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Original article

Does Different Performance of Sampling Gears (Cast Net versus Gill Net) Bring the Inappropriate Estimation of Freshwater Fish in a Large River?

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Abstract The accurate estimation of fish assemblages is highly dependent on the sampling gear used for sampling. We used data from 15 sampling sites along the Nakdong River, which is a large river in South Korea, to identify differences in assemblages and sizes of freshwater fishes collected with either cast nets or gill nets, the two most commonly used sampling gear in South Korea. The two gears differed in the fish assemblages they captured, with more species caught by gill nets. Further, due to its tighter mesh size, the cast net caught significantly smaller fishes than the gill nets (independent t-test, $p < 0.05$). We found the cast net to be appropriate for species that inhabit shallow (less than 2 m) and open water, but inappropriate for deep water, habitats with plant beds, and nocturnal species. Thus, cast net sampling is not efficient in a large river environment, and a combination of sampling methods is more suitable for understanding fish assemblages in such habitats. In general, appropriate selection of fishing methods to specific habitats is necessary to improve data quality and minimize the misrepresentation of environmental conditions.

Key words: cast net, gill net, fish assemblage, large river, size class

INTRODUCTION

Quantitative sampling and identification of fish species in a given region is a fundamental step to fish ecology and has major applications for fisheries, as such data are useful for both environmental assessment and proper management (Pennington and Stromme, 1998; Kennard *et al.*, 2006). However, inaccurate data may result in unsuitable policies and management plans, potentially hampering conservation efforts (Sinclair and Murawski, 1997; Hampton *et al.*, 2005; Maunder *et al.*, 2006; Polacheck, 2006). Thus, appropriate sampling methods (Rozas and Minello, 1997) are required for the most accurate environmental assessment possible. Part of designing appropriate sampling methods involves the

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selection of sampling gear. Equipment type directly relates to fishing yield and the scientific evaluation of fish fauna by, for example, altering the assemblages captured (Knight and Bain, 1996; Rozas and Minello, 1997; Rotherham *et al.*, 2007, 2011; Oliveira *et al.*, 2014). Thus, inappropriate gear is likely to cause inaccurate estimations of fish populations, resulting in sampling data that do not reflect the true status of the species (Rotherham *et al.*, 2007, 2011).

In large warm-water rivers, the most commonly used sampling gears are seine nets, benthic trawls, boat electrofishing, gill nets, and hoop nets (Guy *et al.*, 2009). For commercial fishing, the gill and hoop nets are normally used, but for scientific research, the gill and cast nets are preferred in South Korea (Yoon *et al.*, 2015). The cast net shows high portability and the lack of species specificity (Emmanuel *et al.*, 2008), and its portability allows for convenient application to diverse environments, from small creeks to rivers or reservoirs (e.g. Meador and Kelso, 1990; Stevens, 2006; Stevens *et al.*, 2006; Sheaves and Johnston, 2008). Further, the cast net covers a larger area than a throw net per deployment and can be used in environments where trawling, gill nets, or seine nets cannot (Stein III *et al.*, 2014).

Due to its ubiquity in South Korea, the majority of data used in research, fishery management, and policy come from cast net sampling. However, no studies to date have been conducted on how well cast net sampling represents fish assemblages, in comparison to other methods. Therefore, we examined differences in assemblages and size of a freshwater fish in the Nakdong River, South Korea, collected with a cast net versus multi-mesh gill nets. Based on net characteristics (i.e., mesh size), we hypothesized that: (i) the cast net and multi-mesh gill nets collect different fish assemblages; and (ii) fish size will differ by capture method, with smaller fish captured in the cast net and larger individuals sampled in the gill nets.

MATERIALS AND METHODS

The study was conducted at 15 sites in the main channel of the Nakdong River (over 6th stream order) from its mid-lower to mid-upper reaches, which is approximately 200 km (Fig. 1). Water qualities and physical characteristics of all study sites measured by NRERC (2012) were not different. Stream widths were slightly different across sites, ranging from 350 to 500 m. Maximum depths were about 5 m, and the dominant substrate was sand.

