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Research Article

Differences in diet compositions and feeding strategies of invasive round goby *Neogobius melanostomus* and native black goby *Gobius niger* in the Western Baltic Sea

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Abstract

The round goby *Neogobius melanostomus* (Pallas, 1814) is a global invader that has become established in the Baltic Sea and expands its geographic range further west. Native in the Baltic Sea, the black goby *Gobius niger* Linnaeus, 1758 occupies a similar ecological niche as the round goby. To investigate a potential dietary overlap, we sampled eleven locations between Travemünde and Flensburg by angling. We caught round goby in the coastal areas of the Lübeck Bight, Fehmarnsund and Kiel Fjord, while black goby were caught at all sampling sites except Travemünde. Individuals of round goby and black goby from all sites, except Kappeln, were kept for stomach content analyses. The diet analyses revealed round goby in the Western Baltic to mainly prey on either barnacles or mollusks. Black goby had a broader prey spectrum including large amounts of crustaceans, annelids and mollusks. Furthermore, we revealed some black goby individuals to be specialized on fish. The dietary overlap between the two goby species was low and suggests that the absence of black goby in Travemünde cannot be referred to competition for food with round goby.

Key words: invasion, angling, stomach content analysis, dietary overlap, feeding strategy

Introduction

Biological invasions are a major threat to ecosystems and biodiversity (Allendorf and Lundquist 2003; Flather et al. 2009). The round goby *Neogobius melanostomus* (Pallas, 1814), native in the Ponto-Caspian Area (Miller 1986), invaded large areas in North America and Europe over the last decades (Kornis et al. 2012). In the Baltic Sea, it was first observed in the Gulf of Gdansk in 1990 (Skora and Stolarski 1993) and then rapidly spread in the waters of all neighboring countries (Corkum et al. 2004; Ojaveer 2006; The Swedish Research Council 2008; Møller and Carl 2010; Kvach and Winkler 2011; Knebelsberger and Thiel 2014; Azour et al. 2015; Kotta et al. 2016). The broad diet spectrum is one of round goby's substantial features to successfully expand in new habitats (Marsden et al. 1996; Moskal'kova 1996; Corkum et al. 1998). They mainly feed on mollusks (Ghedotti et al. 1995), but can also successfully colonize areas without mollusks and feed on crustaceans, worms, fish and plants instead (Skora and Rzeznik 2001; Borcherding et al. 2013; Hempel et al. 2019). Round goby prefer areas with hard substrata or territories covered with vegetation over open, flat bottom as habitats (Sapota and Skóra 2005; Kornis et al. 2012). Rocky substrates and structures like concrete blocks and ripraps serve as spawning habitat and refuge to hide from predators (Belanger and Corkum 2003; Sapota and Skóra 2005).

The territory expansion of round goby has already led to competition for food, habitat and nesting sites with other benthic fish species (Dubs and Corkum 1996; Chotkowski and Marsden 1999; Lauer et al. 2004; Bergstrom and Mensinger 2009). Karlson et al. (2007) and Schrandt et al. (2016) already demonstrated the impact of round goby on native flounders *Platichthys flesus* (Linnaeus, 1758) in the Baltic Sea through food competition and predation. The broad adaptive abilities and the successful reproductive strategy of round goby are expected to result in further colonization and competition with other species in the Baltic Sea (Sokołowska and Fey 2011).

The black goby *Gobius niger* Linnaeus, 1758 inhabits estuaries, lagoons and inshore waters of the eastern Atlantic, from Norway to Mauritania as well as the Baltic, Mediterranean and Black Sea (Miller 1986; Muus and Nielsen 2013). Multiple spawning from May to August in the Baltic Sea and nest guarding by the male was observed for black goby (Miller 1986). Black goby prefer habitats with vegetation and they use sea grass, stones and mussel shells for nest building (Vaas et al. 1975; Wiederholm 1987; Muus and Nielsen 2013). Black goby prey on crustaceans including larger amphipods, isopods, shrimps, mysids and small crabs, as well as bivalves, gastropods, chironomids and small fish (Vaas et al. 1975; Miller 1986; Magnhagen 1988; Zander et al. 1993; Josten 2004).

The similar biology including diet and habitat requirements of round and black goby indicate a potential niche overlap of both species in the Western Baltic as already assumed by Skora and Stolarski (1993) and Corkum et al. (2004). The objective of the current study was (I) to analyze the diet of round goby and black goby in the Western Baltic Sea and (II) to investigate a possible food competition between the two species.

