	..	9	..	..	1	6	..	1	..	..
7988...	—	56°00′	6°00′	L 11	46	8	cls	1	—	..	..	11	..	..	..	4	..	12	..	..
7989...	—	56°00′	6°20′	L 11	43	6	ms	1	—	..	..	..	..	..	..	..	..	..	..	..
7990...	—	56°00′	6°40′	L 11	38	15	cos	1	—	..	..	..	..	..	..	..	..	..	..	..
7991 [I]..	—	55°38′	6°31′	L 10	41	18	ms	1	—	..	..	..	..	..	..	..	5	..	..	..
— [II]..	—	55°39′	6°31′	L 10	40	8	ms	1	—	..	..	..	..	..	..	..	8	..	..	..
—[III]..	—	55°40′	6°31′	L 10	42	10	cls	1	—	1	..	1	..	..	..	..	5	..	..	..
7992 [I]..	6-5	55°05′	6°07′	L 9	44	23	scl	1	—	..	..	..	..	..	..	5	..	5	..	..
— [II]..	—	55°06′	6°06′	L 9	45	18	scl	1	—	..	..	..	..	..	..	5	..	5	..	..
—[III]..	—	55°07′	6°06′	L 9	44	20	scl	1	—	..	..	..	..	..	..	5	..	2	..	..
7993...	—	54°58′	4°20′	J 8	49	7	cls	1	—	..	..	6	..	..	..	10	..	..	1	..
7994...	—	54°50′	4°20′	J 8	49	10	cls	1	—	..	..	5	..	..	..	8	..	3	2	..
7995 [I]..	—	54°47′	4°05′	J 8	48	16	cls	1	—	..	..	..	..	..	..	1	..	4	..	..
— [II]..	—	54°48′	4°10′	J 8	48	9	cls	1	—	..	..	1	..	..	..	6	..	3	..	..
—[III]..	—	54°48′	4°08′	J 8	48	8	cls	1	—	..	..	4	..	..	..	1	..	2	..	..
7996...	7-5	54°42′	4°20′	J 8	49	16	scl	1	—	..	..	5	..	..	..	8	..	2	..	..
7997...	—	54°34′	4°20′	J 8	49	22	cls	1	—	..	..	11	..	..	..	..	..	2	5	..
7998...	—	54°26′	4°20′	J 7	48	16	cls	1	—	..	1	1	..	..	..	3	..	6	..	..
7999...	—	54°36′	5°00′	K 8	41	12	ms	1	—	..	..	1	..	..	..	..	..	5	..	..
8000...	—	54°44′	5°00′	K 8	42	12	ms	1	—	..	..	..	..	..	..	..	..	2	..	..
8001...	—	54°52′	5°00′	K 8	40	8	ms	1	—	..	..	..	..	..	..	..	..	5	..	..
8002...	—	55°00′	5°00′	K 9	39	10	ms	1	—	..	..	..	..	..	..	..	..	11	..	..
8003 [I]..	—	54°55′	5°28′	K 8	40	4	ms	1	—	..	..	..	..	..	..	..	..	12	..	..
— [II]..	—	54°55′	5°33′	K 8	40	12	ms	1	—	..	..	..	..	..	..	..	..	14	..	..
—[III]..	—	54°55′	5°30′	K 8	40	10	ms	1	—	..	..	1	..	..	..	..	..	15	..	..
8004 [I]..	—	55°56′	6°44′	L 10	38	6	ms	1	—	..	..	1	2	..	..	..	..	6	..	..
— [II]..	—	55°58′	6°45′	L 10	38	8	cos *st*	1	—	..	..	..	..	..	..	..	2	..	..	..
—[III]..	—	55°57′	6°44′	L 10	39	6	cls (st)	1	—	2	..	..	..	..	..	..	..	3	..	..
8005...	8-5	55°37′	4°42′	J 10	34	11	fs *sh*	1	—	..	..	..	..	..	..	..	..	1	..	..
8007 [I]..	—	55°38′	4°46′	J 10	38	13	fs sh	1	—	..	..	..	..	..	..	4	..	1	..	..
— [II]..	—	55°39′	4°49′	J 10	38	8	fs sh	1	—	..	..	..	..	..	..	9	1	1	..	..
—[III]..	—	55°39′	4°47′	J 10	37	10	fs sh	1	—	..	..	..	..	..	..	1	1	1	..	..
8008 [I]..	—	55°51′	4°23′	J 10	43	8	fs sh	1	—	..	..	..	..	..	..	35	4	2	5	..

1952 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E. indet.*
8008 II	8-5	55°53′	4°20′	J 10	45	7	fs sh	1	02 V	..	..	..	..	..	1	3	1	..	3	..
— III	—	55°52′	4°21′	J 10	44	10	ms	1	—	..	..	..	..	..	1	2	1	5	..	..
8009 I	9-5	55°38′	4°06′	J 10	34	10	fs sh	1	—	..	..	..	..	..	..	..	1	1	..	..
— II	—	55°36′	4°04′	J 10	34	6	fs sh	1	—	..	..	1	..	..	..	5	..	..	..	..
— III	—	55°39′	4°08′	J 10	34	10	fs sh	1	—	..	1	..	..	..	..	2	1	3	..	..
8011	- -	55°23′	7°17′	M 9	26	15	s	1	—	..	..	..	..	..	..	1	5	2	..	..
8012	—	55°24′	7°37′	M 9	25	14	s	1	—	..	..	..	..	..	..	2	27	4	..	..
8013	15-5	54°40′	3°40′	H 8	43	16	ms	1	—	1	..	1	..	..	..	1	..	10	..	..
8014	—	54°48′	3°40′	H 8	45	15	ms	1	—	..	..	..	..	..	..	11	..	..	..	..
8015	—	54°56′	3°40′	H 8	43	10	ms	1	—	..	..	1	..	..	..	13	..	5	..	..
8016 I	—	54°53′	3°00′	H 8	20.5	3	fs *sh*	1	—	..	..	..	..	..	..	..	..	1	..	..
— II	—	54°53′	3°00′	H 8	20.5	8	fs *sh*	1	—	..	..	..	..	..	..	..	..	1	..	..
8018 I	—	54°46′	2°58′	G 8	30	9	fs (sh)	1	—	..	..	..	..	..	..	..	..	2	..	..
— II	—	54°45′	2°58′	G 8	30	8	fs (sh)	1	—	..	..	..	..	..	..	..	..	2	..	..
— III	—	54°45′	2°58′	G 8	32	9	fs (sh)	1	—	..	..	..	..	..	..	..	..	2	..	..
— IV	—	54°45′	2°59′	G 8	33	9	ms (sh)	1	—	..	..	..	..	..	..	..	..	2	..	..
— V	—	54°44′	2°59′	G 8	33	8	fs (sh)	1	—	..	..	..	..	..	..	..	..	5	..	..
8019	—	54°37′	3°00′	H 8	36	6	ms	1	—	..	..	..	..	..	..	..	..	2	..	..
8020	—	54°28′	3°00′	H 7	38	9	ms	1	—	..	..	..	..	..	..	..	..	10	..	..
8021	—	54°21′	3°00′	H 7	41	10	ms	1	—	..	..	4	..	..	..	2	..	3	..	..
8022	16-5	54°13′	3°00′	H 7	43	12	clcos sh st	1	—	..	..	..	..	..	..	..	1	..	..	..
8023	—	54°09′	2°20′	G 7	65	15	clcos sh st	1	—	..	..	4	..	..	..	..	..	..	..	..
8024	—	54°15′	2°20′	G 7	35	9	cos (st)	1	—	..	..	..	..	..	..	1	2	..	..	..
8025	—	54°23′	2°20′	G 7	32	14	cos (sh)	1	—	..	..	..	..	..	..	..	..	1	..	..
8026	—	54°31′	2°20′	G 8	18	8	fs *sh*	1	—	..	..	..	..	..	..	..	..	..	..	..
8027	—	54°39′	2°20′	G 8	24	14	fs sh	1	—	..	..	..	..	..	..	..	..	3	..	..
8028	—	54°46′	2°20′	G 8	22	16	fs *sh*	1	—	..	..	..	..	..	..	..	..	..	..	..
8029	—	54°55′	2°20′	G 8	26	9	fs *sh* (st)	1	—	..	..	..	..	..	..	..	..	3	..	..
8032	—	54°59′	1°13′	F 8	55	13	ms	1	—	..	..	41	1	..	..	..	..	1	2	1
8034	17-5	55°35′	1°40′	F 10	76	4	ms	1	—	..	..	4	..	..	..	..	..	..	..	..
8035	—	55°40′	2°00′	G 10	80	15	cls	1	—	..	..	2	..	..	1	..	..	..	..	1
8036	—	55°45′	2°20′	G 10	82	10	ms	1	—	..	..	..	..	..	2	..	..	..	..	..
8037	—	55°50′	2°40′	G 10	79	14	ms	1	—	..	..	2	..	..	2	..	..	..	..	..
8038	—	55°54′	3°00′	H 10	73	7	ms	1	—	..	..	6	..	..	..	..	..	..	1	..
8039	—	56°00′	3°20′	H 11	70	13	ms	1	—	..	..	3	..	..	..	1	..	..	3	..
8040	—	56°05′	3°40′	H 11	70	18	ms	1	—	..	..	1	..	..	..	1	..	..	1	..
8041	—	56°09′	4°00′	J 11	68	10	ms	1	—	..	..	1	..	..	..	2	..	..	..	..
8042 I	18-5	56°14′	4°20′	J 11	65	2	ms	1	—	..	2	..	..	..	..	..	..	..	..	..
— II	—	56°14′	4°20′	J 11	65	10	ms	1	—	1	..	1	..	..	..	2	..	1	..	..
8043	—	56°19′	4°40′	J 11	60	9	ms	1	—	..	..	1	..	..	..	..	..	1	1	..
8044	—	56°24′	5°00′	K 11	57	13	ms	1	—	..	..	..	..	..	..	..	..	..	2	..
8045	—	56°24′	5°20′	K 11	49	22	cl cos	1	—	..	..	..	..	..	..	..	4	..	..	..
8046	—	56°24′	5°40′	K 11	50	21	cos	1	—	..	..	..	..	..	..	..	34	..	1	..
8047	—	56°24′	6°00′	L 11	39	19	cos	1	—	1	..	..	..	..	..	..	12	..	..	..
8048	—	56°24′	6°15′	L 11	41	18	cos	1	—	..	..	..	..	..	..	4	23	..	2	..
8049	—	56°24′	6°30′	L 11	40	14	cos	1	—	..	..	2	..	..	..	..	1	2	..	..
8051	—	56°24′	7°05′	M 11	33	21	ms	1	—	..	..	1	4	..	..	..	..	3	..	..
8052	—	56°24′	7°15′	M 11	34	8	cls	1	—	1	..	2	4	..	..	..	..	7	..	..
8053	—	56°31′	7°15′	M 12	37	19	ms	1	—	..	..	..	3	..	..	..	..	2	..	..
8054	—	56°38′	7°15′	M 12	35	14	cos	1	—	..	..	..	..	..	..	..	15	..	2	..
8055	—	56°48′	7°15′	M 12	28	10	st (cos)	1	—	..	..	..	..	..	..	..	1	12	..	..
8056	—	56°48′	7°34′	M 12	39	4	s *st*	1	—	..	..	..	..	..	..	1	8	..	..	..
8057	19-5	56°36′	7°34′	M 12	24	14	fs	1	—	..	..	..	..	..	..	1	6	2	..	..
8058	—	56°24′	7°34′	M 11	24	20	fs	1	—	..	..	..	..	..	..	..	1	1	..	..
8059	—	56°15′	7°34′	M 11	32	8	cos	1	—	..	..	..	..	..	..	..	..	..	..	..
8060	—	56°06′	7°34′	M 11	26	12	fs (sh)	1	—	..	..	..	..	..	..	6	31	1	..	..
8061	—	56°06′	7°19′	M 11	28	24	cos *sh*	1	—	..	..	..	..	..	..	..	4	..	..	..
8062	—	56°06′	7°04′	M 11	30	17[1])	cos	1	—	..	..	..	..	..	..	..	3	..	..	..
8063	—	56°17′	7°00′	M 11	36	16	cos	1	—	1	..	..	..	..	..	..	2	2	..	..
8064	—	56°30′	7°00′	M 12	38	12	ms	1	—	..	..	13	3	..	..	..	..	15	..	..
8065	—	56°43′	7°00′	M 12	40	10	scl *st*	1	—	..	1	..	..	..	..	..	3	..	..	..

[1]) Animals from 8.5 l only.

