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Title: Seasonal patterns in round goby (*Neogobius melanostromus*) catch rates, catch composition, and dietary quality.

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Abstract:

The round goby (*Neogobius melanostromus*; Pallas, 1814) is one of the most widespread invasive fish species. It originates from the Black Sea and the Sea of Azov, but has unintentionally been introduced to fresh and brackish water bodies on both sides of the Atlantic. Small-scale fishermen catch large amounts of the invasive round goby in their nets as the species continues to spread and populate new areas of the Baltic Sea. In the present study we were concerned with the possibilities for a “use and reduce” solution to the round goby invasion. However, in order to capture the interest of restaurants, supermarkets, and
distributers, more information is needed. We therefore studied a round goby bycatch fishery in the Western Baltic Sea (Denmark) and described the seasonal dynamics in catch rates, size distribution, condition factor, lipid and protein content, fatty acid profile, and meat texture. We conclude that while the catch rates peaked in spring, oil content and meat texture improved significantly later in the year. Protein content also peaked in late summer and fall, but it was only marginally higher compared to spring. In the discussion, we compared the nutritional quality, including the fatty acid profile, to other species used for human consumption and related the observed seasonal dynamics to what is known about round goby biology.

Key words: round goby, texture, invasive species, fatty acids, dietary quality, lipids

Introduction

Invasive non-indigenous species can put pressure on the native fauna through predation or competition for food and habitat niches (Olenin et al., 2017). In the worst cases, invasive alien species not only act as environmental pressures, but also local societies and economies may suffer. Some examples of this could be touristic disadvantages and declines in fishery and aquaculture opportunities, leading to less production and therefore less employment (Bax et al., 2003). Consequently, much effort has over the years been put into the development of new ways of controlling or reducing invasive species and prevent them from spreading further (Ojaveer et al., 2015).

In the Baltic Sea alone, around 100–118 species have been identified as non-indigenous (HELCOM, 2012). Among those species, one of the most successful invaders is the round goby
(Neogobius melanostomus; Pallas, 1814) originating from the Black Sea and the Sea of Azov. The round goby has spread into various fresh and brackish water bodies on both sides of the Atlantic. It has invaded the Laurentian Great Lakes in North America and connecting rivers and channels (Charlebois et al., 2001; Corkum et al., 2004; Young et al., 2009). In the 1990s, the species was observed for the first time in the Baltic Sea, more specifically in the Gulf of Gdansk (Sapota and Skóra, 2005), where it established a dense population and later spread into adjacent areas (Azour et al., 2015; Kotta et al., 2015; Sapota & Skóra, 2005). It was suggestively introduced via ballast water to the Gulf of Gdansk (Kotta et al., 2015). Nowadays, it is common for small-scale fishermen to find round goby in their nets and traps as by-catch over large parts of the Baltic Sea (Ojaveer, 2006). The spread and the numbers of round goby are increasing, posing a risk to the local environment and biodiversity. It competes for space and food with indigenous fish (Balshine et al., 2005; Karlson et al., 2007), and previous research has shown that round gobies can negatively impact other species of fish in part by eating their eggs and young (Chotkowski and Marsden, 1999; French and Jude, 2001; Steinhart et al., 2004). Moreover, local fishermen experience a loss of income, since fishing their target species has become impossible in some areas due to large amounts of round goby filling up fishing gears.

Among the endeavors to fight invasive species, we find examples of “use and reduce” solutions, which stems from the notion, that if the economical incentive for harvesting an invasive species is high enough, population numbers (of the invasive species) will be reduced over time, and hopefully this will result in a positive feedback on the native fauna, that was pressured by the arrival of the invasive species in the first place (Karp & Wyatt, 2017; Reise, 1998; Wessel, 2004). One of the most famous examples from northern Europe are the red king crab (Paralithodes camtschaticus). In the 1960s, the red king crab was first introduced to the Bering Sea and the Murmansk area (Falk-Petersen et al., 2011; Hjelset, 2014; Orlov and Ivanov, 1978). From here it spread further and the first crabs in Norwegian waters were caught in Varanger in 1977. In 2002, a
commercial fishery was established in Norway, based on a quota system to benefit those
fishermen who suffered economically from the invasive species due to by-catch and destroyed
gear. The fishery is today of high value (app. 9 million Euro in 2003) and local fishermen have
become more or less economically dependent on this species (Wessel, 2004).