Materials and methods

Sample collection

Round goby and black goby were caught by angling during daytime from August to October 2014 at eleven different locations along the coastline of the Western Baltic Sea in Schleswig Holstein, Germany (Figure 1, Supplementary material Table S1). All sampling sites were characterized by anthropogenic

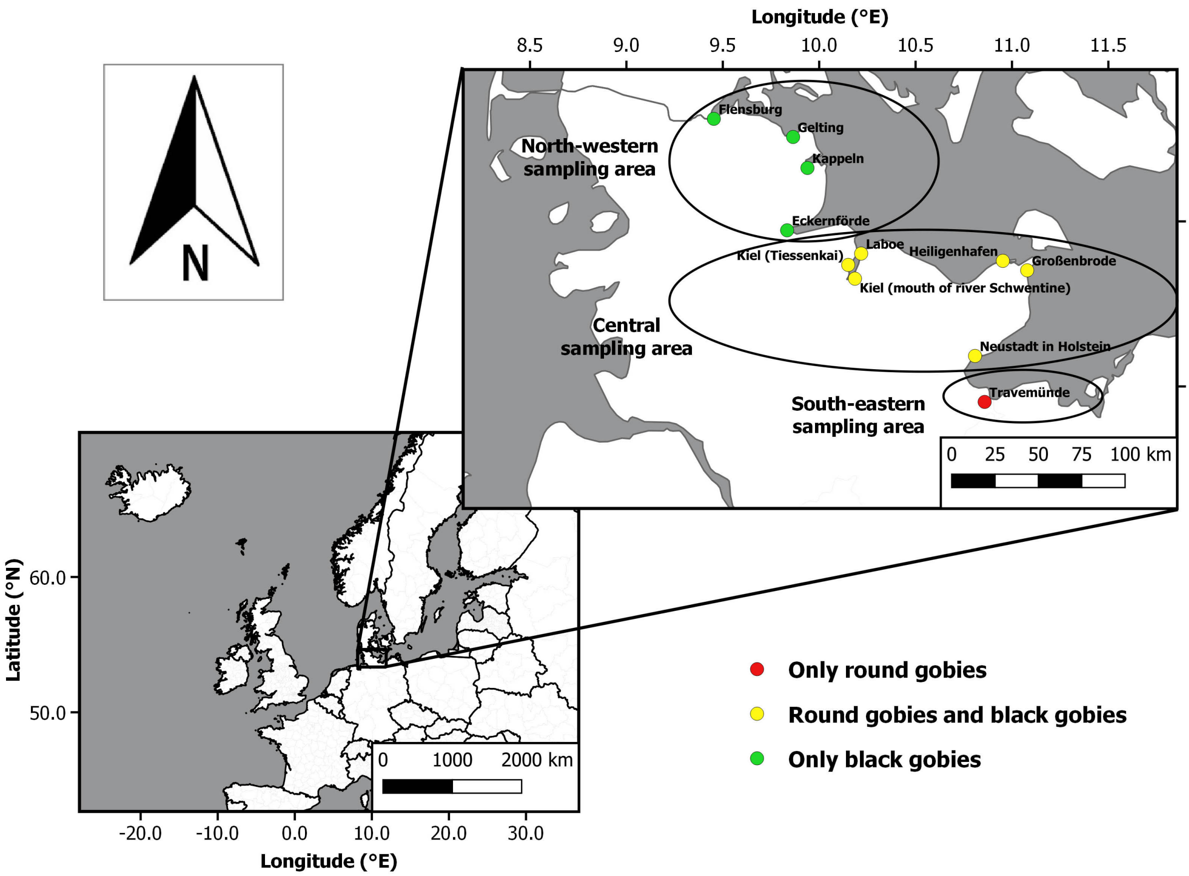

Figure 1. Map of the sampling locations in the Western Baltic Sea, Germany, Europe.

structures like quay walls and pontoons. The bottom was mostly sandy, partly covered with stones, mussels or algae. Ripraps as potential refuge and spawning structures were found close to all sampling sites. Depending on the bottom structure and weather conditions, the baited hook was presented on the bottom or up to 10 cm above the bottom to assure similar sampling efficiencies. During the samplings each angler had one rod with a single hook (size 14) on a 0.18 mm leader that was baited with fly maggots. The first 20 individuals of each species that were caught during the samplings were conserved in 4% formaldehyde for stomach content analyses. The sample size was expanded in the case of exceptionally small or large individuals that were caught later during the sampling. The strived minimum sample size of 20 individuals per species and sampling site was not reached at all sampling sites.

Laboratory analyses

In the lab, the individuals used for stomach content analyses were sexed, the total length was measured to the nearest mm and the wet weight was determined to the nearest 0.1 g. Furthermore, the gape size determined as the height of the gape and measured to the nearest 0.1 mm using a caliper (similar to Ray and Corkum 1997 and Karlson et al. 2007). The gutted fish was dried afterwards for at least 48 hours.