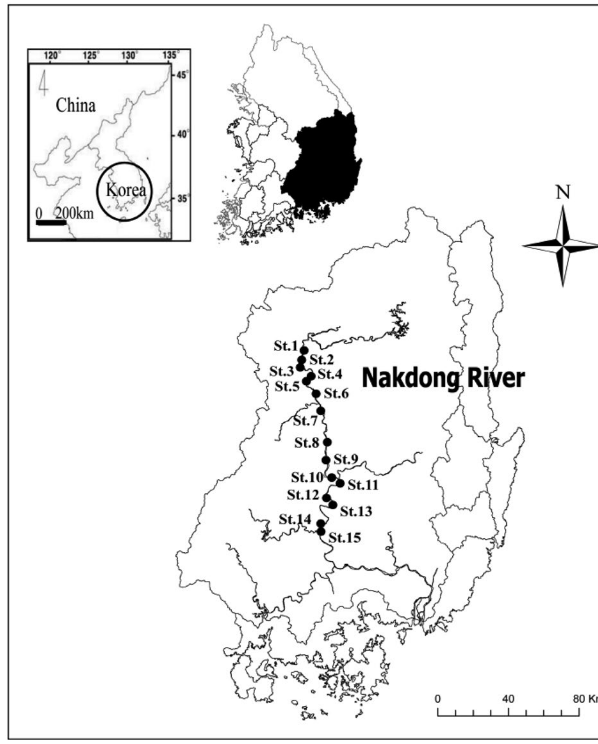

Fig. 1. Map of the 15 stations that were sampled. Sites are distributed from the mid-lower to mid-upper areas of the Nakdong River, South Korea.

Fish were collected during May and October 2012, using both a cast net (mesh 7 mm; area πr^2, 16.6 m^2; r = 2.3 m) and gill nets with two mesh sizes (mesh 30 mm, height 80, length 50 m; mesh 70 mm; height 150 cm, length 50 m). Sinking gill nets were used, and gill nets consisted of two 50-m panels of stretched mesh (30 and 70 mm) connected together. Following the shoreline, 10 deployments were conducted per site using the cast net. Deployments were spaced at least 20 m apart within a 200-m section to minimize any effects from the previous deployment (i.e., fish avoiding the area where the net was cast). The radius of the cast net is 2.3 m, and the linear catching distances were 3.5∼4 m. We considered differences between deployments to be negligible because cast nets were deployed by individuals with more than 10 years of experience. Gill nets were set in the afternoon before sunset and retrieved the next morning after sunrise (approximately 12 hours including two crepuscular periods). We tried to sustain hanging ratio of 0.4.

We calculated the Shannon diversity index and IBI (index of biological integrity) based on the results of our sampling.

The Shannon diversity index (*H*: Magurran, 1998) was computed using the equation: $H = -\sum P_i \times \ln P_i$, where $P_i = n_i / N$, n_i is the number of individuals of *i*th species, and N is the total number of individuals. The IBI is adjusted for Korean freshwater fishes (MOE/NIER, 2011) based on Karr (1981).

Total length (TL, cm) was measured to explore size differences in the collected fishes, depending on gear type. All measurements were processed immediately after fish collection. Fishes were moved to an aerated tank (size: $100 \times 100 \times 80$ cm) and anesthetized using 0.1 g L^{-1} ethyl 3-aminobenzoate methanesulfonate salt (Sigma-Aldrich, Munich, Germany). The TL was measured with a digital caliper to the nearest 1 mm. After measurement, fishes were moved to a different tank and subsequently released at the site of capture once they were fully recovered.

Differences in the species composition between the two sampling gears were analyzed using nonmetric multidimensional scaling (NMDS), analysis of similarities (ANOSIM), similarity profile (Simprof) and similarity percentage (SIMPER) performed with primer 6 software (Primer-E Ltd. Plymouth, UK). NMDS constructs two-dimensional ordination in a manner that best represents relationships between samples in a similarity matrix (Field *et al.*, 1982). Similarity matrices were generated for fish assemblages by square-root-transforming the raw data and calculating Bray-Curtis similarity indices for each pairwise assemblage comparison. The robustness of the ordination is indicated by its stress value, ranging from <0.2 (fair) to <0.05 (excellent) (Clarke and Warwick, 1994). We then characterized the effects of fishing nets on assemblage composition with SIMPER (Clarke, 1993), which was run using the similarity matrices. The average dissimilarity percentages between groups and of the contributing species were identified.

