ICES Journal of Marine Science, 54: 684–694. 1997

Occurrence and consumption of seabirds scavenging on shrimp trawler discards in the Wadden Sea

U. Walter and P. H. Becker

Walter, U. and Becker, P. H. 1997. Occurrence and consumption of seabirds scavenging on shrimp trawler discards in the Wadden Sea. – ICES Journal of Marine Science, 54: 684–694.

The fishery for the brown shrimp (*Crangon crangon*) on the coast of Germany (Lower Saxony) produces a rich food source for ship-following seabirds. Large quantities of discarded fish and invertebrates attract flocks of gulls and terns. Between March 1993 and August 1994 the number and species composition of birds following two shrimp trawlers were determined. The main scavengers were herring gull (*Larus argentatus*) and black-headed gull (*L. ridibundus*). Common gull (*L. canus*), lesser black-backed gull (*L. fuscus*), great black-backed gull (*L. marinus*), and common/arctic tern (*Sterna hirundo/paradisaea*) were less numerous. The distribution of scavenging seabirds behind the shrimp trawlers showed a marked species-specific seasonal and spatial pattern. The scavenging behaviour of seabirds feeding on discards was studied by means of experimental discarding. Of 10 356 items offered, 8253 were picked up by the birds, and in 8072 of these the consuming bird was identified. Herring gulls were most successful. Although this species represents only 45% of all birds counted, they took 82% of the total number of items consumed. In total, ship-following seabirds consumed 41% of the offered mass of flatfish, 79% of the roundfish, and 23% of four invertebrate species. In feeding experiments birds consumed 10% of undersized shrimps. Applying these consumption rates and bioenergetic data to the total quantity of discarded biota, approximately 90 000 seabirds may be supported by this source throughout the entire fishing season (April–November 1993). Potentially, the discards of the shrimp trawler fleet of Lower Saxony were sufficient to meet the energy demand of 60 000 birds for the whole year. The results suggest that discards may have strong effects on the bird populations and the ecosystem of the Wadden Sea.

Key words: discards, feeding experiments, seabirds, shrimp fishery, Wadden Sea.

U. Walter and P. H. Becker: Institut für Vogelforschung 'Vogelwarte Helgoland', An der Vogelwarte 21, D-26386 Wilhelmshaven, Germany. Correspondence to U. Walter: tel: +494421365440.

Introduction

Recent studies have shown that several species of scavenging seabirds follow fishing vessels all over the North Sea (Camphuysen *et al.*, 1993, 1995; Garthe *et al.*, 1996). The birds are attracted by large quantities of discards and offal made available by the fishing fleet and the number and distribution patterns of scavenging seabirds and their seasonal consumption of fishery waste are relatively well known (Camphuysen *et al.*, 1995).

Although there are several older references to discards as part of the diet of gulls in the German Wadden Sea (Leege, 1917; Meijering, 1954; Goethe, 1956; Ehlert, 1961; Kock, 1974), their importance was neglected for a long time compared with the attention given to other sources of scavenged food, e.g. refuse tips (Spaans, 1971; Mudge and Ferns, 1982; Lüttringhaus and Vauk-Hentzelt, 1983). For this reason, our knowledge about seabirds following inshore fisheries like the shrimp trawlers of the Wadden Sea is still insufficient. In recent years, studies by Berghahn and Rösner (1992) and Walter and Becker (1994) have demonstrated that up to 3000 birds may be found astern of a shrimp trawler.

Fishing for the brown shrimp (*Crangon crangon*) is carried out by 118 vessels in Lower Saxony (Prawitt, 1995). These trawlers are equipped with two beam trawls (ca. 8 m width) and fine-meshed nets (mesh size 11 mm in the codend). Consequently, a large number of by-catch organisms are caught, mainly juvenile fish and benthic invertebrates. After sorting the catch, all unwanted organisms are discarded. Walter (in press) estimated a total discard quantity of more than 30 000 t for the shrimp trawler fleet of Lower Saxony in 1993 (April–November), consisting of 27 600 t of undersized

1054–3139/97/040684+11 $25.00/0/jm970239

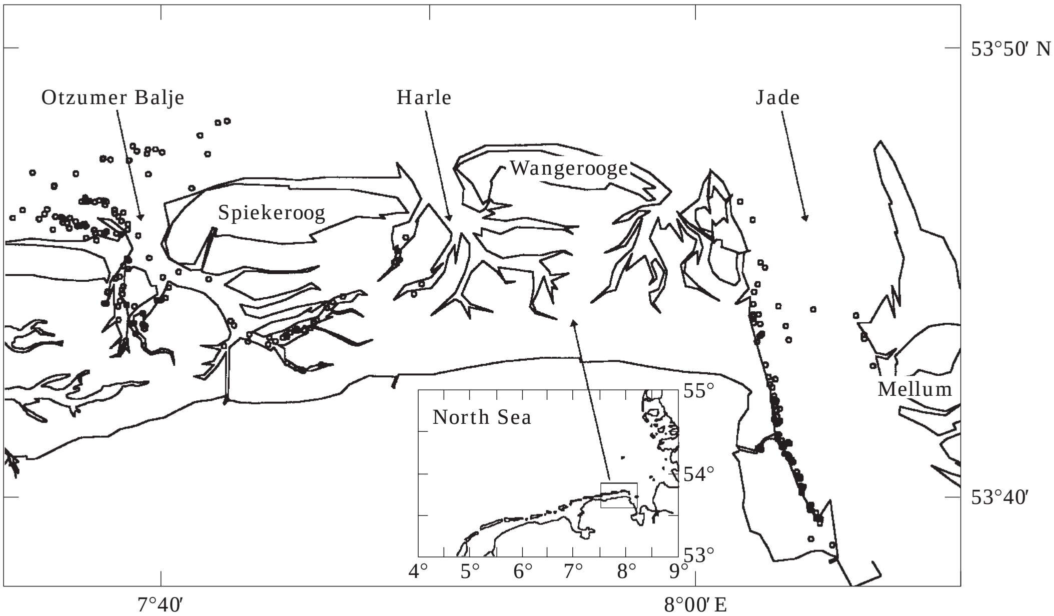

Figure 1. Area of investigation showing position of 229 counts of scavenging seabirds astern of a commercial shrimp trawler in August/September 1993 and August 1994.

shrimps, 4000 t of fish (1700 t flatfish and 2300 t roundfish), and 2100 t of invertebrates other than shrimps. By-catch mortality after sorting is close to 100% for roundfish such as clupeids, e.g. herring (*Clupea harengus*) and sprat (*Sprattus sprattus*); gadoids, e.g. whiting (*Merlangius merlangus*), cod (*Gadus morhua*), bib (*Trisopterus luscus*); and smelts (*Osmerus eperlanus*) (Berghahn *et al.*, 1992). However, mortality of flatfish such as plaice (*Pleuronectes platessa*), flounder (*Platichthys flesus*), sole (*Solea solea*), and dab (*Limanda limanda*) varies between 17% and 100%. Large numbers of moribund and damaged fish floating on the sea surface or unable to escape fast enough are preyed upon by gulls and terns. Feeding rates on smelts and whiting are high (68–90% by number; Berghahn and Rösner 1992), but reliable estimates of consumption on other discarded items are not available.

