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Assessment of the zoobenthos biomass consumed yearly by diving ducks wintering in the Gulf of Gdańsk (southern Baltic Sea)

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Abstract

Numbers, distribution and food contents of seven common diving ducks (*Clangula hyemalis, Melanitta fusca, Melanitta nigra, Aythya marila, Aythya fuligula, Bucephala clangula, Somateria mollissima*) and *Fulica atra* were studied in the Gulf of Gdańsk during September–April, 1987/88–1996/97. The number of animal food taxa consumed was at least 23. The birds fed mainly on bivalves (79.4% of the food volume), and fish (7.1%), gastropods (6.7%) and crustaceans (5.0%) constituted the remaining significant prey. *Mya arenaria, Cerastoderma glaucum* and *Hydrobia sp.* were preferred, while *Mytilus trossulus*, dominating in the shallow parts of the gulf, was taken in lower proportions. Small ducks (*Aythya, Clangula*) selected bivalves of shell length 7–14 mm regardless of their different average size in zoobenthos. The two biggest ducks (*Somateria mollissima* and *Melanitta fusca*) selected the largest (above 30 mm) of the available *Mya arenaria* specimens. Birds consumed proportionally more bivalves in December and January than later in the season. Fish (mainly fish eggs) increased their share in spring. Diving ducks and Coot function generally as first to forth-order carnivores in the food web. As a consequence of their high numbers and long period of stay, annual biomass consumption is considerable: 25,000 tonnes, including 20,000 tonnes bivalves, 1800 tonnes fish, 1700 tonnes gastropods and 1270 tonnes crustaceans. For bivalves this is ca 13 % of the total biomass in the Gulf. The strongest exploitation of bivalves takes place in December–February, when their proportion in the diet is highest and the birds are most numerous, and concerns the shallow water areas where ducks and coots concentrate. In such areas they can exert significant predatory pressure on preferred size classes of their most important prey.

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Introduction

Marine birds constitute an important component of the ecosystem and have a significant impact on its functioning and energy flow, especially in coastal and surface waters (Ashmole 1971, Brown 1980, Powers 1983, Furness & Monaghan 1987, Mehlum & Gabrielsen 1995). The majority of them are predators on detritophages (e.g. such benthophages as diving ducks *Aythya sp.*, *Bucephala sp.*, *Clangula sp.*, *Melanitta sp.*, and *Somateria sp.*) and higher level predators (e.g. fish eating divers *Gavidae*, sawbills *Mergini*, grebes *Podicipedidae*, auks *Alcidae*, cormorants *Phalacrocoracidae*). Exceptions are partly or exclusively herbivorous ducks *Anas sp.*, geese *Anser sp.*, and *Branta sp.*, and swans *Cygnus sp.* feeding in the most shallow, coastal zone (Stempniewicz 1991). Birds can remove as much as 30% of the annual production of fish and marine invertebrates (Wiens & Scott 1975, Furness 1978, 1982, 1990, Ainley & Sanger 1979, Hunt et al. 1981). In the Antarctic they eat much more krill, cephalopods and fish than do the whales, i.e. about 30–40 million tonnes yearly (Croxall & Prince 1980, Croxall et al. 1984, Furness & Monaghan 1987). The excreta of the birds contain soluble inorganic fractions with mineral salts easily assimilated by phytoplankton. In that way areas of the sea where large numbers of marine birds concentrate (breeding, moulting and wintering grounds) are regularly fertilised and are characterised by higher primary productivity (Golovkin 1967, Zelickman & Golovkin 1972, Galkina 1974, 1977, Golovkin & Garkavaya 1975, Bedard et al. 1980, Jorde & Owen 1988).

The Baltic Sea is one of the most important wintering areas for boreal and arctic marine ducks in western Palearctic (Cramp & Simmons 1977, Laursen

1989). During winter, diving ducks usually occupy shallow (3–15 m deep) inshore waters with abundant food making bottom feeding efficient. Some of them (e.g. Long-tailed Ducks *Clangula hyemalis*) can reach depths of 60 m and spend as long as one minute under water (Mathiasson 1970, Nilsson 1972, Cramp & Simmons 1977). Their diets differ regionally and seasonally and consist mainly of marine invertebrates and fish (Madsen 1954, Olney 1963, Pethon 1967, Nilsson 1972, Petersson & Ellarson 1977, Ainley & Sanger 1979, Sanger & Jones 1984, Goudie & Ankney 1986, Durinck et al. 1993). The Gulf of Gdańsk has high biological productivity, and important commercial fisheries. Surveys of marine birds show high concentrations of diving birds in the area between October and May (Górski & Strawiński 1986, Kochan 1993, Meissner 1993a,b, Meissner & Klawikowska 1993, Meissner & Maracewicz 1993, Meissner & Sikora 1993, Michno et al. 1993). Each season about 17,500 ducks drown in fishing nets set in the gulf (Stempniewicz 1994).

There are scarce data on feeding ecology of diving ducks from the Baltic Sea. Madsen (1954) collected data from the Kattegat region, Bagge et al. (1973) from the Gulf of Bothnia, Nilsson (1970, 1972) carried out extensive studies in Swedish coastal waters, and Meissner & Brager (1990) in the region of Schleswig-Holstein, Germany. Only scarce published information (Stempniewicz 1986, 1995) and several MSc Theses (Szuksztul 1975, Mikulak 1989, Jastrzębska 1990, Skowron 1990, Maciejkowicz 1991) are available from southern Baltic including Polish coast. There is no paper considering the complex role of birds in the marine ecosystem of the Gulf of Gdańsk.

The objectives of this study were to determine numbers, phenology, distribution, and food composition of the most common benthophagic diving birds wintering in the area. On that basis the annual consumption of the main prey in the Gulf of Gdańsk has been estimated, and the role of marine birds in the trophic structure of the coastal ecosystem is discussed.

