Copyright ©

Aus dem Institut für Meereskunde an der Universität Kiel

The winter food of the gobies from one of the deeper channels of the Belt Sea, with particular reference to the Sand Goby, *Pomatoschistus Minutus* (Pallas)

Von IVAR H. HESTHAGEN[1])

Die Winternahrung der Gobiiden aus einer der tiefen Rinnen der Kieler Bucht, mit besonderer Berücksichtigung der Sandgrundel, *Pomatoschistus minutus* (Pallas) (Zusammenfassung): Untersucht wurde der Magen- und Darminhalt von 272 Gobiiden, die zu folgenden fünf Arten gehören: *Crystallogobius linearis, Aphia minuta, Chaparrudo flavescens, Pomatoschistus microps* und *Pomatoschistus minutus*. Als Fanggerät diente Beyer's epibenthisches Schließnetz mit 50 cm Eintrittsöffnung. Alle untersuchten Tiere schienen hauptsächlich carnivor zu sein. Die wichtigsten Nährtiere waren Crustaceen.

Obschon sich *Diastylis kathkei*, ein Crustacee geeigneter Größe, am häufigsten in den Netzproben fand, war er doch für den sehr verbreiteten *P. minutus* als Nährtier von geringer Bedeutung. Das ist nur durch das Außenskelett von *Diastylis* zu erklären.

Die Nachtfänge von *P. minutus* waren erheblich größer als die Tagfänge, wohl bedingt durch höhere Aktivität der Gobiiden während der Nacht und/oder die Fische können bei Tage das Netz eher wahrnehmen und entfliehen. Es wird eine tag- und nachtaktive Futtersuche angenommen.

Summary: The contents of the stomach and intestine of 272 gobies of five species, viz. *Crystallogobius linearis, Aphia minuta, Chaparrudo flavescens, Pomatoschistus microps,* and *Pomatoschistus minutus,* collected with Beyer's 50 cm epibenthic closing net were studied. All proved to be principally carnivorous and crustaceans were the most important food organisms.

Although *Diastylis rathkei* was the most frequently found crustacean of suitable size in the net samples, this cumacean was of minor importance as food for *P. minutus,* the most common goby in the material. This discrepancy is explained by the nature of the exo-skeletone of *Diastylis.*

In night samples the number of *P. minutus* caught was much higher than in the hauls taken during day, a result which might be due to higher nocturnal activity in the goby, and/or the fish perceiving the approaching net on daylight and being able to escape. A day and night feeding activity is suggested.

Introduction

The littoral fishes and in particular the gobies have interested man for centuries (cf. GUITEL, 1892), mostly perhaps because they are easy to get at, but also because the biology of these fishes shows many interesting features (cf. GIBSON, 1969). Since the gobies are very numerous in the shore zone, PETERSEN (1916) pointed out that they must represent a very important link in the food chain of these areas. But little attention has been paid to understand the food and feeding relationship of these fishes until quite recently (cf. GIBSON, 1968). However, most of the investigations are restricted to the summer food, while the diet may change with the seasons as a consequence of the migration of these fishes into greater depths. The present paper is a small contribution to the knowledge of the winter food of gobies, particularly some aspects of the food and feeding relationship in *Pomatochistus minutus*.

The opportunity is here taken to express my gratitude to Professor Dr. G. Hempel, Kiel, who kindly offered me the chance to come to Germany and work there. I also want to thank Mr. F. Beyer and Mr. T. A. Schram, Oslo, for critically reading the manuscript.

1) Present address: Institute of Marine Biology, section A
Frederiksgate 3, Oslo 1, Norway

Material and Methods

The present paper is based on the material collected for an investigation of the diurnal vertical migration of the near-bottom fauna, the so-called hyperpelos (BEYER, 1958), which will be published in a subsequent paper.

The material dealt with here was collected by repeated hauls during a 24 hours period at different seasons by means of Beyer's 50 cm epibenthic closing net (cf. HESTHAGEN, 1970) with mesh aperture 500 μ. The net is mounted in a steel toboggan and equipped with a flow-meter. Through tows of half an hour's duration at a speed of approximately 1 knot the ideal volume of seawater filtered would be about 180 m^3. All the material was preserved in 4% neutralized formalin.

Cruises were arranged 16—17 December 1969, 18—19 March and 18—19 June 1970 with R.V. "ALKOR". The 272 gobies contained in the 14 samples from December 1969 form the basis of this work, because in the course of the other cruises only three gobies were caught.