In this investigation, we study the seasonal distribution of ship-following seabirds in the Wadden Sea and their total consumption of discarded organisms. The number of scavenging seabirds supported by the discards of the shrimp trawler fleet of Lower Saxony is also calculated.

Methods

The study was carried out in 1993 and 1994 in the East Frisian Wadden Sea area (Fig. 1). One observer accompanied 70 commercial trips of two shrimp trawlers, 38 in 1993 (March–November) and 32 in 1994 (April–August). The total number of seabirds assembling close to the trawler and the number of each species were counted on 1242 occasions. The position of the ship was determined using a Global Positioning System. The positions of 229 seabird counts in July–August 1993 and August 1994 are shown in Fig. 1.

In order to assess the proportion of the discards consumed by the birds, 157 discard experiments were carried out on 43 cruises using the method of Hudson and Furness (1988). Samples of fish and benthic invertebrates were taken from the hauls, identified and measured to the nearest 0.5 cm and subsequently thrown overboard one by one. Each experiment was carried out during routine discarding activities of the ship, when a steady flow of by-catch organisms (larger ones from the coarse upper sieve and small fish and mainly undersized shrimps from the lower fine-meshed sieve) was washed off the deck and made available to the birds. An experiment took an average of 9 ± 4 min and 53 ± 26 fish or invertebrates were thrown overboard in that time. The fate of the experimentally discarded items was recorded on tape, and the consuming bird species noted. At the end of each experiment the number of birds of each species was counted. A success index was calculated as the percentage of discards swallowed by a specific bird species, divided by the percentage of this species of all seabirds present during the experiment.

Size-specific consumption rates (% of number) were investigated. Based on the species and size composition of 103 trawl samples, the total quantities of all items discarded by the shrimp trawler fleet of Lower Saxony from April to November 1993 were estimated (Walter, in press). These, in turn, were used in converting numerical consumption rates into discard mass consumed by seabirds.

A different approach was used to determine feeding rates on undersized shrimps, given that these small organisms were lost from sight very easily during normal discard experiments. Feeding experiments with a known number of undersized shrimps were conducted only after routine discarding, and were recorded on video. Peck rates and swallowing rates were counted on these video sequences and individual birds were followed with binoculars during routine discarding to count feeding rates on shrimps.

Data on the total quantities of discards from the shrimp trawler fleet of Lower Saxony (Walter, in press) were used to make a crude estimation of the total number of birds which could be sustained by this food source. The following energy equivalents of discarded components, derived from published figures, were used in this study: roundfish 5.5 kJ g^{-1} (owing to the large portion of clupeids), flatfish 4 kJ g^{-1}, shrimps 4.3 kJ g^{-1}, and other invertebrates 3 kJ g^{-1} (Cummins and Wuychek 1971; Wiens and Scott, 1975; Harris and Hislop, 1978; Montevecchi *et al.*, 1984; Rumohr *et al.*, 1987; Furness *et al.*, 1988; Massias and Becker, 1990; Hislop *et al.*, 1991; Camphuysen *et al.*, 1993; Zwarts and Wannink, 1993). The following further assumptions on the energy demand of a seabird were made: (1) the field metabolic rate (FMR) is three times the basal metabolic rate (BMR) (Camphuysen *et al.*, 1993); (2) the daily BMR data for North Sea birds were derived from the equation of Bryant and Furness (1995): BMR (kj d^{-1}) = 2.3 (body mass)$^{0.774}$; and (3) assimilation efficiency = 80% (Camphuysen *et al.*, 1993).

Results

Seasonal and spatial distribution patterns

Herring gulls and black-headed gulls occurred in large numbers behind the shrimp trawlers in the Wadden Sea; they represent 93% of all recorded scavengers (Table 1). Until June, their numbers were lowest (Fig. 2a, b). From July to September, herring gull and black-headed gull numbers were significantly larger than in spring (Nemenyi test), decreasing in late autumn again. Peak numbers of 930 and 1600, respectively, were observed in August/September. Common gulls (Fig. 2c) occurred throughout the fishing season, but substantial numbers were recorded only in March and in autumn (maximum 400 in November). Lesser black-backed gulls (Fig. 2d) and common/arctic terns (Fig. 2f) are summer visitors and they occurred in relatively low numbers between April and September (maximum 250 and 110, respectively). Great black-backed gulls (Fig. 2e) were scarce until July, with slightly larger numbers in late summer and autumn (maximum 45).

Table 1. Species composition of scavenging seabirds in the Wadden Sea. Counts are combined for the fishing seasons 1993 and 1994.

Species	n	%
Herring gull (*Larus argentatus*)	139 000	48
Black-headed gull (*Larus ridibundus*)	130 000	45
Common gull (*Larus canus*)	7 400	3
Lesser black-backed gull (*Larus fuscus*)	5 300	2
Great black-backed gull (*Larus marinus*)	300	0.1
Common/Arctic tern (*Sterna hirundo*/ *S. paradisaea*)	5 800	2
Total	287 800	

The local distribution of the scavenging seabird species showed marked differences (Fig. 3). Lesser black-backed gulls were recorded in larger numbers (>50) only outside the Wadden Sea proper, north of the East Frisian islands. North of the inshore/offshore boundary (Fig. 3a), a significantly higher number of birds was observed than south of this (Mann-Whitney test, $p < 0.001$). Great black-backed gulls showed a similar distribution pattern, but some of them entered the Jade further south. The other extreme is represented by the black-headed gull (Fig. 3b). This species occurred in large numbers (>300) at the stern of shrimp trawlers only in the Wadden Sea or close to the tidal inlet between Spiekeroog and Langeoog. In the Wadden Sea area, the numbers were significantly larger than in the offshore area ($p < 0.001$), where the species occurred less frequently and in smaller numbers. Common gulls and common/arctic terns showed the same local distribution pattern as black-headed gulls. Herring gulls were frequent and numerous scavengers in inshore waters of the Wadden Sea and the Otzumer Balje as well as in offshore areas, and showed no significant preferences for some areas over others (Fig. 3c).