Seen in light of the king crab example and given that the round goby is already commercially
harvested in some parts of the Black Sea region (Jude et al., 1992; Kornis et al., 2012) and sold as
fresh fish or as canned products (Zarev et al., 2013), a “use and reduce solution” for the round
goby appears to be within reach. However, in order to capture the interest of restaurants,
supermarkets, and distributors, more knowledge about the seasonality in availability and
nutritional and sensory quality is needed.

Knowledge about the expected seasonal fluctuations in size, condition (i.e. weight relative to
length) and catch rates provide a useful foundation for planning of fishing activities and
infrastructure. Knowing the chemical composition of the fish meat (i.e. the fillet) may play an
essential role in the marketing process of new fish products. Proteins make up most of fish meat
and the content range from 10 to 25 % in lean fish species (Huss, 1995; Nunes et al., 2006). On
average, more fatty species contain relative less protein, but are often rich in healthy lipids. Fish
lipids are, for example, an excellent source of the long-chain omega 3 unsaturated fatty acids.
These are essential for the human body and leads to a reduced risk of cardiovascular diseases and
improved mental health, immune system and infant brain development (Song et al., 2016;
Wysoczanski et al., 2016; Nichols, et al., 2014). Last, but not least, also the meat firmness (i.e.
texture), which is part of the sensory quality, is very important for the consumer acceptance and
for the processing, especially when the fish is filleted (Rasmussen et al., 201; Ingerslev et al.,
2012).
In the present study we collected round goby bycatch data from three invaded sites in Southern Denmark (Western Baltic Sea) in 2017. With this data we (1) assembled the most (to this date) detailed description of the catch rates and catch composition (from size and gender distribution to the chemical composition of the fillets) of round gobies caught in a commercial fishery, and (2) tested for seasonal patterns in these data (i.e. differences between months).

Materials and Methods

Fishing for round goby I from April 2017 to November 2017 and involved three small scale fishers using fyke nets to target eels. A recent tagging study has shown that during this period the round goby favors shallow, coastal water and thus is caught in the small-scale fisheries operating near the coast (Christoffersen et al., 2019). As reported by the fishermen, the fyke nets were always fishing for 72-94 h and were of similar types and mesh sizes (30 mm fyke nets). The three fishers were located in Guldborgsund, Kalvehave, and Karrebæksminde, respectively (Fig. 1) and were asked to maintain a logbook, recording the amount of by-caught round goby and the number of fyke nets used, which allowed us to use monthly catch per unit effort (CPUE) (i.e. kg/fyke net) as a measure of relative abundance. To reduce the time of handling, the size of catches was approximated by establishing the weight of a 20 L bucket filled with round goby after which all landings were measured in numbers of buckets times the weight of a full bucket. The fishers also put aside two sets of samples during the fishing season. The first set of samples was collected on a monthly basis and consisted of >200 individuals from a random fyke net catch. These samples were placed in a -18C freezer and were later used to determine size, condition factor, and gender distributions. Spread out over the year a total of 3707 fish were measured to the nearest mm (1047, 1516, and 1144 from Guldborgsund, Kalvehave, and Karrebæksminde, respectively). The fish were then sorted into centimeter intervals and 10 fish from each centimeter interval (or all if less
than 10) were saved for further analyses, which involved weighing the fish to the nearest 0.1 grams and determining sex by examination of the urogenital papilla (Charlebois et al., 1997).

Fulton’s condition factor (K) was calculated as \( (W/L^3) \times 10^5 \), where \( W \) is the weight of the fish (in grams) and \( L \) is the standard length in mm (Ricker, 1975).

The second set of samples were collected in April, June, August and November and consisted of 20 fresh fish fillet from each month (80 in total) from relatively large gobies only (>12 cm). Fillets were put on ice and transported to the laboratory on the day of capture and analyzed the next day with respect to fat content, protein content, fatty acid composition, and texture.

