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Introduction of an Electrofishing Technique for Assessments of Fish Assemblages to Korean Watersheds

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The objective of this research was to evaluate an sampling effect of fish species and individual number on sampling techniques of electrofishing and conventional capture methods of cast net and kick net in 38 stream sites sampled during June - September, 2005. For the study, sampling gears were categorized as three types of electrofishing method (EM), conventional sampling technique (CM), and the combined technique (CT) of the electrofishing and the conventional method to compare statistical differences. Major differences of species composition between the CM and EM method were found in some benthic species of *Misgurnus mizolepis* and *Iksookimia koreensis* along with lithophilic species of *Pungtungia herzi*. These species were predominated in the EM rather than the CM, indicating that conventional sampling can underestimate the abundance of benthic or lithophilic species. In contrast, individual number of typical water column species such as *Zacco platypus* and *Zacco temmincki* were more sampled by the CM, so that these fish populations were community overestimated. Also, *t*-tests on the types of sampling gear from various watersheds of Chogang Stream, Yugu Stream, Daejeon Stream, and Gap Stream showed that total individual numbers and species number in each stream were significantly (t values = 2.806 – 6.896, p values < 0.05, n = 5 – 14) greater in the CT than the CM. Similar statistical significance (p < 0.001, n = 10 – 24) on sampling seasons were observed during the monsoon and postmonsoon. These results indicate that if the electrofishing is not added to the conventional gears, the abundance of fish population and community can be underestimated and some benthic or lithophilic species may be excluded from the analysis, resulting in overall errors including sampling, fish fauna, and final judgement of community abundance. Overall our results strongly suggest that new application of electrofishing method along with the conventional sampling gears reduce sampling bias on underestimation of the real fish populations and communities.

Key words : Sampling gear, electrofishing, fish community, stream, casting net

INTRODUCTION

Since 1980s, rapid increases of urban development, industrial complex, and population growth in Korea caused a degradation of stream water quality and ecological disturbance, resulting in decreased diversity of freshwater fish (Lee, 2001). For these reasons, various fish bioassessments, based on community analysis (Yang, 1992; Bae *et*

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al., 2002; Choi *et al*., 2005), population levels (Choi *et al*., 1972; Song and Beak, 2005), and indicator species (Choi, 1986) and ecological monitoring for stream restoration (An and Kim, 2005; An *et al*., 2005) have been widely employed for evaluations of ecosystem health, especially in the polluted or disturbed ecosystems. In these studies, the number of fish species and individual number sampled determine the abundance of fish assemblage such as species diversity index, dominance index, and richness index, resulting in influences on final assessments of ecological health condition. The selections of efficient sampling gear and strategy, thus, are considered as important factors influencing the final judgement of the environmental conditions, and the significance of quantitative sampling in stream fish studies has been frequently discussed (Ohio EPA, 1989; Schreck and Moyle, 1990; Barbour *et al*., 1999; US EPA, 1993).

Various sampling methods, techniques, and equipments exist to sample fish populations and communities in running water ecosystems. It is important to understand the attributes and characteristics of sampling equipment and techniques used in fish bioassessment so that valid conclusions can be drown from the data (US EPA, 1993). Sampling considerations and design (Lagler, 1956; Johnson and Nielson, 1983; Schreck and Moyle, 1990; APHA, 1992) are important because aquatic biologist or fishery scientists spend a major part of their time collecting data, and the study results are determined by use of the data with a variety of techniques and equipment for an assortment of studies (US EPA, 1993).

Reference searches on investigation of fish fauna and communities in lotic ecosystems showed that electrofishing methodology in Korea had been used for fish sampling along with cast net, deep net, and seine net during early 1960−1994 (Choi, 1969; Cho, 1971; Choi, 1978; Byeon *et al*., 1994), but after that not any more till now, according to searches of fish study reference. There is no special clue for the stopping, but the electrofishing with improper battery, in spite of for the research purposes, resulted in killing most of fish in sampling area instead of shocking and might not good to the public eye. However, Barbour *et al*. (1999) and Ohio EPA (1989) pointed out that electrofishing method is recommended for most field surveys in most streams of order 6 or less because of its greater applicability and efficiency. Electrofishing allows greater standardization of catch per unit of effort (CPUE) than any other sampling gears (US EPA, 1993), and requires less time and manpower than some other sampling gears (Hendricks *et al*., 1980). Also, advantages of electrofishing are evident; if properly used, adverse effects on fish are minimized and the method is applied in a variety of habitat such as a pool with sand and silt, riffle with large gravel and rocks, and run−reaches with submerged macroplants. In spite of the various advantages of electrofishing, currently fish biologists in Korea do not use it anymore as the sampling gear for fish fauna and community studies of lotic ecosystems. This fact was evidently shown in numerous reference searches on fish sampling (Song *et al*., 1995; Kim and Lee, 1998).