For the stomach content analysis, the lowest possible taxonomic level of each prey item was determined. Afterwards it was pooled to the following prey categories: fish, crustaceans, barnacles, mollusks, annelids and other items. Barnacles were often covered with *Electra pilosa* (Linnaeus, 1767) and it was not possible to distinguish between these two food sources. In the following text, we refer to this prey category as barnacles. The volumetric share of each taxonomic category was visually estimated as percentage of the total sample volume (Marrero and Lopez-Rojas 1995). Two individuals of black goby with an empty stomach were removed from the further analysis. The weight of the consumed prey (g) was determined as difference between the wet weight of the full stomach and the wet weight of the empty stomach. The index of stomach fullness (ISF) was calculated in order to detect differences in the amount of food consumed between species and sampling sites. It was calculated as the quotient of the stomach content wet weight (g) and the wet weight of the fish (g) and afterwards multiplied by 100 (Hyslop 1980). Schoener's index was chosen to estimate dietary overlap (Linton et al. 1981) for all food categories and the pooled prey categories, with the value 0 as no overlap, the value 0.6 as significant overlap and 1.0 as a total overlap.

All individuals with empty digestive tracts were dried in a compartment dryer at 90 °C for at least 48 hours and the dried fish were weighted to the nearest 0.001g. We used total lengths and dry weights to calculate the species-specific coefficient a and exponent b from a length-weight regression. Afterwards, we calculated the condition factor, based on Fulton's condition factor (Bagenal and Tesch 1978), as the quotient of the dry weight and the product of the species-specific coefficient a and the total length to the power of the species-specific exponent b.

Modified Costello diagram and its interpretation

Feeding strategy and prey importance were visualized with the modified Costello method (Amundsen et al. 1996) to point out differences between samples from different species and habitats. We then divided the number of predators with prey category i in their stomachs by the total number of analyzed predator stomachs to calculate the frequency of occurrence (F_i). It is displayed on the x-axis of the modified Costello diagram. The y-axis shows the percentage of each prey category represented in only those stomachs that contained the prey category. This value is defined as the predator-specific prey distribution.

The feeding strategy is represented along the vertical axis, indicating specialization in the upper part and generalization in the lower part of the diagram (Figure 2). The axis from the lower left to the upper right describes the importance of every prey category. Points in the upper right represent a dominant prey item and points in the lower left display rare prey items. The influence of the niche width is shown from the upper left to the lower

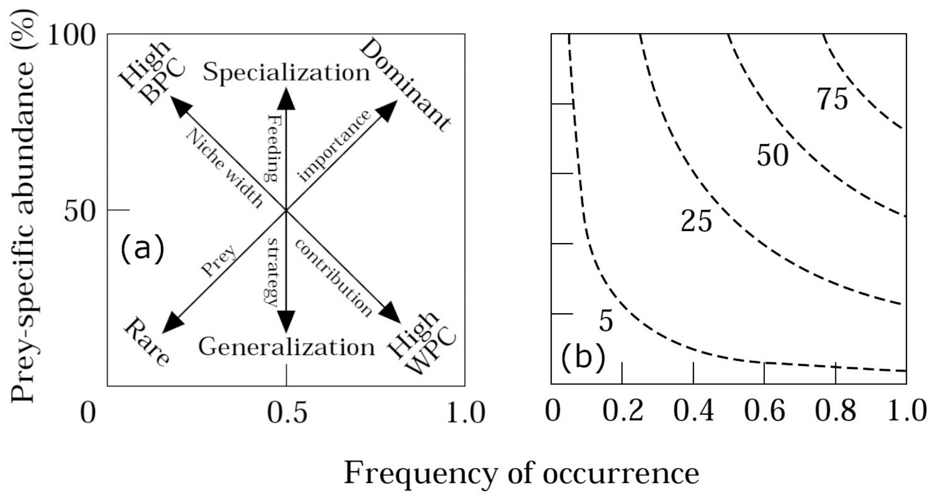

Figure 2. (a) Explanatory diagram for interpretation of feeding strategy, niche width contribution and prey importance. (b) Isolines representing different values of prey abundances (modified after Amundsen et al. 1996).

right with points in the upper left indicating a high between-phenotype component (BPC) and points in the lower right indicating a high within-phenotype component (WPC; (Amundsen et al. 1996)).

Statistical analyses

The ISF values were compared using non-parametric pairwise Wilcoxon tests. An ANCOVA was used to test for differences in the gape size between the two goby species relative to their total length. All statistical analyses were performed using the R software 3.6.2.

Results

Catches of round and black goby

A total of 453 round goby (*Neogobius melanostomus*) and 1168 black goby (*Gobius niger*) were caught during the samplings (Table S2). Furthermore, 62 individuals of 7 bycatch fish species were caught (Table S3). No black goby were caught in the south-eastern sampling area, while no round goby were detected in the north-western sampling area. The sampling sites of the central sampling area were characterized by mixed catches of round and black goby. Round goby were generally larger than black goby and the sex ratio varied between the sampling sites for both species (Table 1). The sex ratio over all sampling sites was balanced for round goby (1.0) and slightly male dominated for black goby (1.1). For round goby the condition factor varied between 1.01 in Laboe (single individual) and 1.17 ± 0.12 in Heiligenhafen and for black goby the condition factor varied between 1.16 ± 0.12 in Gelting and 1.26 ± 0.09 in Großenbrode (Table 1).

