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Is the body condition of the three-spined stickleback (*Gasterosteus aculeatus*) determined by the type of food consumed?

by

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Abstract

The three spine stickleback *Gasterosteus aculeatus* is a small omnivorous, wildly distributed fish. In this study, food uptake and body condition of three spine stickleback, from the Gulf of Gdansk eulitoral was investigated. Samples were taken from three locations of the Gulf of Gdańsk: in vicinities of Sopot, Chałupy and Hel. Copepods were the most quantitive food components in the three spine stickleback stomachs. In spring, at Hel station - Harpacticoida and in Sopot, crustacean and fish eggs, were dominating as a fish prey. During summer, Calanoida were most abundant in stomachs collected from fish caught in Chałupy, fish eggs and Calanoida in those from Hel station. In stomachs of fish from Sopot location most common prey were Cladocera. Comparison of stomach content to food base and Fulton's body condition index revealed that the three spine stickleback uses available food base in efficient way.

Key words: fish, Baltic Sea, Gulf of Gdańsk, food, body condition

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Introduction

Gasterosteus aculeatus is a small fish widely distributed in the northern hemisphere (Wootton 1984). In the Gulf of Gdańsk, it occurs mostly in the inshore shallow waters (Skóra et al. 1992; Sapota & Skóra 1996; Lizińska 2002; Waligóra Borek et al. 2006). This region is also an important feeding and spawning area for many commercial fish species (Skóra 1993). The research on prey of the three-spined stickleback has been carried out by many authors but the results are ambiguous. Manzer (1976), Hosted et al. (1988) and Peltonen et al. (2004) noticed that the sticklebacks prey mainly on plankton, while Thorman & Wiederholm (1986) found mostly benthic organisms in fish stomachs. Other authors observed both planktonic and benthic organisms (Dukowska et al. 2009; Thorman & Wiederholm 1983; Jakobsen et al. 1988; Kislaioglu & Gibson 1977; Wootton 1976). Wootton (1976) reported that *G. aculeatus* eats plankton in summer, while benthic organisms and plants in winter. The stickleback also feeds on spawn and fry of commercial fish (Kotterba et al. 2014; Nikolsky 1956). This may result in the displacement of fry of these species from the shallow water zone and the reduction of their populations (Kotterba et al. 2014; Skóra et al. 1992).

The study from Puck Bay shows that the three-spined stickleback has a wide range of nourishment components and preys on both plankton and benthic organisms (Skóra et al. 1992).

The aim of this study was to compare the body condition of *G. aculeatus* caught in three regions of the western part of the Gulf of Gdańsk (Hel, Chałupy and Sopot), which differ in terms of environmental characteristics and a potential food base of the fish. Due to its high abundance, the species may affect the reproduction and the growth of other fish by feeding on their fry and larvae. The population growth observed in the Baltic Sea may be a cause for concern especially due to the decline in the catches of some important fish species.

Materials and methods

Sampling sites

The Gulf of Gdańsk is located in the Baltic Proper and it represents about 1.3% of the Baltic area and 1.4% of the Baltic water (Sikora 1988). In the northern part of the Gulf, water temperature is always lower and water dynamics (waving) is higher than in the southern part. The salinity is about 7 PSU in the inshore part and higher in the deep zones. The estuarine nature of the Gulf water in the shallow zone permits the coexistence of marine and fresh water organisms (Costello et. al 2002).

The fish were caught in the shallow water zone (up to 1 meter depth), at three locations in the western part of the Gulf of Gdańsk (Fig. 1). The names of the sampling sites were taken from the names of the nearest localities.

Sampling area description:

- Hel – the north-western part of the Gulf of Gdańsk, medium sandy bottom (Dadlez et al. 1995), with no vegetation fixed to the bottom at the sampling site, average salinity 7.5 PSU (Majewski 1990),
- Chałupy – the northern part of the inner Bay of Puck, fine sandy bottom (Dadlez et al. 1995), stones and little water dynamics enable the presence of algal (*Chara* sp., *Enteromorpha* sp., *Cladophora* sp.) and other vegetation fixed to the bottom (ex. *Zannichellia palustris*) (Augustowski 1987; Wiktor 2009), salinity 6.5-7.5 PSU.
- Sopot – the south-western part of the Gulf of Gdańsk, fine sandy bottom (Dadlez et al. 1995), *Pilayella* sp. and *Cladophora* sp. are present in the water column in summer; no vegetation attached to the bottom (Kotwicki et al. 2005).

Those literature descriptions of the sampling areas were confirmed by our observation during the samplings and by the research conducted in 2007-2008 (Węsławski 2009). No algae or plants were noticed in the water column during the material collection in Hel in summer and spring, and in Chałupy and Sopot in spring.