Material and methods

The study area covered the shallow (2–10 m) coastal waters of the whole Polish part of the Gulf of Gdańsk. In the western part of the Gulf, i.e. from Vistula Mouth to Cape Rozewie, birds present within a distance of 600 m were counted from the shore by the Waterfowl Research Group "Kuling" (Meissner 1993a). Six regions with different shore line characteristics, depths, situation in relation to the open sea etc., were distinguished. They were: (1) Vistula Mouth, protected against wind, but periodically covered with abundant ice floes carried by the river (7 km); (2) mostly urbanised coast along Gdańsk, Sopot and Gdynia, with numerous hydrotechnical constructions (ports, piers, promenades; 45 km); (3) Puck Bay, shallow, isolated from the open sea (33.5 km); (4) inner part of the Hel Peninsula not exposed to the open sea (12 km); (5) outer part of the Hel Peninsula exposed to the open sea (31.5 km). The sea shore between Vistula Mouth and Piaski on the Vistula Spit (6) was covered by counts from an airplane. In total, 19 aerial counts were done in all months during the three seasons 1986/87 – 1988/89. Shoreline counting was done once a month (September–April) during 10 winter seasons (1987/88–1996/97). They took place at the same time in all sectors to avoid errors resulting from bird flock movements. In addition, bird distribution was studied from a ship (17 cruises along the same ca 50 km route during the three winter seasons 1985/86 – 1987/88; observers were Stefan Strawiński and Jarmiła Ulatowska) (Figure 1).

According to the recommendations given by Komendeur et al. (1992) and Durinck et al. (1994), the estimation of the total number of birds present in the

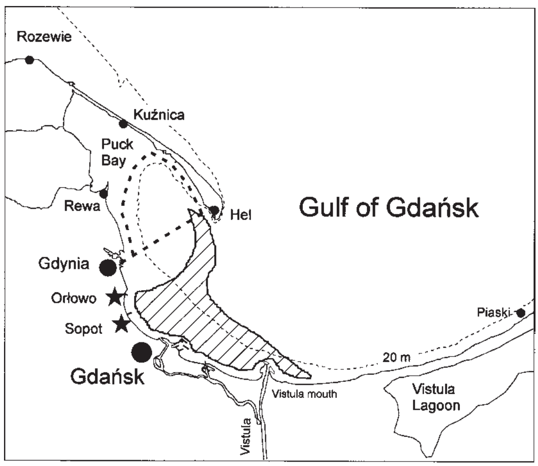

Figure 1. Area of the Gulf of Gdańsk, Southern Baltic (I–VI – sectors, dotted line – ship route, asterisks indicate the fishing ports, Orłowo and Sopot, where net catches were collected; shading indicates fishing grounds).
Gdanskbukten i södra Östersjön med undersökningssektorerna I–VI och räkningsrutt med båt (prickad linje). Asterisker anger fiskehamnarna Orłowo och Sopot, där nätfångade fåglar insamlades. Skuggning anger fiskeområden.

study area was based only on the results of the counts undertaken from the shore (regions 1–5) and from the air (region 6). The results of the boat counts were used only to establish bird distribution.

To estimate the true numbers of birds present in the whole study area, the data from the coastal counts were multiplied by a distribution index (DI) which was calculated on the basis of bird distribution in relation to distance from the shore as recorded from the ship and the airplane. Also, large-scale data on diving bird numbers and distribution in relation to water depth (Durinck et al. 1994) were taken into consideration, as well as results obtained by Sikora (1993) who studied bird distribution and density along the transect between Gdynia and Hel (September–April, four winter seasons, 1985/86 – 1988/89). The DI value differs between bird species and regions, in relation to bottom character, water depth, protection against wind, etc. The following average values of DI have been assumed: 1.0 for Coot *Fulica atra*, 1.1 for *Aythya sp.*, eider *Somateria mollissima* and goldeneye *Bucephala clangula*, 3.0 for scoters *Melanitta sp.*, and 5.0 for Long-tailed Duck.

Birds entangled and drowned in nets were collected from two fishing ports Orłowo and Sopot. Fishing nets are set all year around but the main fishing season (November–April) coincides with the wintering season of the marine birds in the Gulf of Gdańsk. The birds were collected 1–3 times a week over 5 seasons (November–May) from 1986 to 1990. In total 772 food samples including 275 Long-tailed Ducks, 241 Velvet Scoters, 94 Scaups, 52 Common Scoters, 67 Eiders, 18 Tufted Ducks, 13 Goldeneyes and 12 Coots were collected and analysed in detail.

The birds were thoroughly examined and dissected in the laboratory. The total contents of the oesophagus, proventriculus and gizzard were preserved in a 4% formaldehyde solution and analysed later in the laboratory. Each sample was washed on 0.5 mm mesh size screen and analysed under stereo microscope. The material was sorted and then identified to the lowest possible taxonomic level. The number, length and volume of all identifiable food items were noted. The number of fish and polychaetes ingested was estimated as half the number of otholits and jaws found in the samples. To present the results of the

