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

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5

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14

15 Abstract:

16 The round goby (*Neogobius melanostomus*; Pallas, 1814) is one of the most widespread
17 invasive fish species. It originates from the Black Sea and the Sea of Azov, but has un-
18 intentionally been introduced to fresh and brackish water bodies on both sides of the Atlantic.
19 Small-scale fishermen catch large amounts of the invasive round goby in their nets as the
20 species continues to spread and populate new areas of the Baltic Sea. In the present study we
21 were concerned with the possibilities for a “use and reduce” solution to the round goby
22 invasion. However, in order to capture the interest of restaurants, supermarkets, and

23 distributors, more information is needed. We therefore studied a round goby bycatch fishery in
24 the Western Baltic Sea (Denmark) and described the seasonal dynamics in catch rates, size
25 distribution, condition factor, lipid and protein content, fatty acid profile, and meat texture. We
26 conclude that while the catch rates peaked in spring, oil content and meat texture improved
27 significantly later in the year. Protein content also peaked in late summer and fall, but it was
28 only marginally higher compared to spring. In the discussion, we compared the nutritional
29 quality, including the fatty acid profile, to other species used for human consumption and
30 related the observed seasonal dynamics to what is known about round goby biology.

31

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

33

34

35 Introduction

36 Invasive non-indigenous species can put pressure on the native fauna through predation or
37 competition for food and habitat niches (Olenin et al., 2017). In the worst cases, invasive alien
38 species not only act as environmental pressures, but also local societies and economies may suffer.
39 Some examples of this could be touristic disadvantages and declines in fishery and aquaculture
40 opportunities, leading to less production and therefore less employment (Bax et al., 2003).
41 Consequently, much effort has over the years been put into the development of new ways of
42 controlling or reducing invasive species and prevent them from spreading further (Ojaveer et al.,
43 2015).

44 In the Baltic Sea alone, around 100–118 species have been identified as non-indigenous
45 (HELCOM, 2012). Among those species, one of the most successful invaders is the round goby

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

62 Among the endeavors to fight invasive species, we find examples of “use and reduce” solutions,
63 which stems from the notion, that if the economical incentive for harvesting an invasive species is
64 high enough, population numbers (of the invasive species) will be reduced over time, and
65 hopefully this will result in a positive feedback on the native fauna, that was pressured by the
66 arrival of the invasive species in the first place (Karp & Wyatt, 2017; Reise, 1998; Wessel, 2004).
67 One of the most famous examples from northern Europe are the red king crab (*Paralithodes*
68 *camtschaticus*). In the 1960s, the red king crab was first introduced to the Bering Sea and the
69 Murmansk area (Falk-Petersen et al., 2011; Hjelset, 2014; Orlov and Ivanov, 1978). From here it
70 spread further and the first crabs in Norwegian waters were caught in Varanger in 1977. In 2002, a

71 commercial fishery was established in Norway, based on a quota system to benefit those
72 fishermen who suffered economically from the invasive species due to by-catch and destroyed
73 gear. The fishery is today of high value (app. 9 million Euro in 2003) and local fishermen have
74 become more or less economically dependent on this species (Wessel, 2004).

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

81 Knowledge about the expected seasonal fluctuations in size, condition (i.e. weight relative to
82 length) and catch rates provide a useful foundation for planning of fishing activities and
83 infrastructure. Knowing the chemical composition of the fish meat (i.e. the fillet) may play an
84 essential role in the marketing process of new fish products. Proteins make up most of fish meat
85 and the content range from 10 to 25 % in lean fish species (Huss, 1995; Nunes et al., 2006). On
86 average, more fatty species contain relative less protein, but are often rich in healthy lipids. Fish
87 lipids are, for example, an excellent source of the long-chain omega 3 unsaturated fatty acids.
88 These are essential for the human body and leads to a reduced risk of cardiovascular diseases and
89 improved mental health, immune system and infant brain development (Song et al., 2016;
90 Wysoczanski et al., 2016; Nichols, et al., 2014). Last, but not least, also the meat firmness (i.e.
91 texture), which is part of the sensory quality, is very important for the consumer acceptance and
92 for the processing, especially when the fish is filleted (Rasmussen et al., 201; Ingerslev et al.,
93 2012).

94 In the present study we collected round goby bycatch data from three invaded sites in Southern
95 Denmark (Western Baltic Sea) in 2017. With this data we (1) assembled the most (to this date)
96 detailed description of the catch rates and catch composition (from size and gender distribution to
97 the chemical composition of the fillets) of round gobies caught in a commercial fishery, and (2)
98 tested for seasonal patterns in these data (i.e. differences between months).

