J. Appl. Ichthyol. 24 (2008), 601–604

ISSN 0175–8659

Received: June 20, 2007
Accepted: January 21, 2008
doi: 10.1111/j.1439-0426.2008.01100.x

The sampling efficiency of electrofishing for *Neogobius* species in a riprap habitat: a field experiment

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Summary

Even though electrofishing is commonly used to sample *Neogobius* spp. and other swimbladder-lacking benthic fishes, its efficiency is considered poor especially in habitats with abundant interstitial spaces. To determine the efficiency of electrofishing *Neogobius* spp. and quantitatively estimate sampling bias in a riprap (shot rock used to armor shorelines against water erosion) mesohabitat, riprap fragments were set up in a natural riverine environment. The experimental setting enabled us to collect all fish remaining in the riprap fragments after these areas had been electrofished. The sampling efficiency of electrofishing *Neogobius* spp. (dominated by *Neogobius melanostomus*) varied between 17.6 and 47.4% (mean 29.7%), while percids (possessing a well-developed swim bladder) were collected with 74.6% efficiency. Fish size had no effect on the probability of capturing *Neogobius* spp. by electrofishing. Within *Neogobius* spp., *N. melanostomus* was less susceptible to electrofishing than *Neogobius gymnotrachelus* (23.7% and 50.1%, respectively). Decreased electrofishing efficiency in areas of rocky substrate should be considered in estimates of total abundance of *Neogobius* spp., especially if they are to be compared with catches of other species possessing swim bladders.

Introduction

Small-sized benthic fishes are known to sink into interstitial spaces in substrates when stunned during electrofishing and, hence, can be difficult to capture (Jude and DeBoe, 1996; Wiesner, 2004; Reyjol et al., 2005). This decreased efficiency of electrofishing may significantly underestimate population densities of benthic species. This is particularly true for small gobiid fishes that lack swim bladders and inhabit riprap (shot rock used to armor shores against water erosion) shorelines, such as *Neogobius* species (Wiesner, 2004; Erős et al., 2005). Some *Neogobius* species are considered invasive; they establish abundant populations outside their native range (e.g. Copp et al., 2005). This includes round goby *Neogobius melanostomus* (Pallas, 1814), which has established abundant populations in the American Great Lakes region, causing major impacts on the local ecosystem. Because of the significant effects of the alien *Neogobius* populations on native fish communities (e.g. Vanderploeg et al., 2002), reliable estimates of population densities are important for their management.

Only a limited number of studies have attempted to evaluate the efficiency of electrofishing for benthic fishes in rock-dominated habitats by trying to obtain total numbers of fishes exposed to electrofishing. For example, Reyjol et al. (2005) removed bottom substrate consisting of cobbles enabling them to capture fish, including stone loach *Barbatula barbatula* L. (Balitoridae) hidden in interstitial spaces. From this study, they estimated electrofishing efficiency to be approximately 55%. Wiesner (2004) tested the electrofishing efficiency for *Neogobius* spp. under laboratory conditions by providing an artificial riprap analogy to a known number of gobies and estimated electrofishing efficiency to be 30–50%. Unfortunately, no additional information on methodology has been provided. Multiple-pass electrofishing is seldom used to derive density estimates in non-wadeable rivers (e.g. Weissenbacher et al., 1998) because it is difficult to prevent fish emigration ⁄ immigration (Raleigh and Short, 1981) into the sampled reach. Conversely, single-pass electrofishing is commonly used in large rivers, especially for monitoring programs (Kestemont and Goffaux, 2002; Erős et al., 2005; Jurajda et al., 2005; Wiesner, 2005) This method is frequently used to sample *Neogobius* spp., particularly when multiple sites are to be sampled rapidly to avoid influences from changes in environmental conditions (e.g. Erős et al., 2005; Jurajda et al., 2005; Wiesner, 2005). Here, we present a study that combines the approaches of Wiesner (2004) and Reyjol et al. (2005) to determine the efficiency of single-pass electrofishing for *Neogobius* spp. in areas with rocky substrate. Based on the studies above, we also tested the hypothesis of lower efficiency of electrofishing for these benthic species in their natural riverine environment and quantified the efficiency of the sampling method in rocky substrate.