During the Sopot summer sampling described in the literature, the presence of plants in the water column was confirmed. However, the number of plants and algae in the 1 m deep trawling region was not significant.

Sampling

Fish were caught before noon in spring (May, June) and summer (July, August) in 2005. Based on the temperature-dependent growth responses, it was assumed by Lefebure et al. (2011, 2014) that this period should cover the majority of annual growth responses for three-spined sticklebacks in the Baltic Sea. Fish were caught using a two-meter wide trawl

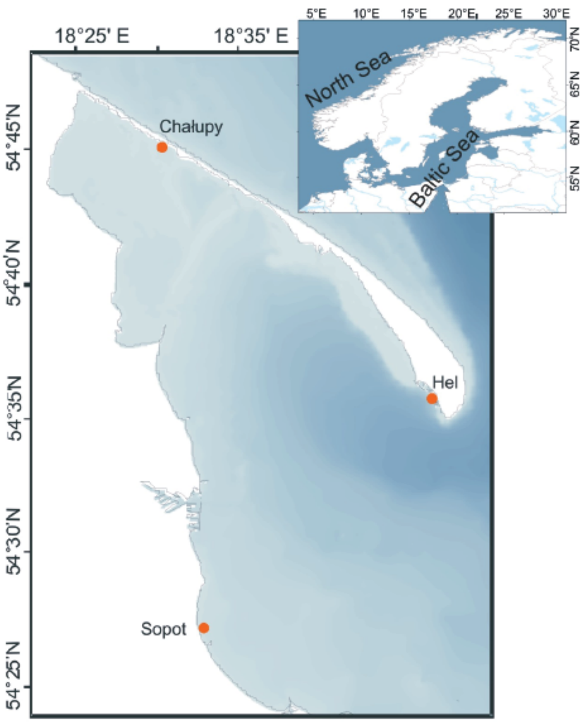


Figure 1

Location of the study area and sampling sites in the western part of the Gulf of Gdańsk

with a mesh size of 6 mm over the whole net and 1 mm at the cod end. The tool was manually towed parallel to the shore at approximately one-meter isobath, at a distance of 100 meter.

The collected fish were preserved in 4% buffered seawater-formaldehyde solution.

Gut content analysis

The body length (*Longitudo totalis*) (to the nearest 1 mm) and formalin wet weight (0.1 g) were determined for each of the 157 fish analyzed. To analyze the ingested food, the guts were dissected and the wet weight (0.001 g) of the content was determined. The prey single components were identified to the lowest possible taxonomic level and counted under a stereoscopic microscope CITOVAL II.

The frequency of occurrence of each food item in the fish stomach was calculated. The food items were grouped into higher taxonomic classes to show their quantity.

Stomach fullness index

The ratio of the gut content weight to the total fish weight yielded the fullness index (Ir) (Hureau 1969 in Berg 1979).

$$Ir = \frac{weight\ of\ ingested\ food}{weight\ of\ fish} \times 100 \qquad (1)$$

Food selectivity index

In order to assess the degree of selection of a particular prey taxon, selectivity values were calculated based on Ivlev's (1955) selectivity indices. Food selectivity indices were calculated for fish from Hel (spring, summer) and Sopot (spring) regions.

$$E = \frac{r - p}{r + p} \quad \text{(Gras \& Saint-Jean 1982)} \qquad (2)$$

where: E – food selectivity index, r – percentage of a given component in the food, p – percentage of a component in the environment, which is calculated only from the prey eaten by the predator.

The range of the index is $-1<E<1$, where negative values indicate that the fish avoid a given food element and positive values indicate that a given food is chosen by the fish.

Fulton's body condition index

Fulton's body condition index (relationship between the total length and the total weight) was evaluated separately for each fish caught (Begenal 1978 in Isnard et al. 2015; Załachowski 1997).

$$K = 100 \times \frac{W}{L^3} \qquad (3)$$

where: W is the fish weight, and L is the total fish length.

The fish body condition factor is commonly used as an indicator of well-being of the species (Isnard et al. 2015), and reflects the effects of seasonal and habitat differences on the organism.

Normality of the data

Data were log (x+1) transformed when necessary to meet the assumption of linearity. Tests for normality was conducted on the basis of the Shapiro-Wilk W statistic. One-way ANOVA was used to determine the significance of differences in the fish body condition. All statistics were carried out in Statsoft Statistica 12.

Food resources at the sampling sites

The information about the potential food base of three-spined sticklebacks in Sopot and Hel was gathered by participants of the COSA project (Coastal Sands as Biocatalytical Filters – the 5th EU Framework project 2002-2005). According to the data collected in Hel, Gastropoda (99%) were the most frequent macrozoobenthos components in spring, while Crustacea (79%) – in summer. Nematoda dominated in meiofauna in both seasons – they accounted for 73% (spring) and 84% (summer) of the collected organisms. Copepoda dominated in zooplankton – they accounted for 46% (spring) and 48% (summer) of the collected organisms, while Bivalvia represented 26% (spring) and 36% (summer) and Cladocera – 0.14% (spring) and 7.5% (summer) of the collected organisms.