Prey amount and composition

In total, the stomach contents of 139 round goby (south-eastern sampling area: n = 57; central sampling area: n = 82) and 222 black goby (central

Table 1. Round goby and black goby information on number of specimen, sex ratio, total length and condition factor used for stomach content analyses. Sex ratio was calculated as the number of males divided by the number of females. In Laboe only one male round goby was caught.

Sampling site	Round goby				Black goby			
	Number of specimen	Sex ratio	Mean total length ± SD (mm)	Mean condition factor ± SD	Number of specimen	Sex ratio	Mean total length ± SD (mm)	Mean condition factor ± SD
Travemünde	57	1.4	110 ± 34	1.07 ± 0.08	–	–	–	–
Neustadt in Holstein	14	0.8	113 ± 25	1.1 ± 0.1	29	0.7	70 ± 14	1.2 ± 0.12
Großenbrode	5	0.3	109 ± 18	1.11 ± 0.11	24	2.0	72 ± 11	1.26 ± 0.09
Heiligenhafen	34	0.8	97 ± 23	1.17 ± 0.12	26	1.9	79 ± 16	1.25 ± 0.14
Laboe	1	–	119	1.01	15	1.5	84 ± 6	1.21 ± 0.13
Kiel (mouth of river Schwentine)	17	1.1	97 ± 11	1.02 ± 0.09	28	1.0	81 ± 10	1.18 ± 0.11
Kiel (Tiessenkai)	11	0.6	116 ± 18	1.14 ± 0.12	37	0.5	86 ± 12	1.19 ± 0.16
Eckernförde	–	–	–	–	20	0.7	84 ± 17	1.25 ± 0.13
Gelting	–	–	–	–	20	1.2	89 ± 9	1.16 ± 0.12
Flensburg	–	–	–	–	23	1.9	86 ± 11	1.19 ± 0.08
Total	139	1.0	106 ± 27	1.1 ± 0.11	222	1.1	81 ± 14	1.21 ± 0.13

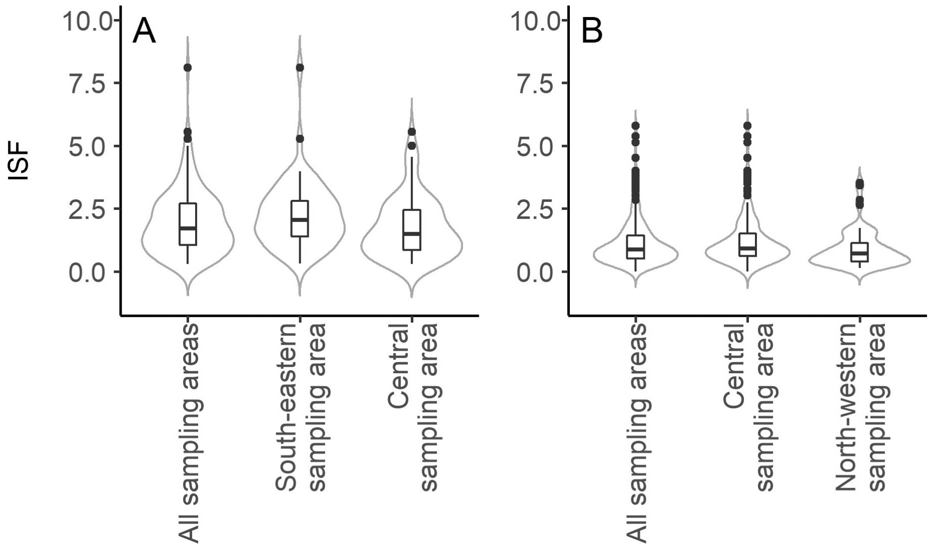

Figure 3. Comparison of the index of stomach fullness (ISF) for round goby (A; all sampling areas: n = 139; south-eastern sampling area: n = 57; central sampling area: 82) and black goby (B; all sampling areas: n = 222; central sampling area: n = 159; north-western sampling area: n = 63).

sampling area: n = 159; north-western sampling area: n = 63) were analyzed. The ISF of round goby varied between 0.29 and 7.78 for all sampling areas with a median of 1.64 (Figure 3). For black goby, the ISF varied between 0.01 and 5.65 with a median of 0.82. The ISF for all sampling areas of round goby was significantly higher compared to the ISF for all sampling areas of black goby (Wilcoxon test: $W = 89194$, $p < 0.001$).