The samples were obtained from Vejsnäs Rinne, which is between 28 and 32 metres deep and located in one of the deeper channels of the Belt Sea, about 8 nautical miles of the Danish island Ärö (cf. KÜHLMORGEN-HILLE, 1963, Abb. 1). The bottom in this region is covered with "sandiger Schlick" or sandy mud (KÜHLMORGEN-HILLE, l. c.), but with a large proportion of decaying plant material. According to SCHWENKE (1964) the bottom in these depths of the Belt Sea is not covered with attached algae. The numerous specimens of kelp and seaweed that were found in the net are supposed to have been drifting along the sea bed or carried to the place by currents and settled.

The total length of the fish was measured to the nearest millimeter. Then the gut was removed and the stomach and intestine contents examined separately and identified as far as this was possible. The result for each species was expressed by the occurrence method (HYNES, 1950), by which the number of fishes containing a certain food item is expressed as the percentage of the total number of fishes examined. This method, being of limited value in quantitative work, is satisfactory here in providing data on the food preference of the individual species and for comparative studies. Because most other methods, reviewed by HYNES (l. c.), are based on volume and weight measurements, the source of error will be significant in small fishes like the gobies. In other cases the number of individuals of each food item is needed, which very often, particularly with polychaetes, is inaccessible.

Results and Discussion

Altogether five species of gobies were found in the present material from the Belt Sea (Table I). By far the most common of these was the Sand Goby, *Pomatoschistus minutus* (PALLAS), of which 219 specimens were collected during the 14 hauls in December 1969. Second in occurrence was the close relative, the Common Goby, *Pomatoschistus microps* (KRÖYER). The three other species were: *Crystallogobius linearis* (DÜBEN), *Aphia minuta* (RISSO) und *Chaparrudo flavescens* (FABRICIUS). The four last mentioned species were relatively rare, and in the following mainly the first species is dealt with.

During the cruises in March and June 1970, with 13 and 14 samples respectively, only three specimens of *P. minutus* but no other goby were collected, whereas more than 200 representatives of this species were caught in December 1969. This is a consequenec of the fact that the gobies, particularly the demersal species *P. microps* and *P. minutus*, are normally inhabiting the littoral zone, but migrate into deeper water in winter, presumably to avoid low temperatures (DUNCKER, 1928; GIBSON, 1969). SWEDMARK (1957) and JONES & MILLER (1966) indicate that if the temperature falls below about

Table 1

Analysis of the food of all the gobies, expressed by percent occurrence of the particular food item. The stomach and intestine contents are combined in the table.

	Crystallo-gobius linearis	*Aphia minuta*	*Chaparrudo flavescens*	*Pomato-schistus microps*	*Pomato-schistus minutus*
Number of fish examined	10	11	3	29	219
Number of empty stomachs	7	4	0	10	39
Algae		9			1
Hydroidae				3	< 1
Polychaeta				10	25
Copepoda		27	+	28	28
Ostracoda					3
Cirripedia, larvae		9			1
Mysidacea		9		14	15
Cumacea				3	3
Tanaidacea					1
Amphipoda			+	14	15
Unidentified Crustacea		9		3	7
Halacaridae				3	7
Bivalvia			+		13
Chaetognatha					1
Pisces, scales			+		1
Sand and unidentified organis material	33	27	+	28	52

When less than 10 examined fishes no percentage is indicated, but the particular food item is indicated by +.

5°C, *P. microps* and *P. minutus* will leave the shores. In December 1969 the surface temperature was measured to 3.6°C. The sampling locality is found in one of the deeper channels in the Belt Sea, and is possibly the "winter quarter" of these fishes, particularly *P. minutus,* which is living slightly deeper than the other (PETERSEN, 1916).