Meiofauna in Sopot was dominated by Nematoda (85%), Rotatoria dominated in zooplankton (85%), while Cladocera represented only 6% of the collected organism.

Results

Stickleback abundance

In spring Hel samplings, the stickleback accounted for 99% of the abundance and 98% of the biomass, while perch accounted for only 1% and 2%, respectively. During the Hel summer sampling, the stickleback dominated in the abundance and biomass (79% and 80%, respectively), followed by round goby (17% and 20%) and nine-spined stickleback (4.3% and 0.3%).

Four fish species were caught during the sampling in Chałupy. Fish abundance and biomass was dominated by *G. aculeatus* – 95% and 68%, respectively, round goby constituted 3% and 28%, sandeel and nine-spined stickleback were present in small numbers.

The most diverse samplings were collected in Sopot. Nine fish species were present in spring. The stickleback was a dominant species, both in terms of abundance and biomass (49% and 56%, respectively), sandeel represented 26% and 12% respectively, flounder – 12% and 13%, and round goby – 5% and 3%. Other species caught included nine-spined stickleback, herring, smelt, pipefish and turbot.

Ten fish species were caught in Sopot in summer, including the most abundant sandeel – 76% and 71% in the biomass. The three-spined stickleback represented 12% of the abundance and 21% of the biomass.

Size of individuals

The total length of fish caught in Sopot (spring) and Hel (spring, summer) samplings ranged from 43 mm to 75 mm. In the region of Chałupy, fish from two size groups were caught, i.e. the first one with the length ranging from 17 mm to 35 mm and the second one – from 49 mm to 78 mm. The largest individuals were caught in Sopot (summer); the largest individual was 76 mm, while the smallest one – 55 mm (Fig. 2).

In four samplings (Hel spring and summer, Sopot spring and summer), the length distribution resembles the normal distribution according to the Shapiro Wilk normality test.

In the Chałupy summer sampling, fish from two length groups were caught (Fig. 2).

Fish stomach content

A total of 29 prey components (identified to the lowest identifiable taxa) were found in the 157 analyzed fish stomachs (Table 1). No empty stomachs were found. Some of the food items were observed only in the fish stomach from one area (Ostracoda, *Mysis* sp.), while others occurred in fish guts from all sampling sites (Cladocera, Insecta, Copepoda eggs, fish eggs). The highest stomach content diversity expressed as a total number of taxa present was determined in Hel during spring (20), and the lowest in Hel during summer (15).

Copepoda eggs were the most numerous food items in the guts from spring samplings (Sopot, Hel; Fig. 3). In Sopot, the diet composition was supplemented with fish eggs, Copepoda and Insecta. In three-spined stickleback stomachs collected in Hel, Cladocera and Copepoda were also found in great numbers.

Planktonic crustaceans (Sopot and Chałupy) and fish eggs (Hel) were the most frequent food components in summer (Fig. 3).

Fish eggs were found in guts from all samplings; they represent from 0.001 to 52% of the gut content. Based on the shape of fish eggs, we are certain that those were not round goby's eggs. It is quite possible that those were eggs of herring or stickleback.

In general, the diet of three-spined sticklebacks contains also benthic organisms – mainly *Bathyporeia* sp., Nematoda and *Gonothyrea* sp. (Table 1) were found in stomachs. Parts of Insecta were present in all samples.

Sand grains were present in stomachs of fish from all sampling sites, but they were most frequent in fish stomachs from the Sopot summer sampling – they occurred in 80% of the stomachs (Table 1).