99

100 Materials and Methods

101 Fishing for round goby I from April 2017 to November 2017 and involved three small scale
102 fishers using fyke nets to target eels. A recent tagging study has shown that during this period the
103 round goby favors shallow, coastal water and thus is caught in the small-scale fisheries operating
104 near the coast (Christoffersen et al., 2019). As reported by the fishermen, the fyke nets were
105 always fishing for 72-94 h and were of similar types and mesh sizes (30 mm fyke nets). The three
106 fishers were located in Guldborgsund, Kalvehave, and Karrebæksminde, respectively (Fig. 1) and
107 were asked to maintain a logbook, recording the amount of by-caught round goby and the number
108 of fyke nets used, which allowed us to use monthly catch per unit effort (CPUE) (i.e. kg/fyke net)
109 as a measure of relative abundance. To reduce the time of handling, the size of catches was
110 approximated by establishing the weight of a 20 L bucket filled with round goby after which all
111 landings were measured in numbers of buckets times the weight of a full bucket. The fishers also
112 put aside two sets of samples during the fishing season. The first set of samples was collected on a
113 monthly basis and consisted of >200 individuals from a random fyke net catch. These samples
114 were placed in a -18C freezer and were later used to determine size, condition factor, and gender
115 distributions. Spread out over the year a total of 3707 fish were measured to the nearest mm (1047,
116 1516, and 1144 from Guldborgsund, Kalvehave, and Karrebæksminde, respectively). The fish
117 were then sorted into centimeter intervals and 10 fish from each centimeter interval (or all if less

118 than 10) were saved for further analyses, which involved weighing the fish to the nearest 0.1
119 grams and determining sex by examination of the urogenital papilla (Charlebois et al., 1997).
120 Fulton's condition factor (K) was calculated as $(W/L^3) \times 10^5$, where W is the weight of the fish (in
121 grams) and L is the standard length in mm (Ricker, 1975).

122 The second set of samples were collected in April, June, August and November and consisted of
123 20 fresh fish fillet from each month (80 in total) from relatively large gobies only (>12 cm). Fillets
124 were put on ice and transported to the laboratory on the day of capture and analyzed the next day
125 with respect to fat content, protein content, fatty acid composition, and texture.

126 The lipid and protein content were determined in altogether 76 fillets (4 fillets were lost during
127 preparation for lab. analyses). The analysis required c. 30 g of tissue per sample and another 30 g
128 were needed for the subsequent fatty acid FAME analysis (see description below). It was therefore
129 necessary to pool fillets in groups of two or three. In total 37 pooled samples were analyzed (11, 6,
130 14, and 6 from April, June, August, and November, respectively). The lipid content was
131 determined by the Bligh & Dyer method (Bligh and Dyer, 1959) using a reduced amount of
132 solvent. Lipid content of the material was extracted by utilizing a homogenous mix of chloroform
133 (CHCl_3), methanol (CH_3OH) and ion-exchanged water, with the ratio of 2:2:1.8. Samples were
134 centrifuged at 2800 rpm for 10 minutes, filtered and dried (here the dry matter of the fillet could
135 also be determined). Final lipid content was determined gravimetrically. The protein content was
136 determined chemically by analyzing the nitrogen content applying the Dumas method for
137 quantitative determination of nitrogen in different matrices (Elementar, Mt. Laurel, NJ, USA).
138 Samples were combusted at 900°C under the influence of oxygen with a flow of 180 ml per
139 minute. The pressure applied was 1450 mbar $\pm$ 50 mbar and for calibration, 250 mg aspartic acid
140 was used as standard. Conversion of the estimated total nitrogen content to the crude protein was
141 done using a conversion factor of 6.25.