The purpose of this study was to compare an sampling efficiency among electrofishing method, conventional method, based on cast net and kick net, and the combined technique of lectrofishing and the conventional methods. For the study, fish were collected from various sampling streams during June−September, 2005. This study provides a sampling efficiency of electrofishing method along with conventional sampling gears when fish fauna and community studies are performed in the field.

MATERIAL AND METHODS

1. Sampling sites and periods

At thirty eight sites, fishes were collected from all types of the habitats including riffle, run, and pool according to the method of the catch per unit of effort (CPUE; Ohio EPA, 1989). The detail descriptions of locations (Site = S) and periods sampled are as follows :

Daejeon Stream

S1: Okye bridge, Okye−dong, Jung−gu, Daejeon metropolitan city (Jul. 13, 2005)
S2: Sunhwa bridge, Sunhwa−dong, Jung−gu, Daejeon metropolitan city (Jul. 13, 2005)
S3: Hyunam bridge, Hyunam−dong, Jung−gu, Daejeon metropolitan city (Jul. 13, 2005)
S4: Okye bridge, Okye−dong, Jung−gu, Daejeon metropolitan city (Sep. 10, 2005)
S5: Munchang bridge, Munchang−dong, Jung−gu, Daejeon city (Sep. 10, 2005)
S6: Sunhwa bridge, Sunhwa−dong, Jung−gu,

Daejeon metropolitan city (Sep. 10, 2005)

S7: Hyunam bridge, Hyunam-dong, Jung-gu, Daejeon metropolitan city (Sep. 10, 2005)

Yudeung Stream

S8: Samcheon bridge, Samcheon-dong, Seo-gu, Daejeon metropolitan city (Sep. 10, 2005)

S9: Jungbang-lee, Yongchon-dong, Seo-gu, Daejeon metropolitan city (Sep. 10, 2005)

Gap Stream

S10: Goegok bridge, Goegok-dong, Seo-gu, Daejeon metropolitan city (Sep. 10, 2005)

S11: Manyeon bridge, Wolpyeong-dong, Seo-gu, Daejeon metropolitan city (Sep. 10, 2005)

S12: Wonchon bridge, Wonchon-dong, Daeduk-gu, Daejeon metropolitan city (Sep. 10, 2005)

S13: Gapcheon bridge, Jeonmin-dong, Daeduk-gu, Daejeon metropolitan city (Sep. 10, 2005)

Yugu Stream

S14: Munsung, Topgok-lee, Yugu-eup, GongJu city, Chungcheongnam-do (Jul. 21, 2005)

S15: Ipseok bridge, Sindal-ri, Yugu-eup, GongJu city, Chungnam (Jul. 21, 2005)

S16: Mancheon bridge, Yugu-ri, Yugu-eup, GongJu city, Chungnam (Jul. 21, 2005)

S17: Dongwon bridge, Gondwon-ri, Sampung-myeon, GongJu city, Chungnam (Jul. 21, 2005)

S18: Yeongjung bridge, Yeongjung-ri, Sampung-myeon, GongJu city, Chungnam (Jul. 21, 2005)

S19: Hwawol bridge, Sagok-myeon, GongJu city, Chungnam (Jul. 21, 2005)

S20: Dongdae bridge, Dongdae-ri, Woosung-myeon, GongJu city, Chungnam (Jul. 21, 2005)

S21: Munsung garden, Tapgok-ri, Yugu-eup, GongJu city, Chungnam (Sep. 25, 2005)

S22: Ipseok bridge, Sindal-ri, Yugu-eup, GongJu city, Chungnam (Sep. 25, 2005)

S23: Mancheon bridge, Yugu-ri, Yugu-eup, GongJu city, Chungnam (Sep. 25, 2005)

