Journal of Great Lakes Research 39 (2013) 182–185

Contents lists available at SciVerse ScienceDirect

Journal of Great Lakes Research

journal homepage: www.elsevier.com/locate/jglr

Note

Can round goby (*Neogobius melanostomus*) caught by rod and line be used for diet analysis?

Pavel Jurajda [a,*], Lucie Všetičková [a,1], Matej Polačik [a,1], Milen Vassilev [b,2]

[a] Institute of Vertebrate Biology, v.v.i., Academy of Sciences of the Czech Republic, Květná 8, 603 65 Brno, Czech Republic
[b] Institute of Zoology, Bulgarian Academy of Sciences, Tsar Osvoboditel Blvd. 1, 1000 Sofia, Bulgaria

ARTICLE INFO

Article history:
Received 3 August 2012
Accepted 21 November 2012
Available online 30 December 2012

Communicated by Thomas Stewart

Keywords:
Neogobius melanostomus
Gobies
Danube
Diet
Sampling methodology
Selectivity

ABSTRACT

Sample structure and diet of round gobies (*Neogobius melanostomus*) captured by angling (ANG) and electrofishing (EF) at adjacent sites in their native distribution range (Bulgarian Danube) were compared to determine whether ANG fish could be used for diet analysis. In total, 100 round gobies were captured, 52 through angling and 48 by electrofishing. EF fish were significantly smaller than ANG fish, though modal size was comparable. There was no significant difference in condition between EF and ANG. Sex ratios did not differ significantly from 1:1 in either sample. ANG fish had significantly more empty stomachs than EF fish (56% and 4%, respectively). Thirteen food items were recorded, with no significant difference in diversity between ANG and EF. Crustaceans dominated in ANG fish diet and molluscs in EF diet, though this may be an artefact of degree of stomach fullness. We suggest that angling alone is unsuitable for sampling fish for diet analysis, as it is highly selective for both fish size and degree of stomach fullness.

Introduction

There are many reasons why biologists and managers need to know about the diets of fishes (Bowen, 1996), including levels of predation, competition and growth. Analysis of stomach contents is a standard practice in fish ecology and the method has been reviewed in detail by Hynes (1950), and more recently by Hyslop (1980). Methods used for catching fish vary according to both species and sample habitat (Murphy and Willis, 1996), with some more useful than others for diet analysis. Electrofishing and/or seine netting, for example, are frequently used, especially in rivers (Carman et al., 2006; Raby et al., 2010; Reynolds, 1996). In lentic waters, such as lakes or reservoirs, gill nets, trap nets and fyke nets are more widely used (Jang et al., 2006; Leonard et al., 2010; Reyjol et al., 2010; Wahl and Stein, 1993). Very occasionally, rod and line sampling (angling) has also been used for collecting fish for scientific purposes (Grey et al., 2002; Hodgson et al., 2008; Raby et al., 2010; Ross et al., 1995).

The use of an inappropriate sampling strategy for diet analysis, however, can lead to bias, e.g. fish held captive for long periods under stressful conditions (e.g. in fyke nets or traps) may regurgitate food, leading to loss of data. Further, longer periods of live captivity can result in partial, or even complete, digestion of food items, especially of smaller, softer items (Cochran and Adelman, 1982). Digestibility of food items, in combination with time before fixation, therefore, can affect the gut contents and, consequently, final determination scores (Bowen, 1996).

The round goby (*Neogobius melanostomus*, Pallas 1811) is an invasive species of particular interest to researchers at the present time. Relatively few studies, however, have examined diet of gobies in Eurasian waters (but see Adámek et al., 2007; Polačik et al., 2009; Simonovič et al., 1998, 2001) and, especially, the effects of different sampling methods on dietary results (but see Ross et al., 1995). Many methods have been used to sample round goby (see Kornis et al., 2012; Polačik et al., 2008), including rod and line (Clapp et al., 2001; Gutowsky et al., 2011; Johnson et al., 2005; MacInnis and Corkum, 2000). In at least one study, rod and line data have been used for diet analysis (Raby et al., 2010). In this study, we use two sampling methodologies (rod and line and electrofishing) to sample round gobies in their native distribution area (Bulgaria, lower Danube) and compare 1) size and sex composition, 2) gut fullness, and 3) diet composition, in order to assess any selectivity displayed by angling catches.

Material and methods

Sampling took place in the species' native range, along the shore of the Bulgarian stretch of the River Danube, near the town of Vidin (river km 791; 22.8912603°E, 43.9953761°N), between the hours of 09:00 and 02:00 on 14 October 2006.