The stomach content composition differed clearly between round and black goby (Figure 4, Table 2). Comparing the volumetric share of the prey categories from all sampling areas revealed, that round goby consumed on average 40.8% mollusks and 32.7% barnacles, while mollusks represented 10.3% and barnacles represented 1.9% of the volumetric share of the stomach content in black goby. In comparison to that, black goby consumed more crustaceans (34.6%), fish (9.2%) and annelids (16.7%) than round goby

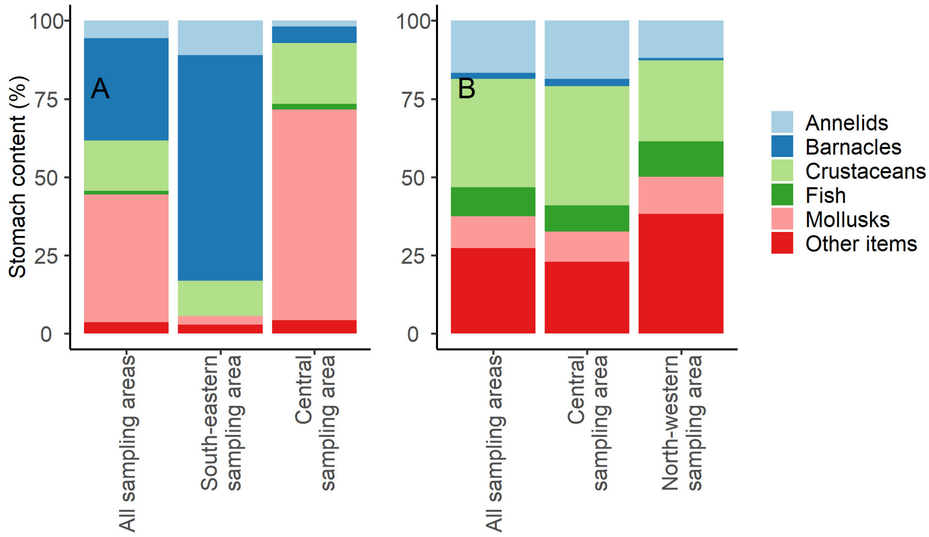

Figure 4. Stomach content of round goby (A) is shown for all sampling areas (n = 139), the south-eastern sampling area (n = 57), and the central sampling area (n = 82). Stomach content of black goby (B) is displayed for all sampling areas (n = 222), the central sampling area (n = 159) and the north-western sampling area (n = 63).

(16.1% crustaceans, 1.1% fish, 5.6% annelids). Other items were found more often in the stomachs of black goby (27.3%) than in round goby (3.7 %).

The diet composition in the central sampling area also differed between the two goby species. Mollusks were a major food source for round goby (67.3%), while they represented only a minor share in the diet of black goby (9.6%). Both species preyed rarely on barnacles in the central sampling area (round goby: 5.3%; black goby: 2.4%). Round goby consumed fewer crustaceans (19.4%), fish (1.8%) and annelids (1.9%) than black goby (38.1% crustaceans, 8.4% fish and 18.6% annelids). The volumetric share of other items was higher in the stomach of black goby (22.9%) than in round goby (4.2%).

Dietary overlap and feeding strategy

Insignificant dietary overlaps were calculated for all sampling areas (0.35; round goby: n = 139; black goby: n = 220) and for the central sampling area (0.38; round goby: n = 82; black goby: n = 159) based on the lowest taxonomic level of the food items. For the pooled prey categories dietary overlap remained insignificant with 0.39 for the all sampling areas and 0.39 for the central sampling area.

The modified Costello diagram of all sampling areas revealed mollusks and barnacles as the most important prey items for round goby (Figure 5). Crustaceans were found in low abundances in more than half of all investigated round goby stomachs. Annelids, fish and other items had a low prey importance for round goby. Round goby mainly prey on barnacles in the south-eastern sampling area and on mollusks in the central sampling area. In comparison to that, black goby had a generally mixed feeding strategy with a few individuals being specialized on fish as food source.

Table 2. Mean volumetric share of the consumed prey categories by round goby and black goby. The values for each species were calculated for all samping areas and separately for the different sampling areas where they were caught.