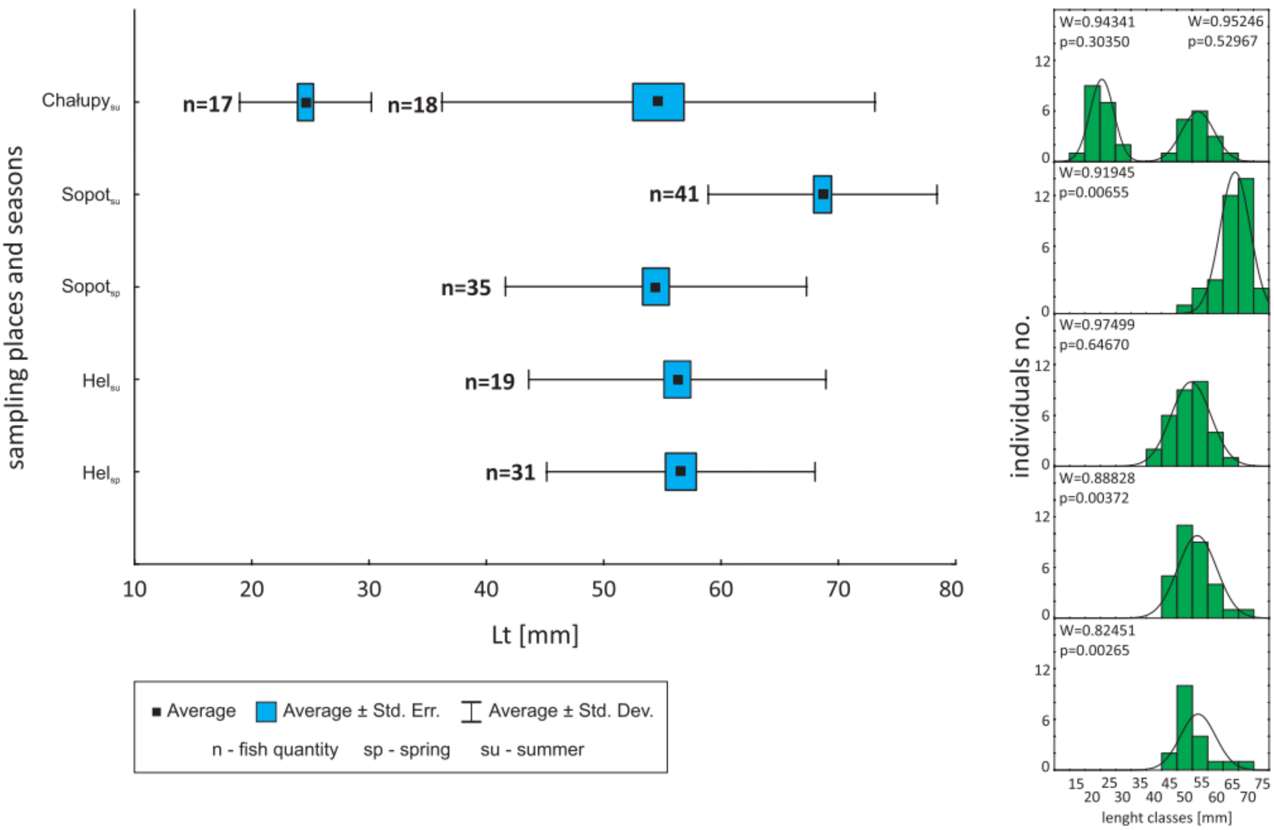


Figure 2

Total length of *G. aculeatus* individuals and the Shapiro-Wilk test for normality

Table 1

Food items and frequency of their occurrence in the guts of three-spined sticklebacks

Food items	ecological formation	Sampling sites and seasons				
		Hel		Sopot		Chałupy
		spring	summer	spring	summer	summer
Crustacea undet.		3		50	73	
Copepoda undet.	p	100	37	41	78	69
Calanoida	p	94	42	6		80
Cyclopoida	p	74	21	3		17
Harpacticoida	b	97	21	6		34
Cladocera	p	94	47		10	14
Evadne sp.	p	65	21			
Podon sp.	p	42	26			
Bosmina sp.	p		42			
Mysidacea undet.	p			19		
Mysis sp.	p	3				
Neomysis integer	p			6	5	
Ostracoda	b				2	
Amphipoda undet.	b	16	32	28		
Gammarus sp.	b				17	3
Batyporeia sp.	b		42	28	27	
Pontoporeia sp.	b	6	11	3		3
Idotea sp.	b				2	3
Bryozoa	b			3		6
Chirodomidae larva	b				29	9
Gonothyrea sp.	b	26		3	2	
Nematoda	b	74			17	
Annelida undet.	b	13		6		3
Hediste diversicolor	b	16				14
Insecta undet.		23	37	63	22	14
Pisces undet.		3				3
Copepoda eggs	p	94	32	41	24	14
fish eggs		19	58	44	7	17
plants		26	5		46	14
sand*		26	37	31	80	20

p – planktonic, b – benthic, * – non-organic food item but frequently observed

The food composition indicated differences in the prey of sticklebacks during seasons and between sampling sites. Fish eggs and Copepoda (mostly Calanoida) were the most numerous food items in Hel. Strong dominance of Copepoda (also Calanoida) was observed in Chałupy. In Sopot, no significant dominance was observed; the main food items were Cladocera, Copepoda undet., Copepoda eggs and Insecta.

The largest number of food items was observed in fish guts from the Hel region – on average 1325 components per fish stomach in spring and 625 in summer, while in Sopot it was about 35-37 components per fish stomach and 98 in Chałupy (Fig. 3).