Discard experiments

A total of 10 356 items of fish, and benthic invertebrate were discarded during the discard experiments; 7668 specimens of 26 roundfish species (74%), 2042 flatfish of eight species (20%), and 646 (6%) discards of nine invertebrate species were offered. Four fish species (herring, smelt, whiting, and plaice) represent 65% of the discarded items. Of these, 1362 items (13%) escaped or sank, and the fate of 741 cases (7%) was unknown. Of 8253 single organisms picked up by the birds, the ultimate consumer was observed in 8072 cases. Most of the consumed discards were seized by herring gulls

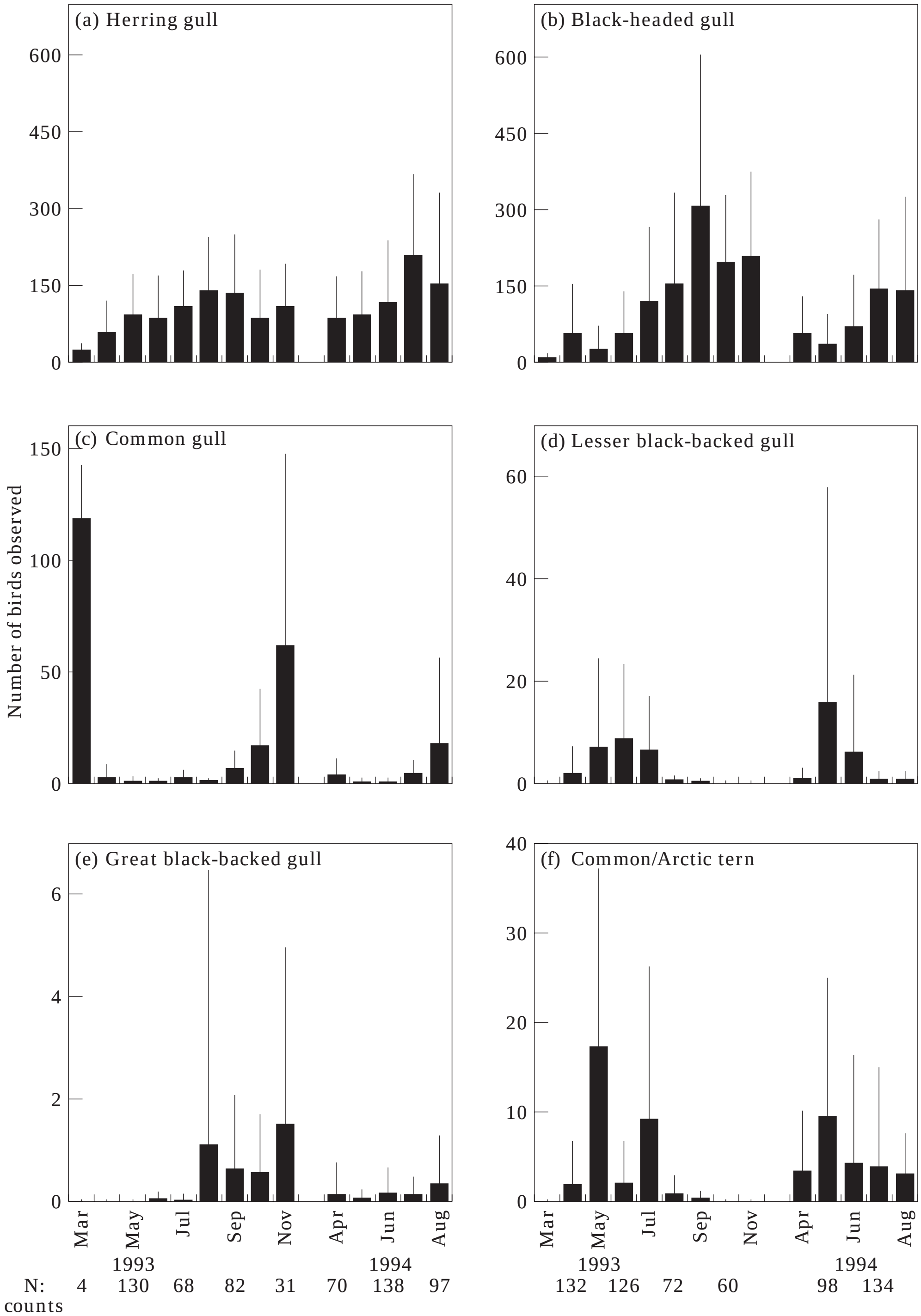

Figure 2a–f. Seasonal patterns in numbers of scavenging seabird species March–November 1993 and April–August 1994 (column: monthly mean, vertical line: +1 S.D.). Total number of counts: 1242.

(82%). Great black-backed gulls (0.1%), common gulls (3%), and common/arctic terns (2%) obtained discards in proportion to their numerical abundance (Table 1). Lesser black-backed gulls (4%) swallowed twice as many discards relative to their number present. Black-headed gulls obtained proportionally