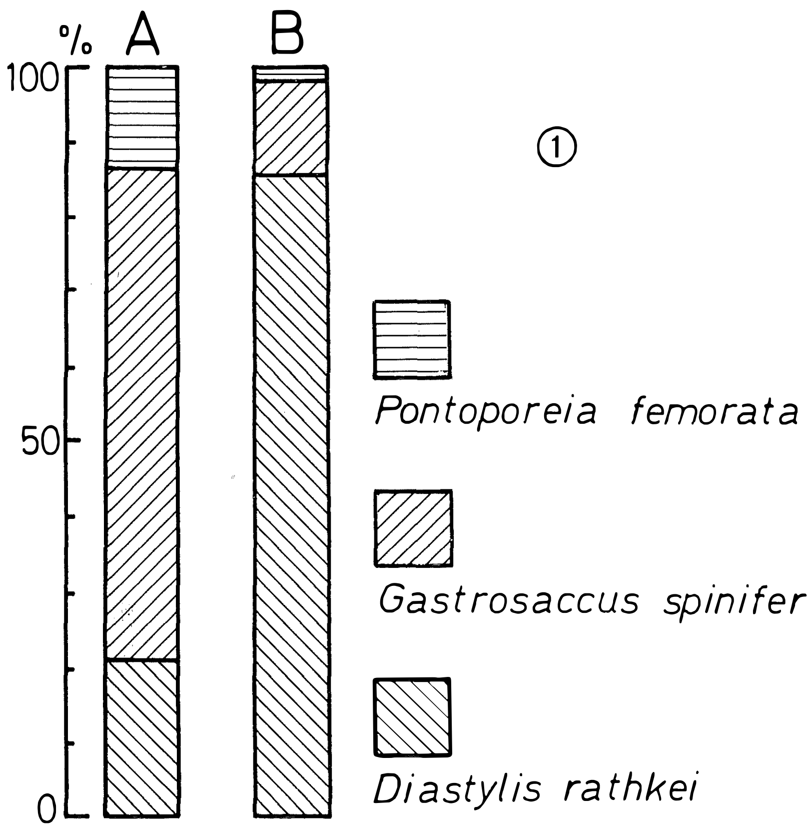
On the other hand, for the more pelagic gobies, *C. linearis* and *A. minuta,* the Belt Sea represents the approximate limit of distribution into the Baltic (WHEELER, 1969). The occurrence of these may, in my view, be a result of inflow of more saline water through the Danish Belts. Such an inflow, spreading as currents near the bottom in the deepest channels (KREY, 1961, Abb. 1), is often leading to finds of indicator species of Kattegat water (KÄNDLER, 1961), among other the mysid *Mesopodopsis slabberi* (VAN BENEDEN). This mysid was also abundant in the samples from December 1969, which might be taken as an indication that an extensive inflow had taken place recently.

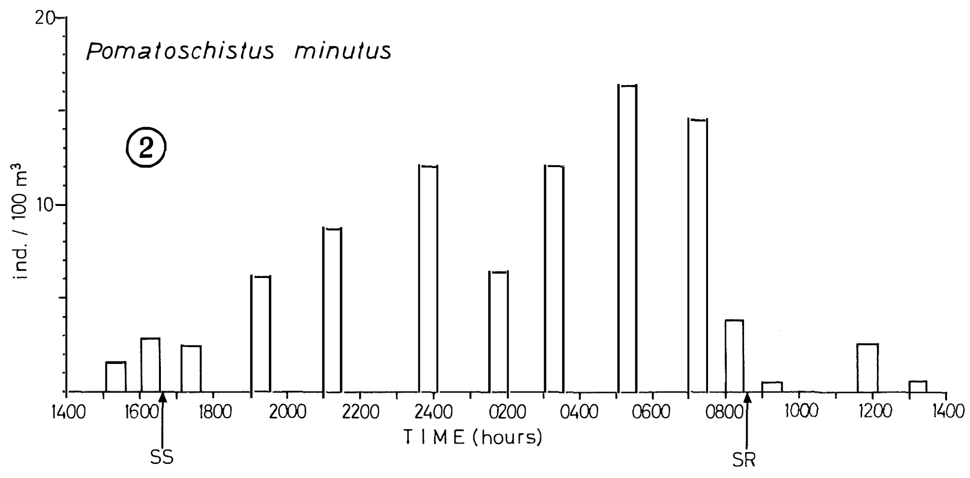
The complete analysis of the stomach and intestine contents of the species collected is presented in Table 1. For three species the material is so scanty that presenting figures for percentage occurrence of these is hardly meaningful. When less than ten fish were examined only the particular food item is indicated by +, or ++ if it is predominant.