Stomach fullness index

The highest stomach fullness index was determined in Chałupy in summer, while the lowest in Sopot in summer. For fish samplings from Hel (spring, summer) and Sopot (spring), the stomach fullness index was similar (Fig. 4). The distribution of index values in three cases (Chałupy, Hel_{sp}, Hel_{su}) was normal (p=0.05). There were statistically significant differences

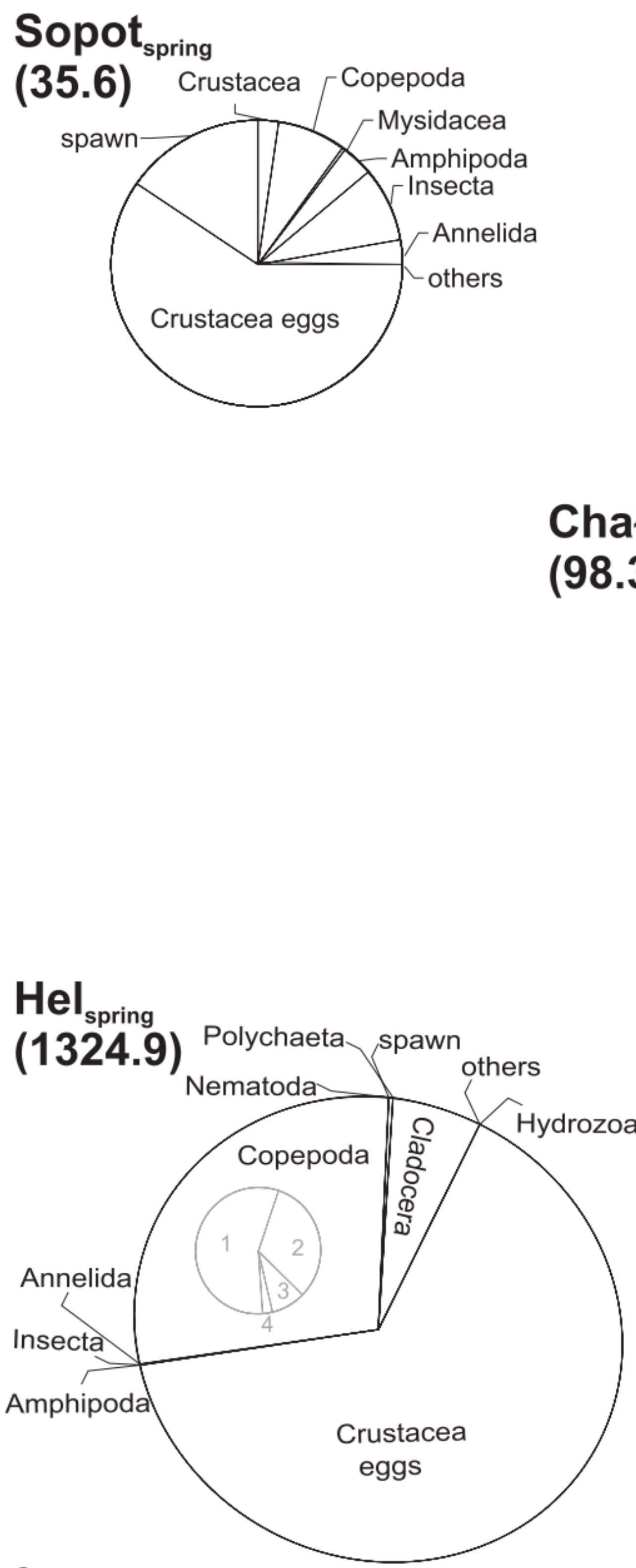


Figure 3

Percentage of food items in stomachs of three-spined sticklebacks. In brackets – the average number of specimens per stomach. The grey color graph shows the composition of Copepoda divided into orders: 1 – Harpacticoida, 2 – Copepoda undet., 3 – Calanoida, 4 – Cyclopoida

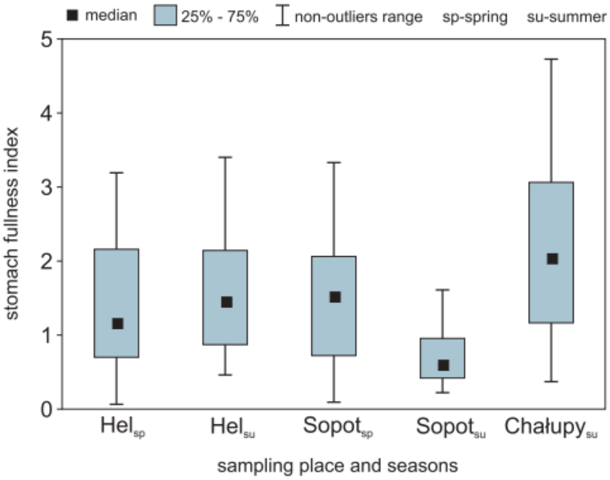


Figure 4

G. aculeatus stomach fullness index

between average values of the stomach fullness index for Chałupy and Hel spring and summer samplings (t-test, p=0.05). Due to the lack of normality, the samplings from Sopot were not analyzed.