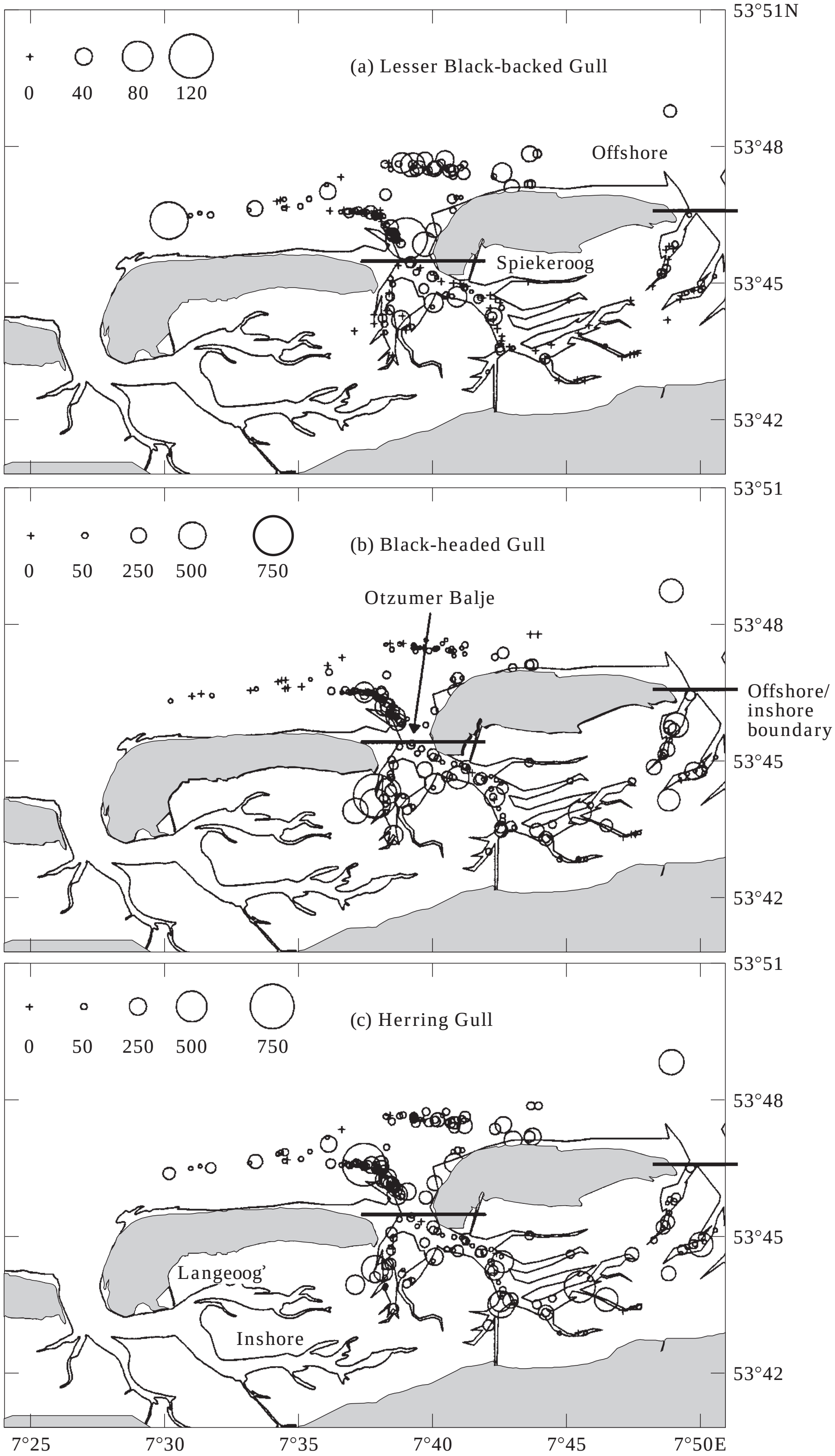

Figure 3a–c. Spatial distribution of three scavenging seabird species around the island of Spiekeroog (June/July 1993 and 1994). Each circle represents a single count; the size increases in proportion to the number of birds present (see scale at upper left). Total number of counts: 211. For analysis of spatial preferences, an inshore/offshore boundary is indicated.

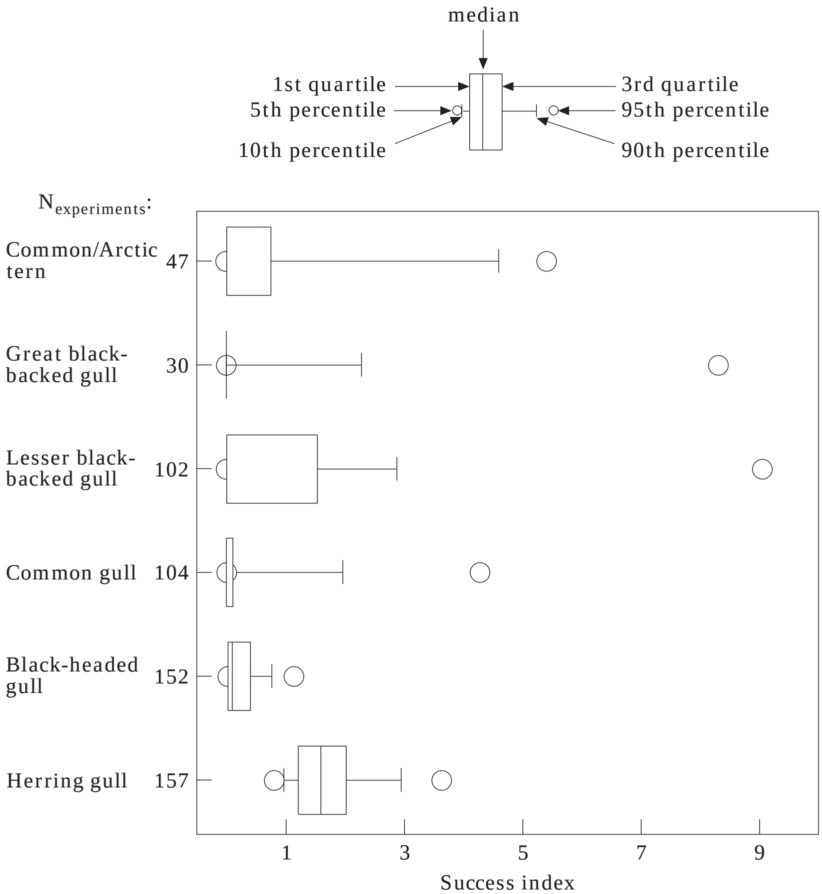

Figure 4. Box-plot graph of the success index of scavenging seabirds during discard experiments. The number of experiments with the species present is given.

fewer discards (9%) than expected by their abundance. Success indices revealed that individual herring gulls were significantly more successful than any other species (Nemenyi test, $p<0.001$; Fig. 4).

Discard experiments showed that seabirds select discards according to the length or width of the discard components. For several discard species, the median length of consumed fish was significantly smaller than that of the specimens escaping, but not for sprats (*Sprattus sprattus*) (Mann-Whitney test). Length-specific consumption rates (Fig. 5) of discarded roundfish and flatfish showed that the chances of being swallowed decrease with increasing size of the discards. The proportion of consumed roundfish was relatively stable at ca. 80% by number. Even half of the largest roundfish offered (>26 cm) were swallowed. Consumption rates of flatfish showed a steady decline with increasing length to less than 40% for the largest flatfish. Length- or width-specific consumption rates of four discarded invertebrate species were determined (Table 2). The median sizes of selected roundfish (11.5 cm) and flatfish (11 cm) offered in the discard experiments were larger compared with catch samples (9 cm and 7 cm, respectively). Potential bias in the estimation of consumption was avoided by converting the consumption rates of certain size classes (by numbers) into mass, based on the actual composition of discards in catch samples. In total, 41% of the discarded flatfish mass, 79% of roundfish, and 23% of four invertebrates were consumed by scavenging seabirds (Fig. 6). This represents a total of ca. 3000 t of discards by the shrimp trawler fleet in Lower Saxony.