S24: Dongwon-bridge, Gondwon-ri, Sampung-myeon, GongJu city, Chungnam (Sep. 25, 2005)

S25: Yeongjung bridge, Yeongjung-ri, Sampung-myeon, GongJu city, Chungnam (Sep. 25, 2005)

S26: Hwawol bridge, Sagok-myeon, GongJu city, Chungnam (Sep. 25, 2005)

S27: Dongdae bridge, Dongdae-ri, Woosung-myeon, GongJu city, Chungnam (Sep. 25, 2005)

Chogang Stream

S28: Hadodae bridge, Hadodae-ri, Sangchon-myeon, Yeongdong-gun, Chungbuk (Sep. 24, 2005)

S29: Dondae bridge, Dondae-ri, Sangchon-myeon, Yeongdong-gun, Chungbuk (Sep. 24, 2005)

S30: Suwon bridge, Suwon-ri, Maegok-myeon, Yeongdong-gun, Chungbuk (Sep. 24, 2005)

S31: Achon stream confluence point, Nochun-ri, Maegok-myeon, Yeongdong-gun, Chungbuk (Sep. 24, 2005)

S32: Haepyung bridge, Gonduk-ri, Maegok-myeon, Yeongdong-gun, Chungbuk (Sep. 24, 2005)

S33: Outlet of Gangjin Reservoir, Gangjin-ri, Maegok-myeon, Yeongdong-gun, Chungbuk (Sep. 24, 2005)

S34: Oksun bridge, Nochun-ri, Maegok-myeon, Yeongdong-gun, Chungbuk (Sep. 24, 2005)

Bochung Stream

S35: Yiwon bridge, Yiwon-ri, Naebuk-myeon, Boeun-gun, Chungbuk (Jun. 18, 2005)

S36: Boeun bridge, Jukjun-ri, Boeun-eup, Boeun-gun, Chungbuk (Jun. 18, 2005)

Okchun Stream

S37: Yijidang, Jio-ri, Gunbuk-myeon, Okchun-gun, Chungbuk (Jun. 18, 2005)

Yeongdong Stream

S38: Chogang bridge, Chogang-ri, Simchun-myeon, Yeongdong-gun, Chungbuk (Jun. 18, 2005)

2. Sampling methods and sampling gears

At each sampling location, stream distance sampled was 100 m and the sampling time elapsed was 60 minutes according to the quantitative sampling method (Barbour *et al*., 1999). The fish collected in the field were separated as two types of sampling gears of electrofishing method and cast net-kick net (conventional) method, and then the number of species and the individual numbers were counted. The electrofishing was designed as 12 volt and 24 ampere (An and Kim, 2005; An *et al*., 2005), and were kept within effective range of the electrical field by electric stimulus and fish were immobilized making it possible to pick them up with long-handled dip net. All the sites sampled had greater 100 μs cm^{-1} conductivity, which is appropriate ionic condition for electrofishing. Other conventional types of cast net and kick net were employed for the sampling and the mesh size of the nets were 5×5 mm and 4×4 mm, respectively, which are appropriate for collection of small size fish as well as large size fish. The sampling strategy was applied to the all sampling sites, and the samplings were conducted toward the upstream direction. Fish species collected were identified according to the methods of species identification (Nelson, 1994; Kim and Park, 2002).

3. Data analysis

Statistical analysis using SPSS (2004, Version 12.0 KO for Windows) were performed to find a significant difference at the level of 95% CI (Confidence interval) among the electrofishing method (EM), conventional method of cast net and kick net (CM), and the combined technique of the electrofishing and conventional methods (CT). Statistical analyses of *t*−test were performed by SPSS 12.0 KO.

RESULTS

Total number of fish species and individual number sampled from 38 stream sites were 49 and 10136, respectively. For analysis the efficiency of individual number and species number on sampling gear, we categorized as three types of sampling gears including electrofishing method (EM), conventional sampling technique (CM), and the combined technique (CT). Total number of fish species, based on the CM, EM, and CT approaches, was 44, 40 and 49, respectively, while total individual number, based on the three approaches, was 4927, 5209 and 10136, respectively.