1952 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E.* indet.
8066...	19-5	56°53′	7°00′	M 12	37	5	cl & cos (st)	2	02 V	..	..	..	..	..	..	..	3	..	..	..
8067...	—	57°00′	7°19′	M 13	31	20[1])	cos	1	—	..	..	..	..	..	..	..	..	..	..	..
8068...	—	57°07′	7°37′	M 13	38	19	cos	1	—	..	..	..	..	..	..	1	..	..	..	..
8069 I-IV	—	57°14′	7°54′	M 13	50	5[2])	clcos st	4	—	..	9	..	..	..	..	..	..	..	1	..
— V	—	57°14′	7°54′	M 13	50	6	clcos *st*	1	—	..	1	..	..	..	..	..	..	..	3	..
8070 I-II	—	57°14′	8°09′	N 13	37	6[2])	3 stones	2	—	..	..	..	..	..	..	..	..	..	..	..
8071...	—	57°14′	8°22′	N 13	25	22	fs	1	—	..	..	1	..	..	..	..	1	..	..	..
8072...	20-5	57°00′	7°49′	M 13	43	25	cos	1	—	..	..	..	..	..	..	1	12	..	..	..
8073...	—	55°33′	6°14′	L 10	42	9	ms	1	—	1	..	1	..	..	..	..	..	9	..	..
8074...	—	55°21′	6°13′	L 9	49	28	scl	1	—	..	..	1	..	..	..	13	..	2	..	..
8076...	21-5	54°53′	5°28′	K 8	41	10	ms	1	—	..	..	4	..	..	..	1	..	3	..	..
8080 I..	22-5	54°53′	5°28′	K 8	41	11	ms	1	—	..	..	..	..	..	..	..	..	13	..	..
— II..	—	54°53′	5°28′	K 8	41	14	ms	1	—	..	..	1	..	..	..	..	..	15	..	..
—III..	—	54°53′	5°28′	K 8	41	11	ms	1	—	..	..	1	..	..	..	1	..	11	..	..
— IV..	—	54°53′	5°28′	K 8	41	16	ms	1	—	..	..	..	..	..	..	..	..	16	..	..
— V..	—	54°53′	5°28′	K 8	41	11	ms	1	—	..	..	1	..	..	..	..	..	12	..	..
— VI..	—	54°53′	5°28′	K 8	41	10	ms	1	—	..	..	1	..	..	..	..	..	9	..	..
8081...	27-5	56°36′	5°00′	K 12	62	17	scl	1	—	..	..	4	..	..	..	1	..	..	..	..
8082...	—	56°48′	5°00′	K 12	60	12	cls sh	1	—	..	..	31	..	..	..	2	..	..	2	..
8083...	—	57°00′	5°00′	K 13	58	6	cos sh st	1	—	..	..	..	..	..	1	..	5	..	..	..
8084...	—	57°00′	4°20′	J 13	63	3	ms sh	1	—	..	..	3	..	..	..	..	..	1	..	..
8085...	—	57°00′	3°40′	H 13	64	13	ms	1	—	..	..	14	..	..	..	..	..	2	2	..
8086...	—	57°00′	3°00′	H 13	65	15.5	fs (sh)	1	—	2	..	23	..	..	..	..	..	1	..	..
8087...	28-5	57°00′	2°20′	G 13	80	14	ms	1	—	..	..	22	..	..	..	..	..	1	..	..
8088...	—	57°00′	1°40′	F 13	96	14	ms	1	—	1	..	..	..	..	1	..	1	..	..	..
8373...	24-8	53°30′	3°00′	H 6	28	5	ms	1	—	..	..	1	..	..	..	..	..	4	..	..
8374...	—	53°50′	3°29′	H 6	28	10	fs (sh)	1	—	..	..	..	..	..	..	..	3	9	..	..
8375...	—	54°12′	3°53′	H 7	43	20	cls	1	—	..	..	50	..	..	..	..	..	8	..	..
8376...	—	54°32′	4°20′	J 8	45	13.5	cls	1	—	..	..	6	..	..	..	..	3	..	2	..
8378...	—	54°51′	4°47′	J 8	41	10	fs sh	1	—	..	..	2	..	..	..	..	..	..	..	..
8379...	—	55°11′	5°13′	K 9	37	7	fs sh	1	—	..	..	..	..	..	..	10	..	2	..	..
8380...	25-8	55°52′	6°07′	L 10	48	9	cls	1	—	1	1	6	1	..	..	29	..	6	..	..
8381...	—	55°51′	6°08′	L 10	43	10	cls	1	—	..	..	11	..	..	..	4	..	2	..	..
8382...	—	56°10′	6°33′	L 11	38	11	ms (sh)	1	—	..	..	8	2	..	..	..	..	6	..	..
8383...	—	56°30′	7°00′	M 12	33	6	fs sh	1	—	..	..	1	4	..	..	..	..	1	..	..

1953 — "Dana".

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E.* indet.
8426...	1-5	54°18′	4°41′	J 7	44	22	cls	1	02 V	1	..	1	..	..	..	..	..	..	..	..
8427...	—	54°18′	5°15′	K 7	41	23	cls	1	—	..	..	1	..	..	..	..	..	6	..	..
8428...	—	54°17′	5°49′	K 7	37	17	cls (sh)	1	—	..	..	3	..	..	..	..	..	8	..	..
8432 I..	2-5	54°55′	5°28′	K 8	40	21	cls	1	—	1	..	1	..	..	..	..	..	15	..	..
— II..	—			K 8	39	10	cls	1	—	..	..	2	..	..	..	..	..	14	..	..
—III..	—	Max. dist.		K 8	38	8	cls	1	—	..	..	2	..	..	..	..	..	11	..	..
— IV..	—	from st. 8432 I:		K 8	38	7	cls	1	—	..	..	2	..	..	..	1	..	13	..	..
— V..	—	1 mile		K 8	39	13	cls	1	—	2	..	1	..	..	..	..	..	10	..	..
— VI..	—			K 8	38	5	cls	1	—	..	..	..	..	..	..	..	..	5	..	..
8434...	—	55°14′	4°20′	J 9	42	9	cls	1	—	1	..	..	..	..	..	8	..	..	..	..
8435...	—	55°22′	4°20′	J 9	40	5	fs (sh)	1	—	..	..	..	..	..	..	2	3	2	..	..
8436...	—	55°30′	4°20′	J 10	30	6	fs *sh*	1	—	..	..	..	..	..	..	..	..	**1**	..	..
8437...	—	55°38′	4°20′	J 10	33	8	fs *sh*	1	—	..	..	..	..	..	..	2	2	..	..	..
8438...	—	55°46′	4°20′	J 10	34	2.5	fs *sh*	1	—	..	..	..	..	..	..	1	..	1	..	..
8439...	—	55°54′	4°20′	J 10	46	7	ms sh	1	—	..	..	1	..	1	1	8	..	1	..	..
8440...	—	56°04′	5°00′	K 11	39	16	s	1	—	..	..	..	..	..	..	..	..	1	..	..
8441...	—	56°00′	5°20′	K 11	36	18	cos	1	—	..	..	..	..	..	..	1	..	..	..	..
8442...	—	55°56′	5°00′	K 10	35	9	cls	1	—	..	..	..	..	..	..	5	..	3	..	..
8443...	—	55°48′	5°00′	K 10	32	9	fs (sh)	1	—	..	..	..	..	..	..	1	2	..	..	..
8444...	3-5	55°40′	5°00′	K 10	41	13	ms	1	—	..	..	..	..	..	..	15	..	5	..	..
8445...	—	55°32′	5°00′	K 10	40	6	ms	1	—	..	..	1	..	..	..	14	..	..	..	..
8446...	—	55°31′	4°50′	J 10	39	11	cls sh	1	—	..	..	..	..	..	..	5	..	9	..	..

[1]) Animals from 10 l only. [2]) Deficient samples.

1953 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E. indet.*
8447...	3-5	55°24′	5°00′	K 9	44	8	cls	1	02 V	1	..	..	..	..	..	9	..	..	..	..
8462...	8-5	54°21′	3°00′	H 7	40	16	cls	1	—	..	..	8	..	..	..	1	..	3	..	..
8463...	—	54°29′	3°00′	H 7	30	11	cls (sh)	1	—	..	..	..	..	..	..	2	..	2	..	..
8464...	—	54°37′	3°00′	H 8	31	6	cls (sh)	1	—	..	..	..	..	..	..	..	..	..	..	1
8465...	—	54°45′	3°00′	H 8	29	13	fs (sh)	1	—	..	..	..	..	..	..	..	..	6	..	..
8466...	—	54°53′	3°00′	H 8	19	12	fs *sh*	1	—	..	..	..	..	..	..	..	..	2	..	..
8467 [1]..	—	55°01′	3°00′	H 9	20	4	fs *sh*	1	—	..	..	..	..	..	..	..	..	..	..	..
— II..	—	55°01′	3°00′	H 9	20	6	fs *sh*	1	—	..	..	..	..	..	..	..	..	1	..	..
8468...	—	55°09′	3°00′	H 9	24	12	fs *sh*	1	—	..	..	..	..	..	..	..	..	2	..	..
8469...	—	55°16′	3°00′	H 9	27	7	fs *sh*	1	—	..	..	..	..	..	..	..	..	..	..	..
8470...	—	55°24′	3°00′	H 9	30	9	fs *sh*	1	—	..	..	1	..	..	..	..	..	..	..	..
8471...	—	55°33′	3°00′	H 10	38	12	fs sh	1	—	..	..	..	..	..	..	2	1	3	..	..
8472...	—	55°37′	3°40′	H 10	35	11	fs sh	1	—	..	..	..	..	..	..	1	2	2	..	..
8473...	9-5	55°29′	3°40′	H 9	30	10	fs *sh*	1	—	..	..	..	..	..	..	..	1	4	..	..
8474...	—	55°21′	3°40′	H 9	25	11	fs *sh*	1	—	..	..	..	..	..	..	..	2	1	..	..
8475...	—	55°13′	3°40′	H 9	35	7	ms sh	1	—	..	..	..	..	..	..	1	..	1	..	..
8476...	—	55°05′	3°40′	H 9	39	15	ms (sh)	1	—	..	..	7	..	..	..	..	..	6	..	..
8477...	—	54°56′	3°40′	H 8	40	13	ms	1	—	..	..	2	..	..	..	6	..	3	..	..
8478...	—	55°17′	3°52′	H 9	35	10	fs (sh)	1	—	..	..	..	..	..	..	..	..	1	..	..
8479 [1]..	—	55°17′	3°55′	H 9	36	7	ms (sh)	1	—	..	..	..	..	..	..	..	..	2	..	..
— II..	—	55°17′	3°55′	H 9	36	7	fs sh	1	—	..	..	..	..	..	..	..	..	1	..	..
— III..	—	55°17′	3°50′	H 9	35	11	ms	1	—	..	..	1	..	..	..	..	..	1	..	..
— IV..	—	55°17′	3°50′	H 9	35	12	fs (sh)	1	—	..	..	1	..	..	..	..	..	2	..	..
8481 [1]..	—	55°37′	4°36′	J 10	36	8	fs (sh)	1	—	..	..	..	..	..	..	10	..	1	..	..
— II..	—	c. 600 m NE of st. 8481 [1]		J 10	36	6	fs (sh)	1	—	..	..	1	..	..	..	5	1	..	..	..
— III..	—	c. 1200 m NE of st. 8481 [1]		J 10	35	7	fs (sh)	1	—	..	..	..	..	..	..	7	2	2	..	..
— IV..	—	c. 1 mile NE of st. 8481 [1]		J 10	35	7	fs (sh)	1	—	..	..	..	..	..	..	7	1	1	..	..
— V..	—	55°38′	4°39′	J 10	35	10	fs (sh)	1	—	..	..	..	..	..	..	10	3	2	..	..
8508 [1]..	17-5	54°40′	1°41′	F 8	19	10	fs sh (st)	1	—	..	..	..	..	..	..	..	..	3	..	..
— II..	—	Max. dist. from st. 8508 [1]: 200 m		F 8	19	8	fs sh (st)	1	—	..	..	..	..	..	..	..	..	3	..	..
— III..	—			F 8	19	12	fs sh (st)	1	—	..	..	..	..	..	..	..	..	..	..	..
— IV..	—			F 8	19	10	fs sh (st)	1	—	..	..	..	..	..	..	..	..	..	..	..
— V..	—			F 8	19	17	cos sh (st)	1	—	..	..	..	..	..	..	..	..	..	..	..
— VI..	—			F 8	19	10	fs sh (st)	1	02 P	..	..	..	..	..	..	..	..	..	..	..
— VII..	—			F 8	19	9	fs sh (st)	1	—	..	..	..	..	..	..	..	..	2	..	..
— VIII .	—			F 8	19	7	fs sh (st)	1	—	..	..	..	..	..	..	..	..	..	..	..
— IX..	—			F 8	19	7	fs sh (st)	1	—	..	..	..	..	..	..	..	..	3	..	..
— X..	—			F 8	19	8	fs sh (st)	1	—	..	..	..	..	..	..	..	..	..	..	..
— XI..	—			F 8	19	12	fs sh (st)	1	02 V	..	..	..	..	..	..	..	..	3	..	..
8512 [1]..	18-5	54°47′	3°00′	H 8	26	12	fs (sh)	1	—	..	..	..	..	..	..	..	..	1	..	..
— II..	—	Max. dist. from st. 8512 [1]: 150 m		H 8	26	11	fs (sh)	1	—	..	..	..	..	..	..	..	..	3	..	..
— III..	—			H 8	26	12	fs (sh)	1	—	..	..	..	..	..	..	1	..	4	..	..
— IV..	—			H 8	26	10	fs (sh)	1	—	..	..	..	..	..	..	..	..	2	..	..
— V..	—			H 8	26	13	fs (sh)	1	—	..	..	..	..	..	..	..	..	3	..	..
— VI..	—			H 8	26	6	fs (sh)	1	02 P	..	..	..	..	..	..	..	..	2	..	..
— VII..	—			H 8	26	7	fs (sh)	1	—	..	..	..	..	..	..	..	..	3	..	..
— VIII .	—			H 8	26	6	fs (sh)	1	—	..	..	..	..	..	..	..	..	1	..	..
— IX..	—			H 8	26	8	fs (sh)	1	—	..	..	..	..	..	..	..	..	2	..	..
— X..	—			H 8	26	8	fs (sh)	1	—	..	..	..	..	..	..	..	..	3	..	..

1954 — "Dana".

8866 [1]..	10-5	54°28′	0°25′W	D 7	51	?	l st	1	02 V	..	96	..	..	..	..	..	..	..	..	..
— II..	—	54°28′	0°22′W	D 7	54	6	clcos st	1	—	..	1	..	..	..	..	..	..	..	..	..
8878...	11-5	54°18′	4°41′	J 7	43	24	cls	1	—	..	..	1	..	..	..	..	..	1	..	..
8879...	—	54°18′	5°15′	K 7	40	28	cls (sh)	1	—	..	..	2	..	..	..	..	..	1	..	..
8881...	—	54°17′	5°49′	K 7	37	21	cls (sh)	1	—	1	2	15	..	..	..	..	..	..	..	..