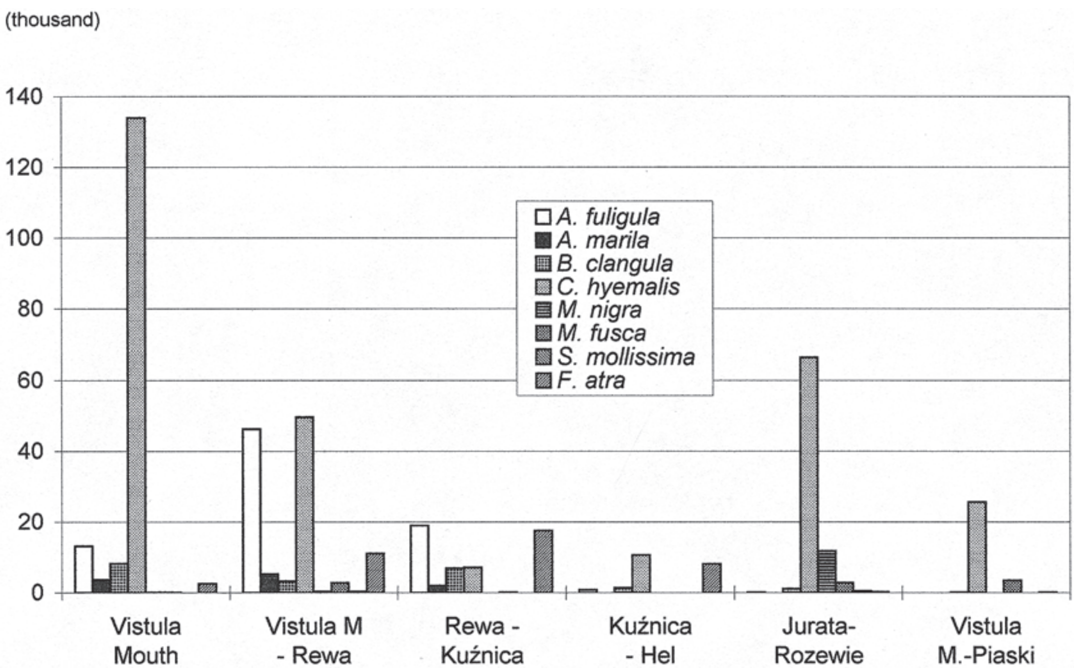

Figure 2. Mean number of diving birds observed in the particular sections of the study area during the whole season (DI taken into account).

Medeltalet dykänder i de olika sektorerna under hela säsongen (efter korrektion; se texten).

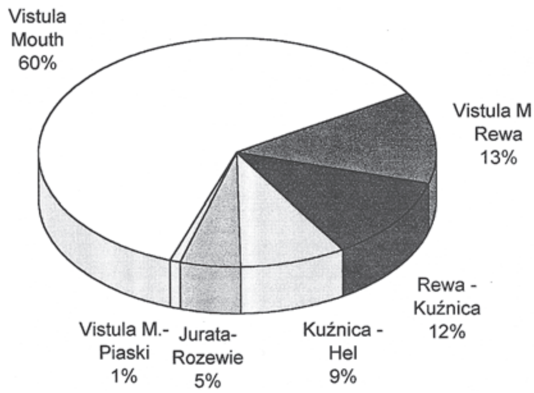

Figure 3. Distribution of the diving birds wintering in the Gulf of Gdańsk (mean number of birds observed during the whole season per 1 km of the sectors, expressed as % of the total number).

Utbredningen av dykande fåglar i Gdanskbukten vintertid (medeltalet fåglar under hela säsongen per kilometer kust, uttrykct som procent av totala antalet)

analyses of the food samples, frequency of occurrence (%FO) was determined as the percentage number of samples containing a given prey type. Also, percentage by volume (%V) of particular prey taxa was calculated from the samples containing more or less intact prey items.

The biomass of benthic animals consumed yearly by the wintering birds was estimated on the basis of bird numbers and period of their stay in the area (number of bird-days calculated as monthly means multiplied by 30 or 31), daily energy demands, food composition and assimilation rate of the main preys.

Results and discussion

Bird numbers and distribution

The most attractive regions for wintering diving birds appeared to be those protected against wind and waves, like Vistula Mouth (sector 1), where the number of birds (especially Long-tailed Ducks) was highest. Also the urbanised coast with numerous ports, piers and promenades (sector 2) and the shallow Puck Bay, isolated from the open sea (sector 3), were inhabited by large flocks of birds. The outer part of the Hel Peninsula and the Vistula Spit (sectors 4–6), exposed to the open sea, were least frequented by birds (Figure 2 and 3).

The highest number of wintering birds (75–90 thousand) was noted in the Gulf in December, January and February. Long-tailed Duck was most numerous, constituting 63–66% of the total number during that period and even exceeding 80% in April. Tufted Duck was the second most common (December–February: 12–22%; max.: November – ca 30%) and Eider was least numerous species (of 7 species taken into account; Table 1, Figure 4).

Food composition

Diving birds wintering in the Gulf of Gdańsk ingested at least 23 animal food taxa. The most important food component, found in almost every sample (%FO=98.5–100.0%), were bivalves. They constituted ca 80 % of the total food content volume (highest value, ca 95%, in Common Scoter and Coot, and lowest, ca 60 %, in Scaup and Goldeneye). *Mya arenaria*, *Mytilus trossulus* and *Cerastoderma glaucum* were taken most often, then *Macoma baltica*. Sand Gaper, the largest bivalve, was preferred

Table 1. Mean number (10 seasons) of common diving birds during each month of their stay in the Gulf of Gdańsk.

Medeltal individer för tio säsonger av vanliga dykande fåglar varje månad under deras vistelse i Gdanskbukten.