The Wilcoxon signed ranks test was used to look for statistical differences between the cast net group versus the gill net group, in the following variables: number of species, number of individuals, the Shannon diversity index, and IBI. TL differences between cast net-caught fish and gill net-caught fish were examined with an independent t-test. These analyses were performed in SPSS 18.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

A total of 1,647 individuals classified into 34 species were caught. The gill nets collected more individuals and species than the cast net (Table 1). Only 13 species were caught by both gears, while 14 (from Bargidae) and seven (from Gobiidae) species were caught exclusively in gill nets and the cast net, respectively. *Pseudogobio esocinus* was the dominant species in both gears, while *Carassius auratus*, *Hemiculter eigenmanni*, and *Opsariichthys uncirostris amurensis* were predominantly caught with gill nets. Differences due to sampling gear were also apparent on the level of individual sites (Table 2). More species (Wilcoxon test, $p = 0.001$) except Site (St.) 14, and more individuals (Wilcoxon test, $p = 0.002$) except St. 2 and St. 14 were collected by gill nets. The Shannon diversity index and IBI of fish caught with gill nets were higher than those caught with the cast net (Wilcoxon test, $p < 0.05$), and values calculated from the combined data of both gear types exceeded those calculated from the data of a single gear.

ANOSIM detected significant differences in fish assemblages between two gears (Global $R = 0.759$, $p = 0.001$). Cast net samples clearly separated from gill net samples in the NMDS ordination plot, with only one sample (St. 11) from the cast net grouping with the gill net samples (Fig. 2). SIMPER analysis identified average similarities of 56.03% and 55.31% for the cast net and gill nets, respectively, while the average dissimilarity was 63.27% (Table 3). Several Cyprinidae contributed to the average dissimilarities of fish assemblages, including *C. auratus* (average dissimilarity, 7.33%) and *Tridentiger brevispinis* (3.33%).

Gill nets collected significantly longer fish than the cast net (Independent t-test, $p = 0.000$; Fig. 3). Fish sampled in the cast net predominantly ranged in TL from 40 to 140 mm, although individuals less than 40 mm were also frequently observed (8.1%), while individuals longer than 240 mm were rare (1.2%). Fish sampled in gill nets mainly ranged from 120 to 220 mm. Smaller fishes (less than 80 mm) were far rarer (0.5%) than bigger fishes (longer than 240 mm; 15.1%) in the gill nets.

DISCUSSION

The catch composition of different fishing equipment is likely to vary depending on the morphology of local species (Huse *et al.*, 2000). For example, fish girth has been demonstrated to affect the composition of gill net catches (Reis and

Table 1. Species composition and number of individuals collected by the cast net and the gill net.

Species	Cast net		Gill net	
	Number of individuals	Relative abundance (%)	Number of individuals	Relative abundance (%)
Family Cyprinidae				
Cyprinus carpio	2	0.4	34	2.8
Carassius auratus	26	5.8	243	20.3
Carassius cuvieri			23	1.9
Acheilognathus lanceolatus			57	4.8
Acheilognathus majusculus			10	0.8
Acheilognathus rhombeus	6	1.3		
Acanthorhodeus macropterus			29	2.4
Pungtungia herzi			1	0.1
Squalidus gracilis majimae	2	0.4		
Squalidus japonicus coreanus	7	1.6		
Squalidus chankaensis tsuchigae	22	4.9	14	1.2
Hemibarbus labeo	27	6.0	34	2.8
Hemibarbus longirostris	9	2.0	3	0.3
Pseudogobio esocinus	156	34.9	283	23.6
Microphysogobio jeoni	1	0.2		
Zacco platypus	68	15.2	67	5.6
Opsariichthys uncirostris amurensis	32	7.2	107	8.9
Erythroculter erythropterus			81	6.8
Culter brevicauda			17	1.4
Hemiculter eigenmanni	2	0.4	124	10.3
Family Cobitidae				
Misgurnus anguillicaudatus			4	0.3
Family Bagridae				
Pseudobagrus fulvidraco			1	0.1
Leiocassis ussuriensis			4	0.3
Leiocassis nitidus			7	0.6
Family Siluridae				
Silurus asotus			5	0.4
Family Centropomidae				
Siniperca scherzeri			7	0.6
Coreoperca herzi	1	0.2	1	0.1
Family Centrarchidae				
Lepomis macrochirus	2	0.4	14	1.2
Micropterus salmoides	28	6.3	22	1.8
Family Odontobutidae				
Odontobutis platycephala	3	0.7	5	0.4
Family Gobiidae				
Rhinogobius giurinus	3	0.7		
Rhinogobius brunneus	11	2.5		
Tridentiger brevispinis	39	8.7		
Family Channidae				
Channa argus			3	0.3
Total	447		1,200	