1954 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E.* indet.
8904 I	14-5	54°40′	1°41′	F 8	19	17	fs (sh)	1	02 V	..	..	..	..	..	..	..	..	1	..	..
— II	—			F 8	19	10	fs (sh)	1	—	..	..	..	..	..	..	..	..	1	..	..
— III	—			F 8	19	15	fs (sh)	1	—	..	..	..	..	..	..	..	..	2	..	..
— IV	—			F 8	19	17	fs (sh)	1	—	..	..	..	..	..	..	..	..	1	..	..
— V	—			F 8	19	25	fs (sh)	1	—	..	..	..	..	..	..	..	..	2	..	..
— VI	—	Ship anchored		F 8	19	20	fs (sh) above	1	01 K	..	..	..	..	..	..	..	..	3	..	..
— VII	—			F 8	19	18	ms (sh) below	1	—	..	..	..	..	..	..	..	..	1	..	..
— VIII	—			F 8	19	25	Same deposit	1	—	..	..	..	..	..	..	..	..	..	..	..
— IX	—			F 8	19	20	as in 8904 VI	1	—	..	..	..	..	..	..	..	..	1	..	..
— X	—			F 8	19	26		1	—	..	..	..	..	..	..	..	..	1	..	..
8909 I	15-5	54°55′	5°30′	K 8	39	23	ms	1	02 V	..	..	5	..	..	..	..	..	3	..	..
— II	—			K 8	39	22	ms	1	—	..	..	2	..	..	..	..	..	11	..	..
— III	—	Max. dist. from		K 8	39	9	ms	1	—	1	..	5	..	..	..	..	..	6	..	..
— IV	—	st. 8909 I:		K 8	39	15	ms	1	—	..	..	13	..	..	..	..	..	2	..	..
— V	—	1 mile		K 8	39	8	ms	1	—	..	..	5	..	..	..	..	..	7	..	..
— VI	—			K 8	39	15	ms	1	—	1	1	4	..	..	..	1	..	4	..	..
8926	22-5	55°33′	3°00′	H 10	42	12	fs (sh)	1	—	..	1	2	..	..	1	..	3	3	..	..
8927	—	55°25′	3°00′	H 9	32	13	fs (sh)	1	—	..	..	1	..	..	..	..	1	1	..	..
8928	—	55°17′	3°00′	H 9	27	14	fs *sh*	1	—	..	..	1	..	..	..	..	..	1	..	..
8929	—	55°09′	3°00′	H 9	23	9	sh fs	1	—	..	..	..	..	..	..	..	..	..	..	..
8930	—	55°01′	3°00′	H 9	20	4	*sh* fs	1	—	..	..	..	..	..	..	..	..	1	..	..
8931	—	54°53′	3°00′	H 8	17	5	fs *sh*	1	—	..	..	..	..	..	..	..	..	2	..	..
8932	—	54°45′	3°00′	H 8	25	6	fs (sh)	1	—	..	1	1	..	..	..	..	..	..	..	..
8933	23-5	54°37′	3°00′	H 8	27	8	fs (sh)	1	—	..	..	..	1	..	..	..	..	..	..	..
8934	—	54°29′	3°00′	H 7	28	17	ms sh	1	—	..	..	1	..	..	..	..	..	1	..	..
8935	—	54°21′	3°00′	H 7	40	23	ms	1	—	..	..	13	..	..	..	..	..	2	..	..
8936 I	—	54°47′	3°00′	H 8	18	7	fs sh	1	—	..	..	1	..	..	..	1	..	1	..	..
— II	—			H 8	18	10	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
— III	—			H 8	18	10	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
— IV	—			H 8	18	14	fs sh	1	—	..	..	..	..	..	..	..	..	..	..	..
— V	—	Ship anchored		H 8	18	22	fs *sh*	1	01 K	..	..	..	..	..	..	..	..	2	..	..
— VI	—			H 8	18	22	fs *sh*	1	—	..	..	..	..	..	..	..	..	..	..	..
— VII	—			H 8	18	20	fs *sh*	1	—	..	..	1	..	..	..	..	..	..	..	..
— VIII	—			H 8	18	25	fs *sh*	1	—	..	..	..	..	..	..	..	..	1	..	..
8937	—	54°56′	3°40′	H 8	38	8	fs	1	02 V	..	..	..	..	..	..	..	..	..	..	..
8938	—	55°05′	3°40′	H 9	34	14	ms (sh)	1	—	..	..	..	..	..	..	4	..	2	..	..
8939	—	55°13′	3°40′	H 9	22	6	fs *sh*	1	—	..	..	..	..	..	..	..	..	3	..	..
8940	—	55°21′	3°40′	H 9	24	10	fs sh	1	—	..	..	1	..	..	..	..	..	2	..	..
8941	—	55°29′	3°40′	H 9	29	12	fs *sh*	1	—	..	..	1	..	..	..	..	..	2	..	..
8942	—	55°37′	3°40′	H 10	34	12	fs sh	1	—	..	..	..	..	..	..	..	..	1	1	..
8945	—	55°54′	4°20′	J 10	42	5	fs sh	1	—	..	..	1	..	..	..	1	2	1	2	..
8946	—	55°46′	4°20′	J 10	?	11	fs *sh*	1	—	..	..	..	..	..	..	25	2	2	1	..
8947	—	55°38′	4°20′	J 10	?	14	fs sh	1	—	..	..	1	..	..	..	4	..	3	..	..
8948	24-5	55°30′	4°20′	J 10	27	5	fs *sh*	1	—	..	..	..	..	..	..	..	..	..	..	..
8949	—	55°22′	4°20′	J 9	40	5	fs (sh)	1	—	..	..	1	..	..	..	20	..	..	3	..
8950	—	55°14′	4°20′	J 9	42	8	ms (sh)	1	—	..	..	1	..	..	..	9	..	..	..	..
8951	—	55°24′	5°00′	K 9	42	10	ms	1	—	..	..	1	..	..	..	3	..	..	..	..
8952	—	55°34′	4°57′	J 10	35	12	ms (sh)	1	—	..	..	..	..	..	..	2	..	4	..	..
8953	—	55°40′	5°00′	K 10	33	16	ms	1	—	..	..	..	..	..	..	6	..	4	..	..
8954	—	55°48′	5°00′	K 10	35	15	ms (sh)	1	—	..	..	..	..	..	..	6	1	..	..	..
8955	—	55°56′	5°00′	K 10	36	10	fs	1	—	..	..	..	..	..	..	1	4	2	..	..
8956	—	56°04′	5°00′	K 11	31	12	fs (sh)	1	—	..	..	..	..	..	..	..	..	1	..	..
8957	—	56°00′	5°20′	K 11	46	14	ms	1	—	..	..	1	..	..	1	4	..	..	..	..
8959	—	55°32′	4°50′	J 10	34	15	ms (sh)	1	—	..	..	..	..	..	..	2	..	3	..	..

1955 — "Dana".

9418 I	21-4	52°48′	2°25′	G 4	48	7	cos *sh* & cl	1	02 V	..	..	..	..	..	1	3	7	..	..	..
— II	—	52°48′	2°25′	G 4	48	11	cos *sh*	1	—	..	..	..	..	..	2	..	1	..	..	..
9419	—	52°32′	1°52′	F 4	29	11	cos sh st	1	—	..	..	..	..	..	..	..	2	..	..	..
9426	25-4	54°17′	5°49′	K 7	38	20	cls (sh)	1	—	..	..	27	..	..	..	..	..	13	..	..

1955 — "Dana" (continued).

St.	Date	Position N	Position E	Square	Depth m	Volume l	Bottom	No. of samples	Sampler	Total no. *A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. aff.*	*O. alb.*	*E. pus.*	*E. cord.*	*E. flav.*	*E.* indet.
9427...	25-4	54°18′	5°15′	K 7	40	22	cls (sh)	1	02 V	..	..	26	..	..	..	..	..	8	..	..
9428...	—	54°18′	4°41′	J 7	45	22	cls	1	—	..	..	8	..	..	..	..	..	1	..	..
9461 I..	4-5	54°55′	5°30′	K 8	41	13	ms	1	—	..	..	25	..	..	..	..	..	5	..	..
— II..	—	Max. dist. from st. 9461 I: 1 mile		K 8	41	16	ms	1	—	1	..	20	..	..	..	..	..	9	..	..
—III..	—			K 8	42	7	ms	1	—	..	..	14	..	..	..	..	..	6	..	..
— IV..	—			K 8	42	14	ms	1	—	..	..	39	..	..	..	..	..	8	..	..
— V..	—			K 8	42	18	ms	1	—	..	..	34	..	..	..	..	..	11	..	..
— VI..	—			K 8	40	9	ms	1	—	..	..	45	..	..	..	1	..	7	..	..
9467...	5-5	55°32′	4°48′	J 10	41	3	fs sh	1	—	..	..	1	..	..	..	4	..	..	..	..
9476 I..	6-5	54°53′	2°36′	G 8	20	3	fs *sh*	1	—	..	..	..	..	..	..	..	..	..	..	..
— II..	—	54°53′	2°36′	G 8	20	4	fs *sh*	1	—	..	..	..	..	..	..	..	..	1	..	..
9506 I..	17-5	55°34′	4°57′	J 10	38	12	ms sh	1	—	..	..	..	..	..	..	7	..	9	..	..
— II..	—	55°33′	4°55′	J 10	38	9	ms sh	1	—	..	..	..	..	..	..	1	..	6	..	..
—III..	—	55°33′	4°53′	J 10	38	10	ms sh	1	—	1	..	..	..	..	..	..	..	9	..	..
— IV..	—	55°31′	4°52′	J 10	38	10	ms sh	1	—	..	..	..	..	..	..	1	..	5	..	..
— V..	—	55°31′	4°50′	J 10	38	7	ms sh	1	—	..	..	..	..	..	..	6	..	5	..	..

Appendix 2.

The lists of 11 species each on which Table 26 is based. Names of species listed in Table 20 (pp. 95–96) or pp. 125–126 are abbreviated.

TEST SERIES

(based on randomized samples)

The North Sea

The poor area	The rich area				Faxa Bay	
	1.	2.	3.	4.	1.	2.
A. fil.	*A. fil.*	*O. alb.*	*O. frag.*	*A. irr.*	*O. aff.*	*O. rob.*
O. alb.	*E. cord.*	*E. pus.*	*L. sar.*	*A. fil.*	*E. flav.*	*A. fil.*
E. cord.	*O. alb.*	*A. fil.*	*A. fil.*	*O. aff.*	*A. fil.*	*E. flav.*
E. pus.	*E. pus.*	*A. irr.*	*O. alb.*	*O. alb.*	*A. rub.*	*P. phan.*
A. rub.	*A. irr.*	*E. flav.*	*E. pus.*	*E. cord.*	*O. alb.*	*L. müll.*
A irr.	*A. brach.*	*E. cord.*	*E. cord.*	*E. pus.*	*S. droe.*	*A. sq.*
S. pur.	*E. flav.*	*B. lyr.*	*O. aff.*	*A. brach.*	*A. sq.*	*O. acul.*
E. flav.	*O. frag.*	*A. brach.*	*S. pur.*	*T. com.*	*O. acul.*	*O. alb.*
O. frag.	*S. pur.*	*C. elong.*	*E. flav.*	*A. rub.*	*B. lyr.*	*Solaster glacialis*
O. aff.	*O. aff.*	*O. aff.*	*T. fus.*	*E. flav.*	*O. rob.*	*S. droe.*
A. brach.	*O. rob.*	*E. pen.*	*A. irr.*	*E. pen.*	*O. text.*	*B. lyr.*

The Adriatic Sea

1.	2.	3.	4.	5.	6.
O. aran.	*O. aran.*	*L. dig.*	*O. quin.*	*L. dig.*	*S. can.*
O. quin.	*T. fus.*	*O. quin.*	*O. alb.*	*O. alb.*	*L. dig.*
A. chi.	*A. chi.*	*H. forsk.*	*A. fil.*	*A. chi.*	*O. aran.*
O. alb.	*O. quin.*	*A. fil.*	*S. can.*	*O. text.*	*A. chi.*
H. forsk.	*O. alb.*	*O. aran.*	*L. dig.*	*A. fil.*	*C. elong.*
L. dig.	*S. can.*	*O. alb.*	*A. chi.*	*O. aran.*	*T. fus.*
A. aur.	*A. fil.*	*T. fus.*	*C. elong.*	*E. med.*	*H. forsk.*
O. frag.	*T. raph.*	*A. chi.*	*O. frag.*	*C. elong.*	*O. frag.*
A. fil.	*L. dig.*	*L. gal.*	*T. fus.*	*S. can.*	*A. fil.*
C. terg.	*E. med.*	*S. can.*	*O. aran.*	*O. quin.*	*O. alb.*
P. mem.	*A. aur.*	*A. irr.*	*P. micr.*	*H. forsk.*	*O. quin.*

7.	8.	9.	10.	11.	12.
A. chi.	*A. chi.*	*A. chi.*	*A. bisp.*	*O. alb.*	*O. quin.*
O. quin.	*O. aran.*	*S. can.*	*O. text.*	*L. dig.*	*A. chi.*
O. aran.	*L. dig.*	*C. elong.*	*L. dig.*	*A. fil.*	*P. urna*
C. terg.	*S. can.*	*T. fus.*	*S. can.*	*O. quin.*	*A. med.*
L. dig.	*O. alb.*	*L. dig.*	*E. med.*	*O. aran.*	*A. fil.*
S. can.	*T. raph.*	*O. alb.*	*A. fil.*	*P. micr.*	*O. aran.*
T. fus.	*A. fil.*	*A. fil.*	*C. terg.*	*H. forsk.*	*O. frag.*
O. alb.	*C. elong.*	*O. quin.*	*A. aur.*	*E. med.*	*L. dig.*
A. fil.	*T. inerm.*	*O. aran.*	*A. chi.*	*A. chi.*	*P. mem.*
S. reg.	*A. gib.*	*O. frag.*	*O. aran.*	*L. phal.*	*T. fus.*
A. med.	*O. pent.*	*O. pent.*	*T. fus.*	*C. terg.*	*E. med.*