Species Art	September	October	November	December	January	February	March	April	in total
A. fuligula	258	10527	17915	17428	12128	11213	7565	3490	80524
A. marila	31	1541	1505	1949	2903	2237	1233	220	11620
B. clangula	168	463	1779	617	7065	7071	3288	309	20760
C. hyemalis	8	29185	29546	48945	56710	59216	37501	32707	293820
M. nigra	342	572	2180	2733	1836	2066	1243	1464	12437
M. fusca	12	83	267	1302	1686	2995	2076	511	8931
S. mollissima	157	182	83	138	106	101	74	100	942
F. atra	10890	8179	5247	3594	3364	4156	4065	1047	40542
in total	11864	50732	58523	76707	85799	89056	57046	39849	469576

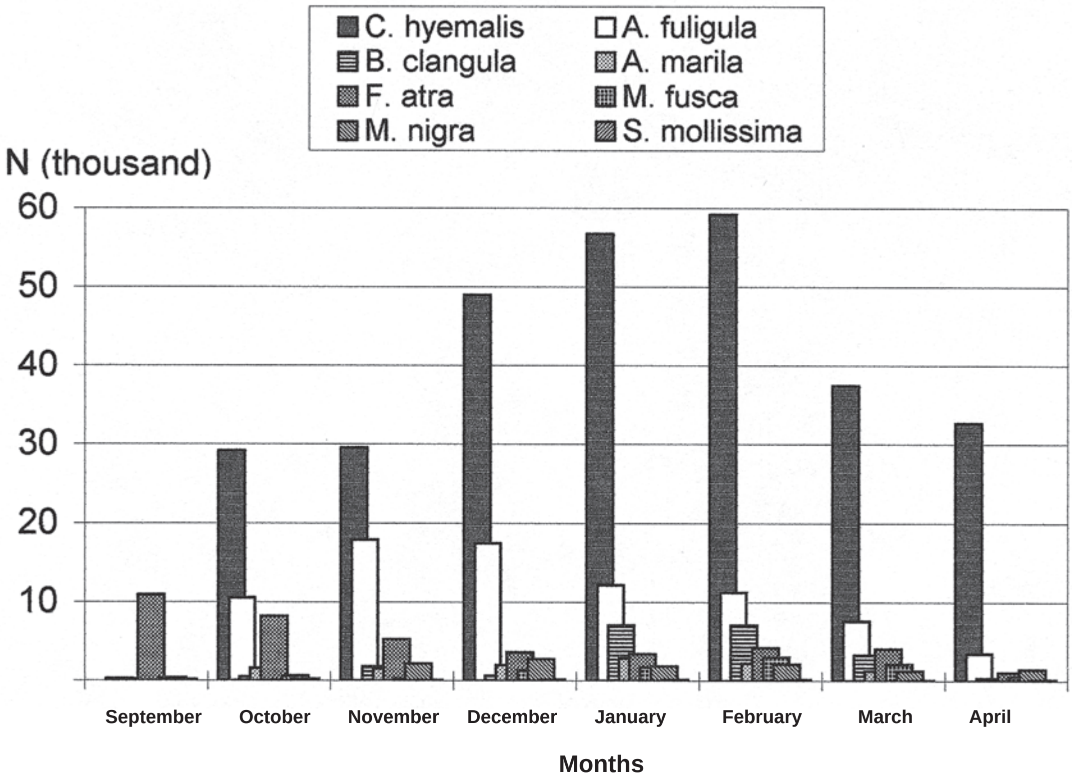

Figure 4. Seasonal changes in number of birds wintering in the Gulf.
Säsongsmässiga förändringar i antalet övervintrande fåglar i Gdanskbukten.

by the biggest ducks, Eider and Velvet Scoter (51 %V and 41 %V, respectively). Blue Mussel, the most abundant bivalve in the gulf was taken in highest proportions by Coot (ca 90 %V) and Goldeneye (ca 50 %V). Fish, mostly sandlances *Ammodytidae*, as well as fish eggs constituted 7.1% of total stomach contents. Their share was highest in Velvet Scoter (ca 23 %V) and Eider (ca 14 %). Gastropods (6.7%V in total) were taken in considerable amounts by *Aythya* ducks (Scaup – ca 40 %V and 98 %FO; Tufted Duck – 12 %V and 67 %FO). Crustaceans were ingested in smaller amounts (5.0 %V in total), mainly by Goldeneyes. Polychaetes and plants were found incidentally in food samples (Table 2, Figure 5). However, these quantitative results should be interpreted with caution. Proportions of particular food items found in the diet are almost certainly biased due to different digestion rates of hard-shelled and soft-bodied prey. Bivalves are usually over-represented in samples where gizzard contents predominate, and abundant small prey is overestimated by the frequency of occurrence coefficient (Sanger & Jones 1984, Stempniewicz 1995).

In general, the food selection of the diving birds reflects roughly the food resources in the Gulf of Gdańsk. However, the Blue Mussel, being an absolute dominant in the Gulf, was taken by birds in less proportions. On the other hand, the Sand Gaper, constituting one of the most important food prey, belongs to the least numerous bivalves in the Gulf (Beil 1977, Gostkowska & Turas 1988). However, such comparisons are risky because data for zoobenthos are large scale and average for the whole Gulf. Diving birds feed in preferred areas which certainly differ very much from the general picture of numbers, distribution and proportions of benthic animals.

The proportion of bivalves in the diving birds' diet tended to decrease with the progress of the wintering season in the Gulf of Gdańsk. This is a result of a sharp decrease in the share of blue mussel and also cockle in the food samples towards the spring. Fish,

Table 2. Mean volume (%V) and frequency of occurrence (%FO) of the food taxa taken by diving birds wintering in the Gulf of Gdańsk.

Medelvolym (%V) och förekomstfrekvens (%FO) av olika födoslag tagna av övervintrande dykande fåglar i Gdanskbukten.