* Corresponding author. Tel.: +420 543422523.
E-mail addresses: jurajda@brno.cas.cz (P. Jurajda), lucka.kocanda@seznam.cz (L. Všetičková), polacik@ivb.cz (M. Polačik), m.vv@abv.bg (M. Vassilev).
[1] Tel.: +420 543422523.
[2] Tel.: +359 889547.

0380-1330/$ – see front matter
http://dx.doi.org/10.1016/j.jglr.2012.12.002

The electrofishing sample (EF) was collected by wading along a 100 m stretch of river, 5–7 m parallel to the bank, using a battery operated SEN backpack unit (Bednář Ltd., Czech Republic; for further methodological details see Polačik et al., 2008). Water depth along the stretch was <0.8 m, with negligible current and a gravel/stone bottom structure. The angling sample (ANG) was collected by a local angler using a float ledger baited with maggots held approx. 10 cm above the river floor. Sampling took place at approximately the same distance from the bank as electrofishing (depth 0.8–1.3 m) and over an area of approx. 5 × 5 m. Both sample sites (EF and ANG) were adjacent to each other and so habitat character and all water parameters were comparable. Water temperature throughout the sampling period ranged from 16.5 to 17.0 °C. Fish collected by both methods were immediately sacrificed by overdosing with clove oil prior to fixation in 4% formaldehyde.

In the laboratory, fish were measured for standard length (SL, mm), the stomach removed and eviscerated body weight (W_{evis}; 0.1 g) calculated (Table 1). Sex was determined visually (external genital papillae) and through gonad character. Fish condition was calculated using Fulton's condition factor (using eviscerated weight to discount the effects of sex and gonad condition):

$$Fc = W_{evis} * 10^5 / SL^3.$$

After initial weighing, stomachs were dissected, their contents removed and the stomachs then reweighed to derive the weight of food. The contents were identified to the lowest feasible taxonomic group (family, genus and/or species).

Diet composition was expressed as percentage bulk weight ($\%W_i$) of each prey taxon (see Hyslop, 1980), calculated as:

$$\%W_i = 100 \cdot \left(W_i / \sum_{i=1}^{n} W_t \right),$$

where n = total number of prey items, W_i = wet weight of prey item i, and W_t = total wet weight of stomach contents for the entire sample.

The percentage frequency of occurrence ($\%F_i$) was defined as the percentage of stomachs containing food item i, described by the equation:

$$\%F_i = 100 * (n_i / n),$$

where n_i is the number of fish with food item i in their stomachs, and n is the total number of fish with food recorded in their stomach, i.e. fish with empty stomachs were not taken into account to avoid dividing by zero.

Table 1
Diet composition of round gobies sampled by angling and electrofishing from the River Danube (Vidin, Bulgaria) in October 2006. Note: IF = index of fullness; SL = standard length; W_{evis} = eviscerated weight; %Wi = food items by weight percentage; %Fi = frequency of occurrence; IP = index of preponderance (Note: + = <0.05; IF calculated using W_{evis}).

Capture method	Angling			Electrofishing		
Food type	%Wi	%Fi	IP	%Wi	%Fi	IP
Theodoxus	0.5	5.0	0.1	1.7	19.6	0.6
Dreissena polymorpha	19.4	24.0	14.9	54.4	65.2	68.3
Corbicula	3.6	5.0	0.6	9.5	26.1	4.8
Sphaeridae				0.9	6.5	0.1
Cyclopoida				+	2.2	+
Jaera sarsi				0.1	4.4	+
Dikerogammarus villosus	18.0	29.0	16.7	12.1	22.0	5.1
Corophium curvispinum	24.2	24.0	18.6	11.6	58.7	13.1
Hydropsyche	7.5	14.0	3.3	2.2	15.2	0.6
Chironomidae	1.1	5.0	0.2	1.4	37.0	1.0
Terrestrial insect	0.7	5.0	0.1			
Unidentified organic material	24.9	57.0	45.4	6.1	54.0	6.4
Total number of fish	52			48		
Fish with empty stomachs	31			2		
IF (Φ ± SD)	149 ± 93			190 ± 133		
SL (Φ ± SD) mm	73.74 ± 10.17			66.46 ± 12.07		
W_{evis} (Φ ± SD) g	9.53 ± 4.27			7.37 ± 6.28		

Food bulk weight was assessed to the nearest mg and presented as an index of gut fullness (IF) in ‰; calculated as a ratio between food (w) and eviscerated fish weights (W_{evis}):

$$IF = 10^4 * (w / W_{evis}).$$

Fish with empty stomachs were included into the calculation of average IF values as zero food bulk weight.

Grading of the "importance" of an individual food item (i) was performed using the index of preponderance (IP_i) of Natarajan and Jhingran (1961):

$$IP_i = (\%W_i \%F_i) / \left(\sum \%W_i \%F_i \right) * 100,$$

where $\%W_i$ = weight percentage of food item I, and $\%F_i$ = frequency of occurrence of food item i.