142 The contribution of different fatty acid methyl esters to the total lipid pool in fillets from
143 Guldborgsund was quantified and described using gas liquid chromatography. All fatty acids in
144 the triglycerides, phospholipids and free fatty acids were converted into fatty acid methyl
145 esters. Fatty acid profile was determined based on the American Oil Chemist's Society
146 (AOCS) official method Ce 1b-89 and Ce 1i-07 with some modifications. Approximately 2 g
147 of Bligh & Dyer extract was weighted in methylation glass tube and evaporated under a stream
148 of nitrogen until dryness. A mixture containing 100 μ L of internal standard solution (C23:0),
149 200 μ L of heptane with BHT and 100 μ L of toluene was added to the dry extract. Samples
150 were methylated in a microwave oven (Microwave 3000 SOLV, Anton Paar, Ashland, VA,
151 USA) for 5 min. at 100 °C and power of 500 watts. After methylation, heptane with BHT (0.7
152 mL) and saturated salt water (1 mL) were added. The upper phase (heptane) was transferred
153 into HPLC vials and analysed by gas chromatography (HP-5890 A, Agilent Technologies,
154 Santa Clara, CA, USA). Fatty acid methyl esters were separated by the GC column Agilent DB
155 wax 127-7012 (10 μ m x 100 μ m x 0.1 μ m) (Agilent technologies, Santa Clara, CA, USA).
156 Standard mix of fatty acids methyl esters (Sigma, St. Louis, MO, USA) was used for fatty acid
157 identification. Fatty acids were quantified as area % of total fatty acids. Analyses were carried
158 out in duplicate. The different types of fatty acids were grouped into six categories commonly
159 reported in nutritional studies: MUFA (monounsaturated fatty acids), DHA (Docosahexaen
160 acid, 22:6 n-3), EPA (Icosapentaen acid, 20:5 n-3), PUFA (polyunsaturated fatty acids), PA
161 (palmitic acid, C16:0), SFA (saturated fatty acids), n-3 (omega-3 fatty acid), and n-6 (omega-6
162 fatty acid). Note that although we refer to these as fatty acid groups, some, such as DHA, EPA,
163 and PA constitute single fatty acids. Note also that n-3 and n-6 is contained also within PUFA,
164 just as PA is contained within SFA.

165

166 The firmness (i.e. texture) of the meat was measured with a TPA on all 80 fish fillets, using
167 compression test on raw fillet, two measuring point on each fillet (see figure 2). The force, [N], at
168 a single compression to 40% of initial sample thickness was recorded (TA.XT2® Texture
169 Analyser). The compression was performed in longitudinal configuration with a 10 mm probe
170 with rounded edges and the probe speed was 1 mm/sec (for further details see Rasmussen et al.
171 2011).

172

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

178

179

180 Results

181 Significant differences in CPUE was found between months (ANOVA: $F_{7, 124}=34.1$, $p<0.001$) and
182 study areas (ANOVA: $F_{2, 124}=3.64$, $p= 0.029$). May was the month with the highest CPUE at all
183 three location. Mean CPUE ranged between 7 and 10 kg per net in May and the overall highest
184 CPUE was observed for Kalvehave. Except for Guldborgsund, where CPUE in April was nearly
185 as high as in May, all other months produced CPUEs that was <50% of May. In Guldborgsund,
186 there was a second peak in CPUE in September, although much smaller than in May. Whereas, in
187 Kalvehave and Karrebækssminde, CPUEs dropped rapidly after May and faded more or less out
188 from July and onwards (Fig. 3 and Table 1).

189 The majority of fish were males in all locations (average: 74.6 %). There was also a common
190 seasonal pattern, characterized by a peak in the percentage of males during mid-summer and a low
191 in fall (Fig. 4).

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

201 Condition factor (K) did not differ significantly between months (ANOVA: $F_{7, 1059}=32.9$, $p<$
202 0.001) and study areas (ANOVA: $F_{2, 1059}=31.4$, $p< 0.001$). A visual inspection of the seasonal
203 dynamics revealed a distinct pattern common for all three areas (most pronounced in Kalvehave
204 and Karrebæksminde) (Fig. 7). In all three areas a peak in K was observed in May, hereafter K
205 decreased gradually from June to August, and from August to November K increased again. Table
206 1 summarizes average values of CPUE, length, weight, and K.

207 The assessment of the nutritional profile and meat firmness was based on data from Guldborgsund
208 only. Mean oil content differed significantly between months (ANOVA: $F_{3, 33}=49.0$, $p < 0.001$),
209 gradually increasing from spring towards fall. Lipid content peaked at 1% in November (opposed
210 to 0.64% in April) (Fig. 8). The protein content increased significantly from 17.3% in April to
211 18.8% in August (ANOVA: $F_{3, 33}=21.75$, $p < 0.001$), where after a small drop occurred between

212 August and November (Fig. 8). Firmness of fillets was highest in November ($2.70 \text{ N} \pm 0.58$) and
213 lowest in June ($0.83 \text{ N} \pm 0.32$) (ANOVA: $F_{3,76}=61.7$, $p < 0.001$) (Fig. 9).