Table 2. Number of fish species and individuals, the Shannon diversity index, and IBI (index of biological integrity) of fishes caught by the cast net and gill nets.

Site	Number of species			Number of individuals		Shannon's *H*			IBI		
	CN	GN	Total	CN	GN	CN	GN	Total	CN	GN	Total
St. 1	8	14	18	38	179	1.67	2.08	2.21	50.0	62.5	68.8
St. 2	9	12	15	51	41	1.67	2.00	2.08	56.3	62.5	68.8
St. 3	6	13	17	17	80	1.62	2.10	2.32	43.8	62.5	68.8
St. 4	7	10	12	28	56	1.40	1.98	2.02	31.3	56.3	56.3
St. 5	9	12	15	37	109	1.89	1.77	2.03	56.3	62.5	75.0
St. 6	9	14	17	29	73	1.93	2.04	2.19	56.3	62.5	68.8
St. 7	7	11	12	18	51	1.72	1.92	1.94	56.3	62.5	62.5
St. 8	7	13	16	28	110	1.61	2.13	2.20	50.0	62.5	75.0
St. 9	8	11	16	21	59	1.91	1.96	2.34	50.0	56.3	56.3
St. 10	6	10	14	19	35	1.67	1.95	2.27	56.3	50	56.3
St. 11	8	11	14	25	77	1.64	2.00	2.08	56.3	56.3	62.5
St. 12	7	13	17	22	82	1.58	2.17	2.40	50.0	62.5	75.0
St. 13	9	12	17	43	49	1.21	2.05	2.20	37.5	62.5	68.8
St. 14	12	10	16	42	36	2.12	1.96	2.33	75.0	68.8	75.0
St. 15	8	11	13	29	163	1.68	1.64	1.78	50.0	50.0	56.3