Food selectivity

For fish caught during the Sopot spring sampling, the selectivity index was calculated only for Copepoda and its value was zero. For Hel spring samplings the selectivity index was calculated for Copepoda, Cladocera and Nematoda; for Nematoda and Copepoda, it was negative and for Cladocera – positive (Table 2). For Hel summer samplings, it was possible to calculate the selectivity index for two items found in the fish guts, i.e. Copepoda and Cladocera (negative for the former and positive for the latter (Table 2).

Table 2

Food selectivity indices (Ivlev 1955) for fish caught in the region of Hel (spring, summer) and Sopot (spring)

	Sopot	Hel	Hel
	spring		summer
Copepoda	0.000	-0.074	-0.041
Cladocera		0.951	0.205
Nematoda		-0.650	
Crustacea	No data on specimens in the environmental samples from a similar time of the year		
Mysidacea			
Amphipoda			
Insecta			
Hydrozoa			
Annelida			
Polychaeta			
Bryozoa			
Pisces			
Arthropoda eggs			
Fish eggs			

Fish body condition index

Fulton's index for fish from all sampling sites ranges from 0.0006 to 0.0014 (Fig. 5). There were no statistical differences between mean values of the body condition index (p=0.005) (Fig. 5). Distribution of Fulton's condition rate was illustrated separately for two length groups from Chałupy.

The null hypothesis assuming no significant differences in the fish body condition, determined by the size of fish, the sampling site location or season, was tested by ANOVA (p=0.05). The results show that the stickleback body condition was dependent on the sampling location (p=0.1134) and the total fish length (p=0.0556) (downward trend of the condition factor with the length of fish is observed) and independent from the season (p=0.000083).

Discussion

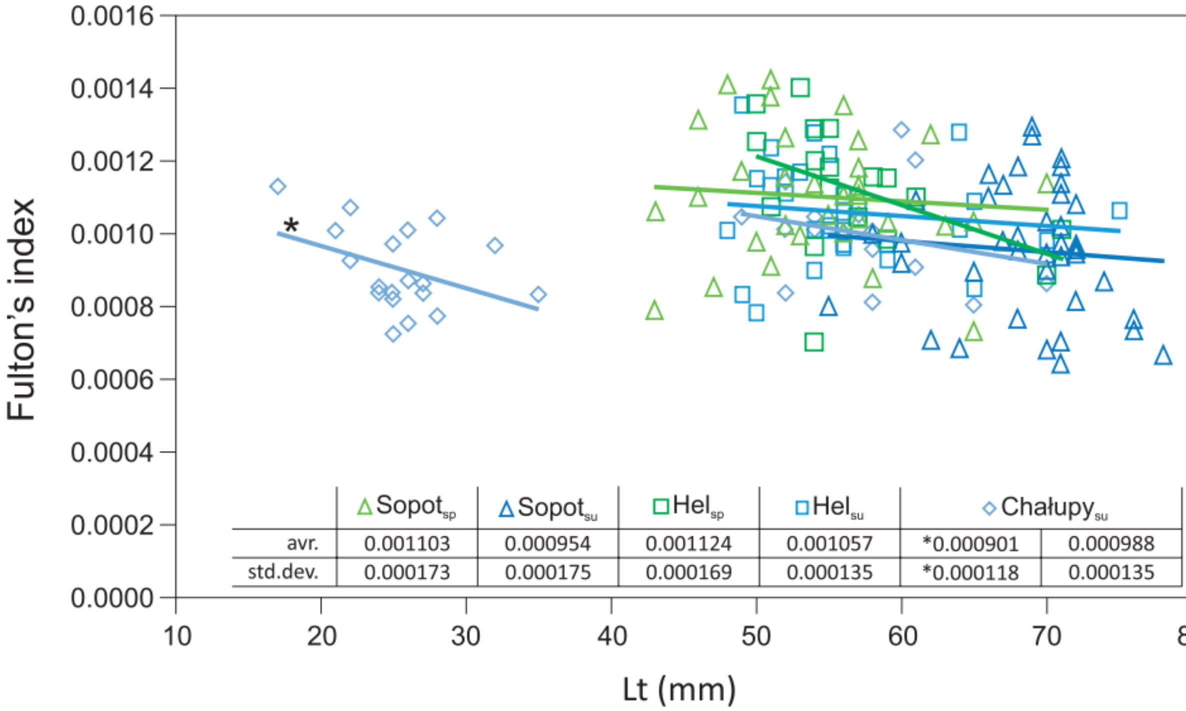
The study of diets and food habitats of fish and other marine vertebrates through the examination of stomach contents is still a standard practice (Hyslop 1980; Cortéz 1997; Brush et al. 2012). The most commonly used measurements (numerical abundance, frequency of occurrence and volume or weight) provide different types of information on feeding habits (Macdonald & Green 1983; Bigg & Perez 1985; Cortés 1997; Cortés 1998). This information combined with the body condition index could partly reflect the exploitation of the available food resources (Cortés 1998).