Materials and methods

This study was carried out at a beach (pebbles up to 8 cm in diameter) in the main channel of the Danube River in the town of Vidin in Bulgaria (native range of all considered *Neogobius* spp., rkm 791) between 16 and 18 October 2006 during daylight. In this time of the year, *Neogobius* spp. in the examined area have already finished the spawning season but have not yet migrated to deeper water for overwintering (Gheorghiev, 1966).

To simulate shelter-providing, rocky substrate, 12 artificial riprap fragments, 3.1–4.1 m long (mean = 3.5 m) and 0.5–0.8 m (mean = 0.64 m) wide, were set-up at sites approx. 4 m from the shoreline (water depths ranging from 0.5 to 0.7 m). To provide a range of interstitial spaces, the fragments consisted of completely submerged coarse, angular shot rocks 0.15–0.6 m in the longest dimension, freely piled up to a maximum height of 0.5 m. The arrangement of the experimental fragments and high water transparency (Secchi disc reading > 1.5 m) provided clear visibility and easy access for electrofishing. The riprap fragments were allowed to be colonized by fish for 48 h prior to sampling. Water temperature at sampling sites was 16°C and water conductivity 315 μS cm^{-1}. The study was conducted at typical autumn conditions. Water level was 210 cm (gauging station in Vidin) with very slow current, not ballooning the beach seines (see below).

To determine the number of all fish exposed to electrofishing, riprap fragments were carefully surrounded, leaving approx. 0.4 m of homogenous gravel substrate around them, by two beach seines 5 and 7 m long equipped with weighted bottom lines (Fig. 1a). The two nets were fixed together to prevent enclosed fish from escapement. Fragments were surrounded and enclosed in a way that prevented accidental collection of fish not occupying the fragment itself. Surrounded fragments were sampled by a single pass electrofishing, using our standard sampling method for populations of *Neogobius* spp. (backpack unit LENA, pulsed DC, frequency 85 Hz, output 300 V, equipped with elliptical stainless-steel anode of 40×20 cm and 4 mm mesh size non-conductive netting and 0.6 m long stripe-shaped copper cathode) (Jurajda et al., 2005). Subsequently, the rocks in the fragments were manually removed to make the area suitable for seine netting. Both seines (still fixed together) were simultaneously drawn to the shore with care taken to prevent escapement of enclosed fish (Fig. 1b). During this exercise, the front 5 m beach seine ploughed the surface of the substrate in front of the 7 m net, thus avoiding accidental collection of fish from outside the enclosed area (Fig. 1b).

The two percid fish species captured, *Gymnocephalus baloni* (Holčík and Hensel 1974) and *Perca fluviatilis* (L.), were pooled as 'percids' for analyses. Binomial general linear model (GLM-b) ANCOVA was used to determine whether fragment identity (categorical predictor), species (categorical predictor) and fish size (covariate) influenced the probability of *Neogobius* spp. being captured (response variable with Bernoulli distribution; every individual coded as 1 or 0 as captured or not captured by electrofishing, respectively). Single- and multiple- GLM-b ANOVA comparisons were used to test for differences in the probability of being captured between percids and *Neogobius* spp., and among particular *Neogobius* species. Bonferroni correction of significance level was used for multiple comparisons. Data analyses were performed using R 2.0.1. (R Development Core Team, 2004).

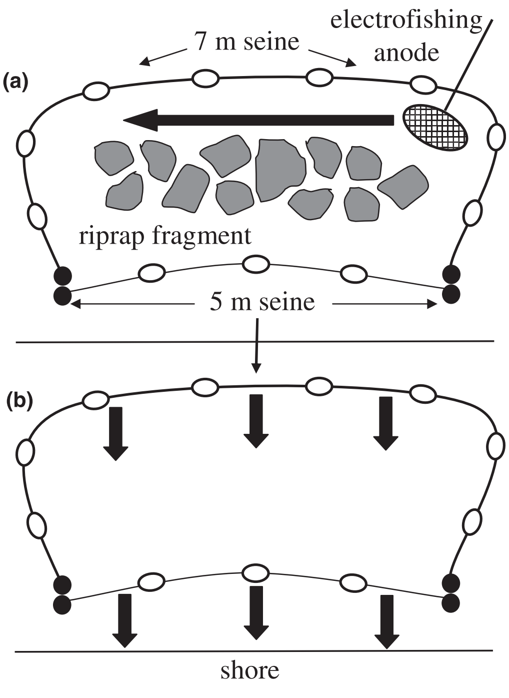

Fig. 1. Arrangement of enclosed riprap fragments during sampling (a) and after sampling when seine nets were simultaneously drawn to the shore (b)

Results

During electrofishing, electroshocked fishes were observed to emerge from riprap fragments rather than swimming outside the rocky areas within the enclosures. At larger distances from the anode, where the electric field was weakened, some *Neogobius* individuals swam out from interstitial spaces after electroshocking. Despite the limited control of their movement (wriggling motion) they were able to return to the interstitials. Further, a sinking of stunned individuals that fell down into interstitials was observed. This was caused by the water movement resulting from the anode stir.