SERIES TESTED

(these lists are not based on randomized samples)

The Scoresby Sound	Spitsbergen	The Faroes		The northern North Sea
		1.	3.	
Myriotrochus rinki	*S. droe.*	*O. acul.*	*S. droe.*	*E. flav.*
O. ser.	*O. rob.*	*O. frag.*	*E. pen.*	*O. aff.*
Eupyrgus scaber	*O. acul.*	*Henricia sp.*	*Brisaster fragilis*	*A. chi.*
Trochoderma elegans	*Ophiacantha bidentata*	*S. droe.*	*S. pur.*	*A. irr.*
O. rob.	*Amphiura sundevalli*	*A. rub.*	*Amphiura securigera*	*A. fil.*
Stephanasterias albula	*C. frond.*	*O. text.*	*E. pus.*	*H. phryg.*
Ophiopleura borealis	*Myriotrochus rinki*	*A. fil.*	*O. sar.*	*O. text.*
Ophiacantha bidentata	*Eupyrgus scaber*	*E. pen.*	*O. aff.*	*O. alb.*
Amphiura sundevalli	*Chiridota laevis*	*O. alb.*	*O. alb.*	*E. cord.*
Ctenodiscus crispatus	*O. ser.*	*E. pus.*	*O. bal.*	*E. pus.*
Hymenaster pellucidus	*Ctenodiscus crispatus*	*Amphiura securigera*	*A. sq.*	*S. pur.*

The North Sea, by squares

F–K 13, H–K 14	C–D 10	D–E 7, E 8	H–M 7, L 8, L–M 9	L 10–11	L–M 12
A. irr.	*O. frag.*	*O. frag.*	*A. fil.*	*A. rub.*	*A. fil.*
O. aff.	*A. fil.*	*O. acul.*	*O. alb.*	*A. fil.*	*O. aff.*
E. pus.	*O. bal.*	*O. nig.*	*E. cord.*	*A. brach.*	*O. alb.*
B. lyr.	*O. nig.*	*P. mil.*	*A. rub.*	*E. cord.*	*T. com.*
A. fil.	*O. aff.*	*E. pus.*	*E. pus.*	*E. pus.*	*E. pus.*
E. cord.	*O. rob.*	*A. fil.*	*S. pur.*	*A. irr.*	*E. pen.*
O. alb.	*O. alb.*	*S. pur.*	*E. flav.*	*O. alb.*	*E. cord.*
E. flav.	*S. droe.*	*E. flav.*	*A. irr.*	*E. flav.*	*O. frag.*
P. phan.	*E. pus.*	*A. brach.*	*C. elong.*	*E. pen.*	*T. fus.*
A. chi.	*S. pur.*	*O. aff.*	*O. frag.*	*O. frag.*	*A. brach.*
O. ser.	*E. flav.*	*C. lac.* (?)	*O. aff.*	*C. elong.*	*E. flav.*

J 10–11	F–H 10, F 9	F 7	K 10	K 11	G 9
E. pus.	*A. fil.*	*A. brach.*	*A. fil.*	*A. fil.*	*A. fil.*
O. alb.	*E. flav.*	*E. pus.*	*O. alb.*	*O. alb.*	*O. aff.*
E. cord.	*O. alb.*	*E. cord.*	*E. cord.*	*E. cord.*	*O. alb.*
A. fil.	*E. pus.*	*A. fil.*	*E. flav.*	*E. pus.*	*E. pus.*
O. frag.	*E. cord.*	*O. alb.*	*C. elong.*	*E. flav.*	*E. cord.*
E. flav.	*L. sar.*	*E. flav.*	*A. rub.*	*B. lyr.*	*E. flav.*
A. rub.	*O. aff.*	*C. elong.*	*E. pus.*	*A. irr.*	*A. brach.*
O. aff.	*O. frag.*	*O. frag.*	*O. aff.*	*O. aff.*	*O. frag.*
O. text.	*A. irr.*	*P. mil.*	*A. irr.*	*O. rob.*	*P. mil.*
A. irr.	*A. brach.*	*O. aff.*	*O. frag.*	*O. frag.*	*A. sq.*
S. pur.	*A. sq.*	*A. irr.*	*B. lyr.*	*C. elong.*	*A. rub.*

Horn's Reef	NE. North Sea	Helg. tiefe Rinne	The Oslo Fjord 1.	The Oslo Fjord 2.	The Skagerrak
O. text.	*A. irr.*	*A. irr.*	*A. norv.*	*A. norv.*	*A. chi.*
O. alb.	*A. rub.*	*A. fil.*	*A. chi.*	*A. chi.*	*A. fil.*
E. cord.	*A. fil.*	*O. alb.*	*A. fil.*	*A. fil.*	*O. alb.*
A. rub.	*O. alb.*	*S. pur.*	*O. alb.*	*O. sar.*	*O. text.*
A. brach.	*O. aff.*	*E. cord.*	*O. aff.*	*O. aff.*	*B. lyr.*
E. pen.	*O. text.*	*C. elong.*	*A. irr.*	*O. frag.*	*E. cord.*
A. fil.	*E. pus.*	*A. rub.*	*B. lyr.*	*A. irr.*	*E. flav.*
E. pus.	*S. pur.*	*O. frag.*	*E. cord.*	*B. lyr.*	*C. elong.*
O. frag.	*E. cord.*	*P. mil.*	*P. mil.*	*E. cord.*	*L. inhaer.*
A. irr.	*E. flav.*	*E. pus.*	*E. pus.*	*E. flav.*	*O. aff.*
O. aff.	*E. pen.*	*T. fus.*	*C. elong*	*Cucumaria sp.*	*O. sar.*

Eastern Kattegat	The Samsø Belt 1.	The Samsø Belt 2.	The Great Belt	The Sound 1.	The Sound 2.
A. irr.	*A. rub.*	*A. rub.*	*O. acul.*	*A. irr.*	*A. rub.*
A. chi.	*O. acul.*	*O. acul.*	*O. alb.*	*A. chi.*	*A. fil.*
A. fil.	*A. fil.*	*A. fil.*	*O. rob.*	*A. fil.*	*O. alb.*
O. sar.	*O. text.*	*O. text.*	*H. sang.*	*O. alb.*	*O. aff.*
O. alb.	*O. aff.*	*O. rob.*	*A. rub.*	*O. text.*	*O. rob.*
O. rob.	*O. rob.*	*O. alb.*	*E. pus.*	*O. rob.*	*O. text.*
O. acul.	*O. alb.*	*S. droe.*	*S. droe.*	*O. aff.*	*A. chi.*
E. cord.	*S. droe.*	*E. pus.*	*T. pell.*	*E. cord.*	*O. acul.*
E. flav.	*E. pus.*	*E. cord.*	*P. phan.*	*T. pell.*	*E. pus.*
B. lyr.	*E. cord.*	*T. pell.*	*S. papp.*	*P. phan.*	*E. cord.*
C. elong.	*P. phan.*	*P. phan.*	*E. cord.*	*A. rub.*	*T. pell.*

Plymouth 1.	Plymouth 2.	Plymouth 3.	The Mediterranean	The Irish Sea
O. aff.	*E. pus.*	*E. cord.*	*Astrop. jonstoni*	*A. sq.*
E. pus.	*O. frag.*	*A. fil.*	*Genocid. maculata*	*O. alb.*
T. fus.	*O. nig.*	*O. text.*	*A. fil.*	*O. aff.*
E. cord.	*A. rub.*	*C. elong.*	*A. chi.*	*A. fil.*
A. fil.	*E. flav.*	*Synaptidae*	*O. aran.*	*A. chi.*
A. brach.	*S. pur.*	*E. pus.*	*E. cord.*	*E. flav.*
O. frag.	*A. fil.*	*A. rub.*	*S. can.*	*B. lyr.*
C. elong.	*E. cord.*	*L. sar.*	*B. lyr.*	*E. pus.*
T. raph.	*A. irr.*	*O. frag.*	*L. dig.*	*L. inhaer.*
C. lac.	*O. text.*	*O. nig.*	*C. elong.*	*L. busk.*
A. sq.	*Synaptidae*	*O. bal.*	*T. fus.*	*E. cord.*

Appendix 3 A—G.

The number of specimens of each species of echinoderms obtained in individual statistical squares in all, and on various kinds of bottom deposit. 652 samples (0.2 m² each) taken in April and May 1950–55. Cf. Figs. 79–83.

App. 3 A. All samples, irrespective of bottom deposit.

Square	No. of samples	*A. irr.*	*L. sar.*	*A. rub.*	*O. frag.*	*O. nig.*	*O. bal.*	*O. acul.*	*A. fil.*	*A. brach.*	*A. sq.*	*O. text.*	*O. alb.*	*O. rob.*	*O. aff.*	*P. mil.*	*S. droe.*	*E. pus.*	*S. pur.*	*E. cord.*	*E. flav.*	*E. penn.*	(*E.* sp.)	*B. lyr.*	*C. elong.*	*C. lac.?*	*T. fus.*	*T. com.*	Total	Mean no. per sample
C 10	1	..	..	..	39	2	9	..	..	1	..	..	..	2	..	..	..	3	..	..	..	..	..	..	..	..	..	..	56	56
D 10	3	..	..	..	2	..	..	..	7	..	..	..	1	..	4	..	2	24	3	..	2	..	..	..	..	..	..	..	45	15.0
D 7	3	..	..	..	100	1	..	5	..	..	..	..	..	..	..	2	..	3	..	..	..	..	..	..	..	..	..	..	111	37.0
E 15	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0
E 10	4	..	..	..	..	..	..	..	15	..	..	..	..	..	..	..	..	6	..	2	1	..	..	..	..	..	..	..	24	6.0
E 8	1	..	..	..	1	..	..	..	19	..	..	..	..	..	..	..	..	1	..	..	1	..	..	..	..	1	..	..	23	23
E 7	4	..	..	..	..	..	..	..	4	2	..	..	..	..	1	..	..	9	2	..	3	..	2	..	..	..	..	..	23	5.8
F 13	2	1	..	..	..	..	..	..	1	..	..	..	..	..	1	..	..	1	..	..	..	..	..	2	..	..	..	..	6	3.0
F 10	2	1	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6	3.0
F 9	18	1	..	..	..	..	..	..	27	9	..	..	21	1	4	..	..	51	..	16	14	..	1	..	..	..	..	..	145	8.1
F 8	43	..	..	..	..	..	..	..	155	89	..	..	8	..	4	..	..	52	..	48	12	1	..	..	..	..	..	..	369	8.6
F 7	21	1	..	..	25	..	..	..	380	172	..	..	68	..	1	1	..	65	..	98	12	..	..	..	3	..	..	..	826	39.3
F 6	1	1	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	2
F 4	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	2	2
G 13	1	..	..	..	..	..	..	..	22	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	23	23
G 10	5	..	..	..	..	..	..	..	9	..	..	..	..	..	8	..	..	..	..	1	..	..	1	..	..	..	..	..	19	3.8
G 9	23	..	..	..	1	..	..	..	22	1	1	..	49	..	9	2	..	82	..	35	16	..	..	..	..	..	..	..	218	9.5
G 8	24	..	..	1	..	..	..	..	1	..	..	..	1	..	..	..	..	1	..	30	..	..	..	..	..	..	..	..	34	1.4
G 7	15	..	..	..	..	..	..	..	311	3	..	..	11	..	..	1	..	7	..	28	3	..	..	..	3	..	1	..	368	24.5
G 4	2	..	..	..	..	..	..	..	..	..	..	..	3	..	3	..	..	8	1	..	..	..	..	..	..	..	..	..	15	7.5
H 13	3	3	..	..	..	..	..	..	58	..	..	..	1	..	1	..	..	..	..	4	3	..	..	..	..	..	..	..	70	23.3
H 12	1	..	..	..	..	..	..	..	28	..	..	..	2	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..	32	32
H 11	6	..	..	..	..	..	..	..	44	..	..	..	4	..	2	..	..	..	3	..	9	..	..	..	..	..	..	..	62	10.3
H 10	26	1	1	..	1	..	..	..	13	..	..	..	46	..	14	..	..	66	..	26	9	..	3	..	..	..	..	..	180	6.9
H 9	60	..	..	..	..	..	..	..	22	..	..	..	57	..	..	..	..	18	..	72	..	..	..	..	..	..	..	..	169	2.8
H 8	43	3	..	..	1	..	..	..	8	1	..	..	130	..	1	..	..	..	..	81	..	..	..	..	..	..	..	..	225	5.2
H 7	15	..	..	2	..	..	..	..	47	..	..	..	83	..	..	..	..	3	1	41	..	..	1	..	..	..	..	..	178	11.9
J 13	1	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	4	4
J 11	8	3	..	..	2	..	..	..	3	..	..	..	6	..	6	..	..	1	2	11	2	..	..	..	..	..	..	..	36	4.5
J 10	69	1	..	1	1	..	..	..	10	..	..	1	364	..	4	..	..	42	..	140	22	..	15	..	..	..	..	..	601	8.7
J 9	33	2	..	..	1	..	..	..	6	..	..	..	465	..	6	..	..	8	..	109	2	..	..	..	..	..	..	..	599	18.2
J 8	13	2	..	..	..	..	..	..	32	..	..	..	85	..	..	..	..	..	1	29	12	..	..	..	..	..	..	..	161	12.4
J 7	9	6	..	..	1	..	..	..	27	..	..	..	4	..	..	..	..	..	..	17	1	..	..	..	1	..	..	..	57	6.3
K 13	1	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	5	..	..	..	..	..	..	..	..	..	..	6	6
K 12	2	..	1	..	..	..	..	..	35	..	..	..	3	..	..	..	..	..	..	..	2	..	..	..	..	..	..	..	41	20.5
K 11	26	4	..	..	2	..	..	..	165	..	..	..	127	1	4	..	..	56	..	17	8	..	..	6	3	..	..	..	393	15.1
K 10	31	5	..	1	1	..	..	..	206	..	..	..	282	..	3	..	..	7	..	50	4	..	3	1	3	..	..	..	566	18.3
K 9	11	3	..	..	1	..	..	..	1	..	..	..	88	..	1	..	..	..	..	33	1	..	..	..	..	..	..	..	128	11.6
K 8	37	6	..	1	1	..	..	..	229	..	..	..	8	..	..	..	..	..	..	331	..	..	..	..	..	..	..	..	576	15.6
K 7	10	2	..	..	2	..	..	..	77	..	..	..	1	..	..	..	..	..	..	75	..	..	..	..	..	..	..	..	157	15.7
L 12	4	..	..	..	..	..	..	..	8	..	..	..	2	..	1	..	..	5	..	1	..	2	..	..	..	..	..	1	20	5.0
L 11	9	1	..	2	..	..	..	..	21	9	..	..	8	..	..	..	..	37	..	26	2	1	..	..	..	..	..	..	107	11.9
L 10	15	7	..	..	..	..	..	..	4	2	..	..	8	..	..	..	..	69	..	93	..	..	..	..	..	..	..	..	183	12.2
L 9	12	1	..	..	..	..	..	..	2	..	..	..	98	..	1	..	..	62	..	57	..	..	..	..	23	..	..	..	244	20.3
L 8	4	..	..	..	..	..	..	..	..	..	..	..	17	..	..	..	..	2	..	61	..	..	..	..	..	..	..	..	80	20.0
L 7	4	..	..	..	..	..	..	..	1	..	..	..	25	..	..	..	..	..	..	24	..	..	..	..	..	..	..	..	50	12.5
M 13	3	..	..	..	1	..	..	..	..	..	..	..	2	..	..	..	..	12	..	..	3	..	..	..	..	1	..	..	19	6.3
M 12	8	..	..	..	1	..	..	..	13	6	..	..	2	..	..	..	..	36	..	31	2	..	..	..	..	..	1	..	92	11.5
M 11	6	2	..	..	..	..	..	..	3	8	..	..	6	..	..	..	..	34	..	14	..	..	..	..	..	..	..	..	67	11.2
M 9	4	..	..	..	..	..	..	..	..	..	..	..	4	..	..	..	..	32	..	10	..	..	..	..	..	..	..	..	46	11.5
M 7	2	..	..	..	..	..	..	..	..	..	..	..	19	..	..	..	..	..	..	12	..	..	..	..	..	..	..	..	31	15.5
N 13	1	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	2	2
Total	652	57	2	8	184	3	9	5	2045	304	1	1	2109	4	81	6	2	811	13	1626	146	4	26	9	36	2	2	1	7497	
Mean no. per sample		0.087	0.003	0.012	0.282	0.005	0.014	0.008	3.137	0.466	0.002	0.002	3.235	0.006	0.124	0.009	0.003	1.244	0.020	2.494	0.224	0.006	0.040	0.014	0.055	0.003	0.003	0.002		11.498