CN, Cast net; GN, Gill nets; Total, Gill net + Cast net

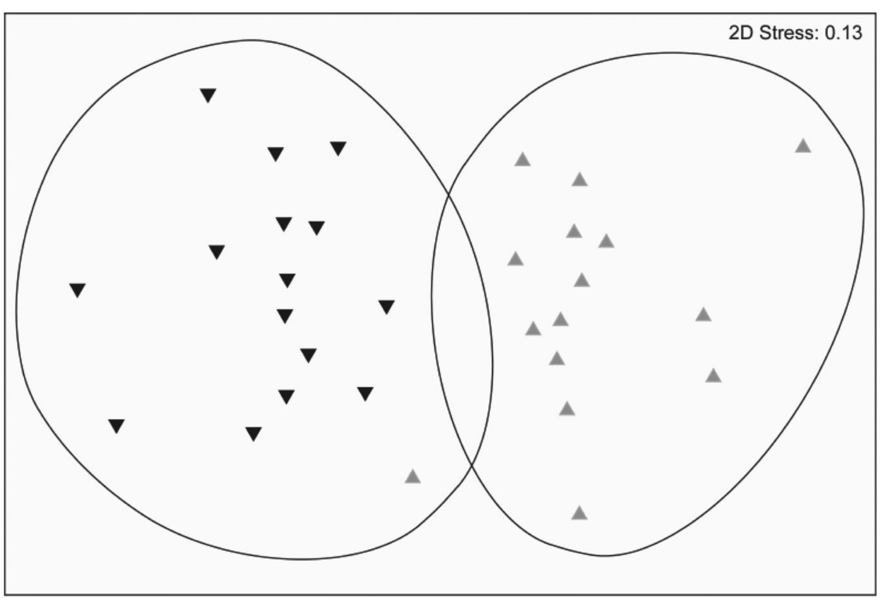

Fig. 2. Non-metric multidimensional scaling of samples based on Bray-Curtis similarities. Grey triangles indicate cast net sampling sites and black triangles indicate gill net sampling sites. The sites are grouped based on the Simprof test from a cluster analysis. One cast net site is grouped with the gill net sites.

Pawson, 1999). Although we did not statistically examine the relationship between morphology and gill net collection, we observed effects of body depth and serrated spine presence. Specifically, gill nets tended to catch large, fusiform fish of high body depth. Moreover, gill nets frequently captured Bagridae and Siluridae, which possess serrated spines that

Table 3. SIMPER analysis results representing the contributions of species to the differentiation between the cast net (CN) and the gill net (GN). The total average dissimilarity between two groups was 63.27% and a cumulative percent reaches 90% was considered the cut-off.

Species	Average abundance		Average dissimilarity	Contribution %	Cumulative %
	CN	GN			
Carassius auratus	0.90	3.81	7.33	11.59	11.59
Erythroculter erythropterus	0.00	2.12	5.43	8.59	20.18
Pseudogobio esocinus	3.04	4.04	4.26	6.73	26.91
Hemiculter eigenmanni	0.13	1.70	3.89	6.15	33.06
Opsariichthys uncirostris amurensis	1.21	2.37	3.88	6.14	39.20
Tridentiger brevispinis	1.30	0.00	3.33	5.26	44.46
Zacco platypus	1.91	1.73	3.29	5.20	49.66
Hemibarbus labeo	0.81	1.24	2.96	4.67	54.33
Cyprinus carpio	0.13	1.25	2.90	4.59	58.92
Squalidus chankaensis tsuchigae	1.07	0.44	2.56	4.05	62.97
Acheilognathus lanceolatus	0.00	1.12	2.52	3.99	66.96
Micropterus salmoides	1.07	0.94	2.30	3.64	70.60
Acanthorhodeus macropterus	0.00	0.87	2.16	3.41	74.01
Culter brevicauda	0.00	0.74	2.01	3.17	77.19
Carassius cuvieri	0.00	0.75	1.94	3.07	80.26
Rhinogobius brunneus	0.69	0.00	1.80	2.85	83.11
Lepomis macrochirus	0.13	0.55	1.54	2.44	85.55
Acheilognathus majusculus	0.00	0.36	1.05	1.67	87.21
Hemibarbus longirostris	0.31	0.20	1.01	1.59	88.81
Siniperca scherzeri	0.00	0.38	0.97	1.53	90.33

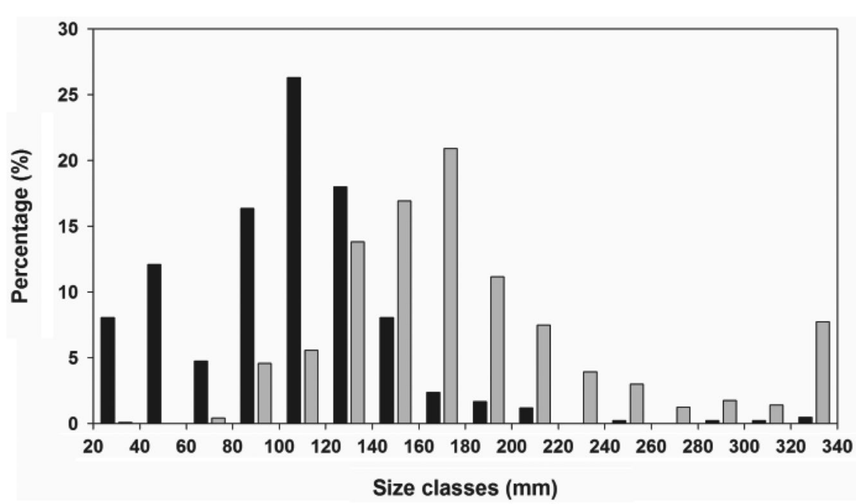

Fig. 3. Sizes of fishes collected with cast nets and gill nets from fifteen study sites. Total lengths were grouped in 20 mm blocks, starting from 20 mm to longer than 320 mm. Black and grey bars indicate the percentages of fishes collected with cast nets and gill nets, respectively.