The lipid and protein content were determined in altogether 76 fillets (4 fillets were lost during preparation for lab. analyses). The analysis required c. 30 g of tissue per sample and another 30 g were needed for the subsequent fatty acid FAME analysis (see description below). It was therefore necessary to pool fillets in groups of two or three. In total 37 pooled samples were analyzed (11, 6, 14, and 6 from April, June, August, and November, respectively). The lipid content was determined by the Bligh & Dyer method (Bligh and Dyer, 1959) using a reduced amount of solvent. Lipid content of the material was extracted by utilizing a homogenous mix of chloroform \((\text{CHCL}_3)\), methanol \((\text{CH}_3\text{OH})\) and ion-exchanged water, with the ratio of 2:2:1.8. Samples were centrifuged at 2800 rpm for 10 minutes, filtered and dried (here the dry matter of the fillet could also be determined). Final lipid content was determined gravimetrically. The protein content was determined chemically by analyzing the nitrogen content applying the Dumas method for quantitative determination of nitrogen in different matrices (Elementar, Mt. Laurel, NJ, USA).

Samples where combusted at 900°C under the influence of oxygen with a flow of 180 ml per minute. The pressure applied was 1450 mbar ± 50 mbar and for calibration, 250 mg aspartic acid was used as standard. Conversion of the estimated total nitrogen content to the crude protein was done using a conversion factor of 6.25.
The contribution of different fatty acid methyl esters to the total lipid pool in fillets from Guldborgsund was quantified and described using gas liquid chromatography. All fatty acids in the triglycerides, phospholipids and free fatty acids were converted into fatty acid methyl esters. Fatty acid profile was determined based on the American Oil Chemist’s Society (AOCS) official method Ce 1b-89 and Ce 1i-07 with some modifications. Approximately 2 g of Bligh & Dyer extract was weighted in methylation glass tube and evaporated under a stream of nitrogen until dryness. A mixture containing 100 μL of internal standard solution (C23:0), 200 μL of heptane with BHT and 100 μL of toluene was added to the dry extract. Samples were methylated in a microwave oven (Microwave 3000 SOLV, Anton Paar, Ashland, VA, USA) for 5 min. at 100 °C and power of 500 watts. After methylation, heptane with BHT (0.7 mL) and saturated salt water (1 mL) were added. The upper phase (heptane) was transferred into HPLC vials and analysed by gas chromatography (HP-5890 A, Agilent Technologies, Santa Clara, CA, USA). Fatty acid methyl esters were separated by the GC column Agilent DB wax 127-7012 (10 μm x 100 μm x 0.1 μm) (Agilent technologies, Santa Clara, CA, USA). Standard mix of fatty acids methyl esters (Sigma, St. Louis, MO, USA) was used for fatty acid identification. Fatty acids were quantified as area % of total fatty acids. Analyses were carried out in duplicate. The different types of fatty acids were grouped into six categories commonly reported in nutritional studies: MUFA (monounsaturated fatty acids), DHA (Docosahexaen acid, 22:6 n-3), EPA (Icosapentaen acid, 20:5 n-3), PUFA (polyunsaturated fatty acids), PA (palmitic acid, C16:0), SFA (saturated fatty acids), n-3 (omega-3 fatty acid), and n-6 (omega-6 fatty acid). Note that although we refer to these as fatty acid groups, some, such as DHA, EPA, and PA constitute single fatty acids. Note also that n-3 and n-6 is contained also within PUFA, just as PA is contained within SFA.
The firmness (i.e. texture) of the meat was measured with a TPA on all 80 fish fillets, using a compression test on raw fillet, two measuring point on each fillet (see figure 2). The force, [N], at a single compression to 40% of initial sample thickness was recorded (TA.XT2® Texture Analyser). The compression was performed in longitudinal configuration with a 10 mm probe with rounded edges and the probe speed was 1 mm/sec (for further details see Rasmussen et al. 2011).

For CPUE, length, and condition factor the null hypothesis, stating that there were no differences between the different sample months and study areas, was tested using two-way ANOVA statistics. For lipid content, protein content, and firmness, only differences between months were investigated (using one-way ANOVA), since the proximate chemical composition and firmness was only determined in samples from Guldborgsund.