Legende zu den nebenstehenden Abbildungen (Tafel 1)

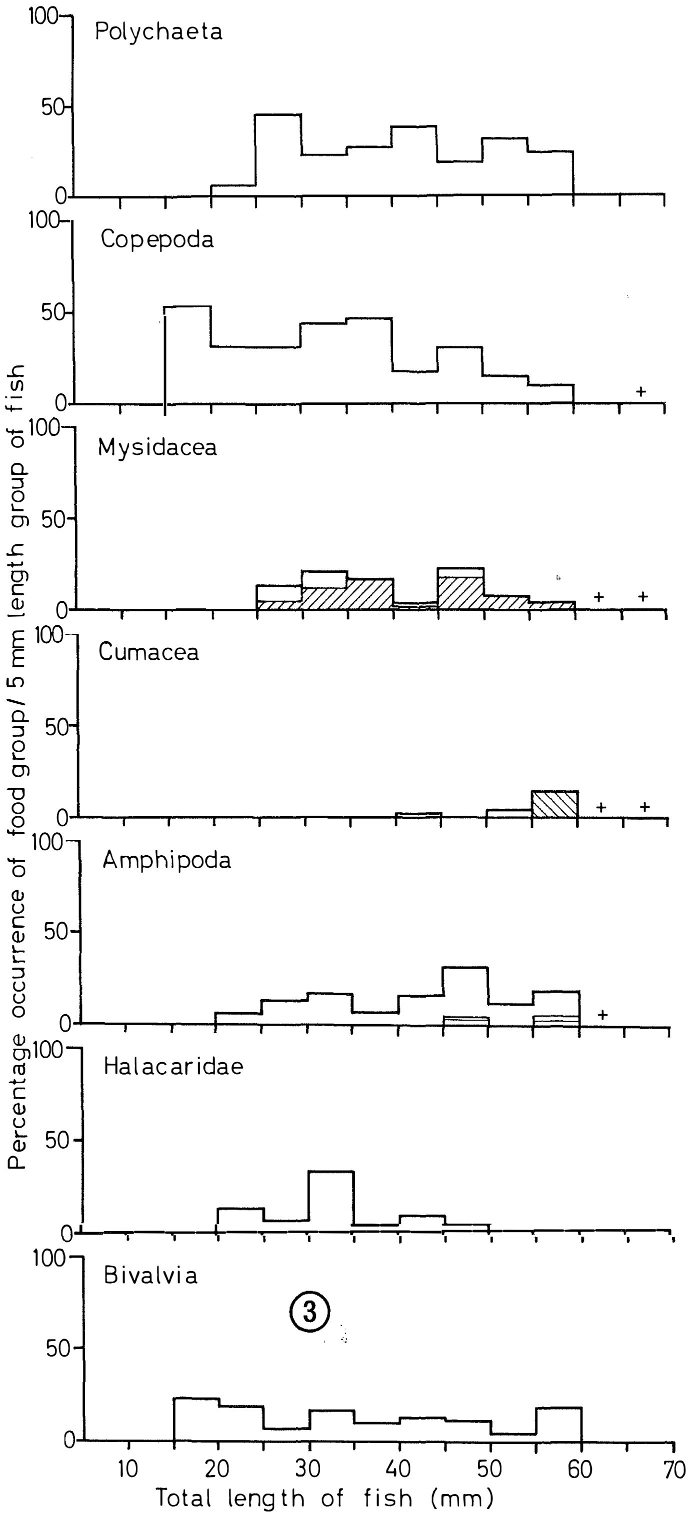
Fig. 1: The relative abundance of three food organisms in the guts of *Pomatoschistus minutus* (A) and in the corresponding 14 toboggan net samples (B).

Fig. 2: Diurnal variations in number of *Pomatoschistus minutus* collected along the bottom in December 1969 by means of Beyer's 50 cm epibenthic closing net. SS = sunset; SR = sunrise.





Tafel 1 (zu I. H. Heesthagen



Tafel 2 (zu I. H. Heesthagen)

Moreover, the group "sand and unidentified organic material", which is the most frequently occurring group in all cases, is mostly expressing the occurrence of sand in the stomach or of digestion remnants in the intestines. In volume and weight this group is unimportant.

Table 1 reveals that the fish examined were mainly carnivores, maybe with the exception of *C. linearis* in which the stomach contents could not be identified. The presence of algae in some individuals may just be a result of the fish feeding on animals found on drifting algae. According to GIBSON (1968) and WHEELER (1969) the gobies include carnivores and omnivores, as well as fish which are mainly herbivorous, like larger specimens of *Gobius cobitis* PALLAS (GIBSON, 1970). Variations are likely to occur seasonally, because of the reduction of green algae in winter and the migration of the fish into greater depths where other food items are available.