In total, 293 fish comprising six species were captured of which 271 individuals belonged to one of four *Neogobius* species. *Neogobius* density (fish m^{-1} of riprap fragment) was 7 fish m^{-1} and the standard length of *Neogobius* spp. ranged from 19 to 110 mm (mean 45.1 ± 0.85). Round goby *N. melanostomus* was the most common species (74% of all *Neogobius* individuals), followed by racer goby *Neogobius gymnotrachelus* (Kessler, 1857) (12%), monkey goby *Neogobius fluviatilis* (Pallas, 1814) (11%) and bighead goby *Neogobius kessleri* (Günther, 1861) (3%). Other species (Danube ruffe *Gymnocephalus baloni* and perch *Perca fluviatilis*, both Percidae) were rare (Table 1). The electrofishing efficiency for all *Neogobius* fishes combined ranged from 17.6% to 47.4% (mean efficiency 29.7 ± 2.9%). The electrofishing efficiency for percids was significantly higher than for *Neogobius* fishes (GLM-b ANOVA, $P < 0.001$), with a mean efficiency of 74.6 ± 11.1%).

The GLM-b ANCOVA revealed no significant differences in electrofishing efficiency among individual fragments ($P > 0.05$); therefore, fish from all fragments were pooled into one group for further analyses. Fish size had no effect on the electrofishing capture probability of *Neogobius* spp. (GLM-b ANCOVA, $P_{size} > 0.05$; $P_{size:species} > 0.05$). However, there was a significant difference in the probability of capture among *Neogobius* species (GLM-b ANCOVA, $P < 0.01$), with electrofishing being significantly more efficient in capturing *N. gymnotrachelus* compared to *N. melanostomus* (GLM-b ANOVA multiple comparisons, $P < 0.001$; significant after Bonferonni correction to $\alpha' = 0.0083$; Table 1). No other significant differences were found in electrofishing efficiency among *Neogobius* species.

Discussion

The finding that the *Neogobius* fishes (dominated by *N. melanostomus*) rapidly colonized experimentally added fragments supports other reports of a preference of particular *Neogobius* species for habitats with rocky substrates (Jude and DeBoe, 1996; Erős et al., 2005; Creque et al., 2006).

Restricted buoyancy due to lack of a swim bladder, in combination with a tendency to sink into interstitial spaces when stunned by electrofishing are likely to be the major factors that decreased the efficiency of electrofishing. In

Table 1
Composition, numbers and standard lengths of fishes that colonized artificial riprap fragments and their numbers captured by electrofishing in these areas

	Total no. individuals	No. electrofished individuals	Proportion (%) in the total catch	Mean (±SE) efficiency (%)	Range SL (mm)	Mean (±SE) SL (mm)
Neogobius fluviatilis	29	11	9.9	35.4 (10.5)	35–77	47.8 (1.8)
Neogobius gymnotrachelus	34	18	11.6	50.1 (9.1)	35–70	51.2 (1.5)
Neogobius kessleri	8	1	2.7	16.7 (16.7)	55–110	78.1 (6.7)
Neogobius melanostomus	200	47	68.3	23.7 (4.1)	19–94	42.4 (0.9)
Neogobius spp.	271	77	92.5	29.7 (2.9)	19–110	45.1 (0.9)
Percids	22	17	7.5	74.6 (11.1)	46–89	62.4 (2.1)

contrast, species possessing swim bladders (percids) demonstrated considerably higher mobility within the electric field, were attracted to the anode, and swam out of the riprap fragments, allowing them to be captured more readily.