Difference in length was determined using the Student's t-test, with the size of fish log-transformed to meet t-test assumptions (i.e. normality and homogeneity of variance). Differences in IF (log-transformed to meet analysis assumptions) and Fc were determined using analysis of covariance (ANCOVA; length as covariate to account for size class); while differences in the percentage of fish with empty stomachs were determined using the binomial test.

Results

Sample characteristics

One hundred round gobies were captured in total, 52 through angling and 48 by electrofishing. ANG fish had a mean SL of 73.7 mm (range 52.3–98.4), while EF fish were significantly smaller, with a mean length of 66.5 mm (range 50.8–114.2) (t-test, $t = 3.62$, $df = 98$, $P < 0.001$; Table 1). In each case, however, the modal size interval was comparable at 60–70 mm (Fig. 1). There was no significant difference

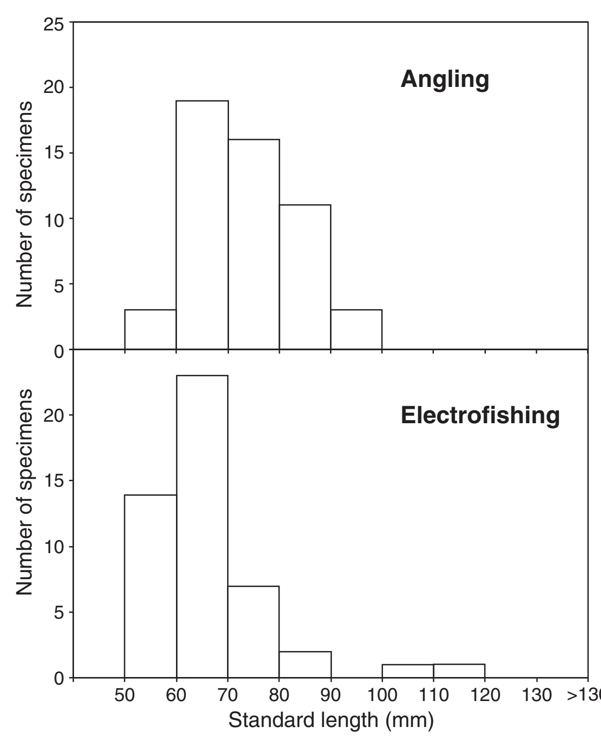

Fig. 1. Length–frequency distribution of round gobies sampled by angling and electrofishing from the River Danube (Vidin, Bulgaria) in October 2006.

in condition between ANG (Fc = 2.230; SD = 0.154) and EF samples (Fc = 2.185; SD = 0.206; ANCOVA, df = 1,97, F = 0.02, P = 0.876) after accounting for length (length was a significant covariate in the ANCOVA model; df = 1,97, F = 23.04, P < 0.001).

The proportion of males to females in both ANG (m = 25, f = 27) and EF samples did not differ significantly from 1:1, despite an apparent female bias in the EF sample (m = 18, f = 30; chi-square, $\chi^2 = 3$, df = 1, P = 0.08).

ANG fish had significantly more empty stomachs than EF fish (56% compared to 4%; binomial test, P < 0.001). When all fish were compared (including those with empty stomachs), EF fish had significantly higher IF (IF = 182) than ANG fish (IF = 58) (ANCOVA, df = 1,97, F = 58.98, P < 0.001); length was a non-significant covariate in the model (ANCOVA, df = 1,97, F < 0.01, P = 0.984).

Diet composition

In total, 13 different food components were recorded in the diet (Table 1), with similar diversity between the two methods (12 and 10 components for EF and ANG fish, respectively). Unidentified organic material (e.g. undigested food, detritus, etc.) was recorded more frequently in ANG fish (25%) than EF (6%). Crustaceans (*Dikerogammarus villosus* and *Corophium curvispinum* [combined]) dominated the diet of ANG fish at 42% (compared to 24% in EF fish), while molluscs (67% [combined]; mainly zebra mussel *Dreissena polymorpha* at 54%) were the dominant food item in EF fish (24% in ANG fish). Two water insect larvae, caddis fly (*Hydropsyche*) and chironomid (Chironomidae) were of incidental importance, contributing just 9 and 4% (combined) in ANG and EF fish, respectively.

Unidentified organic material had the highest IP in ANG fish (45%), followed by *C. curvispinum*, *D. villosus* and *D. polymorpha* (19, 17 and 15%, respectively). In EF fish, the highest values were observed for *D. polymorpha* (68%), followed by *C. curvispinum* (13%).