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

219

220

221 Discussion

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

228 Round goby catch per unit effort (CPUE) was highest in May and lowest in July/August,
229 suggesting that a fishery for this species would be most efficient during late spring. The observed
230 CPUE ranged between less than 1 kg/net up to a maximum of 10 kg/net (or 1 tons of round goby
231 landed during a single fishing session, which equals 100 fyke nets left at sea for 3-4 days). As
232 these data are based on bycatch of round goby in a fishery targeting flatfish and European eel,
233 higher CPUE may indeed be achieved in a fishery targeting round goby. In support of the potential
234 for high catch rates of round goby, an ongoing data-collection program, between researchers and

235 fishermen, have shown that round goby is more frequently encountered in catches than some of
236 the most common indigenous species, such as European flounder (*Platichthys flesus*, L.) and
237 eelpout (*Zoarces viviparus*, L.) (Støttrup et al., 2018). This agrees well with densities of c. two
238 round goby m⁻², which was recorded during snorkel surveys in the same areas (Azour et al., 2015;
239 Christoffersen et al., 2019). In Muuga Bay (Gulf of Finland), the fish accounts for more than 80%
240 of the catches in gillnets of mesh size 36-44 mm (ICES, 2017), and along the quite limited
241 Lithuanian coastal area (100 km wide) over 200 tons of gobies were caught in 2016 and 2017
242 (NRC 2016, 2017). Still, the largest round goby landings in the Baltic Sea are currently taking
243 place in Latvian coastal waters, where fishery logbook data evidence a sharp increase in catches
244 from less than 1 ton in 2011 to over 500 tons in 2016 (Kornilovs, 2017).

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

254 All three locations in the present study were dominated by male round gobies. The areas were
255 invaded between 2009 and 2011 (Azour et al., 2015), and the populations of round gobies here
256 may thus be considered well established. Compared to more recently established populations,
257 older populations are often characterized by having male bias (Brandner et al., 2013; Grul'a et al.,
258 2012; Gutowsky and Fox, 2012), which confers with the present findings. Males however are also
259 considered to be more active than females and hence more prone to be caught by passive gear,

260 which may be one additional factor explaining the male bias in the present catches (Marentette et
261 al., 2011; Skabeikis and Lesutiene, 2015).

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

272 As mentioned above, the breeding season peak in July and August (Skabeikis and Lesutiene,
273 2015), where round goby consequently display reduced feeding activity (MacInnis and
274 Corkum, 2000; Skabeikis and Lesutiene, 2015). Condition factor often follows feeding and
275 breeding cycles (Rätz and Lloret., 2003; Mozsár et al., 2015). Hence, the observed low
276 condition between June and August is probably related to weight loss resulting from spawning
277 and nest guarding behavior. After the spawning period, feeding resume and the condition
278 increases again prior to winter (Skabeikis and Lesutiene, 2015).

279

280 Firmness refers to the physical and sensorial properties of the meat and is used as an indicator
281 of quality in food science (Chen and Rosenthal 2015). The firmness of the round goby fillet,
282 measured in present study, was 0.8 – 2.7 N. For comparison, Rasmussen et al. (2011) reported
283 the firmness of farmed trout (*Oncorhynchus mykiss*) to be between 1.1 and 3.3 N, whereas,
284 herring fillets (*Clupea harengus*) measured in Nielsen et al. (2005) was considerably firmer

285 (2.45 – 5.88 N compressed to 60%; as opposed to 40% in the present study). As expected
 286 seasonal differences in firmness of round goby followed dynamics in the condition factor and
 287 proximate chemical composition (lipids and proteins).
 288
 289 The chemical composition of fish depends on food intake and season (Aidos et al., 2002; Huss
 290 1995; Skabeikis and Lesutiene, 2015). Especially, the lipid content of fish may undergo
 291 considerable fluctuations during the course of a year (Aidos et al., 2002; Aro et al., 2000;
 292 Gladyshev et al., 2009). Fish gather energy prior to spawning and use that energy during
 293 spawning, resulting in a rapid decline in lipids (Love, 1988). As mentioned above, the main
 294 spawning period for round goby is July and August, possibly explaining the decrease in lipid
 295 content observed in the present study. The observed decline of DHA in August may also be related
 296 to spawning, as DHA is used for egg production (Tocher, 2010). The remaining fatty acids and
 297 fatty acid groups presented here (EPA, MUFA, n-3, n-6, PA, PUFA, and SFA) remained relatively
 298 stable between sample months.
 299 In general, the fish were rather lean (fat content up to 1%) with a high protein content (17-19%).
 300 Protein content was comparable to that of cod fillets (*Gadus morhua*) (16-19%), whereas, the lipid
 301 content was slightly higher (0-0.4% in cod fillets) (Waterman, 2001), but still much lower than
 302 reported for more fatty species, such as herring (*Clupea harengus*), which, can amount up to 17-
 303 25% (Jensen et al., 2007; van Deurs et al., 2018). The lipid and protein content found here also
 304 resembled that of a previous round goby study, which found mean lipid content of 0.67% and
 305 mean protein content of 16.6% in April (Melve et al., 2017).
 306 Compared to Strobel et al. (2012), the proportion of EPA and DHA in cod is much higher than in
 307 round goby analyzed in the present study. Strobel et al. (2012) showed mean values of around 51
 308 % EPA+DHA, compared to c. 30% in the present study. In comparison, Jensen et al. (2007) found
 309 that EPA+DHA varied from 14 to 21.6 % in herring and Strobel et al. (2012) found that rainbow