Large numbers of scavenging black-headed gulls (45% of all birds counted; Table 1) and their small share (less than 9%) of all consumed discarded fishes and invertebrates suggested that the smaller gulls may feed on undersized shrimps. Observations of individual birds, during routine discarding situations, show mean swallowing rates of 1.3 shrimps min^{-1} for black-headed gulls (98 birds observed) and 0.4 min^{-1} for herring gulls (110 birds). Applying these rates to three discard experiments, carried out with a known number of

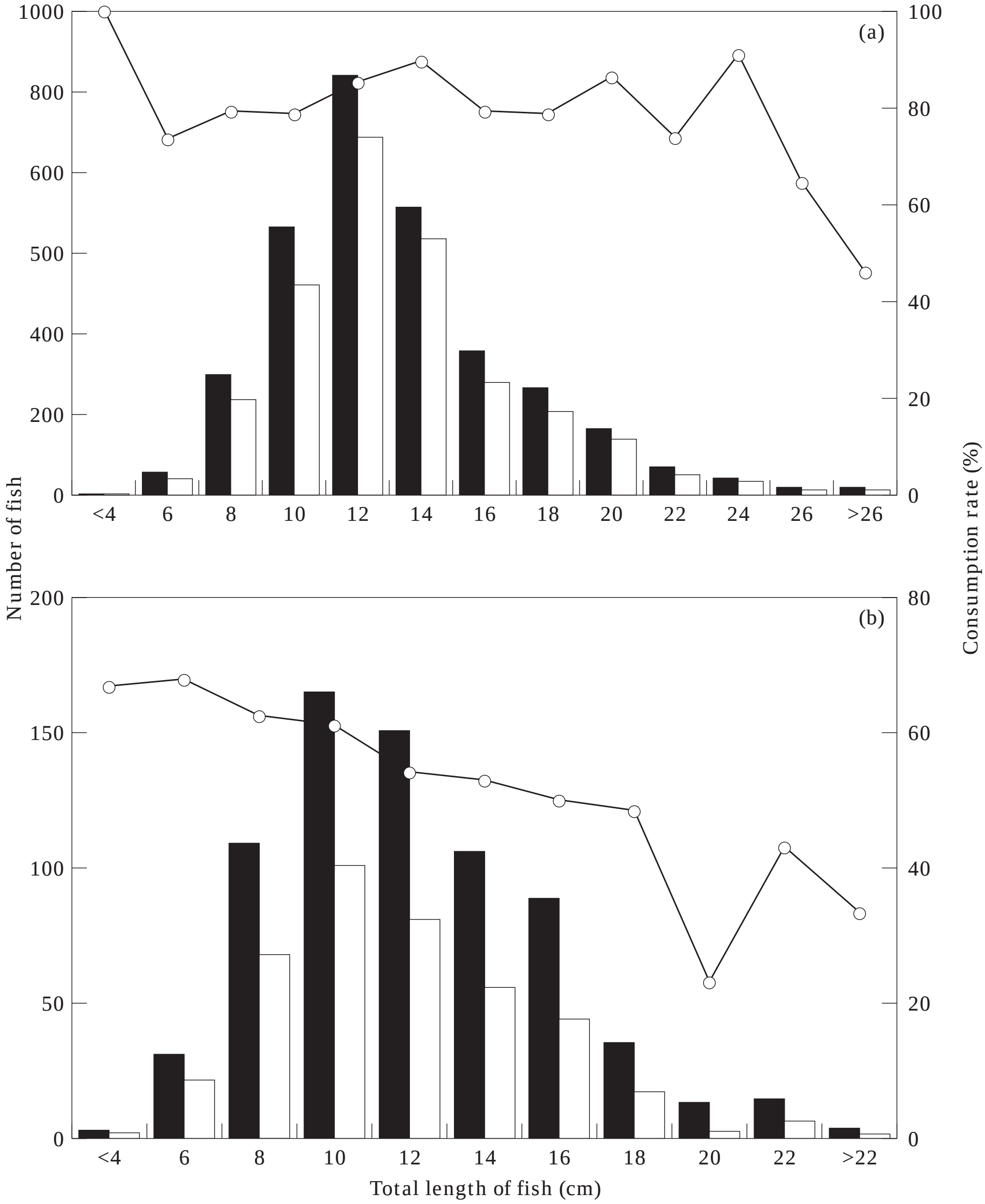

Figure 5. Consumption rates (line), length distribution of experimentally discarded (dark bars) and consumed roundfish and flatfish (white bars). Only freshly caught discards are combined for this figure. Length is classified in 2 cm steps, upper limits marked.

undersized shrimps, reveals that 6–14% (mean 9.8%) of the total number of discarded shrimps were consumed by scavenging seabirds (Table 3), corresponding to an overall consumption of roughly 2500 t of shrimps per year (Fig. 6 and Table 2).

Number of seabirds sustained by shrimp trawler discards

From the total quantity of ca. 33 000 t of discards from the shrimp trawler fleet of Lower Saxony from April–November 1993 (Walter, in press), an estimated total of 5 500 t were consumed by scavenging seabirds. This discard mass represents an energy value of 25×10^9 kJ (Fig. 6).

Data on body masses of species of seabirds range from 0.12 kg for the common tern to 1.6 kg for the great black-backed gull (Glutz von Blotzheim, 1982a, b). Applying these data and the given formulae for the energy requirements of seabirds (see above) allows daily energy demands of 360–2600 kJ to be calculated. Weighting these energy demands of the species against

Table 2. Numerical consumption rates of experimentally discarded flatfish, roundfish, and invertebrates of different studies. For this study, mass related consumption rates are also presented.