Discussion

Capture method

Angling is a relatively inexpensive and simple technique that has proven useful for sampling gobies larger than 50 mm, especially in situations where gobies can evade capture or detection using other methods (Gutowsky and Fox, 2011; Gutowsky et al., 2011). Indeed, Fig. 1 suggests that angling may be better at targeting larger gobies than electrofishing; with fewer fish in the 70–100 mm size ranges caught using the latter method. On the other hand, fewer smaller fish were caught using rod and line, possibly due to selectivity caused by, for example, hook size and/or bait size.

No significant selectivity was observed as regards sex. Gutowsky and Fox (2011), who used angling to sample round gobies from a relatively newly-established riverine population in Canada, found that sex ratios were male biased at all sample sites, a situation mirrored in other studies of recently introduced round gobies. For example, Corkum et al. (2004) noted male-biased sex ratios of 3:1 for the Gulf of Gdansk (Baltic Sea) and 6:1 in Lake Erie and the Detroit River (USA). Kovtun (1979), however, sampling by rod and line in the round gobies' native range (Sea of Azov), also observed a ratio closer to 1:1. While our sampling only took place on one day and may contain sampling bias, the results suggest that sex ratios may differ in established and establishing populations, with a male bias in newly introduced or expanding populations.

If we assume that electrofishing catches all fish irrespective of feeding activity (and hence represents the background level of "hungry"/"satiated" fish in the environment), our results indicate a bias toward hungry fish in angling catches, i.e. angling catches those fish that are actively searching for food. Laboratory studies have shown that hungry round gobies are physically attracted to live (or moving) angling baits (see Gutowsky et al., 2011). Indeed, a complaint of anglers of the Great Lakes region of the USA after the round goby's introduction in 1990 (Jude et al., 1992) was its habit of taking bait intended for other species and its consequent increase as unwanted by-catch (Clapp et al., 2001; Dunning et al., 2006).

Diet composition

As our results are based on a single sampling event, they can only represent a "snapshot" of dietary items taken on one day in mid-autumn and care should be taken in extrapolating the results further, particularly as diet can vary both seasonally and diurnally. Even so, our results do indicate that bias in dietary analysis is quite likely using fish caught by rod and line.

In this study, molluscs (mainly *D. polymorpha* and *Corbicula fluminea*) and crustaceans (mainly *C. curvispinum* and *D. villosus*) were the most important food items, a situation noted in a number of previous studies (e.g. Simonovič et al., 1998, 2001). In general, studies have tended to show molluscs as dominant in larger, slower water bodies (e.g. the Laurentian Great Lakes, the lower Danube) and amphipods/crustaceans dominating in tributaries and streams of the Great Lakes and in the middle/upper Danube (see review in Kornis et al., 2012). Polačik et al. (2009), in a laboratory study, simultaneously presented both bivalves and amphipods to experimental fish, concluding that round gobies showed a strong preference for amphipods. Molluscs, therefore, appear to be an alternative rather than preferred prey; though low abundance or high turbidity/macrophyte abundance may lead to conditions where molluscs are the most viable option.

In our study, molluscs were found considerably more often in the stomachs of EF fish. However, as there was no significant difference in dietary diversity between EF and ANG fish, and no difference in sample habitat, it is possible that this was an artefact of the high percentage of empty stomachs in ANG fish and further studies are needed to confirm or deny any difference.

Unidentified organic material was the only other dietary component taken in larger quantities. However, the role of unidentified organic material in round goby nutrition is questionable as it is impossible to judge whether it comprised undigested prey remains, actively consumed detritus or whether it was ingested unintentionally while eating other items or as gut contents in prey.

Other items, such as chironomids and caddis fly larvae, played a marginal role in this study. As highlighted above, however, this study took place at one site on one day in autumn and, as both goby diet and item availability can differ greatly both diurnally (Carman et al., 2006) and seasonally, the importance of these items could change.

In conclusion, we recommend that fish caught by angling alone should not be used for diet analysis until all sources of bias have been identified. In our study, angling proved highly selective for both fish size and degree of stomach fullness. In addition, there were indications of a difference in diet between ANG and EF fish, though this may be an artefact of difference in degree of stomach fullness. As feeding activity may differ with time of day, season, and, probably, differences in male/female behaviour patterns over the reproductive period, we recommend that further, longer-term studies are undertaken to confirm such biases.

Acknowledgement

This study was supported as a part of grant no. P505/11/1768 of the Grant Agency of the Czech Republic. We would like to thank the Regional Departments of the Bulgarian Agency of Fisheries and Aquaculture in Vidin and their Chief, Milen Metodiev, for their cooperation and support during field work. We also thank Zdeněk Adámek, Zdenka Valová, Radim Blažek, Markéta Dušková, and Teodora Trichkova for field assistance and help with fish dissections. Finally, we thank Kevin Roche for numerous helpful comments and for correcting the English language.

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