In the 1980s and the 1990s, *G. aculeatus* was the most abundant species in the shallow coastal area of the Gulf of Gdańsk (Lizińska 2002; Sapota & Skóra 1996; Skóra et al. 1992; Skóra 1993). The occurrence of *Neogobius melanostomus* in the Baltic ecosystem changed the fish community structure. Since 2004, we have observed the dominance of two species, i.e. round goby and stickleback, in the shallow water (Sapota 2004; Sapota & Skóra 2005). The number of round goby nests in this area is very high (Sapota et al. 2014).

Consequently, a question arises whether the stickleback grazes on round goby eggs, thereby reducing the rate of invasion?

During the conducted research, individuals of *G. aculeatus* were caught in the shallow water zone of the Gulf of Gdańsk. It was a dominant or co-dominant species in all samples.

The sampling region is characterized by the variability in environmental conditions and heterogeneous bottom (sand, stones, vegetation). Specific conditions



	Sopot$_{sp}$	Sopot$_{su}$	Hel$_{sp}$	Hel$_{su}$	Chałupy$_{su}$	
avr.	0.001103	0.000954	0.001124	0.001057	*0.000901	0.000988
std.dev.	0.000173	0.000175	0.000169	0.000135	*0.000118	0.000135

Figure 5

Body condition index of fish caught during sampling (figures – sampling sites; colors – seasons: green – spring, blue – summer; * – group of smaller fish from Chałupy site); average and standard deviation of the Fulton index for fish from sampling sites

in the eulittoral zone affect the quality, composition and quantity of a potential food base (Kotwicki 1997; Elliott et al. 2002) and this determines the fish feeding strategy (Morawski 1978; Costa et al. 2002). The majority of energy-cost processes (intensive growth, spawning) of sticklebacks occur in spring and summer (Wootton 1984) and according to Wootton (1994), the metabolic demands increase with temperature.

Stickleback is a well-known omnivorous opportunistic feeder (Wootton 1984). It feeds on various animals depending on the biocenosis structure and environmental conditions. Quantitatively the most important food components in three-spined stickleback guts were *Crustacea* – planktonic (Calanoida, Cladocera) and benthic Harpacticoida. According to Peltonen (2004), sticklebacks prey mostly on planktonic crustaceans. Copepoda eggs, which quantitatively dominated in spring samplings most likely get into the fish guts together with the consumed females. Benthic components were represented by *Batyporeia* sp., Nematoda and *Gonothyrea* sp. According to the study conducted in the Archipelago of SW Finland, *Corophim volutator, Hediste diversicolor, Gammarus* sp., Chironomids and plankton were the most important prey (Rajasilta 1980). Based on the analysis of the stickleback diet, the potential competition for food between stickleback and young round gobies can be excluded. According to Rzeźnik and Skóra (2001), young round goby (20-40 mm) in the Gulf of Gdańsk feed mostly on Polycheta and Crustacea.

Fish eggs were found in the guts of fish from all samples. It is possible that herring eggs were present in the Sopot area in spring. According to Kotterba et al. (2014), the three-spined stickleback is considered to be the most important piscine herring-spawn predator within the Baltic Sea lagoons and estuaries, and the Sopot sampling site is located near the potential herring spawning area (BRISK 2010).

Fish eggs were present in large quantities in the stomachs of fish collected during summer in Hel. They were probably stickleback eggs coming from damaged nests. Hynes (1950) reported that it is a common situation that males eat eggs from their nests and non-breeding males and females raid the eggs from nests.

Parts of the imago of insects found in the samples from all the locations were an interesting finding. Large quantities of insect remains in the fish stomachs may prove intentional selection of this dietary component. Insects probably accidentally fell into the water or were feeding on algae decomposing on the shore and were washed away by waves. It is known that stickleback can feed near water surface (Peltonen et al. 2004). In the literature, we found only a short report about the remains of insects in the stomachs of sticklebacks in the publication by Hynes (1950) – the author referred to the research by Blegvard (1917) on the diet of stickleback – and a short note about insects found in the diet of stickleback from Estonia (Saat & Turovski 2003). Taking into account our data, it would be useful to analyze the significance of insects in the diet of sticklebacks from the shallow coastal seawaters.