310 trout contained 16.6 % EPA+DHA. The proportion of total PUFA (50.6 %) was at the same level
311 as that found in pollock and Alaska pollock and much higher than that found in herring, tuna and
312 rainbow trout (Strobel et al., 2012). The proportion of palmitic acid in round goby is comparable
313 to that in herring, salmon and rainbow trout. The proportion of SFA in round goby is low (23.2 %)
314 and at the same level as that in herring, pollock, Alaska pollock and rainbow trout, but much lower
315 than that in tuna (34.8 %) (Strobel et al., 2012).

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

324

325

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333

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494 Table 1. Summary of fisheries data.

	Sex	Guldborgsund	Kalvehavesund	Karrebæksmindesminde	All Areas	Min	Max
Length (cm)	All	9.7 ± 2.2	12.9 ± 2.0	11.9 ± 1.8	11.3 ± 2.5	0.5	22.0
	Male	9.9 ± 2.3	13.2 ± 1.9	12.1 ± 1.7	11.7 ± 2.5		
	Female	9.5 ± 2.0	11.5 ± 1.9	11.2 ± 1.8	10.2 ± 2.1		
Weight (g)	All	23.5 ± 16.2	29.1 ± 25.2	29.7 ± 19.6	32.4 ± 22.1	1.0	176.0
	Male	25.8 ± 17.3	42.3 ± 24.6	32.5 ± 19.9	34.7 ± 22.5		
	Female	19.4 ± 13.2	26.0 ± 23.1	17.7 ± 13.4	21.1 ± 17.2		
K- factor	All	1.5 ± 0.2	1.6 ± 0.2	1.5 ± 0.2	1.5 ± 0.2	0.5	2.4
	Male	1.5 ± 0.2	1.6 ± 0.2	1.5 ± 0.2	1.6 ± 0.2		
	Female	1.5 ± 0.2	1.6 ± 0.3	1.4 ± 0.2	1.5 ± 0.2		
CPUE (kg/net)		2.6 ± 2.3	1.3 ± 2.3	1.1 ± 1.5	1.4 ± 2.1	0.0	10.0
values are shown as mean ± standard deviation							

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

500

Fatty acid group	Mean %	Standard deviation
EPA	14.7	0.5
DHA	17.2	4.6
PUFA	50.6	6.1
Total n-3	38	4.3
Total n-6	10.7	1.3

PA	15.6	1
MUFA	14.6	3
SFA	23.2	1.1

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

506

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

508

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

511

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

514

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

520

521 Figure 6. Length frequency distribution in (A) Guldborgsund, (B) Kalvehave and (C)
522 Karrebækssminde.

523

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

529

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

534

535 Figure 9. Firmness (i.e. texture) of the meat measured in number of Newtons (N) it takes to
536 compress the meat to 40% of initial thickness. The boxes encapsulate all data points between the
537 25% and 75% quantiles and the horizontal black bar represents the median. Error bars represents
538 5% and 95% quantiles. Horizontal dashed lines represent the overall mean length across all
539 months and locations.

540

541 Figure 10. Fatty acid (fatty acid methyl esters) composition in round goby fillets from
542 Guldborgsund. Fatty acids were grouped into six categories commonly reported in nutritional
543 sciences: MUFA (monounsaturated fatty acids), DHA (Docosahexaen acid), EPA (Icosapentaen

544 acid), PUFA (polyunsaturated fatty acids), PA (palmitic acid), SFA (saturated fatty acids), n-3
545 (omega-3 fatty acid), and n-6 (omega-6 fatty acid). Columns show the percentage of total fatty
546 acids.

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