As shown in Fig. 1, the fish fauna comprising >2% of the total individuals were compared among the CM, EM, and CT methods. Fish fauna using the CM method was 6 species such as *Zacco platypus* (54.9%), *Zacco temmincki* (10.9%), *Microphysogobio yaluensis* (6.3%), *Acheilognathus lanceolatus* (5.7%), *Pseudogobio esocinus* (3.6%), and *Hemibarbus longirostris* (2.5%). In the mean time, fish species using EM method was 10 species such as *Zacco platypus* (45.2%), *Acheilognathus lanceolatus* (6.1%), *Zacco temmincki* (5.4%), *Hemibarbus longirostris* (5.2%), *Misgurnus mizolepis* (4.5%), *Pungtungia herzi* (4.5%), *Rhynchocypris oxycephalus* (3.9%), *Microphysogobio yaluensis* (3.8%), *Pseudogobio esocinus* (3.8%), and *Iksookimia koreensis* (3.5%). The major difference between the CM and EM method was found in some benthic species of *Misgurnus mizolepis* and *Iksookimia koreensis* along with lithophilic species of *Pungtungia herzi*. These species were sampled not in the CM but in the only EM, indicat-

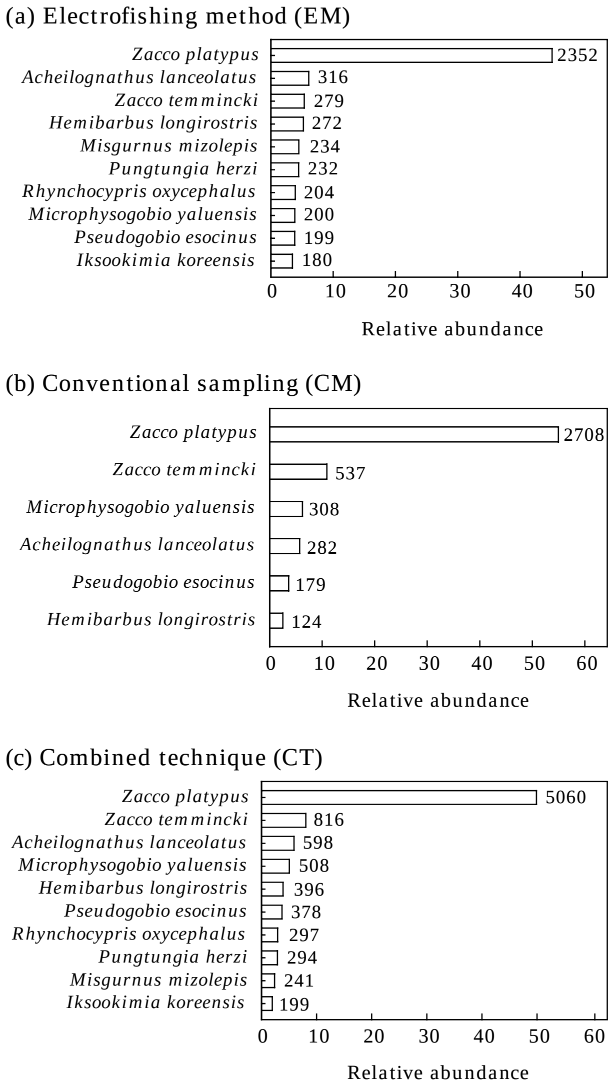

Fig. 1. Relative fish composition by electrofishing method (a), conventional sampling (b) of cast net and kick net, and the combined technique (c) of the electrofishing and conventional capture method. The numbers in the figure indicate the individual number of each fish.

Table 1. The comparison of fish species composition, depending on the sampling gears of conventional sampling (CM) and electrofishing method (EM). The numbers in the CM and EM indicate total number of fish individual sampled. Fish list was rearranged by the sequence of the ratios of EM to CM