We estimated electrofishing efficiency of *Neogobius* fishes to be between 17.6% and 47.4%, which is consistent with the finding of Wiesner (2004). Unfortunately, detailed information on his laboratory experiment was absent, preventing a closer comparison. A slightly higher efficiency can be deducted from data from Weissenbacher et al. (1998). In the first out of three successive electrofishing passes on a single stretch of riprap shoreline (model species: *N. kessleri*) these authors captured 63% of the theoretical [calculated according to the regression model of De Lury (in Bagenal, 1978)] total number of fish occupying the study site. However, since the total number of fish was not determined experimentally but based exclusively on the model's calculations, the empirically exact value of the total abundance is unknown and estimated numbers may differ from real abundance to an unknown extent.

Data regarding electrofishing efficiency in our experiment were strongly related to the use of the electrofishing technique, i.e. wading with backpack electrofishing gear along the shoreline. This technique is commonly used for sampling *Neogobius* spp. (e.g. Phillips et al., 2003; Jurajda et al., 2005; Wiesner, 2005; Sindilariu et al., 2006; Polačik et al., 2008). Boat electrofishing, which is sometimes used for sampling *Neogobius* fishes, is considered even less efficient (Erős et al., 2005). A capture of electrofishing-stunned gobiids scattered in a rocky substrate requires precise operating with collecting dip nets if the fish are not to be harmed. This is difficult to achieve when maneuvering a boat during boat electrofishing. In addition, *Neogobius* fishes frequently use shallow water and occur in shelters near shorelines, which are not accessible from a boat.

Our results showed significant differences in the probability of capture between *N. gymnotrachelus* and *N. melanostomus*. This may be merely statistical coincidence and more data are needed to confirm this finding. Alternatively, higher susceptibility to electrofishing may be related to territorial behavior, with *N. gymnotrachelus* being smaller and more delicate species than *N. kessleri* and *N. melanostomus* and therefore more likely to be chased to marginal interstitial areas by the aggressive *N. melanostomus* (Balshine et al., 2005). *Neogobius kessleri* showed similarly low susceptibility to capture by electrofishing as with *N. melanostomus*, but lower sample sizes for this species and also consequently the power of statistical analysis yielded only non-significant results.

Interstitial spaces are not typically inhabited by *N. fluviatilis,* which usually avoid rocky areas (Erős et al., 2005; Sindilariu et al., 2006; Polačik et al., 2008). Their presence in our samples is probably the consequence of an ecotone effect as experimental riprap fragments were laid on finer substrate, preferred by *N. fluviatilis* (Erős et al., 2005).

The efficiency of electrofishing may be influenced by various factors, often with combined, non-isolable effects (Reynolds, 1996) that may play a role in applying our results in other studies. However, according to our experience in sampling *Neogobius* spp. in different environmental conditions, e.g. water temperature, does not appear to affect the electrofishing efficiency for *Neogobius* spp. In contrast, we consider water transparency to be a significant factor, since *Neogobius* fishes only rarely swim up to the water surface when sampled by electrofishing; hence they usually need to be dipped from a dark, non-contrasting bottom (although their paler ventral colours made them easier to locate). Further, composition of the bottom substrate directly affects the fishing range of an electrofishing gear, with mud substrate having a weakening effect on the electric field (Scholten, 2003).

Larger fish are reported to be more susceptible to electrofishing (Reynolds, 1996), but fish size had no effect on the probability of capturing *Neogobius* spp. in our study. This may be explained by high water transparency, with even the smallest fishes clearly visible to the electroshocker operator. Similarly, Wiesner (2004) successfully collected *Neogobius* individuals as small as 19 mm total length. Another plausible explanation, with regard to the small-sized *Neogobius* fishes (Miller, 2003), is that the range of fish sizes is relatively small in general (Table 1) and thus all fishes are equally prone to be affected by the electric field (Reynolds, 1996).

This study has demonstrated the low efficiency of single-pass electrofishing for *Neogobius* spp. in riprap habitats (20–50%), but it remains an appropriate method for comparisons of *Neogobius* spp. abundance between sites. However, our data demonstrate that total abundance estimates of small-sized benthic fishes based on single-pass electrofishing should take the efficiency of the method into account.

Acknowledgements

We thank all our friends who helped us with the strenuous fieldwork. We also thank S.A. Hardie, M. Reichard, H. Rosenthal and S. M. White for comments on the manuscript. The project was funded by the Centre of Excellence LC 522, Ministry of Education, Youth and Sports of the Czech Republic and Bulgarian Science Fund, Project B-1510/05.

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