App. 3 B. Samples of coarse sand.

Square	No. of samples	*A. irr.*	*O. frag.*	*O. nig.*	*O. bal.*	*O. acul.*	*A. fil.*	*A. brach.*	*A. sq.*	*O. alb.*	*O. rob.*	*O. aff.*	*P. mil.*	*E. pus.*	*S. pur.*	*E. cord.*	*E. flav.*	*E. pen.*	(*E.* sp)	*T. com.*	Total	No. per sample
C 10	1	..	39	2	9	..	..	1	..	..	2	..	..	3	..	..	..	..	..	..	56	56
D 10	1	..	..	..	..	..	..	..	..	1	..	4	..	5	..	..	1	..	..	..	11	11
D 7	2	..	99	1	..	5	..	..	..	..	..	..	2	3	..	..	..	..	..	..	110	55.0
F 9	2	1	..	..	..	..	..	..	..	..	1	1	..	2	..	2	1	..	..	..	8	4.0
F 8	12	..	..	..	..	..	13	7	..	4	..	..	..	42	..	7	4	1	1	..	79	6.6
F 7	1	..	..	..	..	..	1	..	..	3	..	..	..	20	..	1	1	..	..	..	26	26
F 4	1	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	..	2	2
G 9	3	..	1	..	..	..	..	..	1	..	..	..	2	..	..	3	..	..	..	..	7	2.3
G 8	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	..	2	2
G 7	3	..	..	..	..	..	2	2	..	1	..	..	1	7	..	1	3	..	..	..	17	5.7
G 4	2	..	..	..	..	..	..	..	..	3	..	3	..	8	1	..	..	..	..	..	15	7.5
H 9	4	..	..	..	..	..	..	..	..	1	..	..	..	1	..	1	..	..	..	..	3	0.8
J 11	1	1		..	..	..	..	..	..	..	..	3	..	1	..	1	..	..	..	..	6	6
J 10	1	..	..	..	..	..	..	..	..	23	..	..	..	..	..	..	..	..	..	..	23	23
K 13	1	..	..	..	..	..	..	..	..	..	..	1	..	5	..	..	..	..	..	..	6	6
K 11	8	2	..	..	..	..	1	..	..	1	..	..	..	51	..	7	1	..	..	..	63	7.9
L 12	3	..	..	..	..	..	2	..	..	2	..	1	..	3	..	..	..	2	..	1	11	3.7
L 11	4	1	..	..	..	..	2	..	..	4	..	..	..	36	..	2	2	1	..	..	48	12.0
L 10	3	1	..	..	..	..	..	..	..	..	..	..	..	65	..	9	..	..	..	..	75	25.0
L 9	1	1	..	..	..	..	..	..	..	..	..	..	..	60	..	..	..	..	..	..	61	61
M 13	2	..	..	..	..	..	..	..	..	2	..	..	..	12	..	..	..	..	..	..	14	7.0
M 12	3	..	..	..	..	..	..	..	..	1	..	..	..	24	..	12	2	..	..	..	39	13.0
M 11	2	1	..	..	..	..	..	..	..	..	..	..	..	2	..	2	..	..	..	..	5	2.5
M 9	4	..	..	..	..	..	..	..	..	4	..	..	..	32	..	10	..	..	..	..	46	11.5
Total	66	8	139	3	9	5	21	10	1	50	3	13	5	384	1	60	15	4	1	1	733	
Mean no. per sample		0.121	2.106	0.045	0.136	0.076	0.318	0.152	0.015	0.758	0.045	0.197	0.076	5.818	0.015	0.909	0.227	0.061	0.015	0.015		11.106

App. 3 C. Samples of clayey coarse sand.

Square	No. of samples	*A. irr.*	*A. rub.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. alb.*	*O. aff.*	*S. droe.*	*E. pus.*	*S. pur.*	*E. cord.*	*E. flav.*	(*E.* sp.)	*C. elong.*	*C. lae.?*	*T. fus.*	Total	No. per sample
D 10	1	..	..	..	2	..	..	..	2	17	3	..	..	..	..	..	..	24	24
D 7	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1
F 7	1	..	..	..	15	..	2	..	..	..	9	2	..	..	..	..	..	28	28
G 7	1	..	..	..	4	..	..	..	..	..	..	..	..	..	2	..	1	7	7
H 7	2	..	2	..	1	..	..	..	..	1	1	2	..	..	..	..	..	7	3.5
K 11	7	1	..	1	13	..	11	2	..	5	..	4	2	2	..	..	..	41	5.9
K 10	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0
K 8	1	..	..	..	..	..	2	..	..	..	..	9	..	..	..	..	..	11	11
L 11	3	..	1	..	15	5	4	..	..	1	..	17	..	..	..	..	..	43	14.3
M 13	1	..	..	1	..	..	..	..	..	..	..	..	3	..	..	1	..	5	5
M 12	1	..	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..	3	3
Total	20	1	3	3	50	5	19	2	2	27	4	41	7	2	2	1	1	170	
Mean no. per sample		0.05	0.15	0.15	2.50	0.25	0.95	0.10	0.10	1.35	0.20	2.05	0.35	0.10	0.10	0.05	0.05		8.50

App. 3 D. Samples of fine sand.

Square	No. of samples	*A. irr.*	*L. sar.*	*A. rub.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. alb.*	*O. aff.*	*E. pus.*	*S. pur.*	*E. cord.*	*E. flav.*	(*E.* sp.).	Total	No. per sample
E 10.....	1	..	..	..	..	1	..	..	..	3	..	..	..	..	4	4
E 7.....	2	..	..	..	..	1	1	..	..	6	1	..	2	2	13	6.5
F 9.....	9	..	..	..	..	1	6	16	2	47	..	10	8	..	90	10.0
F 8.....	25	..	..	..	..	3	35	2	3	3	..	35	..	..	81	3.2
F 7.....	4	1	..	..	..	2	26	..	1	18		5	..	..	53	13.2
G 9.....	16	..	..	..	..	6	1	42	9	81	..	23	13	1	176	11.0
G 8.....	21	..	..	1	..	1	..	1	..	1	..	26	..	..	30	1.4
G 7.....	3	..	..	..	..	1	..	..	..	..	..	..	..	..	1	0.3
H 13	2	3	..	..	..	44	..	1	1	..	..	2	1	..	52	26.0
H 10	19	..	1	..	1	4	..	35	9	65	..	25	5	..	145	7.6
H 9	49	..	..	..	..	7	..	31	..	17	..	64	..	..	119	2.4
H 8	30	1	..	..	1	2	1	24	..	..	..	45	..	2	76	2.5
H 7	1	..	..	..	..	2	..	..	..	2	..	3	..	..	7	7
J 11.....	1	..	..	..	..	..	..	1	2	..	1	2	1	..	7	7
J 10.....	46	..	..	..	1	5	..	215	1	40	..	56	15	13	346	7.5
J 9.....	7	..	..	..	..	1	..	30	..	3	..	11	..	..	45	6.4
K 11	1	..	..	..	..	..	..	..	..	..	..	1	..	..	1	1
K 10	5	..	..	..	..	..	..	48	..	5	..	7	..	..	60	12.0
L 9.....	1	..	..	..	..	..	..	..	..	2	..	7	..	..	9	9
L 8.....	1	..	..	..	..	..	..	2	..	2	..	..	..	..	4	4
M 12	1	..	..	..	..	..	..	1	..	6	..	2	..	..	9	9
M 11	2	..	..	..	..	..	..	6	..	32	..	2	..	..	40	20.0
N 13	1	..	..	..	..	1	..	..	..	1	..	..	..	..	2	2
Total.....	248	5	1	1	3	82	70	455	28	334	2	326	45	18	1370	
Mean no. per sample		0.020	0.004	0.004	0.012	0.331	0.282	1.835	0.113	1.347	0.008	1.315	0.181	0.073		5.524

App. 3 E. Samples of sandy clay.

Square	No. of samples	*A. irr.*	*L. sar.*	*A. rub.*	*O. frag.*	*A. fil.*	*O. alb.*	*O. aff.*	*E. pus.*	*S. pur.*	*E. cord.*	*E. flav.*	(*E.* sp.)	*B. lyr.*	*C. elong.*	*T. fus.*	Total	No. per sample
E 15.....	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0
F 13.....	1	..	..	..	..	1	..	..	..	..	..	..	..	1	..	..	2	2
G 7.....	1	..	..	..	..	14	..	..	..	..	..	..	..	..	..	..	14	14
J 9.....	1	..	..	..	..	..	12	..	2	..	23	1	..	..	..	..	38	38
J 8.....	6	2	..	..	..	5	27	..	..	1	6	4	..	..	..	..	45	7.5
J 7.....	5	5	..	..	..	16	1	..	..	..	9	1	..	..	..	..	32	6.4
K 12	1	..	1	..	..	4	1	..	..	..	..	..	..	..	..	..	6	6
K 11	5	..	..	..	1	137	105	..	..	..	1	3	..	6	3	..	256	51.2
K 10	12	2	..	1	1	205	126	2	..	..	26	5	..	1	3	..	372	31.0
K 7	1	..	..	..	..	..	..	..	..	..	4	..	..	..	..	..	4	4
L 9.....	8	..	..	..	..	2	75	..	..	..	17	..	1	..	23	..	118	14.7
M 12	1	..	..	..	1	..	..	..	3	..	..	..	..	..	..	1	5	5
Total....	43	9	1	1	3	384	347	2	5	1	86	14	1	8	29	1	892	
Mean no. per sample		0.209	0.023	0.023	0.070	8.930	8.070	0.047	0.116	0.023	2.000	0.326	0.023	0.186	0.674	0.023		20.744

App. 3 F. Samples of muddy sand.