**Results**

Significant differences in CPUE was found between months (ANOVA: $F_{7, 124}=34.1$, $p<0.001$) and study areas (ANOVA: $F_{2, 124}=3.64$, $p=0.029$). May was the month with the highest CPUE at all three location. Mean CPUE ranged between 7 and 10 kg per net in May and the overall highest CPUE was observed for Kalvehave. Except for Guldborgsund, where CPUE in April was nearly as high as in May, all other months produced CPUEs that was <50% of May. In Guldborgsund, there was a second peak in CPUE in September, although much smaller than in May. Whereas, in Kalvehave and Karrebæksminde, CPUEs dropped rapidly after May and fated more or less out from July and onwards (Fig. 3 and Table 1).
The majority of fish were males in all locations (average: 74.6%). There was also a common seasonal pattern, characterized by a peak in the percentage of males during mid-summer and a low in fall (Fig. 4).

Average length was 12.0 cm. Significant differences in length were found between months (ANOVA: $F_{7, 4668}=140.0$, $p<0.001$) and study areas (ANOVA: $F_{2, 4668}=981.2$, $p<0.001$). However, a visual inspection of the monthly differences did not reveal any common seasonal patterns (Fig. 5). In Karrebækminde, the largest fish were found during summer (July and August), whereas, spring yielded the largest mean lengths in Kalvehave. In Guldborgsund, mean length fluctuated from month to month, with no apparent seasonal pattern. However, all differences were minute and were presumably only tested significant because of the relatively large sample sizes. All length distributions appeared unimodal, making it impossible to distinguish between cohorts based on length alone (Fig. 6).

Condition factor ($K$) did not differ significantly between months (ANOVA: $F_{7, 1059}=32.9$, $p<0.001$) and study areas (ANOVA: $F_{2, 1059}=31.4$, $p<0.001$). A visual inspection of the seasonal dynamics revealed a distinct pattern common for all three areas (most pronounced in Kalvehave and Karrebækminde) (Fig. 7). In all three areas a peak in $K$ was observed in May, hereafter $K$ decreased gradually from June to August, and from August to November $K$ increased again. Table 1 summarizes average values of CPUE, length, weight, and $K$.

The assessment of the nutritional profile and meat firmness was based on data from Guldborgsund only. Mean oil content differed significantly between months (ANOVA: $F_{3, 33}=49.0$, $p<0.001$), gradually increasing from spring towards fall. Lipid content peaked at 1% in November (opposed to 0.64% in April) (Fig. 8). The protein content increased significantly from 17.3% in April to 18.8% in August (ANOVA: $F_{3, 33}=21.75$, $p<0.001$), where after a small drop occurred between
August and November (Fig. 8). Firmness of fillets was highest in November (2.70 N ± 0.58) and lowest in June (0.83 N ± 0.32) (ANOVA: $F_{3.76}=61.7$, $p < 0.001$) (Fig. 9).

DHA was the most common of the fatty acid methyl esters (averaging 17.2% of the total pool of fatty acids across months) (Table 2) and the only fatty acid to show a notable seasonal pattern, displaying a significant drop around August (Fig. 10). The overall mean proportion of PUFA (across months) was 50.6 %, whereas, MUFA only constituted 14.6% on average. The omega-3 type of fatty acids (n-3) constituted 38% of the total pool of fatty acids.

Discussion

Local fishermen and ecosystems in the Baltic Sea are pressured by the sheer number of round gobies invading coastal areas including estuaries and shallow bays. In the present study, fishermen from three locations in southern Denmark (western Baltic) reported all by-catches of round goby in 2017 and collected monthly samples for detailed analysis of seasonal catch composition, catch efficiency and quality of the fish. All to assess the potential for a cost-efficient, use and reduce commercial fishery for a species, which is currently unwanted bycatch in many coastal fisheries.