Source	Area, season	Flatfish (%)	Roundfish (%)	Invertebrates (%)	
Hudson and Furness (1988)	Shetland, summer	5	58	—	
Garthe (1993)	Around Helgoland,				
	summer	30	79	11	
	winter	31	85	56	
	North Sea,				
	spring/summer	8	84	—	
Camphuysen (1993)	Southern North Sea, summer	34	85	0.3	
Camphuysen (1994)	Southern North Sea, summer	31	71	0.3	
Garthe and Hüppop (1994a)	Skagerrak/Kattegat,				
	winter, day	16	86	—	
	winter, night	24	48	—	
Garthe and Hüppop (1994b)	North Sea, summer	8	84	—	
Camphuysen *et al.* (1993)	North Sea, winter	36	92	17	
Camphuysen *et al.* (1995)	North Sea, spring	22	76		
	summer	10	70	6	
	autumn	20	82		
				10	*Crangon crangon*
				0–33	*Carcinus maenas*
				8–13	*Liocarcinus holsatus*
	Wadden Sea			0–76	*Asterias rubens*
This study	spring/autumn	33–68	46–91	75–100	*Allotheutis subulata*
		41 (mass)	79 (mass)	23 (mass)	(excl. *C. crangon*)

their relative frequency in all counts (Table 1), amounts to an average energy intake of a ‘‘model’’ scavenging seabird in the Wadden Sea of 1145 kJ d^{-1} and 418 100 kJ yr^{-1}. These calculations result in a potential number of 60 000 birds being supported by shrimp trawler discards in Lower Saxony per year, or 90 000 birds during the 8 months of the fishing season in 1993 (Fig. 6).

Discussion

In contrast to the situation in the open North Sea, where six of eight bird species are common scavengers behind fish trawlers (Camphuysen *et al.*, 1993, 1995), the species composition of scavenging seabirds in inshore areas is simple. In the Wadden Sea flocks of ship-following birds were dominated for the whole fishing season by only two species, the herring gull and the black-headed gull. The former is a coastal species that is mainly found within 10 km of the coast (Camphuysen, 1993a, b). The latter species is typically an inland bird that has been breeding in the German Wadden Sea since the 1940s (Bezzel, 1985), and where it is now a frequent inshore scavenger. Therefore, our results do not support the view of Furness (1992) that scavenging behind fishing boats may be insignificant for black-headed gulls.

In spring, herring gulls were the most abundant species behind shrimp trawlers, reaching maximum numbers at the end of the breeding season in July and August. In autumn, the number of scavenging herring gulls decreased in the Wadden Sea, while their numbers increased in the North Sea (Camphuysen *et al.*, 1995). The spatial distribution of herring gulls revealed no preference for inshore or offshore areas. In late summer and autumn black-headed gulls were temporarily most numerous, having a restricted distribution in the Wadden Sea. Other species, such as lesser black-backed gull and great black-backed gull, which are frequent scavengers further off the coast (Camphuysen, 1993a, b), occurred mainly outside the Wadden Sea. These species were abundant only in summer (lesser black-backed gull) or autumn in the Wadden Sea (great black-backed gull). The distribution of common gulls and common/arctic terns resembled the spatial pattern of black-headed gulls, but common gulls were abundant astern of shrimp trawlers only in colder seasons and the terns only in the summer months. Overall, seasonal fluctuations and spatial distribution of scavenging seabirds in the coastal area of Lower Saxony correspond with the results of Camphuysen and Leopold (1994) on the occurrence and distribution of seabirds in the southern North Sea.

Discard experiments were conducted following the method used by Hudson and Furness (1988). On a commercial shrimper a water flushed sieve separates both large and small-sized individuals of the by-catch species from the fraction of the commercial shrimps. The

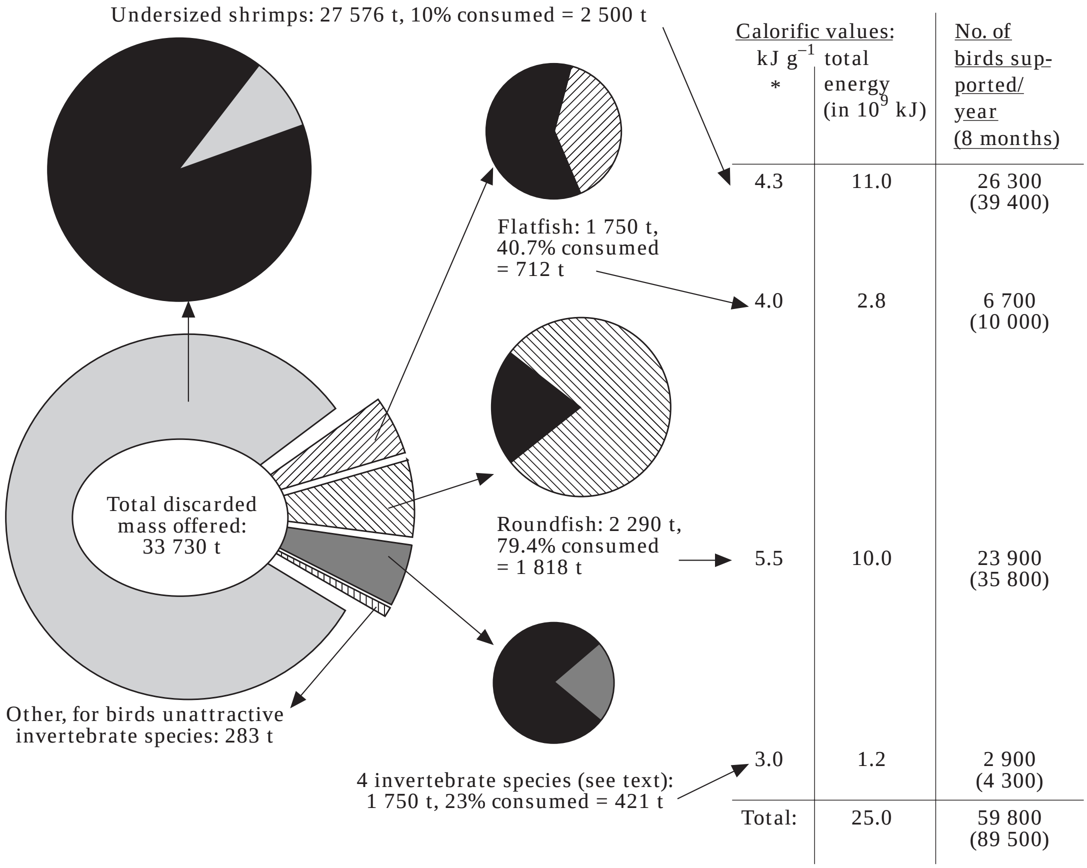

Figure 6. Balance of the total quantities of discards offered by the shrimper fleet of Lower Saxony and proportion of discards consumed by scavenging seabirds. The total energy of the consumed discards and number of birds sustained by shrimp trawler discards are calculated. *Sources for calorific values: see text.