Square	No. of samples	*A. irr.*	*A. rub.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. alb.*	*O. aff.*	*E. pus.*	*S. pur.*	*P. mil.*	*E. cord.*	*E. flav.*	(*E.* sp.)	*B. lyr.*	Total	No. per sample
E 10.....	1	..	..	..	4	..	..	..	..	..	..	..	..	..	..	..	4	4
E 7.....	2	..	..	..	3	1	..	..	1	3	1	..	..	1	..	..	10	5.0
F 13.....	1	1	..	..	..	..	..	..	1	1	..	..	..	..	..	1	4	4
F 10.....	2	1	..	..	5	..	..	..	..	..	..	..	..	..	..	..	6	3.0
F 9.....	5	..	..	..	13	3	..	5	1	2	..	..	4	5	..	..	33	6.6
F 8.....	4	..	..	..	113	40	..	1	1	7	..	..	4	7	..	..	173	43.2
F 7.....	12	..	..	25	267	142	..	47	..	27	..	1	64	7	..	..	580	48.3
F 6.....	1	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	2	1
G 13.....	1	..	..	..	22	..	..	..	..	..	..	..	1	..	..	..	23	23
G 10.....	4	..	..	..	7	..	..	..	7	..	..	..	1	..	..	..	15	3.8
G 9.....	3	..	..	..	14	..	..	6	..	..	..	..	2	2	7	..	31	10.3
G 8.....	2	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	2	2
G 7.....	4	..	..	..	1	..	..	10	..	..	..	..	10	..	..	..	21	5.2
H 13	1	..	..	..	14	..	..	..	..	..	..	..	2	2	..	..	18	18
H 12	1	..	..	..	28	..	..	2	1	..	..	..	1	..	..	..	32	32
H 11	6	..	..	..	44	..	..	4	2	..	3	..	..	9	..	..	62	10.3
H 10	6	1	..	..	9	..	..	2	5	1	..	..	1	4	2	..	25	4.2
H 9	7	..	..	..	15		..	25	..	..	..	..	17	..	..	..	57	8.1
H 8	10	1	..	..	4	..	..	92	..	..	..	..	29	..	..	..	126	12.6
H 7	8	..	..	..	33	..	..	75	..	..	..	..	28	..	1	..	137	17.1
J 13	1	..	..	..	3	..	..	..	..	..	..	..	1	..	..	..	4	4
J 11	6	2	..	2	3	..	..	5	1	..	1	..	8	1	..	..	23	3.8
J 10	21	1	1	..	5	..	1	121	3	2	..	..	75	7	2	..	218	10.4
J 9.....	15	..	..	1	4	..	..	247	4	3	..	..	31	1	1	..	292	19.5
K 11	3	..	..	..	4	..	..	4	1	..	..	..	..	2	..	..	11	3.7
K 10	12	3	..	..	1	..	..	103	1	2	..	..	13	..	3	..	126	10.5
K 9	7	2	..	1	1	..	..	45	..	..	..	..	26	..	..	..	75	10.7
K 8	30	3	1	1	221	..	..	5	..	..	..	..	254	..	..	..	485	16.2
L 12.....	1	..	..	..	6	..	..	..	..	2	..	..	1	..	..	..	9	9
L 11.....	2	..	1	..	4	4	..	..	..	..	..	..	7	..	..	..	16	8.0
L 10.....	8	2	..	..	2	2	..	8	..	4	..	..	63	..	7	..	88	11.0
M 12	2	..	..	..	13	6	..	..	..	..	..	..	17	..	..	..	36	18.0
M 11	1	..	..	..	1	4	..	..	..	..	..	..	3	..	..	..	8	8
Total	190	18	3	30	864	203	1	807	29	54	5	1	665	48	23	1	2752	
Mean no. per sample		0.095	0.016	0.158	4.547	1.068	0.005	4.247	0.153	0.284	0.026	0.005	3.500	0.253	0.121	0.005		14.484

App. 3 G. Samples of clayey sand.

Square	No. of samples	*A. irr.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. alb.*	*O. rob.*	*O. aff.*	*E. pus.*	*E. cord.*	*E. flav.*	(*E.* sp.)	*C. elong.*	*C. lac.?*	Total	No. per sample
D 10	1	..	2	5	..	..	..	..	2	..	1	..	..	..	10	10
E 10.....	2	..	..	10	..	..	..	..	3	2	1	..	..	..	16	8.0
E 8.....	1	..	1	19	..	..	..	..	1	..	1	..	..	1	23	23
F 9.....	2	..	..	13	..	..	..	..	..	..	..	1	..	..	14	7.0
F 8.....	2	..	..	26	7	1	..	..	..	1	1	..	..	..	36	18.0
F 7.....	3	..	..	95	4	16	..	..	..	19	2	..	3	..	139	46.3
G 10.....	1	..	..	2	..	..	..	1	..	..	..	1	..	..	4	4
G 9.....	1	..	..	2	..	1	..	..	1	..	..	..	..	..	4	4
G 7.....	3	..	..	289	1	..	..	..	..	17	..	..	1	..	308	102.7
H 10	1	..	..	..	..	9	..	..	..	..	..	1	..	..	10	10
H 8	3	1	..	2	..	14	..	1	..	5	..	..	..	..	23	7.7
H 7	4	..	..	11	..	8	..	..	..	8	..	..	..	..	27	6.5
J 10.....	1	..	..	..	..	5	..	..	..	9	..	..	..	..	14	14
J 9.....	9	2	..	1	..	155	..	1	..	39	..	..	..	..	198	22.0
J 8.....	7	..	..	27	..	58	..	..	..	23	8	..	..	..	116	16.6
J 7.....	4	1	1	11	..	3	..	..	..	8	..	..	1	..	25	6.2
K 12	1	..	..	31	..	2	..	..	..	..	2	..	..	..	35	35
K 11	2	1	..	10	..	6	1	1	..	2	..	..	..	..	21	10.5
K 10	1	..	..	..	..	5	..	..	..	3	..	..	..	..	8	8
K 9	4	1	..	..	..	43	..	1	..	7	1	..	..	..	53	13.2
K 8	6	3	..	8	..	1	..	..	..	68	..	..	..	..	80	13.3
K 7	9	2	2	77	..	1	..	..	..	71	..	..	..	..	153	17.0
L 10.....	4	4	..	2	..	..	..	..	..	14	..	..	..	..	20	5.0
L 9.....	2	..	..	..	..	23	..	1	..	32	..	..	..	..	56	28.0
L 8.....	3	..	..	..	..	15	..	..	..	61	..	..	..	..	76	25.3
L 7.....	4	..	..	1	..	25	..	..	..	24	..	..	..	..	50	12.5
M 11	1	1	..	2	4	..	..	..	..	7	..	..	..	..	14	14
M 7	2	..	..	..	..	19	..	..	..	12	..	..	..	..	31	15.5
Total.....	84	16	6	644	16	410	1	6	7	432	17	3	5	1	1564	
Mean no. per sample		0.190	0.071	7.667	0.190	4.881	0.012	0.071	0.083	5.143	0.202	0.036	0.060	0.012		18.619

Appendix 4 (A—G).

Wet weight (in grammes) of each species of echinoderms obtained in individual statistical squares in all, and on various kinds of bottom deposit. 654 samples (0.2 m² each) taken in April and May 1950—55. Text p. 152. Names of species are abbreviated. The full names are found, e. g., in Table 20, pp. 95–96. *E.* sp. = *Echinocardium* species, unidentified.

The tables are abstracted from similar tables in which the weights are listed with three decimals. Small errors are introduced with the "rounding off" so that marginal sums and means do not correspond exactly to the initial weights listed.

App. 4 A. All samples.

Square	No. of samples	*A. irr.*	*L. sar.*	*A. rub.*	*O. frag.*	*O. nig.*	*O. bal.*	*O. acul.*	*A. fil.*	*A. brach.*	*A. sq.*	*O. text.*	*O. alb.*	*O. rob.*	*O. aff.*	*P. mil.*	*S. droe.*	*E. pus.*	*S. pur.*	*E. cord.*	*E. flav.*	*E. pen.*	(*E.* sp.).	*B. lyr.*	*C. elong.*	*C. lac.?*	*T. jus.*	*T. com.*	Total	Mean weight per sample
C 10 ...	1	..	..	..	34.0	4.3	0.2	..	..	0.0	..	..	..	0.0	..	..	..	0.2	..	..	..	..	..	..	..	..	..	..	38.7	38.7
D 10 ...	3	..	..	..	0.5	..	..	..	0.3	..	..	..	0.0	..	0.1	..	0.3	0.3	20.0	..	15.0	..	..	..	..	..	..	..	36.6	12.2
D 7 ...	3	..	..	..	45.0	0.1	..	1.9	..	..	..	..	..	..	..	0.7	..	0.1	..	..	..	..	..	..	..	..	..	..	47.8	15.9
E 15 ...	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0
E 10 ...	4	..	..	..	..	..	..	..	1.8	..	..	..	..	..	..	..	..	0.1	..	45.4	14.0	..	..	..	..	..	..	..	61.2	15.3
E 8 ...	1	..	..	..	0.1	..	..	..	1.8	..	..	..	..	..	..	..	..	0.0	..	..	5.8	..	..	..	..	0.1	..	..	7.8	7.8
E 7 ...	4	..	..	..	..	..	..	..	0.3	0.0	..	..	..	..	0.0	..	..	0.1	0.0	..	4.7	..	21.0	..	..	..	..	..	26.1	6.5
F 13 ...	2	0.0	..	..	..	..	..	..	0.0	..	..	..	..	..	0.0	..	..	0.0	..	..	..	..	..	31.9	..	..	..	..	31.9	16.0
F 10 ...	2	3.5	..	..	..	..	..	..	0.1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3.6	1.8
F 9 ...	18	2.5	..	..	..	..	..	..	1.7	0.8	..	..	3.4	0.0	0.1	..	..	0.4	..	262.7	23.3	..	0.1	..	..	..	..	..	295.0	16.4
F 8 ...	43	..	..	..	..	..	..	..	17.8	25.6	..	..	0.2	..	0.0	..	..	0.7	..	1389.1	48.0	42.5	..	..	..	..	..	..	1523.8	35.4
F 7 ...	21	4.1	..	..	8.8	..	..	..	54.1	27.5	..	..	9.3	..	0.0	7.6	..	0.7	..	1257.4	118.5	..	..	..	4.5	..	..	..	1492.4	71.1
F 6 ...	1	2.1	..	..	..	..	..	..	..	0.0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2.1	2.1
F 4 ...	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0.0	..	..	..	..	..	..	..	..	..	..	0.0	0.0
G 13 ...	1	..	..	..	..	..	..	..	2.4	..	..	..	..	..	..	..	..	..	..	0.3	..	..	..	..	..	..	..	..	2.7	2.7
G 10 ...	5	..	..	..	..	..	..	..	0.6	..	..	..	..	..	0.1	..	..	..	..	6.6	..	..	21.0	..	..	..	..	..	28.3	5.7
G 9 ...	23	..	..	..	0.0	..	..	..	1.0	0.0	0.0	..	4.9	..	0.1	1.7	..	1.3	..	721.1	24.3	..	..	..	..	..	..	..	754.5	32.8
G 8 ...	24	..	..	9.0	..	..	..	..	0.1	..	..	..	0.1	..	..	..	..	0.0	..	671.2	..	..	..	..	..	..	..	..	680.4	28.3
G 7 ...	14	..	..	..	..	..	..	..	47.6	0.0	..	..	0.4	..	..	2.8	..	0.1	..	394.8	0.3	..	..	..	5.6	..	5.0	..	456.7	32.6
G 4 ...	2	..	..	..	..	..	..	..	..	..	..	..	0.1	..	0.1	..	..	..	158.0	..	..	..	..	..	..	..	..	..	158.5	79.2

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App. 4 B. Samples of coarse sand.

Square	No. of samples	*A. irr.*	*O. frag.*	*O. nig.*	*O. bal.*	*O. acul.*	*A. fil.*	*A. brach.*	*A. sq.*	*O. alb.*	*O. rob.*	*O. aff.*	*P. mil.*	*E. pus.*	*S. pur.*	*E. cord.*	*E. flav.*	*E. pen.*	*T. comm.*	Total	Mean weight per sample
C 10	1	..	34.0	4.3	0.2	..	..	0.0	..	..	0.0	..	..	0.2	..	..	..	..	..	38.7	38.7
D 10	1	..	..	..	..	..	..	..	..	0.0	..	0.1	..	0.0	..	..	0.0	..	..	0.2	0.2
D 7	2	..	45.0	0.1	..	1.9	..	..	..	..	..	..	0.7	0.1	..	..	..	..	..	47.8	23.9
F 9	2	2.5	..	..	..	..	..	..	..	..	0.0	0.0	..	0.0	..	27.0	4.5	..	..	34.1	17.0
F 8	12	..	..	..	..	..	0.8	2.1	..	0.1	..	..	..	0.6	..	201.0	11.9	42.5	..	258.9	21.6
F 7	1	..	..	..	..	..	0.1	..	..	0.4	..	..	..	0.2	..	27.0	15.4	..	..	43.1	43.1
F 4	1	..	..	..	..	..	..	..	..	..	..	..	..	0.0	..	..	..	..	..	0.0	0.0
G 9	3	..	0.0	..	..	..	..	..	0.0	..	..	..	1.7	..	..	102.0	..	..	..	103.7	34.6
G 8	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	57.0	..	..	..	57.0	57.0
G 7	2	..	..	..	..	..	0.2	0.0	..	0.1	..	..	2.8	0.1	..	..	0.3	..	..	3.6	1.8
G 4	2	..	..	..	..	..	..	..	..	0.1	..	0.1	..	0.3	158.0	..	..	..	..	158.5	79.2
H 9	4	..	..	..	..	..	..	..	..	0.2	..	..	..	0.0	..	25.0	..	..	..	25.2	6.3
J 11	1	0.0	..	..	..	..	..	..	..	..	..	0.0	..	0.1	..	12.9	..	..	..	13.1	13.1
J 10	1	..	..	..	..	..	..	..	..	0.3	..	..	..	..	..	..	..	..	..	0.3	0.3
K 13	1	..	..	..	..	..	..	..	..	..	..	0.0	..	0.1	..	..	..	..	..	0.1	0.1
K 11	8	5.7	0.0	..	..	..	0.0	..	..	..	..	..	..	1.0	..	102.4	12.9	..	..	122.0	15.3
L 12	3	..	..	..	..	..	0.0	..	..	0.0	..	0.0	..	0.1	..	..	..	1.0	10.0	11.1	3.7
L 11	4	0.0	..	..	..	..	0.2	..	..	0.1	..	..	..	1.2	..	73.5	11.9	3.0	..	89.9	22.5
L 10	3	1.5	..	..	..	..	..	..	..	..	..	..	..	0.3	..	116.4	..	..	..	118.2	39.4
L 9	1	6.4	..	..	..	..	..	..	..	..	..	..	..	1.3	..	..	..	..	..	7.7	7.7
M 13	2	..	..	..	..	..	..	..	..	0.3	..	..	..	0.7	..	..	..	..	..	1.0	0.5
M 12	3	..	..	..	..	..	..	..	..	0.1	..	..	..	0.4	..	83.6	24.2	..	..	108.3	36.1
M 11	2	1.8	..	..	..	..	..	..	..	..	..	..	..	0.0	..	90.5	..	..	..	92.3	46.2
M 9	4	..	..	..	..	..	..	..	..	0.3	..	..	..	0.3	..	221.0	..	..	..	221.6	55.4
Total	65	18.0	79.0	4.4	0.2	1.9	1.3	2.1	0.0	1.9	0.0	0.3	5.2	7.0	158.0	1139.2	81.2	46.5	10.0	1556.3	
Mean weight per sample		0.276	1.216	0.068	0.003	0.030	0.021	0.032	0.000	0.030	0.000	0.005	0.080	0.107	2.431	17.527	1.249	0.715	0.154		23.944

App. 4 C. Samples of clayey coarse sand.