Prey category		Round goby			Black goby		
		All sampling areas (n = 139)	South-eastern sampling area (n = 57)	Central sampling area (n = 82)	All sampling areas (n = 222)	Central sampling area (n = 159)	North-western sampling area (n = 63)
Fish		1.07	0.00	1.82	9.21	8.41	11.25
	Unidentified fish	0.36	0.00	0.61	6.60	6.33	7.29
	Goby	0.71	0.00	1.21	2.61	2.08	3.97
Crustaceans		16.12	11.37	19.41	34.60	38.05	25.90
	Unidentified crustacea	0.26	0.00	0.44	2.76	2.70	2.90
	Malacostraca	0.76	0.00	1.28	2.13	1.97	2.54
	Decapoda	0.32	0.35	0.30	0.56	0.47	0.79
	Ostracoda	0.40	0.00	0.68	0.00	0.00	0.00
	Cumacea	0.00	0.00	0.00	0.02	0.03	0.00
	Copepoda	0.00	0.00	0.00	0.39	0.03	1.29
	Isopoda	0.00	0.00	0.00	0.09	0.13	0.00
	Amphipoda	8.04	4.40	10.57	16.09	19.77	6.81
	Mysidae	0.58	0.00	0.98	1.05	1.43	0.08
	Palaemon sp.	0.83	0.00	1.40	4.51	4.56	4.38
	Corophium sp.	0.09	0.21	0.00	0.00	0.01	0.00
	Idotea sp.	1.65	0.00	2.80	4.67	5.11	3.57
	Diastylis rathkai	0.00	0.00	0.00	0.41	0.00	1.43
	Hyperia galba	0.00	0.00	0.00	0.44	0.00	1.56
	Sphaeroma hookeri	0.56	0.09	0.89	1.25	1.53	0.56
	Carcinus maenas	2.63	6.32	0.06	0.23	0.31	0.00
Barnacles		32.68	72.12	5.26	1.89	2.35	0.71
	Balanidae	3.17	5.28	1.70	0.47	0.66	0.00
	Balanidae with *Electra pilosa*	17.59	42.89	0.00	1.21	1.69	0.00
	Cirripedia of Balanidae	6.61	11.23	3.40	0.20	0.00	0.71
	Electra pilosa	5.31	12.72	0.16	0.00	0.00	0.00
Mollusks		40.82	2.67	67.34	10.26	9.61	11.89
	Unidentified mollusca	1.19	0.00	2.01	0.95	0.19	2.86
	Bivalvia	0.63	0.04	1.04	1.09	1.13	1.00
	Gastropoda	0.24	0.00	0.40	0.23	0.31	0.03
	Cerastoderma sp.	1.25	0.00	2.12	0.00	0.00	0.00
	Littorina saxatilis	0.15	0.00	0.26	0.00	0.00	0.00
	Hydrobia sp.	19.55	0.00	33.13	2.46	2.16	3.21
	Mytilus sp.	14.91	1.14	24.49	5.00	5.09	4.79
	Macoma balthica	0.92	0.18	1.44	0.27	0.38	0.00
	Mya arenaria	1.99	1.32	2.45	0.23	0.31	0.00
	Mya truncata	0.00	0.00	0.00	0.02	0.03	0.00
Annelids		5.65	10.98	1.94	16.75	18.64	11.98
	Unidentified annelida	0.00	0.00	0.00	0.65	0.06	2.14
	Polychaeta	5.47	10.98	1.63	12.74	13.89	9.84
	Aciculata	0.00	0.00	0.00	2.50	3.49	0.00
	Nereis sp.	0.18	0.00	0.30	0.86	1.19	0.00
Other items		3.67	2.86	4.23	27.29	22.94	38.25
	Insecta larvae	0.01	0.02	0.00	0.00	0.00	0.00
	Insecta (adult)	0.00	0.00	0.00	0.07	0.00	0.24
	Chironomidaen larvae	0.16	0.00	0.27	0.64	0.89	0.00
	Diptera (adult)	0.05	0.00	0.09	0.07	0.09	0.00
	Arachnida	0.00	0.00	0.00	0.45	0.63	0.00
	Alge/seaweed	0.56	0.04	0.93	2.31	2.42	2.02
	Plant material	0.12	0.00	0.21	1.42	0.47	3.81
	Sand/stones	0.04	0.00	0.06	0.28	0.00	0.98
	Unidentified Material	0.00	0.00	0.00	0.61	0.63	0.56
	Unidentified Invertebrate	0.97	0.00	1.65	6.40	6.48	6.21
	Synthetic fibre	0.00	0.00	0.00	0.09	0.13	0.00
	Mucus	1.76	2.81	1.04	14.96	11.21	24.44