For all the fish examined the crustaceans formed the most important food. Among these the copepods were most abundant, and with only few exceptions all copepods were harpacticoids. But these are so small compared to other major food components that they are quantitatively of little importance in spite of their frequent occurrence. It is particularly interesting to note that *A. minuta* had eaten harpacticoid copepods and sand, which demonstrates that this fish is not exclusively eating pelagically.

Amphipods and mysids are presumably more valuable contributors to the diet of the gobies. In most instances it was possible to identify the species, which very often were relatively large ones. Among the amphipods these were *Pontoporeia femorata* Kröyer and *Phtisica marina* Slabber, and the most frequent mysid was *Gastrosaccus spinifer* (Goes), but also *Mesopodopsis slabberi* and *Praunus inermis* (Rathke) were found in the digestive tract of *P. microps* and *P. minutus*.

Of the polychaetes almost only the bristles were found in the guts, and it is consequently difficult to assess the importance of this group. Based on the bristles *Harmothoe* sp., *Pholoe* sp., *Lepidonotus squamatus* (L.), *Castalia punctata* (O. F. Müller) and *Pectinaria* sp. were found.

Except for some bivalves, mostly spat, found in the stomach of *P. minutus*, no other food item than those already mentioned was found to be of any importance.

The composition of the food found in *P. minutus* and the other gobies is more or less the same as that emerging from already known data (WHEELER, 1969), which, however, in most cases are based only on summer collections. BLEGVAD (1916) studied the food of *P. minutus* (probably also including *P. microps*) in Danish waters, and he found that the amphipods, both with respect to number and weight, were the most important food group. His fishes, however, were collected from many localities in different seasons and years. MACER (1967) found that *P. minutus* from the Red Wharf Bay (North Wales) was also mainly feeding on amphipods, but his data, too, were presented as the average for one year.

Variations may naturally occur between different localities as well as different seasons. Seasonal variations can probably be ascribed to variations in food availability, even though the fish may be selective feeders. In Fig. 1, the relative abundance of three species of food organisms frequently found in the stomach of *P. minutus* is compared

Legende zu der nebenstehenden Abbildung (Tafel 2)

Fig. 3: The differences in the diet of *Pomatoschistus minutus* with size of the fish, in December 1969. The fractions of the mysid *Gastrosaccus spinifer*, the cumacean *Diastylis rathkei* and the amphipod *Pontoporeia femorata* are indicated, with the same symbols as in Fig. 1, in their respective group. The + (explained in the text) of these same groups is also referring to the three mentioned species.

with the occurrence of the same species in the toboggan net. These three species were the dumacean *Diastylis rathkei* Kröyer, the mysid *Gastrosaccus spinifer* and the amphipod *Pntoporeia femorata*.

Although we are not allowed to assume that the relative abundance of the different food organisms cought in the net is representative of the abundance of the same species in nature, I shall mention reasons for still making such a comparison between net samples and stomach contents. The sampling gear is fishing from the bottom, mostly including the topmost sediment, to a level of about 80 cm above the bottom. *Diastylis* is partly living in the topmost layer of the sediment, and partly swimming off the bottom (FORSMAN, 1938), particularly at night (personal observations). Also when frightened, as when the toboggan is approaching, *D. rathkei* will leave the hiding place in the mud and swim up (FORSMAN, l. c.). This would mean that this species should be most available to the goby at night. The mysid *G. spinifer* is found in swarms close to the bottom, or partly buried in the mud (TATTERSALL & TATTERSALL, 1951) and the amphipod *P. femorata* is more or less a burrower (KAESTNER, 1963). Consequently all three species are found in the region sampled by the net. The amphipod and the cumacean are caught to about the same extent, whilst the net will have a small preference for the mysid. This means that the mysid fraction in Fig. 1 (B) will be slightly exaggerated compared to the ratio in nature. This relation may, however, change in the course of the day, because, according to my observations, both *Diastylis* and *Pontoporeia* tend to leave the bottom region at night, whereas such a tendency is less pronounced in *Gastrosaccus*. By comparing A and B in Fig. 1 it appears that the *Gastrosaccus*-fraction in the guts of *P. minutus* has increased to more than 65% from only 12% in the net samples. The corresponding comparison for *Diastylis* reveals a decrease from 85% to about 20%. Thus the fish eats relatively less cumaceans than mysids and amphipods, whilst the proportion between the latter two is maintained. The reason why the goby eats comparatively less *Diastylis* is not immediately obvious. The aversion to *D. rathkei* compared with the other two species might be due to a complex of factors like shape, nature of the exo-skeleton and extremities as well as taste of the prey, or in the feeding behaviour of the fish. According to the diameter of the three species, *Diastylis* does not seem to be more difficult to engulf than the other two. Regarding the extremities, this factor would be a lesser obstacle to the fish eating it in *D. rathkei* than in both *P. femorata* and *G. spinifer*.