Square	No. of samples	*A. irr.*	*A. rub.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. alb.*	*O. aff.*	*S. droe.*	*E. pus.*	*S. pur.*	*E. cord.*	*E. flav.*	*C. elong.*	*C. lac.?*	*T. fus.*	Total	Mean weight per sample
D 10 ...	1	..	..	..	0.1	..	..	..	0.3	0.3	20.0	..	..	..	..	..	20.7	20.7
D 7 ...	1	..	..	0.0	..	..	..	..	..	..	..	..	..	..	..	..	0.0	0.0
F 7 ...	1	..	..	..	0.5	..	0.8	..	..	..	..	138.0	17.2	..	..	..	156.5	156.5
G 7 ...	1	..	..	..	0.1	..	..	..	..	..	..	..	..	3.3	..	5.0	8.4	8.4
H 7 ...	2	..	2.2	..	0.1	..	..	..	..	0.0	122.0	33.8	..	..	..	..	158.1	79.1
K 11 ...	7	4.0	..	3.0	0.6	..	3.9	0.0	..	0.1	..	62.5	38.3	..	..	..	112.5	16.1
K 10 ...	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0
K 8 ...	1	..	..	..	..	..	0.5	..	..	..	..	29.6	..	..	..	..	30.1	30.1
L 11 ...	2	..	0.2	..	0.3	0.3	..	..	..	0.0	..	73.0	..	..	..	..	73.8	36.9
M 13 ...	1	..	..	0.5	..	..	..	..	..	..	..	..	20.1	..	0.1	..	20.7	20.7
M 12 ...	1	..	..	..	..	..	..	..	..	0.1	..	..	..	..	..	..	0.1	0.1
Total ...	19	4.0	2.4	3.5	1.7	0.3	5.2	0.0	0.3	0.4	142.0	336.8	75.6	3.3	0.1	5.0	580.9	
Mean weigh per sample ..		0.211	0.126	0.185	0.091	0.017	0.276	0.002	0.018	0.023	7.475	17.731	3.979	0.174	0.003	0.263		30.574

App. 4 D. Samples of fine sand.

Square	No. of samples	*A. irr.*	*L. sar.*	*A. rub.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. alb.*	*O. aff.*	*E. pus.*	*S. pur.*	*E. cord.*	*E. flav.*	(*E.* sp.)	Total	Mean weight per sample
E 10	1	..	..	..	..	0.1	..	..	..	0.1	..	..	..	..	0.2	0.2
E 7	2	..	..	..	..	0.0	0.0	..	..	0.0	0.0	..	4.7	21.0	25.8	12.9
F 9	9	..	..	..	..	0.0	0.2	3.0	0.0	0.4	..	141.7	1.0	..	146.3	16.3
F 8	25	..	..	..	..	0.2	8.8	0.1	0.0	0.4	..	1103.2	..	..	1112.2	44.5
F 7	4	4.1	..	..	..	0.2	3.4	..	0.0	0.3	..	5.8	..	..	13.8	3.5
G 9	16	..	..	..	..	0.2	0.0	4.8	0.1	1.2	..	468.8	0.3	..	475.5	29.7
G 8	21	..	..	9.0	..	0.1	..	0.1	..	0.0	..	592.7	..	..	601.9	28.7
G 7	3	..	..	..	..	0.1	..	..	..	..	..	..	..	..	0.1	0.0
H 13	2	6.5	..	..	..	8.8	..	0.0	0.0	..	..	47.0	0.0	..	62.3	31.2
H 10	19	..	7.9	..	0.0	0.2	..	4.4	0.2	0.9	..	497.4	2.6	..	513.7	27.0
H 9	49	..	..	..	..	0.7	..	4.2	..	0.4	..	2017.9	..	..	2023.1	41.3
H 8	30	3.3	..	..	0.1	0.1	0.0	3.9	..	..	..	1208.9	..	..	1216.2	40.5
H 7	1	..	..	..	..	0.0	..	..	..	0.0	..	53.2	..	..	53.2	53.2
J 11	1	..	..	..	..	..	..	0.0	0.0	..	0.0	58.0	0.0	..	58.0	58.0
J 10	46	..	..	..	0.0	0.0	..	39.2	0.0	1.0	..	943.4	138.4	459.0	1581.1	34.4
J 9	7	..	..	..	..	0.1	..	4.4	..	0.1	..	237.4	..	..	242.0	34.6
K 11	1	..	..	..	..	..	..	..	..	..	..	47.5	..	..	47.5	47.5
K 10	5	..	..	..	..	..	..	11.3	..	0.0	..	206.1	..	..	217.4	43.5
L 9	1	..	..	..	..	..	..	..	..	0.0	..	114.2	..	..	114.2	114.2
L 8	1	..	..	..	..	..	..	0.3	..	0.0	..	..	..	..	0.3	0.3
M 12	1	..	..	..	..	..	..	0.0	..	0.1	..	73.5	..	..	73.6	73.6
M 11	2	..	..	..	..	..	..	1.1	..	0.2	..	38.3	..	..	39.6	19.8
N 13	1	..	..	..	..	0.0	..	..	..	0.0	..	..	..	..	0.0	0.0
Total	248	13.9	7.9	9.0	0.1	10.8	12.5	76.7	0.4	4.8	0.0	7854.9	147.0	480.0	8618.1	
Mean weight per sample		0.056	0.032	0.036	0.001	0.043	0.050	0.309	0.002	0.019	0.000	31.673	0.593	1.936		34.750

App. 4 E. Samples of sandy clay.

Square	No. of samples	*A. irr.*	*L. sar.*	*A. rub.*	*O. frag.*	*A. fil.*	*O. alb.*	*O. aff.*	*E. pus.*	*S. pur.*	*E. cord.*	*E. flav.*	*B. lyr.*	*C. elong.*	*T. fus.*	Total	Mean weight per sample
E 15	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0
F 13	1	..	..	..	..	0.0	..	..	..	..	..	..	7.9	..	..	7.9	7.9
G 7	1	..	..	..	..	1.0	..	..	..	..	..	..	..	..	..	1.0	1.0
J 9	1	..	..	..	..	..	0.1	..	0.0	..	2.5	0.4	..	..	..	3.1	3.1
J 8	6	0.4	..	..	..	0.0	6.7	..	..	0.0	13.2	0.3	..	..	..	20.6	3.4
J 7		6.7	..	..	..	0.7	0.5	..	..	..	63.0	3.1	..	..	..	74.0	14.8
K 12	1	..	8.9	..	..	0.4	0.0	..	..	..	..	..	..	..	..	9.3	9.3
K 11	5	..	..	..	4.0	19.5	..	8.3	..	..	8.2	18.9	45.9	2.1	..	106.9	21.4
K 10	12	11.6	..	5.4	0.0	28.0	14.4	0.0	..	..	54.2	29.9	0.2	7.1	..	151.0	12.6
K 7	1	..	..	..	..	..	..	..	..	..	23.8	..	..	..	..	23.8	23.8
L 9	8	..	..	..	..	0.0	5.3	..	..	..	136.8	..	..	2.6	..	144.8	18.1
M 12	1	..	..	..	1.6	..	..	..	0.2	..	..	..	..	..	0.1	1.9	1.9
Total	43	18.6	8.9	5.4	5.6	49.7	35.4	0.0	0.2	0.0	301.8	52.6	54.0	11.8	0.1	544.2	
Mean weight per sample		0.434	0.207	0.126	0.131	1.155	0.823	0.000	0.005	0.000	7.018	1.223	1.257	0.274	0.002		12.655

App. 4 F. Samples of muddy sand.

Square	No. of samples	*A. irr.*	*A. rub.*	*O. frag.*	*A. fil.*	*A. brach.*	*O. text.*	*O. alb.*	*O. aff.*	*P. mil.*	*E. pus.*	*S. pur.*	*E. cord.*	*E. flav.*	(*E.* sp.)	*B. lyr.*	Total	Mean weight per sample
E 10 ...	1	..	..	..	0.4	..	..	..	..	..	..	..	..	..	..	..	0.4	0.4
E 7 ...	2	..	..	..	0.2	0.0	..	..	0.0	..	0.0	0.0	..	0.0	..	..	0.3	0.2
F 13 ...	1	0.0	..	..	..	..	..	..	0.0	..	0.0	..	..	..	..	24.0	24.0	24.0
F 10 ...	2	3.5	..	..	0.1	..	..	..	..	..	..	..	..	..	..	..	3.6	1.8
F 9 ...	5	..	..	..	0.6	0.6	..	0.4	0.0	..	0.0	..	94.0	17.9	..	..	113.4	22.7
F 8 ...	4	..	..	..	13.6	12.3	..	0.1	0.0	..	0.1	..	54.0	36.0	..	..	116.0	29.0
F 7 ...	12	..	..	8.8	40.3	23.6	..	4.0	..	7.6	0.2	..	896.2	55.9	..	..	1036.6	86.4
F 6 ...	1	2.1	..	..	..	0.0	..	..	..	..	..	..	..	..	..	..	2.1	2.1
G 13 ...	1	..	..	..	2.4	..	..	..	..	..	..	..	0.3	..	..	..	2.7	2.7
G 10 ...	4	..	..	..	0.4	..	..	..	0.1	..	..	..	6.6	..	..	..	7.1	1.8
G 9 ...	3	..	..	..	0.8	..	..	0.2	..	..	..	..	150.3	24.0	..	..	175.3	58.4
G 8 ...	2	..	..	..	..	..	..	..	..	..	..	..	21.5	..	..	..	21.5	10.8
G 7 ...	4	..	..	..	0.0	..	0.3	..	..	..	..	..	222.1	..	..	..	222.5	55.6
H 13 ...	1	..	..	..	3.9	..	..	..	..	..	..	..	48.0	7.6	..	..	59.5	59.5
H 12 ...	1	..	..	..	3.7	..	..	0.0	0.0	..	..	..	0.3	..	..	..	4.0	4.0
H 11 ...	6	..	..	..	3.9	..	..	0.2	0.0	..	0.0	..	..	45.3	..	..	49.4	8.2
H 10 ...	6	0.0	..	..	0.5	..	..	0.0	0.1	..	0.0	..	31.0	13.4	7.6	..	52.6	8.8
H 9 ...	7	..	..	..	1.2	..	0.2	..	..	..	..	..	394.5	..	..	..	396.0	56.6
H 8 ...	10	5.9	..	..	0.1	..	10.6	..	..	..	..	..	198.2	..	..	..	214.8	21.5
H 7 ...	8	..	..	..	3.9	..	3.5	..	..	..	..	..	270.9	..	5.0	..	283.3	35.4
J 13 ...	1	..	..	..	0.8	..	..	..	..	..	..	..	7.5	..	..	..	8.4	8.4
J 11 ...	6	5.1	..	2.9	0.0	..	..	0.0	0.1	..	..	0.0	95.0	19.0	..	..	122.1	20.4
J 10 ...	21	2.5	25.0	..	0.4	..	0.1	21.5	0.0	..	0.0	..	1217.0	0.8	50.0	..	1317.3	62.7
J 9 ...	15	..	..	0.0	0.0	..	..	32.6	0.1	..	0.1	..	272.7	0.1	..	..	305.6	20.4
K 11 ...	3	..	..	..	0.2	..	..	0.6	0.0	..	..	..	..	13.0	..	..	13.9	4.6
K 10 ...	12	1.0	..	..	0.0	..	..	23.5	0.0	..	0.0	..	375.8	..	79.0	..	479.3	39.9
K 9 ...	11	0.7	..	0.0	0.0	..	..	19.2	0.1	..	..	..	252.8	..	..	..	272.8	24.8
K 8 ...	30	5.6	7.4	0.0	18.8	..	..	0.0	..	..	..	..	1881.6	..	..	..	1913.4	63.8
L 12 ...	1	..	..	..	0.2	..	..	..	..	..	0.1	..	19.0	..	..	..	19.2	19.2
L 11 ...	2	..	0.3	..	0.8	0.4	..	..	..	..	..	..	135.5	..	..	..	137.0	68.5
L 10 ...	8	12.0	..	..	0.0	0.0	..	0.0	..	..	0.0	..	537.0	..	..	..	549.1	68.6
M 12 ...	2	..	..	..	1.8	0.4	..	..	..	..	..	..	111.0	..	..	..	113.2	56.6
M 11 ...	1	..	..	..	0.2	1.7	..	..	..	..	..	..	91.9	..	..	..	93.8	93.8
Total ...	194	38.5	32.7	11.8	99.3	39.1	0.1	117.1	0.5	7.6	0.5	0.0	7384.5	232.9	141.6	24.0	8130.1	
Mean weight per sample		0.198	0.168	0.061	0.512	0.201	0.000	0.603	0.003	0.039	0.003	0.000	38.064	1.200	0.730	0.124		41.906

App. 4 G. Samples of clayey sand.