Table 3. Results of discard experiments using undersized shrimps with herring gulls and black-headed gulls.

Experiment	Date	No. of herring gulls present	No. of black-headed gulls present	Consumption rate per min	Duration (min)	No. of shrimps consumed	Total no. of shrimps consumed	No. of shrimps offered	% Shrimps consumed
A	8.7.94	430		0.41	2.5	440			
			260	1.28	2.5	830	1270	20 400	6.2
B	14.7.94	60		0.41	3.75	90			
			310	1.28	3.75	1630	1720	19 000	9.1
C	22.7.94	400		0.41	4.5	740			
			280	1.28	4.5	1610	2350	16 700	14.1
Total									9.8

unwanted part of the catch is discarded in a steady flow of organisms and not *en masse*. Only heavy species, such as hermit crabs for example, and undamaged, mobile individuals may sink or escape. In this study, only one-fifth of all discarded individuals escaped. The by-catch organisms that are strongly affected by both capture and sorting, especially moribund roundfish, are mostly eaten by seabirds. For the seabirds, food choice is, therefore, unchanged by adding single organisms experimentally one by one to the large number of floating and sinking discards. For that reason, discard experiments may be considered representative of commercial discarding practices on a shrimper.

However, established feeding rates may be influenced by the selection of the researcher, because more roundfish, fewer flatfish and invertebrates, and also fewer larger fish relative to their abundance in the catch were collected and offered to the birds. In order to solve this problem, the size-specific consumption rates were applied to a catch of known composition (103 samples). The difference between the original and the reduced data set provided an unbiased figure of consumed discard mass.

The Hudson and Furness (1988) method of discarding proved to be unsuitable for the largest group of discards, namely the undersized shrimps (because of their small size). The large numbers of black-headed gulls present at shrimp trawlers and their low success rates on fish and larger invertebrates during discard experiments, indicate that undersized shrimps may play a more important role for small gulls than other discard components. Although our calculation of the consumed proportion of small shrimps may be crude, our results confirm this.

Owing to the smaller size of the majority of by-catch organisms, some of the consumption rates of birds at the stern of a trawler are higher than those reported in other studies, especially those on flatfish and benthic invertebrates (Table 3). Discard experiments revealed the dominant position of herring gulls in the hierarchy of the seabird community, although there were no signs of aggressive competition between herring and lesser black-backed gull behind shrimp trawlers.

The estimated number of birds potentially supported by shrimp trawler discards is conservative because we used the lowest estimated quantity of total discards (Walter, in press), and consumption rates were based only on freshly caught by-catch organisms. In contrast to discard experiments carried out from research vessels (Camphuysen *et al.*, 1995), the discarding practice and rates on a commercial shrimp trawler allowed a more realistic assessment to be made of seabird selection of discarded organisms. Consequently, our results serve as a rough indication at least of the extent to which seabirds rely on shrimper discards.

The shrimp fishery of Lower Saxony produces large amounts of discards, potentially supporting 60 000 scavenging birds for the whole year. The catch of this fleet, however, represents only one-fifth of all landings of shrimps from the coastal area of The Netherlands, Germany, and Denmark (annual mean total landings of 20 000 t between 1983 and 1992; Lozán, 1994). The estimated quantity of discards from other fisheries is 789 000 t and the number of birds theoretically sustained by this type of food is 5.9 million individuals (Garthe *et al.*, 1996). While only 1% of this figure can be supported in the Wadden Sea area of Lower Saxony, discards are proportionally more important given the number of breeding birds of the scavenging species in the same area (150 000 individuals; Südbeck and Hälterlein, 1995). The intense use of shrimp trawler discards suggests that they are an important food source for coastal seabirds especially during the breeding period, as was demonstrated for herring and lesser back-backed gulls in The Netherlands (Spaans, 1971; Noordhuis and Spaans, 1992), and also during migration, as in black-headed and common gulls.

Acknowledgements

Thanks are due to the crews of ''Polaris'' and ''Falke'', E. Ahrensfeld for assistance and K. Wilson for language support. We are grateful to several persons for advice during the project, and Jane Lancaster and an anonymous referee for valuable help. The work was supported by the Federal Environmental Agency, Environmental Research Plan of the Minister for the Environment, Nature Conservation and Nuclear Safety of the Federal Republic of Germany (Grant 108 02 085/21) and by the state of Lower Saxony. This is publication no. 266 of the project Ecosystem Research Wadden Sea.

References

Berghahn, R. and Rösner, H.-U. 1992. A method to quantify feeding of seabirds on discard from the shrimp fishery in the North Sea. Netherlands Journal of Sea Research, 28: 347–350.

Berghahn, R., Waltemath, M., and Rijnsdorp, A. D. 1992. Mortality of fish from the bycatch of shrimp vessels in the North Sea. Journal of Applied Ichthyology, 8: 293–306.

Bezzel, E. 1985. Kompendium der Vögel Mitteleuropas – Nonpasseriformes. Aula-Verlag, Wiesbaden.

Bryant, D. M. and Furness, R. W. 1995. Basal metabolic rates of North Atlantic seabirds. Ibis, 137: 219–226.

Camphuysen, C. J. 1993a. Scavenging seabirds behind fishing vessels in the Northeast Atlantic with emphasis on the southern North Sea. NIOZ Rapport 1993–1. 83 pp.

Camphuysen, C. J. 1993b. Feeding opportunities for seabirds in beamtrawl fisheries: a pilot study. Sula, 7: 81–104.

Camphuysen, C. J. 1994. Flatfish selection by herring gulls *Larus argentatus* and lesser black-backed gulls *Larus fuscus* scavenging at commercial beamtrawlers in the southern North Sea. Netherlands Journal of Sea Research, 32: 91–98.

Camphuysen, C. J., Calvo, B., Durinck, J., *et al.* 1995. Consumption of discards by seabirds in the North Sea. NIOZ Report 1995–5. 202 pp.

Camphuysen, C. J., Ensor, K., Furness, R. W., *et al.* 1993. Seabirds feeding on discards in winter in the North Sea. NIOZ Rapport 1993–8. 142 pp.

Camphuysen, C. J. and Leopold, M. F. 1994. Atlas of seabirds in the southern North Sea. IBN Research Report 94/6, NIOZ Rapport 1994–8. 126 pp.

Cummins, K. W. and Wuycheck, J. C. 1971. Caloric equivalents for investigations in ecological energetics. Mitteilungen der internationalen Vereinigung für theoretische und angewandte Limnologie, 18: 1–158.