Round goby catch per unit effort (CPUE) was highest in May and lowest in July/August, suggesting that a fishery for this species would be most efficient during late spring. The observed CPUE ranged between less than 1 kg/net up to a maximum of 10 kg/net (or 1 tons of round goby landed during a single fishing session, which equals 100 fyke nets left at sea for 3-4 days). As these data are based on bycatch of round goby in a fishery targeting flatfish and European eel, higher CPUE may indeed be achieved in a fishery targeting round goby. In support of the potential for high catch rates of round goby, an ongoing data-collection program, between researchers and
fishermen, have shown that round goby is more frequently encountered in catches than some of the most common indigenous species, such as European flounder (*Platichthys flesus*, L.) and eelpout (*Zoarces viviparous*, L.) (Støttrup et al., 2018). This agrees well with densities of c. two round goby m\(^{-2}\), which was recorded during snorkel surveys in the same areas (Azour et al., 2015; Christoffersen et al., 2019). In Muuga Bay (Gulf of Finland), the fish accounts for more than 80\% of the catches in gillnets of mesh size 36-44 mm (ICES, 2017), and along the quite limited Lithuanian coastal area (100 km wide) over 200 tons of gobies were caught in 2016 and 2017 (NRC 2016, 2017). Still, the largest round goby landings in the Baltic Sea are currently taking place in Latvian coastal waters, where fishery logbook data evidence a sharp increase in catches from less than 1 ton in 2011 to over 500 tons in 2016 (Kornilovs, 2017).

When using passive fishing gear, such as fyke nets, catch rates are highly dependent on fish behavior and activity (Diana et al., 2006), and the present pronounced difference in CPUE between months (with the same overall trend for all three areas) may reflect behavioral changes of the round goby, rather than actual difference in number of fish in the areas. For example, round goby feed intensively during the pre-spawning spring period, inferring high activity and mobility, and then start aggregating in June, where males prepare the nests and females swim around and choose nests (Meunier et al., 2009). In July and August, the fish are rather stationary and immobile as the males guard the nests and the females spawn (Meunier et al., 2009; Skabeikis and Lesutiene, 2015).

All three locations in the present study were dominated by male round gobies. The areas were invaded between 2009 and 2011 (Azour et al., 2015), and the populations of round gobies here may thus be considered well established. Compared to more recently established populations, older populations are often characterized by having male bias (Brandner et al., 2013; Gruľa et al., 2012; Gutowsky and Fox, 2012), which confers with the present findings. Males however are also considered to be more active than females and hence more prone to be caught by passive gear,
which may be one additional factor explaining the male bias in the present catches (Marentette et al., 2011; Skabeikis and Lesutiene, 2015).

Not only the amount caught in the fishery, but also the size composition and quality of the catch is of utmost importance, as this largely determines its utilization and hence prize. Round goby is a relatively small fish and in the present three study areas the length averaged 12 cm. Round goby may occasionally attain an average size of up to 19 cm in some parts of the Baltic Sea (Melvere et al., 2017). However, a maximum length of 22 cm, as found in the present study, suggested that the growth potential here is similar to most areas in the Baltic Sea, where studies have reported maximum lengths between 18 cm and 23 cm (Mierzwicka, 2000; Pliszka, 2002; Skora and Stolarski, 1996; Sokołowska and Fey, 2011); and higher compared to its native range (the Ponto-Caspian region and the Black Sea), where maximum length range from 18 cm to 19 cm (Apostolou et al., 2014; Macun, 2018).

As mentioned above, the breeding season peak in July and August (Skabeikis and Lesutiene, 2015), where round goby consequently display reduced feeding activity (MacInnis and Corkum, 2000; Skabeikis and Lesutiene, 2015). Condition factor often follows feeding and breeding cycles (Rätz and Lloret., 2003; Mozsár et al., 2015). Hence, the observed low condition between June and August is probably related to weight loss resulting from spawning and nest guarding behavior. After the spawning period, feeding resume and the condition increases again prior to winter (Skabeikis and Lesutiene, 2015).

Firmness refers to the physical and sensorial properties of the meat and is used as an indicator of quality in food science (Chen and Rosenthal 2015). The firmness of the round goby fillet, measured in present study, was 0.8 – 2.7 N. For comparison, Rasmussen et al. (2011) reported the firmness of farmed trout (Oncorhynchus mykiss) to be between 1.1 and 3.3 N, whereas, herring fillets (Clupea harengus) measured in Nielsen et al. (2005) was considerably firmer.
(2.45 – 5.88 N compressed to 60%; as opposed to 40% in the present study). As expected seasonal differences in firmness of round goby followed dynamics in the condition factor and proximate chemical composition (lipids and proteins).