	Clangula hyemalis		*Melanitta fusca*		*Melanitta nigra*		*Aythya marila*		*Aythya fuligula*		*Somateria mollissima*		*Bucephala clangula*		*Fulica atra*		*Mean*
Taxon	%V	%FO	%V	%FO	%V	%FO	%V	%FO	%V	%FO	%V	%FO	%V	%FO	%V	%FO	%V
Plantae in total	x	17.8	x	4.3	-	-	2.2	51.0	-	-	0.8	10.4	-	-	4.6	38.4	0.9
Polychaeta in total	6.4	26.7	0.4	23.9	-	-	0.1	6.4	-	-	x	3.0	-	-	-	-	0.9
Priapulida	x	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x
Mya arenaria	27.2	68.5	41.0	86.7	34.0	72.5	28.6	100	5.7	77.8	50.9	82.1	5.0	33.3	3.0	24.7	24.4
Macoma baltica	25.5	52.0	22.5	76.5	24.7	51.0	2.7	71.2	24.2	88.9	1.5	12.0	3.3	33.3	1.1	9.8	13.2
Cerastoderma glaucum	11.2	32.9	10.2	32.1	35.0	56.9	26.4	97.9	54.1	83.3	2.2	20.9	5.8	33.3	1.3	11.2	18.3
Mytilus trossulus	15.3	36.3	2.2	15.3	0.2	3.9	0.8	20.2	4.4	22.2	28.7	55.2	47.1	100	89.2	100	23.5
Bivalvia in total	79.2	99.3	75.9	98.5	93.8	100	58.5	100	88.4	100	83.3	100	61.2	100	94.6	100	79.4
Hydrobia ventrosa	1.8	24.0	0.1	10.9	x	2.0	39.3	97.9	11.6	66.7	0.2	11.9	-	-	-	-	6.6
Gastropoda in total	1.8	28.8	0.1	13.0	x	2.0	39.3	97.9	11.6	66.7	0.2	13.4	0.7	33.3	-	-	6.7
Cirripedia	0.1	4.1	x	3.8	-	-	-	-	x	11. 1	1.2	29.9	2.3	33.3	0.8	28.1	0.5
Amphipoda	0.4	7.5	-	-	-	-	-	-	-	-	x	5.9	23.7	100	x	16.2	3.0
Mysidacea	0.6	9.6	-	-	-	-	-	-	-	-	-	-	9.4	66.7	-	-	1.2
Decapoda	0.5	3.4	x	0.5	-	-	-	-	-	-	x	1.5	-	-	-	-	0.1
Isopoda	x	9.8	0.2	1.5	-	-	-	-	-	-	-	-	-	-	-	-	x
Crustacea in total	2.3	24.7	0.2	4.5	-	-	-	-	x	11.1	1.3	32.8	35.4	100	0.8	31.0	5.0
Ammodytidae	2.5	13.7	10.1	16.2	6.2	19.2	-	-	-	-	-	-	2.0	33.3	-	-	1.7
other	0.7	11.8	1.0	14.3	-	-	x	1.1	x	11.1	4.3	25.4	0.7	33.3	-	-	0.7
fish eggs	6.3	8.9	1.0	9.9	x	7.1	-	-	-	-	4.3	25.4	-	-	-	-	1.4
Pisces in total	10.2	19.2	23.4	44.0	6.2	19.2	x	1.1	x	11.1	14.4	34.3	2.7	33.3	-	-	7.1

x - traces.

and particularly fish eggs, generally increased their share during the wintering season constituting as much as ca 40% of food volume in the spring months (Figure 6).

Prey size

Mean size of the three most important food items, i.e. *Macoma baltica, Mya arenaria* and *Mytilus trossulus*, taken by diving birds was similar (7–14.1 mm) in spite of the fact that these bivalves differ largely in size (Frączkowska 1974, Beil 1977, Cuena & Wołowicz 1981, Wołowicz 1984). It seems that the birds selected mainly one size class from a much wider spectrum of prey sizes. However, the mean size of Sand Gapers taken by Eiders and Velvet Scoters (36.1 and 32.1 mm, respectively) differ considerably from those of other bivalves, as well as from the average size of Sand Gapers found in zoobenthos (Beil 1977). This suggests that large ducks prefer large food items and actively select them from their available food (Figure 7).

The size of prey is limited by the size of the bill and throat of the birds. Bivalves of ca. 7–14 mm length appear to be optimal food for all small ducks (Long-tailed Duck, Scaup, Tufted Duck). Specimens of that size class are common in all bivalve species occurring in the Gulf (Frączkowska 1974, Beil 1977, Cuena & Wołowicz 1981, Wołowicz 1984). Feeding on smaller bivalves could be less efficient despite their higher numbers. Larger specimens, however, contributing more energy because of size and higher

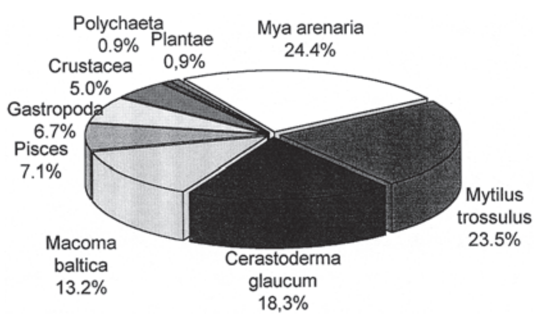

Figure 5. Mean food content (% volume) of 8 common benthophagic diving birds.
Medeltal för födoinnehållet (% volym) för 8 vanliga dykande fåglar som lever av bottenorganismer.

body to shell ratio, occur in much lower density, making feeding on them (time spent for searching) often less profitable. The largest bivalves found in the food samples were 55.0 mm Sand Gapers. According to optimal foraging theory (Krebs & Davies 1981, Draulans 1982, Ydenberg 1988) diving birds select as large available items (contributing much energy) as they are able to catch and swallow.

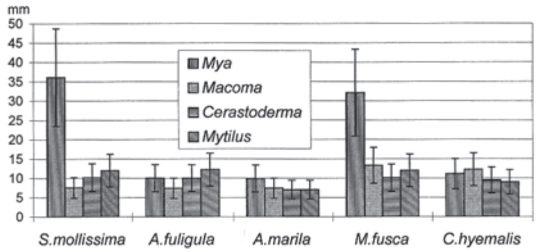

Figure 7. Mean size (± SE) of four bivalve species taken by 5 diving ducks in the Gulf of Gdańsk.
Medelstorleken (± SE) hos fyra musslor som tas av fem dykänder på botten av Gdanskbukten.