Ehlert, W. 1961. Weitere Untersuchungen über die Nahrungswelt der Silbermöwe (*Larus argentatus*) auf Mellum. Vogelwarte, 21: 48–50.

Furness, R. W. 1992. Implications of changes in net mesh size, fishing effort and minimum landing size regulations in the North Sea for seabird populations. Joint Nature Conservation Committee Report No. 30. 60 pp.

Furness, R. W., Hudson, A. V., and Ensor, K. 1988. Interactions between scavenging seabirds and commercial fisheries around the British Isles. *In* Seabirds and other vertebrates: competition, predation and other interactions, pp. 240–268. Ed. by J. Burger. Columbia University Press, Columbia.

Garthe, S. 1993. Quantifizierung von Abfall und Beifang der Fischerei in der südöstlichen Nordsee und deren Nutzung durch Seevögel. Hamburger avifaunistische Beiträge. 25: 125–237.

Garthe, S., Camphuysen, C. J., and Furness, R. W. 1996. Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. Marine Ecology Progress Series, 136: 1–11.

Garthe, S. and Hüppop, O. 1994a. Gulls and fulmars following ships and feeding on discards at night. Ornis Svecica, 3: 159–161.

Garthe, S. and Hüppop, O. 1994b. Distribution of ship-following seabirds and their utilization of discards in the North Sea in summer. Marine Ecology Progress Series, 106: 1–9.

Glutz von Blotzheim, U. 1982a. Handbuch der Vögel Mitteleuropas, Band 8/I Charadriiformes (3. Teil). Akademische Verlagsgesellschaft, Wiesbaden. 699 pp.

Glutz von Blotzheim, U. 1982b. Handbuch der Vögel Mitteleuropas, Band 8/II Charadriiformes (3. Teil). Akademische Verlagsgesellschaft, Wiesbaden. 571 pp.

Goethe, F. 1956. Die Silbermöwe. A. Ziemsen, Wittenberg Lutherstadt. 95 pp.

Harris, M. P. and Hislop, J. R. G. 1978. The food of young puffins *Fratercula arctica*. Journal of Zoology, London, 185: 213–236.

Hislop, J. R. G., Harris, M. P., and Smith, J. G. M. 1991. Variation in the calorific value and total energy content of lesser sandeels (*Ammodytes marinus*) and other fish preyed on by seabirds. Journal of Zoology, London, 224: 501–517.

Hudson, A. V. and Furness, R. W. 1988. Utilization of discarded fish by scavenging seabirds behind whitefish trawlers in Shetland. Journal of Zoology, London, 215: 151–166.

Kock, K.-H. 1974. Nahrungsökologische Untersuchungen an Mantelmöwen (*Larus marinus*) auf Helgoland. Helgoländer wissenschaftliche Meeresuntersuchungen, 26: 88–95.

Leege, O. 1917. Die Nahrung der Silbermöwen an der ostfriesischen Küste. Ornithologische Monatsschrift 43: 110–116, 123–134.

Lozán, J. L. 1994. Über die ökologische und wirtschaftliche Bedeutung der Nordseegarnele im Wattenmeer mit Bemerkungen über andere Krebsarten. *In* Warnsignale aus dem Wattenmeer, pp. 117–122. Ed. by J. L. Lozán, E. Rachor, K. Reise, H. von Westernhagen, and W. Lenz. Blackwell Wissenschafts-Verlag, Berlin. 387 pp.

Lüttringhaus, C. and Vauk-Hentzelt, E. 1983. Ein Beitrag zur Ernährung auf Müllplätzen gesammelter Silber-, Sturm- und Lachmöwen (*Larus argentatus*, *L. canus*, *L. ridibundus*) von Emden und Leer. Vogelwelt, 104: 95–107.

Massias, A. and Becker, P. H. 1990. Nutritive value of food and growth in common tern *Sterna hirundo* chicks. Ornis Scandinavica, 21: 187–194.

Meijering, M. P. D. 1954. Zur Frage der Variationen in der Ernährung der Silbermöwe *Larus argentatus* Pont. Ardea, 42: 163–175.

Montevecchi, W. A., Rickleffs, R. E., Kirkham, I. R., and Gabaldon, D. 1984. Growth energetics of nestling northern gannets (*Sula bassana*). Auk, 101: 334–341.

Mudge, G. P. and Ferns, P. N. 1982. The feeding ecology of five species of gulls (Aves: Larini) in the inner Bristol Channel. Journal of Zoology, London, 197: 497–510.

Noordhuis, R. and Spaans, A. L. 1992. Interspecific competition for food between herring *Larus argentatus* and lesser black-backed gulls *L. fuscus* in the Dutch Wadden Sea area. Ardea, 80: 115–132.

Prawitt, O. 1995. Untersuchungen zur Bestimmungen der Fangkraft und des Fischereiaufwands von Krabbenkuttern. Diplomarbeit Universität Kiel. 82 pp.

Rumohr, H., Brey, T., and Ankar, S. 1987. A compilation of biometric conversation factors for benthic invertebrates of the Baltic Sea. Baltic Marine Biologist, 9: 1–56.

Spaans, A. L. 1971. On the feeding ecology of the herring gull *Larus argentatus* Pont. in the northern part of the Netherlands. Ardea, 59: 73–188.

Südbeck, P. and Hälterlein, B. 1995. Brutvogelbestände an der deutschen Nordseeküste im Jahre 1993–Siebte Erfassung durch die Arbeitsgemeinschaft ''Seevogelschutz''. Seevögel, 16: 25–30.

Walter, U. Quantitative analysis of discards from brown shrimp trawlers in the coastal area of the East Frisian islands. Archive of Fishery and Marine Research, 45 (i), in press.

Walter, U. and Becker, P. H. 1994. The significance of discards from the brown shrimp fisheries for seabirds in the Wadden Sea – preliminary results. *In* Birds and their ecology in the Wadden Sea, pp. 253–262. Ed. by M. Frederikson and K. Dahl. Ophelia (Supplement 6), Helsingör. 357 pp.

Wiens, J. A. and Scott, J. M. 1975. Model estimation of energy flow in Oregon coastal seabird populations. Condor, 77: 439–452.

Zwarts, L. and Wannink, J. H. 1993. How the food supply harvestable by waders in the Wadden Sea depends on the variation in energy density, body weight, biomass, burying depth and behaviour of tidal-flat invertebrates. Netherlands Journal of Sea Research, 31: 441–476.