The chemical composition of fish depends on food intake and season (Aidos et al., 2002; Huss 1995; Skabeikis and Lesutiene, 2015). Especially, the lipid content of fish may undergo considerable fluctuations during the course of a year (Aidos et al., 2002; Aro et al., 2000; Gladyshev et al., 2009). Fish gather energy prior to spawning and use that energy during spawning, resulting in a rapid decline in lipids (Love, 1988). As mentioned above, the main spawning period for round goby is July and August, possibly explaining the decrease in lipid content observed in the present study. The observed decline of DHA in August may also be related to spawning, as DHA is used for egg production (Tocher, 2010). The remaining fatty acids and fatty acid groups presented here (EPA, MUFA, n-3, n-6, PA, PUFA, and SFA) remained relatively stable between sample months.

In general, the fish were rather lean (fat content up to 1%) with a high protein content (17-19%). Protein content was comparable to that of cod fillets (Gadus morhua) (16-19%), whereas, the lipid content was slightly higher (0-0.4% in cod fillets) (Waterman, 2001), but still much lower than reported for more fatty species, such as herring (Clupea harengus), which, can amount up to 17-25% (Jensen et al., 2007; van Deurs et al., 2018). The lipid and protein content found here also resembled that of a previous round goby study, which found mean lipid content of 0.67% and mean protein content of 16.6% in April (Melvere et al., 2017).

Compared to Strobel et al. (2012), the proportion of EPA and DHA in cod is much higher than in round goby analyzed in the present study. Strobel et al. (2012) showed mean values of around 51% EPA+DHA, compared to c. 30% in the present study. In comparison, Jensen et al. (2007) found that EPA+DHA varied from 14 to 21.6% in herring and Strobel et al. (2012) found that rainbow
trout contained 16.6 % EPA+DHA. The proportion of total PUFA (50.6 %) was at the same level as that found in pollock and Alaska pollock and much higher than that found in herring, tuna and rainbow trout (Strobel et al., 2012). The proportion of palmitic acid in round goby is comparable to that in herring, salmon and rainbow trout. The proportion of SFA in round goby is low (23.2 %) and at the same level as that in herring, pollock, Alaska pollock and rainbow trout, but much lower than that in tuna (34.8 %) (Strobel et al., 2012).

Overall, these data suggested that round goby has a favorable fatty acid composition and meat quality comparable to other species used for human consumption. Catch rates peaked in spring, whereas meat firmness, lipids and protein peaked in the second half of the year. However, while nearly a doubling in lipid content could be achieved by targeting round goby in fall, opposed to spring, the relative gain in terms of protein, from a targeting round goby in late summer, is minute. Hence, in the cases where lean fish is favored, the high catch rates achieved in spring may be what determines what is the best fishing season. Average size was more or less the same throughout the year, therefore size optimization should be made with gear choice rather than timing the fishery.

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Table 1. Summary of fisheries data.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Guldborgsund</th>
<th>Kalvehavesund</th>
<th>Karrebeksminde</th>
<th>All Areas</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (cm)</td>
<td>All</td>
<td>9.7 ± 2.2</td>
<td>12.9 ± 2.0</td>
<td>11.9 ± 1.8</td>
<td>11.3 ± 2.5</td>
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<td></td>
<td>Male</td>
<td>9.9 ± 2.3</td>
<td>13.2 ± 1.9</td>
<td>12.1 ± 1.7</td>
<td>11.7 ± 2.5</td>
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<tr>
<td></td>
<td>Female</td>
<td>9.5 ± 2.0</td>
<td>11.5 ± 1.9</td>
<td>11.2 ± 1.8</td>
<td>10.2 ± 2.1</td>
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<tr>
<td>Weight (g)</td>
<td>All</td>
<td>23.5 ± 16.2</td>
<td>29.1 ± 25.2</td>
<td>29.7 ± 19.6</td>
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<td></td>
<td>Male</td>
<td>25.8 ± 17.3</td>
<td>42.3 ± 24.6</td>
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<td>34.7 ± 22.5</td>
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<tr>
<td></td>
<td>Female</td>
<td>19.4 ± 13.2</td>
<td>26.0 ± 23.1</td>
<td>17.7 ± 13.4</td>
<td>21.1 ± 17.2</td>
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<td>K- factor</td>
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<td>1.5 ± 0.2</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>Female</td>
<td>1.5 ± 0.2</td>
<td>1-6 ± 0.3</td>
<td>1.4 ± 0.2</td>
<td>1.5 ± 0.2</td>
<td></td>
</tr>
<tr>
<td>CPUE (kg/net)</td>
<td>All</td>
<td>2.6 ± 2.3</td>
<td>1.3 ± 2.3</td>
<td>1.1 ± 1.5</td>
<td>1.4 ± 2.1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