On the other hand, since the exo-skeleton of *Diastylis*, particularly the carapax, is palpably harder and stiffer than in the mysid and the amphipod, the cumacean would not so easily take the shape of the mouth or the throat of the fish, which thus may have difficulties in ingesting the whole animal. This is obviously more felt in smaller fishes, and we should expect that *D. rathkei* is eaten by relatively larger fish than *P. femorata* and *G. spinifer*. Such a size dependent selectivity is, in fact, indicated in Fig. 3, which also clearly shows that there are differences in the diet of different size groups of fish, even though these are not so pronounced as in gobies with greater maximum body length (cf. GIBSON, 1970, Fig. 5).

A subjective quality like taste of the food can hardly be tested, but it should be nothed that *Diastylis rathkei* represents an important contribution to the diet of many young demersal fishes (HERTLING, 1928).

Behaviour is still another factor influencing the diet of the fish. *P. minutus* tends to lie hidden in the sediment, very often with only the eyes projecting (HASS, 1936), and then, like many gobies (BODDEKE, 1963), sprint to capture the prey when it comes into view. To my knowledge, however, it is not known whether or not the activity in the gobies may change in the course of the day. According to Fig. 2, considerably more specimens of *P. minutus* were caught in the night samples than during the day. This might be due to the fish being more active in the dark hours, or simply to the fish observing and escaping the approaching toboggan in daylight. But the first explanation does not exclude the other. In many demersal fishes higher locomotory activity at night, not necessarily associated with feeding, may often lead to larger night catches (Woodgead, 1966).

It can, however, not be ruled out that the fish is feeding mainly nocturnally, i. e. being more active and easily cought. Ensuing from this should be a diurnal variation in the filling of the stomach (Müller, 1968). According to Table 2 the material from the hours between sunrise and sunset is too sparse to produce a conclusive proof. Nevertheless, the results in Table 2 suggest that *P. minutus* is feeding both during day and night, because there are no changes in the relative abundance of empty stomachs throughout the day. This is further supported by the findings of undigested as well as partly digested food at all hours, and the fact that there is no significant alteration in the diet from sample to sample.

Table 2

Analysis of stomach and intestine contents of *Pomatoschistus minutus* caught at different times of day, expressed by percent occurrence of the particular food item.

	Time of sampling (begin and end of towing)													
	15.05—15.36	16.01—16.31	17.10—17.40	19.02—19.34	21.00—21.30	23.40—00.10	01.33—02.02	03.03—03.33	05.04—05.35	07.00—07.30	08.00—08.30	09.00—09.32	11.40—12.11	13.00—13.29
Number of fish examined .	4	6	6	15	20	30	16	38	39	27	9	1	7	1
Number of empty stomachs .	0	2	1	2	1	8	3	5	6	2	5	0	1	0
Algae							13							
Hydroidae										3				
Polychaeta			+	27	25	37	38	21	20	41	+			
Copepoda		++	+	13	25	17	31	37	31	30	+	+	++	
Ostracoda							6	5	5	7				
Cirripedia, larvae						3		2						
Mysidacea	+	+		7	15	37	6	18	13	7			+	
Cumacea				7	20			5						+
Tanaidacea								2					+	
Amphipoda			+		5	13	13	24	28	11			+	
Unidentified Crustacea . .	++			7		3		5	15	11				
Halacaridae						10	6	13	10	3				
Bivalvia						13	13	29	5	19	++	+		
Chaetognatha					10									
Pisces, scales										7				
Sand and unidentified organic material	++	++	++	74	50	40	75	42	36	78	++		+	+

When less than 10 examined fishes no percentage is indicated, but the particular food item is indicated by +, or ++ when it is predominant.

References

BEYER, F. (1958): A new, bottom-living Trachymedusa from the Oslosfjord. Nytt Mag. Zool. **6**, 121—143.

BLEGVAD, H. (1916): Om Fiskernes Föde i de danske Farvande inden for Skagen. Rep. Danish biol. Sta. **24**, 17—72.