Assessment of annual food consumption

Body size, ambient temperature, type of flight, activity, etc. largely influence daily energy expenditure in birds (Kendeigh et al. 1977, Whittow & Rahn 1984). For diving seabirds with an active type of flight, staying in a cold water zone, the regression equation (derived using double labelled water) relating field metabolic rate and body weight has the form: log y = 3.24 + 0.727 log x; where y is field metabolic rate (FMR) in kJ/24h, and x is body weight in kg (Birt-Friesen et al. 1989). By substituting the mean body weight of the most common small ducks (Cramp & Simmons 1977, Stempniewicz, unpubl. data) the value of their FMR amounts to at least 1500 kJ/24h.

The average values of water content (57.8%), proportion of shell to body weight (85.9%) and thus energetic value (21 kJ/g dry weight) for the bivalves from the Gulf of Gdańsk were taken from Szaniawska et al. (1986) and Pazikowska & Szaniawska (1988). Based on these assumptions, an average value of energy content of wet mass of four bivalve species was calculated to be 1.2 kJ/g. Assuming 70% assimilation rate (Wiens & Scott 1975, Furness 1978, Whittow & Rahn 1984), the diving birds wintering in the Gulf of Gdańsk assimilate ca. 0.84 kJ from 1 g of wet mass of bivalves (with shell) or 6.12 kJ from 1 g of wet body mass (without shell). Taking 1500 kJ as the daily energy demand, this equals the consumption of 1786 g and 245 g, respectively, of wet bivalve mass. On that basis, the equivalent bivalve biomass (food demand) was estimated. A similar procedure was used when estimating consumption of fish, gastropods and crustaceans. Their average energetic contents were taken from the literature (Brown & Nettleship 1984, Jorde & Owen 1988).

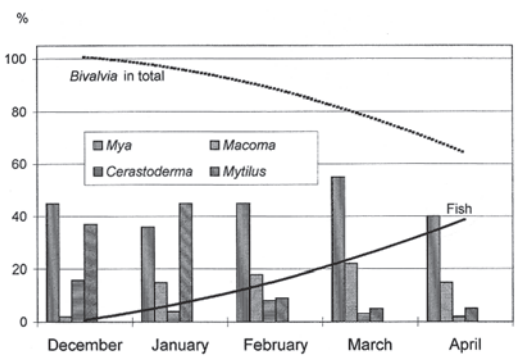

Figure 6. Seasonal changes in % volume of bivalves and fishes in diets of 3 common diving ducks (Long-tailed Duck, Velvet Scoter and Eider). Lines: multinomial trends (solid line – fish in total, dotted line – bivalves in total).
Säsonsmässiga förändringar i % volym av musslor och fiskar i dieten för 3 vanliga dykänder (alfågel, svärta och ejder).

Assessment of annual consumption of the main preys taken by birds in the Gulf of Gdańsk based on mean number of birds in the study area, period of staying (birds x days) and their food composition. During one wintering season, the diving ducks and the Coot consume ca. 20,000 tonnes of bivalves, 1800 tonnes of fish, 1700 tonnes of gastropods and 1270 tonnes of crustaceans. Consumption of prey taxa constituting less than 1% of diet was not estimated (Table 3, Figure 8).

Benthic invertebrates may suffer higher mortality caused by feeding birds than estimated for some reasons. Not all common diving ducks were included in the estimate because of lack of food content data (e.g. Pochard *Aythya ferina*). As it was pointed in an earlier paper (Stempniewicz 1995), birds (especially Coots) often damage bivalves when pecking off a lump of blue mussels picked up from the bottom onto the surface (Stempniewicz 1974) or by cutting and eating only siphons of large Sand Gapers (e.g. Long-tailed Duck). As a result, the material removed (MR) by feeding birds may be considera-

Table 3. Estimated energy demand and biomass of main food taxa consumed by diving birds during one wintering season.
Uppskattat energibehov och biomassa för de huvudsakliga födoslag som konsumeras av dykande fåglar under en vinter.

Months *Månad*	September	October	November	December	January	February	March	April	In total
Total number of birds[1] *Totalt antal fåglar[1]*	11.9	50.7	58.5	76.7	85.8	89.1	57.0	39.9	469.6
N x days (D)[2] N x dagar (D)[2]	357.0	1571.7	1755.0	2377.7	2659.8	2494.8	1767.0	1197.0	14180.0
Energy demand[3] *Energibehov[3]*	5.36E+08	2.36E+09	2.63E+09	3.57E+09	3.99E+09	3.74E+09	2.65E+09	1.8E+09	2.13E+10
Biomass consumed[4] *Konsumerad biomassa[4]*	637.5	2806.6	3133.9	4245.9	4749.6	4455.0	3155.4	2137.5	25321.4
Bivalvia	527	2270	2490	3390	3780	3559	2510	1700	20105.2
Mya arenaria									6178.4
Macoma baltica									3342.4
Cardium glaucum									4633.8
Mytilus edulis									5950.5
Pisces									1797.8
Gastropoda									1696.5
Crustacea									1266.1

[1] Sum of mean monthly numbers of birds (N, thousands) *Summa av medeltalet fåglar varje månad (N, tusental)*
[2] N x days of staying (D, in thousands) *N x antalet vistelsedagar (D, tusental)*
[3] Energy demand (D x 1500 kJ/24h) *Energibehov (D x 1500 kJ/24 timmar)*
[4] Biomass (t) consumed per season (70% assimilation) *Biomassa (t) konsumerad under en säsong (70% assimilation)*

bly larger than that consumed. Moreover, the proportions of fine and soft animals (crustaceans, polychaetes, oligochaetes, insect larvae, etc.) are usually underestimated in water birds diets (Nilsson 1972, Sanger & Jones 1984, Goudie & Ankney 1986). This also concerns the results of the present paper. The reason is that soft-bodied animals are crumbled, digested and assimilated much easier and faster than those covered with shell or hard carapace. Bivalves, for instance, stay in the duck alimentary tract for 30–40 min. (Grandy 1972).