The feeding patterns are influenced by environmental, behavioral and physiological factors (Cortés 1997). The research was carried out during warm months, which excludes a negative effect of biotic (lack of food) or abiotic factors (temperature changes) affecting the feeding (Thorman & Wiederholm 1983; Złoch et al. 2005). The observed differences in the stomach fullness index must due to other factors. It should be kept in mind that feeding is also related to the fish size (Grodziński 1971; Herczeg et al. 2013), because the diet composition changes during the ontogenesis of fish (Złoch et al. 2005). It can be noticed that smaller fish feed more intensively than the larger ones, probably due to their faster growth rate (Grodziński 1971; Kapoor & Bhavna Khanna 2004; Wootton 1984, 1994). At the early stage of development, fish need to cover the cost of a higher metabolic rate, with becomes slower in the case of adult fish (Nikolski 1963). The highest stomach fullness index was determined in Chałupy, probably because the smallest fish were caught there in large quantities (Fig. 2, Fig. 4). The smallest value of the index value was determined in Sopot in summer due to the presence of the largest fish (Fig. 2, Fig. 4).

The stickleback stomach analysis has shown that planktonic prey includes both Cladocerans and Copepods (Peltonen et al. 2004). In the presented work, the food selectivity index was calculated for three food items (Cladocera, Copepoda, Nematoda), because data on the quantity of other items in the environment were not available or they were defined as absent. Ivlev's indices shows that the three-spine stickleback was avoiding Copepoda at the Hel sampling location in spring and summer, while choosing Cladocera in both seasons. According to Peltonen et al. (2004), three-spined sticklebacks in the Gulf of Finland (the East Baltic) feed mostly on zooplankton. It is known that periodical accessibility of the easily available food categories changes the food preferences (Dukowska et al. 2009). The research of Lefebure et al. (2014) shows an increase in *G. aculeatus* attack rates with temperature, and Persson (1987) concludes that this fish has generally a higher attack rate in the case of slow moving cladocerans compared to the fast moving copepods. This may suggests that fish select from the available food types those prey that provide the highest net energy gain (Stephens & Krebs 1986).

Fulton's body condition was treated as an index reflecting the use of environmental resources.

The body condition index was calculated separately for all individuals caught at all three sampling locations. There were no significant differences in the index values (Fig. 5). According to ANOVA analysis, the *G. aculeatus* body condition in spring and summer was independent from the season and dependent on the total fish length and sampling location.

During the spring research on benthos and plankton structure in Sopot (data from the COSA project), macrobenthos was dominated by *Crustacea* (*Bathyporeia* sp.), meiofauna by Nematoda and zooplankton by Rotatoria. Some of these taxa (Rotatoria) were not found in the stomach of three-spined sticklebacks from this region. A similar situation was also observed at other sampling sites – the organisms dominant in the environment were not always the most abundant food items in the fish stomachs. This means that not all the dominant organisms in the environment are eaten by the three-spined stickleback. This may suggest that *G. aculeatus* does not choose the dominant organisms but easy-to-catch or energy efficient prey. Stephens & Krebs (1986) suggested that the handling time (the amount of time spent by a predator to search and catch the prey) is balanced by the energy gained from eating the prey. Gill & Hart (1994) concluded that the decision whether to consume the prey depends on the relations between the size of prey, the size of predatory fish and the stomach fullness. This could be an explanation for the absence of some taxa in the fish stomach, while found in the environment.

It is also known that the composition of fish food may change during the day (Złoch et al. 2005) and seasons. The examined fish specimens were caught mostly during the morning samplings in warm months of the year, while the research carried out for 24 hours throughout the year could give us a different perspective on the food composition of the three-spined stickleback. Due to the annual changes in the food base as well as seasonal and daily changes in the metabolic rate of stickleback, we can expect differences in the food composition and quantity.

Despite the time of the study (2005), current random analyses of the stickleback gut content in similar locations show no significant differences in the prey of sticklebacks. The described feeding patterns are still observed.

Conclusions

The results of the research show that the three-spined stickleback can effectively prey on various food items, in various habitats of the Gulf of Gdańsk. Its body condition remains stable. No statistically significant differences in the fish body condition were found irrespective of the stomach content and the local food base in the study area.

All food items found in the fish stomachs were characteristic of the shallow water zone. The comparison of Fulton's body condition index, the stomach content and the food selectivity index values in relation to environmental conditions reveals that the three-spined stickleback may effectively use the available food resources in spring and summer, regardless of their local composition.

Although there is no evidence that the stickleback can reduce the invasion of round goby by preying on its eggs, it is an important predator of eggs of other fish species in the shallow water zone.

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