Square	No. of samples	*A. irr.*	*O. frag.*	*A. fil.*	*A. brach*	*O. alb.*	*O. rob.*	*O. aff.*	*E. pus.*	*E. cord.*	*E. flav.*	(*E.* sp.)	*C. elong.*	*C. lac.?*	Total	Mean weight per sample
D 10	1	..	0.5	0.2	..	..	..	..	0.0	..	15.0	..	..	..	15.7	15.7
E 10	2	..	..	1.3	..	..	..	..	0.0	45.4	14.0	..	..	..	60.7	30.4
E 8	1	..	0.1	1.8	..	..	..	..	0.0	..	5.8	..	..	0.1	7.8	7.8
F 9	2	..	..	1.1	..	..	..	..	..	..	..	0.1	..	..	1.2	0.6
F 8	2	..	..	3.2	..	0.0	..	..	..	31.0	0.1	..	..	..	36.7	18.4
F 7	3	..	..	13.0	0.5	4.0	..	..	..	190.4	30.0	..	4.5	..	242.4	80.8
G 10	1	..	..	0.2	..	..	..	0.0	..	..	..	21.0	..	..	21.2	21.2
G 9	1	..	..	0.0	..	0.0	..	..	0.0	..	..	..	..	..	0.0	0.0
G 7	3	..	..	46.2	0.0	..	..	..	..	172.7	..	..	2.3	..	221.1	73.7
H 10	1	..	..	..	..	2.7	..	..	..	..	..	25.0	..	..	27.7	27.7
H 8	3	0.5	..	0.0	..	1.9	..	0.0	..	23.6	..	..	..	..	26.1	8.7
H 7	4	..	..	1.4	..	0.2	..	..	..	142.2	..	..	..	..	143.8	36.0
J 10	1	..	..	..	..	1.2	..	..	..	94.5	..	..	..	..	95.7	95.7
J 9	9	3.0	..	0.0	..	21.6	..	0.0	..	125.0	..	..	..	..	149.7	16.6
J 8	7	..	..	0.1	..	6.9	..	..	..	97.7	15.3	..	..	..	120.0	17.1
J 7	4	1.4	0.0	0.9	..	1.0	..	..	..	54.0	..	0.6	..	..	57.8	14.5
K 12	1	..	..	5.1	..	0.0	..	..	..	..	12.3	..	..	..	17.4	17.4
K 11	2	0.0	..	0.7	..	0.4	0.0	0.0	..	43.0	..	..	..	..	44.1	22.1
K 10	1	..	..	..	..	0.3	..	..	..	96.5	..	..	..	..	96.8	96.8
K 9	4	0.0	..	..	..	11.2	..	0.0	..	47.3	0.2	..	..	..	58.6	14.7
K 8	6	6.7	..	0.2	..	0.0	..	..	..	563.0	..	..	..	..	569.9	95.0
K 7	9	8.9	0.1	10.1	..	0.3	..	..	..	441.6	..	..	..	..	461.0	51.2
L 11	1	..	..	1.6	..	0.0	..	..	..	51.8	..	..	..	..	53.4	53.4
L 10	4	5.2	..	0.0	..	..	..	..	..	113.4	..	..	..	..	118.7	29.7
L 9	2	..	..	..	..	3.1	..	0.0	..	109.7	..	..	..	..	112.8	56.4
L 8	3	..	..	..	..	3.3	..	..	..	248.4	..	..	..	..	251.7	83.9
L 7	4	..	..	0.0	..	7.1	..	..	..	226.6	..	..	..	..	233.7	58.4
M 11	1	2.0	..	0.2	0.4	..	..	..	..	141.1	..	..	..	..	143.6	143.6
M 7	2	..	..	..	..	4.5	..	..	..	83.0	..	..	..	..	87.5	43.8
Total	85	27.8	0.7	87.3	3.3	69.7	0.0	0.1	0.1	3141.8	92.7	46.1	7.4	0.1	3477.0	
Mean weight per sample		0.327	0.008	1.027	0.039	0.820	0.000	0.001	0.001	36.963	1.090	0.543	0.087	0.001		40.907

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Dansk resumé.

En kvantitativ undersøgelse af pighudenes forekomst i den centrale Nordsø.

Undersøgelsen er begrænset til de arter, der i Nordsøen er kendt fra dybder under 100 m. Pighudene fra ca. 700 bundprøver, der er taget med en 0,2 m² modificeret VAN VEEN bundhenter i 1950—55, er artsbestemt, talt, målt og for manges vedkommende vejet. Til støtte for undersøgelsen benyttedes yderligere ca. 500 bundprøver indsamlet i 1932—48 og materialet fra flere hundrede træk med snurrevod, trawl og skraber, som blev taget i 1922—55. Indsamlingsarbejdet er foretaget fra danske undersøgelsesskibe, først og fremmest "Dana".

I 1950—54 var bundhenterens gennemsnitlige indhold af bundmateriale 8—16 l, varierende med bundarten. Hverken artsantal, individantal eller vægtmængde var — for så vidt pighudene angår — afhængigt af mængden af bundmateriale i prøven.

Der er givet en kort oversigt over de enkelte arters udbredelse i Nordsøen og så vidt muligt også over deres vækstforhold, levetid, etc. Bundtemperaturens, bundartens og andre faktorers mulige indflydelse på udbredelsen er gennemgået. Kun få arter er kendt fra den centrale og sydøstlige Nordsø (Doggerbanken og området syd og øst for denne). Adskillige arter er i Nordsøområdet kun fundet ved Nordengland og Skotland, på Doggerbankens vestkant og i området mellem Doggers nordøstlige hjørne og Jylland. Mange arter, især blandt de mindre almindelige, er udbredt over hele den nordlige Nordsø, men er kun sjældent eller aldrig fundet i den sydlige Nordsø. Nogle arter synes i Nordsøområdet kun at findes langs den skotske kyst og på kanten af den norske rende. En del arter har en tydeligt todelt udbredelse i Nordsøen og de indre danske farvande. Som eksempel kan nævnes slangestjernen *Amphiura chiajei*, der er meget talrig i skotske kystfarvande samt i Skagerrak og Kattegat, men som er sjælden eller ligefrem mangler i store dele af Nordsøen, selv hvor dybde og bundart synes passende.

De enkelte arters udbredelse er tilsyneladende kun lidt afhængig af temperaturforhold, saltholdighed og bundart. Den synes snarere at stå i forbindelse med udbredelsen af forskellige planktonsamfund, der er kendt som indikatorer for bestemte vandmasser. For eksempel har mange arter af pighude omtrent samme udbredelse i Nordsøen som de atlantisk prægede vandmasser, der især er karakteriseret ved forekomsten af pilormen *Sagitta elegans*. Der er til gengæld kun få arter af pighude i den del af den centrale Nordsø, der er kendt som *Sagitta setosa* området.

Når pighud-arterne fra bundhentermaterialet arrangeres i rækkefølge efter deres talrighed vil man få omtrent den samme rækkefølge overalt i Nordsøen, undtagen måske i det britiske kystfarvand. De almindeligste arter er imidlertid mindre dominerende i den nordlige Nordsø (d. v. s. i *Sagitta elegans* vandet) end i den centrale og sydlige Nordsø (*Sagitta setosa* vandet). På den anden side er de sjældnere arter mere almindelige i den nordlige Nordsø end i den sydlige. Forholdet kan anskueliggøres ved et eksempel: En faunaliste på 20 arter af pighude

kan fås i den nordøstlige Nordsø ved hjælp af ca. 100 bundprøver. I den sydlige Nordsø vil ca. 20.000 bundprøver være nødvendige. De to faunalister vil imidlertid være næsten ens. Resultatet er, at en almindelig art, f. eks. *Echinocardium cordatum*, vil fremtræde som en sydlig form i Nordsøen, fordi den forekommer i en større procentdel af prøverne fra den sydlige Nordsø, selv om den har samme nummer på faunalisten i den sydlige og den nordlige Nordsø. En mere sjælden art, der f. eks. er opført som nr. 20 på begge faunalister, vil fremtræde som en nordlig form i Nordsøen, fordi det i praksis er umuligt at fremskaffe art nr. 20 i den sydlige Nordsø.

De arter, som er mest almindelige i Nordsøen, har en overvejende sydlig udbredelse uden for Nordsøen. De nordlige arter, som findes i Nordsøen, er gennemgående mindre almindelige dér (d. v. s., de står langt nede på faunalisterne). Dette medfører, at en nordlig art i praksis kun kan findes på artsrige lokaliteter, altså i *Sagitta elegans* vand. Temperaturforholdene på sådanne steder behøver ikke at være mere egnede for nordlige end for sydlige arter.

En sammenligning af faunalister (kun pighude), baseret på bundhentermateriale, fra forskellige lokaliteter i Nordsøen med faunalister af samme længde fra et sydligt og et nordligt havområde (Adriaterhavet og Faxa Bugt i Island) viste, at det sydlige faunaelement tiltager i styrke fra den nordvestlige til den sydøstlige Nordsø. For eksempel havde faunalister på 11 arter hver fra Adriaterhavet gennemsnitlig 3 arter fælles med tilsvarende lister fra Helgolandsbugten, men kun 2 arter fælles med faunalister fra den nordvestlige Nordsø. En påfaldende lighed mellem faunalister fra Faxa Bugt og fra Bælthavet skyldes måske, at rheophile arter med et stort fødebehov spiller en fremtrædende rolle begge steder. Rheophile arter er ikke så almindelige i Nordsøen; de lever ofte kommensalt med kolonidannende dyr, (svampe, koraller) som opretholder en stadig vandbevægelse i deres nærmeste omgivelser.

Der kunne hos flere arter konstateres udbredelsesforandringer i den centrale og sydlige Nordsø i dette århundrede. Der synes imidlertid ikke at være forbindelse mellem disse forandringer og den temperaturstigning, der ad flere veje har kunnet konstateres. Hvis der overhovedet er en sammenhæng mellem de konstaterede udbredelsesforandringer, er det snarere sådan, at de almindelige arter er blevet endnu almindeligere og de sjældnere arter endnu sjældnere. Dette kunne tyde på, at grænsen mellem *Sagitta elegans* vandet i den nordlige Nordsø og den centrale og sydlige Nordsøs vandmasser, især *Sagitta setosa* vandet, er blevet mere udpræget i de senere år. Nogle få arter gik stærkt tilbage under den kolde vinter i 1947, men tog atter til i årene efter.

Pighudenes individtæthed er særlig lav (5—10 pr. prøve à 0.2 m^2) på og omkring Doggerbanken. De fleste andre steder i Nordsøen fandtes 10—20 individer pr. prøve. Individtætheden var overalt, også i Doggerområdet, størst på blød bund. Den er i Nordsøen omtrent som i Kattegat, men større end de fleste andre steder i det nordatlantisk-mediterrane område. *Echinocyamus* var den mest almindelige art i groft sand. *Ophiura albida* var den almindeligste i fint sand; sammen med *Amphiura filiformis* dominerede den blødbundsprøverne. *Echinocardium cordatum* var almindelig overalt.

E. cordatum fandtes i flere prøver end nogen anden art, men *Ophiura albida* forekom i større individantal. Den må derfor have været mindre jævnt udbredt på havbunden end *E. cordatum*. Det er vanskeligt at sammenligne de enkelte arters „klumpning" (d. v. s. afvigelse fra jævn udbredelse), fordi „klumpningen" bliver mere iøjnefaldende, jo større middeltal man arbejder med. Jo større bundhenteren er, og jo mere almindelig arten er, desto mere påfaldende bliver afvigelsen fra jævn udbredelse. Et indtryk af „klumpningsgraden", næsten uafhængigt af middeltallet, kan fås ved logaritmisk afbildning af forholdet mellem middeltal og spredning hos de enkelte arter. Når undersøgelsen baseredes på prøver indsamlet inden for et område af 2—3

kvadratsømil, kunne „klumpning" ikke påvises. Ved undersøgelse af prøver taget inden for et område på ca. 1000 kvadratsømil fandtes „klumpning" af alle arter. *E. cordatum* var den jævnest udbredte art, *Echinocyamus* den mest „klumpede".

Vægtmængden pr. arealenhed var omtrent den samme (ca. 30 g pr. 0.2 m^2) over hele det undersøgte område. Ca. 90 % af vægtmængden bestod af søpindsvin af sømusenes familie, hvoraf *Echinocardium cordatum* var den mest almindelige. En lignende dominans af sømus synes at forekomme overalt i det boreo-lusitanske område undtagen måske på lokaliteter, hvor det rheophile faunaelement med filtrerende slangestjerner og søpølser dominerer. Lignende vægtmængder af pighude, som ved denne undersøgelse er fundet i Nordsøen, forekommer i Kattegat, men næppe andre steder i det nordatlantisk-mediterrane område.

De enkelte arters andel i produktionen er søgt belyst ved omregning af råvægten til tørstofvægt og ved hensyntagen til individets omtrentlige levetid. Sømusenes betydning som producenter overvurderes noget, når man ser udelukkende på råvægten. Disse dyr har nemlig lav tørstofprocent og lang levetid. Produktionen af pighude egnet som fiskeføde synes at være mindre på Doggerbanken end andre steder i Nordsøen.

Også sømusenes betydning som forbrugere overvurderes noget, når man ser på råvægten alene. De er store dyr med et forholdsvis lille varmetab til omgivelserne og, sandsynligvis, med et tilsvarende lavt iltforbrug.

15.2.1960 - 1200.