During winter, the stocks of epibenthic molluscs are depleted as a result of storms which destroy especially the Blue Mussel beds (Rees et al. 1977), and due to waterfowl and fish consumption. These two phenomena (consumption and hydrodynamic abrasion) most possibly reinforce each other (Brager et al. 1995). The infauna (Mya, Macoma, Cerastoderma) may also be better exposed and more easily available to diving birds soon after storms (Leipe 1985).

By feeding on marine invertebrates birds remove part of the yearly production. Very rough estimation of total mussel biomass in the Polish part of the Gulf of Gdańsk, based on the average combined density of the four bivalves in the 0–20 m. deepth zone (200 g/m2; M. Wołowicz, personal information) and the area of that zone (765 km^2; J. Cyberski, personal information), gives a value of ca 153,000 tonnes.

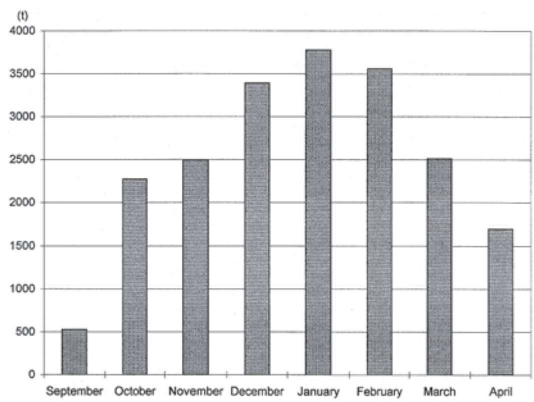

Figure 8. Estimated biomass of bivalves (t) consumed by birds during consecutive months of the wintering season in the Gulf of Gdańsk (70% assimilation).
Uppskattad biomassa av musslor (t) som konsumeras av fåglar olika måndader av vintern i Gdanskbukten.

Then, yearly consumption of benthophagic birds would constitute as much as ca 13% of the total bivalve resources in the gulf. Most probably, these losses are easily supplemented by the high production of the mussels. However, the predatory pressure of diving birds is temporally and spatially unequal. During the winter months (December–February), with the highest numbers of marine birds in the shallow zone (0–20 m.) and particularly in areas with great aggregations of feeding birds (e.g. the regions of Vistula Mouth and Puck Bay), the diving birds exert a significant pressure on bivalves of preferred age and size classes. The carrying capacity of shallow waters is limited by the food resources which may be locally reduced below a level of profitable feeding.

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Sammanfattning

Beräkning av de övervintrande dykändernas årliga konsumtion av bottendjur i Gdanskbukten

Marina fåglar utgör en viktig del av ekosystemen och har stor inverkan på deras funktion och energiflöden, särskilt nära kusterna och i ytvattnen. De flesta är predatorer på detritusätare (flertalet dykänder) eller på predatorer högre upp i näringskedjorna (fiskätande lommar, skrakar, doppingar, alkor och skarvar). Undantag är växtätande simänder, gäss och svanar, som lever i de allra grundaste kustnära områdena. Fåglar kan konsumera så mycket som 30% av den årliga produktionen av fisk och marina evertebrater. I Antarktis konsumerar fåglarna mer krill, bläckfiskar och fiskar än valarna.

Östersjön är en av de viktigaste övervintringsområdena för boreala och arktiska dykänder i västra Palearktis. Med undantag för alfågeln, som kan dyka till 60 m djup, söker de flesta övriga arter sin föda på 3–15 m djup. Gdanskbukten har hög biologisk produktivitet och viktigt kommersiellt fiske. Inventeringar har visat att det finns stora koncentrationer av sjöfåglar i bukten mellan oktober och maj. En indikation på detta är också att omkring 17.500 änder drunknar i fisknät varje säsong.

Det finns förhållandevis litet information om födokonsumtionen bland dykänder från Östersjöområdet och ingen undersökning som behandlar deras komplexa roll i det marina ekosystemet i Gdanskbukten. I denna uppsats redogör jag för antal, säsongsuppträdande och födoval hos de vanligaste dykänder som hämtar sin föda från bottnen. På detta sätt kan deras roll i det marina ekosystemets trofiska struktur uppskattas.

Material och metodik

Undersökningen täcker vattnen med djup på 2–10 m längs hela den polska delen av Gdanskbukten. I västra delen, mellan Vistulas mynning och Kap Rozewie, räknades fåglarna ut till 600 m från land. Kusten indelades i sex regioner med olika egenskaper: (1) Vistulas mynning, vindskyddad men periodvis täckt av is, 7 km, (2) mestadels urbaniserad och industrialiserad kust vid Gdansk, Sopot och Gdynia, 45 km, (3) Puckbukten, grund och isolerad från öppna havet, 33,5 km, (4) inre delen av halvön Hel, skyddad från öppna havet, 12 km, (5) yttre delen av Hel, exponerad för öppna havet, 31,5 km samt (6) kusten mellan Vistulas mynning och Piaski. Områdena 1–5 räknades från land och område 6 från flygplan. Landräkningarna utfördes en gång i månaden (september – april) under tio vintrar (1987/88 – 1996/97). Flygräkningarna utfördes vid 19 tillfällen månatligen under tre säsonger, 1986/87 – 1988/89. Dessutom utfördes 17 räkningar från båt längs en 50 km lång fast rutt de tre säsongerna 1985/86 – 1987/88, vilka dock endast användes för att fastställa fåglarnas utbredning.