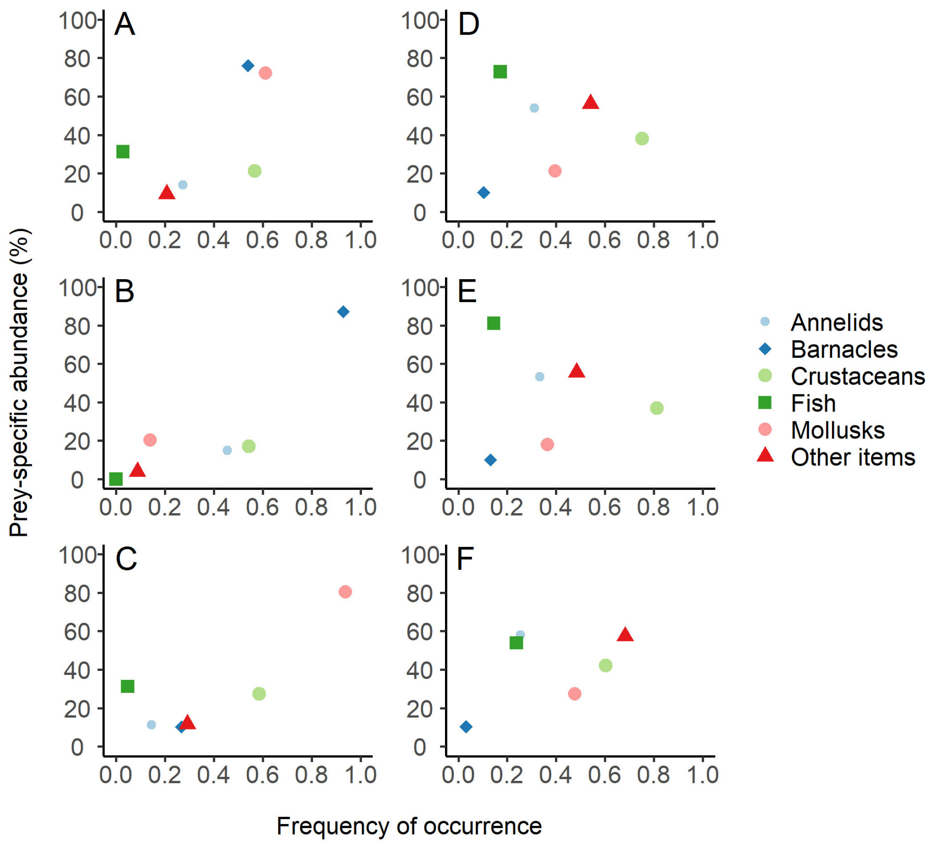

Figure 5. The feeding strategy displayed in the modified Costello diagram for the round goby of all sampling areas (A; n = 139), of the south-eastern sampling area (B; n = 57) and of the central sampling area (C; n = 82) and for the black goby of all sampling areas (D; n = 222), of the central sampling area (E; n = 159) and the north-western sampling area (F; n = 63).

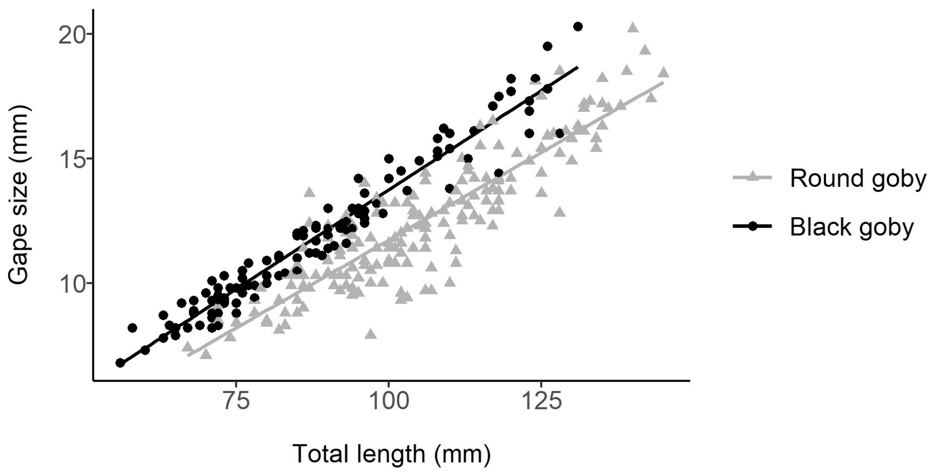

Figure 6. The gape size (mm) of round and black goby plotted against the total length (mm) using a linear regression of y = a * x + b with a = 0.141 and b = −2.354 (adjusted $R^2 = 0.792$) for round goby and a = 0.159 and b = −2.166 (adjusted $R^2 = 0.945$) for black goby.

A linear regression of the total length (mm) and the gape size (mm) was calculated for round goby with y = 0.141 * x - 2.354 (adjusted $R^2 = 0.792$) and for black goby with y = 0.159 * x - 2.166 (adjusted R^2 = 0. 945; Figure 6). Black goby were found to have a larger gape size than round goby at the same total length. An ANCOVA revealed the differences to be significant

($F_{1,285} = 180.9$; $p < 0.001$). At a total length of 100 mm round goby had an average gape size of 11.7 mm, whereas the average gape size of black goby measured 13.7 mm.

Discussion

Diet of round and black goby

Round goby in the Western Baltic Sea showed different feeding strategies. In the south-western sampling area round goby mainly preyed on barnacles, while round goby at all sampling sites of the central sampling area mainly consumed mollusks. However, the south-western sampling area was represented by only one sampling site. Hempel et al. (2019) demonstrated, that crustaceans and annelids had the highest relative importance as food source for round goby in the brackish Kiel Canal. This result does not necessarily stress our findings, as round goby are described to have a broad diet spectrum and can adapt to various food sources (Nurkse et al. 2016). In addition to that, we demonstrated that round goby can also adapt to other food sources such as barnacles without effects on their condition. In other studies about the diet of round goby in the Eastern Baltic Sea barnacles played only a minor role (Skora and Rzeznik 2001; Karlson et al. 2007; Skabeikis and Lesutiene 2015). This high adaptation for various food sources underlines the invasion potential of round goby as also demonstrated by Nurkse et al. (2016).