are easily entangled in the mesh. With the exception of *Misgurnus anguillicaudatus*, gill nets used in this study do not generally appear to be effective for collecting small and eel-like fish.

In contrast, ecological features such as habitat exert a greater effect on cast net catches than fish morphology. We did not find support for the suggestion that cast nets would be useful in aquatic plant beds (Stein III *et al.*, 2014). Fishes predominantly caught in the cast net (*P. esocinus*, *Zacco platypus*, *Hemibarbus labeo*, and Gobiidae) prefer shallow water with little shelter, and actual catching efficiency in habitats with plant beds was substantially lower than gill nets, which were able to capture species that favor such habitats (e.g., *C. auratus* and genus *Acheilognathus*) during their daily migration to open water. The lower efficiency of cast nets is likely due to impediment from aquatic plants that prevent the net from touching the bottom, allowing fishes to escape. Further, the cast net is not effective at water depths greater than 2 m, as the increased length of time for the net to reach the bottom allows fish to avoid capture. Finally, we found that the cast net rarely caught nocturnal species, such as Bagridae and *Silurus asotus*, likely because they were inactive and hidden during the daytime. We conclude that the cast net is inadequate for deep water, habitats with plant beds, and nocturnal species, but it is well-suited for sampling in shallow and open water (e.g., Jang *et al.*, 2005; Stevens *et al.*, 2006; Emmanuel *et al.*, 2008; Sheaves and Johnston, 2008; Stein III *et al.*, 2014).

Gill net catches tend to exhibit bell-shaped selectivity curves, as the mesh size results in frequent capture of medium-sized fish (Huse *et al.*, 2000; Jørgensen *et al.*, 2009). In general, we found that gill nets caught fish with greater TLs than the cast net, but allowed small fish (<80 mm) to escape. Thus, gill net catches tend to underestimate the number of small individuals in a fish assemblage (Rulifson, 1991; Eros *et al.*, 2009). Using a cast net, with its smaller mesh, should therefore provide complementary data on smaller fish. Alternatively, using gill nets with a wide range of mesh sizes could also effective for catching variety size of fish.

In support of our hypothesis, we found consistent differences between fish assemblages caught with a cast net versus gill nets. In particular, gill net sampling resulted in higher species richness than cast net sampling. One possible reason for this difference could be the limited, briefer deployment of cast nets (10 times per site) compared with the gill nets (in the water for 12 hours per site). However, fish assemblages collected by the cast net exhibited similar patterns and generally grouped together across sites, indicating that increasing deployment should not significantly alter the patterns we found. Nonetheless, we acknowledge the difficulty in directly comparing the collection outcomes of gill nets (passive) and cast nets (active), due to the numerous related variables involved beyond sampling effort, such as net characteristics, fishing methods, and river habitats.

In summary, we found that fish richness was lower when using only a single gear for sampling. Our results are in line with conclusions from previous studies indicating that data collected with one method is limited, and a single, universal method of investigating ichthyofauna does not exist (Penczak *et al.*, 1998; Loisl *et al.*, 2014). Thus, the combined use of diverse sampling methods is more likely to improve study reliability (Loisl *et al.*, 2014; Oliveira *et al.*, 2014). This is particularly important in South Korea, as cast nets are predominantly used in research for their convenience, even in habitats where they are inefficient. The data from studies using inappropriate or limited gear could lead to a misunderstanding of environmental conditions and the establishment of problematic management plans that are time-consuming and expensive, without being effective (Polacheck, 2006; Rotherham *et al.*, 2011). Therefore, to improve data quality, researchers should seek to use multiple types of sampling gear that suit specific habitats.

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