Den information om fåglarnas utbredning från kusten och utåt som erhölls från flyg och båt, tillsammans med annan information om fåglarnas val av vattendjup, användes för att korrigera räkningssiffrorna till mera korrekta värden. Sifforna multiplicerades med följande faktorer: 1,0 för sothöna, 1,1 för *Aythya*-arterna, ejder och knipa, 3,0 för för svärta och sjöorre samt 5,0 för alfågel.

Vi samlade också in de fåglar som hade drunknat i fisknät i hamnarna Orlowo och Sopot under november – maj åren 1986 – 1990. Maginnehållet analyserades i detalj hos 275 alfåglar, 241 svärtor, 94 bergänder, 52 sjöorrar, 67 ejdrar, 18 viggar, 13 knipor och 12 sothöns. Resultaten presenteras som andelen prov med förekomst av olika byten, men även volymsprocent ges för prover med mer eller mindre intakta bytesrester. Mängden konsumerade byten beräknades på grundval av antal fåglar, antal dagar de vistades i området, energibehovet, födans sammansättning samt assimilationshastigheten för de viktigste bytesslagen.

Resultat och diskussion

Det högsta antalet fåglar (75.000 – 90.000) registrerades i december, januari och februari. Alfågeln var vanligast och utgjorde 63–66% av alla individer och kunde nå upp till 80% i april, och viggen var näst vanligast med 12–22% i december – februari och maximalt 30% i november (Tabell 1, Figur 4). De attraktivaste områdena var de som var skyddade från vind och vågor, såsom Vistulas mynning (sektor 1). Andra viktiga områden var sektorerna 2 och 3, medan de exponerade sektorerna 4–6 hade färre fåglar (Figur 2 och 3).

Totalt registrerades byten från 23 olika djurgrupper. Viktigast var musslor, som förekom i nästan alla prover. Volymsmässigt utgjorde musslor 80% av födan, mest, 95%, hos sjöorre och sothöna och minst, 60%, hos bergand och knipa. Detaljerna framgår av Tabell 2 och Figur 5. Dessa resultat måste dock tolkas med försiktighet eftersom olika födoslag har olika nedbrytningshastighet. Exempelvis överskattas ofta små bytens betydelse med frekvensvärdena. Överlag speglar bytesvalet de olika bytesslagens förekomst i Gdanskbukten. Undantag är blåmusslan, som är den absolut dominerande arten, men vars förekomst i proverna var lägre än dess andel av bottenfaunan. Motsatsen gäller sandmusslan, som var ett av de viktigaste bytena, men som är en av de mindre vanliga arterna på bottnen. Även här måste tolkningen ske med reservationer eftersom kännedomen om bottenfaunan gäller hela Gdanskbukten medan fåglarna söker föda i utvalda områden som kan ha annan sammansättning. Säsongsmässigt sjönk musslornas betydelse på senvintern medan betydelsen av fiskägg ökade och kunde uppgå till så mycket som 40% av volymen på våren (Figur 6).

De olika änderna valde musslor inom ett ganska snävt och likartat storleksintervall (7–14 mm) trots att musslorna varierar mycket i storlek. Däremot var ejdrarnas och svärtornas val av storlek på sandmusslor annorlunda än för andra musslor (36 resp. 32 mm), och dessa mått var också andra än genomsnittet på bottnarna. De större änderna väljer således aktivt de största musselindividerna (Figur 7). Bytesstorleken begränsas av näbbens och matstrupens vidd, och för de mindre änderna verkar en storlek på 7–14 mm vara den optimala, en storlek som är vanlig bland alla musselarterna. Mindre exemplar, som är ännu mycket talrikare på bottnen, ger inte tillräckligt med energi i förhållande till tiden det tar att plocka upp dem.

För att beräkna ändernas årliga konsumtionen av bottendjur utgick vi från att de kan tillgodogöra sig 0,84 kJ per gram våtmassa av musslor med skal eller 6,12 kJ våtmassa per gram utan skal. Det dagliga energibehovet uppskattas till 1500 kJ, vilket motsvarar 1786 och 245 g musslor, med resp. utan skal. På motsvarande sätt gjordes uppskattningar för fisk, gastropoder och kräfdjur. Multiplicering med antalet fågeldagar var resulterade i att dykänderna och sothönsen i Gdanskbukten konsumerar 20.000 ton musslor, 1800 ton fisk, 1700 ton gastropoder och 1270 ton kräftdjur. Detaljer ges i Tabell 3 och Figur 8.

Den totala konsumtionen kan vara högre än den beräknade, bl.a. för att vi inte kunde inkludera alla fågelarter, t.ex. brunand, för vilken vi saknade födoanalyser. Därtill kommer att fåglarna, särskilt sothönsen, ofta skadar musslorna när de drar upp ett knippe musslor till havsytan, eller genom att de bara äter sifonerna på sandmusslorna, särskilt alfåglar. Därtill kommer också att mängden små och mjuka byten ofta blir underskattade vid denna typ av undersökningar.

Grova uppskattningar av den totala biomassan av fyra viktiga arter musslor inom den polska delen av Gdanskbukten (0–20 m djup, 765 kvadratkilometer, 200 g/kvadratmeter) ger en förekomst om 153.000 ton. Därmed skulle fåglarnas uttag vara så stort som 13%. Detta kompenseras dock lätt av den rikliga föryngringen. Men under slutet av vintern, i den grundaste zonen på 0–20 m och lokalt där dykänderna är talrikast, kan dock pressen på bestånden av de fördragna storleksklasserna bland bytena vara signifikant.