values are shown as mean ± standard deviation

Table 2. Summary of the relative contribution (%) of the different fatty acid groups to the overall pool of fatty acids in the fillet.

<table>
<thead>
<tr>
<th>Fatty acid group</th>
<th>Mean %</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPA</td>
<td>14.7</td>
<td>0.5</td>
</tr>
<tr>
<td>DHA</td>
<td>17.2</td>
<td>4.6</td>
</tr>
<tr>
<td>PUFA</td>
<td>50.6</td>
<td>6.1</td>
</tr>
<tr>
<td>Total n-3</td>
<td>38</td>
<td>4.3</td>
</tr>
<tr>
<td>Total n-6</td>
<td>10.7</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>PA</td>
<td>15.6</td>
<td>1</td>
</tr>
<tr>
<td>MUFA</td>
<td>14.6</td>
<td>3</td>
</tr>
<tr>
<td>SFA</td>
<td>23.2</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Figure 1. Map of survey sites. The study locations are indicated by dots connected to the name of the location.

Figure 2. The points on the fish fillet, where the texture measurements were conducted.

Figure 3. Average catch per unit effort (CPUE; kg/net) of round goby calculated by month and location: Guldborgsund (white), Kalvehave (grey), and Karrebæksminde (black).

Figure 4. Gender proportions in percentages calculated for each month and study area, respectively. Males (Black) and females (grey).

Figure 5. Length distributions presented for each month and study area: (A) Guldborgsund, (B) Kalvehave and (C) Karrebæksminde. Horizontal dashed lines represent the overall mean length across all months and locations. The boxes encapsulate all data points between the 25% and 75% quantiles and the horizontal black bar represents the median. Error bars represents 5% and 95% quantiles.
Figure 6. Length frequency distribution in (A) Guldborgsund, (B) Kalvehave and (C) Karrebæksminde.

Figure 7. Condition factor presented for each month and study area: (A) Guldborgsund, (B) Kalvehave and (C) Karrebæksminde. Horizontal dashed lines represent the overall mean length across months and locations. The boxes encapsulate all data points between the 25% and 75% quantiles and the horizontal black bar represents the median. Error bars represents 5% and 95% quantiles.

Figure 8. Dietary quality of round goby fillets from Guldborgsund presented for each month (76 fillets). (A) Total lipid content (% of wet weight), (B) total protein content (% of wet weight). The boxes encapsulate all data points between the 25% and 75% quantiles and the horizontal black bar represents the median. Error bars represents 5% and 95% quantiles.

Figure 9. Firmness (i.e. texture) of the meat measured in number of Newtons (N) it takes to compress the meat to 40% of initial thickness. The boxes encapsulate all data points between the 25% and 75% quantiles and the horizontal black bar represents the median. Error bars represents 5% and 95% quantiles. Horizontal dashed lines represent the overall mean length across all months and locations.

Figure 10. Fatty acid (fatty acid methyl esters) composition in round goby fillets from Guldborgsund. Fatty acids were grouped into six categories commonly reported in nutritional sciences: MUFA (monounsaturated fatty acids), DHA (Docosahexaen acid), EPA (Icosapentaen...
acid), PUFA (polyunsaturated fatty acids), PA (palmitic acid), SFA (saturated fatty acids), n-3 (omega-3 fatty acid), and n-6 (omega-6 fatty acid). Columns show the percentage of total fatty acids.
Fig 2
Fig 3

Fig 4
Fig 5
Fig 6
Fig 7