In comparison to round goby, black goby had similar diets at all sampling sites. Their diet was broad including mostly crustaceans and other items. The modified Costello diagram also revealed that some black goby individuals specialized on fish as diet. These findings are in line with other studies, that showed black goby to prey on crustaceans including larger amphipods, isopods, shrimps, mysids and small crabs, as well as bivalves, gastropods, chironomids and small fish (Vaas et al. 1975; Miller 1986; Magnhagen 1988; Zander et al. 1993; Josten 2004).

Competition of round and black goby

We detected a low dietary overlap between round and black goby for the detailed food categories as well as for the pooled prey categories. Round goby are known to be highly competitive for food and thereby negatively influencing competitors (Karlson et al. 2007). However, in our study we could not detect changes in the feeding strategy of black goby in the absence and presence of round goby. This finding fits to the detection of different feeding strategies for the two species with a mixed feeding strategy for black goby and a diet dominated by either barnacles or mollusks for round goby (Figure 5). Furthermore, we revealed a larger gape size of black goby compared to round goby at the same total length. Like other fish species, gobies are gape size limited regarding their prey size and a larger gape size allows for larger and also more diverse prey items (Paine 1976; Ray and Corkum 1997; Nilsson and Brönmark 2000). This further underlines the differences in diet, at least for similar sized individuals of round and black goby.

The ISF was significantly higher for round goby compared to black goby, however, a large share of prey organisms (mollusks and barnacles) in round goby stomachs contained shells. Round goby usually crack shells of prey organisms with their teeth, remove the flesh and eject the non-digestible shells (Ghedotti et al. 1995; Ray and Corkum 1997). Nevertheless, remaining parts of shells are often found in the digestive tract of round goby, that are excreted as faeces (Ray and Corkum 1997; Karlson et al. 2007; Walsh et al. 2007). As the shells are not digested, the calculated ISF in this study does not display a measurement of energy intake, but only the relation of prey weight to predator body weight. The share of mollusks and barnacles and, thus, their prey importance in terms of energy intake for round goby might be overestimated in this study. However, this issue does not affect the species-specific proportions of the different food items and therefore, the dietary overlap between the two species remains low.

We caught round and black goby partly at the same sampling sites (central sampling area) as both species are described to prefer similar habitats with stones and vegetation (Vaas et al. 1975; Wiederholm 1987; Belanger and Corkum 2003; Sapota and Skóra 2005; Kornis et al. 2012; Muus and Nielsen 2013). Round goby can compete with native fish for nesting spots (Janssen and Jude 2001) and due to their aggressiveness they can even force competitive species to other habitats (Dubs and Corkum 1996; French and Jude 2001; Corkum et al. 2004). This often results in reduced abundances of the native species (van Kessel et al. 2016). As we caught no black goby in the most western sampling site (Travemünde; south-eastern sampling area), it can be speculated that either competition for habitat and nesting sites or the absence of adequate prey organisms has caused the absence of black goby. However, further investigations have to be undertaken to detect the cause black goby's absence in Travemünde.

Robustness of the results

Angling is described as an effective sampling method for round goby (Clapp et al. 2001; Johnson et al. 2005). However, smallest size classes are not representatively caught by angling and, thus, this method does not display the population structure for small size classes as also mentioned by Gutowsky et al. (2011). Activities like nest guarding of male round and black goby (Magnhagen 1990; Macinnis and Corkum 2000; Meunier et al. 2009) can affect the sex-specific catch rates (Gutowsky et al. 2011). Furthermore, as passive sampling gear, angling with a baited hook requires an active behavior of the fish to be caught, which can be affected by other various factors such as the presence of a potential predator. Hence, catch rate and sex ratio in this study might be biased and further investigations with other sampling technics are needed to gain more reliable data on abundances and sex ratio.

The stomach content analyses showed an insignificant dietary overlap between the two goby species. The diet of round goby also strongly differed between sampling areas. However, these differences might not reflect different feeding habits, but differences in the food availability between the sampling sites. Availability and density of food sources can influence the diet of round goby (French and Jude 2001). As prey availability was not investigated in this study, the results might only reflect the prey availability at the sampling sites rather than potential prey specializations. Further studies are needed to properly investigate food preferences of round and black goby in the Western Baltic.

Conclusions

We demonstrated that round goby in the Western Baltic mainly preyed on mollusks, but also consumed other benthic invertebrates such as crustaceans and annelids. In addition to that, we showed that round goby can also use barnacles as main prey in certain locations, which underlines their generally broad diet spectrum and the ability to adjust to different prey sources. For black goby, we observed a broad diet spectrum with a mixed feeding strategy, including mainly crustaceans, annelids, mollusks and fish. However, no significant dietary overlap was detected between round and black goby. Hence, it can be suggested that the absence of black goby in Travemünde is caused by other factors than food competition with round goby.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Coordinates of sampling locations.
Table S2. Information on sampling events, environmental variables and catches.
Table S3. Information on the bycatch during the samplings.

This material is available as part of online article from:
http://www.reabic.net/aquaticinvasions/2021/Supplements/AI_2021_Matern_etal_SupplementaryTables.xlsx