BODDEKE, R. (1963): Size and feeding of different types of fishes. Nature, Lond. **197**, 714—715.

DUNCKER, G. (1928): Teleostei Physoclisti. 9. Gobiiformes. In: Tierwelt der Nord- und Ostsee **12g**, 121—148, Grimpe und Wagler, Leipzig.

FORSMAN, B. (1938): Untersuchungen über die Cumaceen des Skageraks. Zool. Bidr. Uppsala **18**, 1—162.

GIBSON, R. N. (1968): The food and feeding relationships of littoral fish in the Banyuls Region. Vie et Milieu **19**, 447—456.

GIBSON, R. N. (1969): The biology and behaviour of littoral fish. Oceanogr. Mar. Biol. Ann. Rev. **7**, 367—410.

GIBSON, R. N. (1970): Observations on the biology of the giant goby *Gobius cobitis* Pallas. J. Fish Biol. **2**, 281—288.

GUITEL, F. (1892): Observations sur les moeurs du *Gobius minutus*. Arch. Zool. exp. gén. **10**, 499—555.

HASS, G. (1936): Variabilitätsstudien an *Gobius niger* L., *Gobius minutus* PALLAS und *Cottus scorpius* L. Kieler Meeresforsch. **1**, 279—321.

HERTLING. H. (1928): Untersuchungen über die Ernährung von Meeresfischen. I. Quantitative Nahrungsuntersuchungen an Pleuronectiden and einigen anderen Fischen der Ostsee. Ber. dt. wiss. Komm. Meeresforsch. **4**, 179—215.

HESTHAGEN, I. H. (1970): On the near-bottom plankton and benthic invertebrate fauna of the Josephine Seamount and the Great Meteor Seamount. "Meteor" Forsch.-Ergeb. (D) **8**, 61—70.

HYNES, H. B. N. (1950): The food of the fresh-water sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*), with a review of methods used in studies of the food of fishes. J. Anim. Ecol. **19**, 36—58.

JONES, G. & P. J. MILLER (1966): Seasonal migrations of the common goby, *Pomatoschistus microps* (Kroyer), in the Morecambe Bay and elsewhere. Hydrobiologia **27**, 515—528.

KÄNDLER, R. (1961): Über das Vorkommen von Fischbrut, Decapodenlarven und Medusen in der Kieler Förde. Kieler Meeresforsch. **17**, 48—64.

KAESTNER, A. (1963): Lehrbuch der speziellen Zoologie. **I** (2). Gustav Fischer Verlag, Jena. 485—1423.

KREY, J. (1961): Beobachtungen über den Gehalt an Mikrobiomasse und Detritus in der Kieler Bucht 1958—1960. Kieler Meeresforsch. **17**, 163—175.

KÜHLMORGEN-HILLE, G. (1963): Quantitative Untersuchungen der Bodenfauna in der Kieler Bucht und ihre jahreszeitlichen Veränderungen. Kieler Meeresforsch. **19**, 42—66.

MACER, C. T. (1967): The food web in Red Wharf Bay (North Wales) with particular reference to young plaice (*Pleuronectes platessa*). Helgoländer wiss. Meeresunters. **15**, 560—573.

MÜLLER, A. (1968): Die Nahrung junger Plattfische in Nord- und Ostsee. Kieler Meeresforsch. **24**, 124—143.

PETERSEN, C. G. J. (1916): Om vore almindelige Kutlingers (*Gobius*) Udvikling fra Ägget til voksen Fisk m.m. Rep. Danish biol. Sta. **24**, 3—16.

SCHWENKE, H. (1964): Vegetation und Vegetaionsbedingungen in der westlichen Ostsee (Kieler Bucht). Kieler Meeresforsch. **20**, 157—168.

SWEDMARK, M. (1957): Variation de la croissance et de la taille dans différentes populations du téléostéen *Gobius minutus.* Ann. biol. Copenh. **33**, 163—170.
TATTERSALL, W. M. & O. S. TATTERSALL (1951): The British Mysidacea. Roy. Soc. Publs. **136**, 1—460.
WHEELER, A. (1969): The fishes of the British Isles and North-West Europe. MacMillan, London. 613pp.
WOODHEAD, P. M. J. (1966): The behaviour of fish in relation to light in the sea. Oceanogr. Mar. Biol. Ann. Rev. **4**, 337—403.