Fish compositions	CM	EM	Ratios of EM to CM
*Misgurnus mizolepis**	7	234	33.43
*Cobitis lutheri**	1	14	14.00
*Coreoperca herzi**	1	12	12.00
Acheilognathus macropeterus	2	23	11.50
*Misgurnus anguillicaudatus**	1	11	11.00
*Odontobutis interrupta**	10	100	10.00
Rhodeus uyekii	6	58	9.67
*Iksookimia koreensis**	19	180	9.47
*Liobagrus mediadiposalis**	1	9	9.00
*Pseudopungtungia nigra**	1	7	7.00
*Pseudobagrus koreanus**	3	19	6.33
*Rhinogobius brunneus**	7	27	3.86
*Pungtungia herzi**	62	232	3.74
*Tridentiger brevispinis**	15	50	3.33
Rhodeus notatus	5	16	3.20
Rhynchocypris oxycephalus	93	204	2.19
Hamibarbus longirostris	124	272	2.19
Gnathopogon strigatus	33	67	2.03
Cyprinus carpio	6	12	2.00
*Silurus asotus**	0	2	†
*Silurus microdorsalis**	0	1	†
*Anguilla japonica**	0	2	†
Acheilognathus koreensis	0	1	†
Acheilognathus signifer	0	1	†
*Odontobutis platycephala**	20	35	1.75
Pseudorasbora parva	12	15	1.25
Carassius auratus	71	83	1.17
Acheilognathus lanceolatus	282	316	1.12
*Pseudogobio esocinus**	179	199	1.11
Squalidus gracilis	1	1	1.00
*Pseudobagrus fulvidraco**	2	2	1.00
*Coreoleuciscus splendidus**	94	94	1.00
Acheilognathus yamatsuate	50	48	0.96
Zacco platypus	2708	2352	0.87
*Microphysogobio yaluensis**	312	200	0.65
Zacco temmincki	537	279	0.52
Acheilognathus rhombeus	31	16	0.52
Micropterus salmoides	9	3	0.33
Squalidus japonicus coreenus	88	11	0.13
Opsariichthys uncirostris amurensis	57	1	0.02
*Channa argus**	1	0	0.00
Hemibarbus labeo	45	0	0.00
Rhodeus pseudosericeus	3	0	0.00
Carassius cuvieri	1	0	0.00
Hypomesus nipponensis	14	0	0.00
Plecoglossus altivelis	5	0	0.00
Sarcocheilichthys vari. wakiyae	1	0	0.00
Hemiculter eigenmanni	8	0	0.00
Squaliobarbus curriculus	3	0	0.00

†: Caught by Electrofishing only
*: Benthic or lithophilic species

ing that conventional sampling can underestimate the fish communities, which occupy in benthic habitat or are lithophilic. In contrast, individual number of typical water column species such as *Zacco platypus* and *Zacco temmincki* were more sampled by the CM as shown in the Fig. 1.

The difference of occurrence frequency are well demonstrated by habitat guilds in the water column species and benthic species between CM and EM (Table 1). Fish species, showing frequency ratios of EM and CM of >2, were *Hemibarbus longirostris*, *Misgurnus mizolepis*, *Pungtungia herzi*, *Rhynchocypris oxycephalus*, and *Iksookimia koreensis*. Especially, *Misgurnus mizolepis* (33.4), *Cobitis lutheri* (14.0), *Coreoperca herzi* (12.0), *Acheilognathus macropeterus* (11.5), *Misgurnus anguillicaudatus* (11.0), and *Odontobutis interrupta* (10.0) had the ratios of EM: CM greater than 10, indicating that benthic or lithophilic species were predominated in the EM (Table 1). In contrast, fish species with the ratios of <1 were *Sarcocheilichthys vari. wakiyae*, *Carassius cuvieri* and *etc.* (Table 1). and these species were mainly composed of water column species. These outcomes suggest that if the EM is added to the conventional sampling method of cast net and kick net, the number of benthic or lithophilic species will be increased by 33 fold. Under this situation, assessments of fish abundance in terms of community and population can be underestimated. In fact, casting net is frequently confined to mainly run and pool reaches and shallow riffle area with small pabbles and cobbles, while hand net is mainly applied to reaches dominated by aquatic plants and with riffles with small rocks. One of major problems in the conventional gears is inaccessability in large grabble reach and large rocky area. Such disadvantage, however, can be supplemented by electrofishing gear.

Total number of individuals and species number varied depending on the sampling sites (Fig. 2). In the CM, 9 sites (S2, S17, S18, S19, S23, S25, S35, S36, and S37) had individual number of >200 were and 6 sites (S3, S11, S12, S27, S31, and S33) had <50 (Fig. 2a), thus resulting in large differences of more than 3 fold. Also, comparisons of between CM and ET showed that total individual number at same sites, except for some sites, was largely greater in the EM than CM (Fig. 2a), while species number at each site, except for some sites, had hardly differences between EM and CM (Fig. 2b). In particular, there was distinct differences of the individual number and species number between CT and CM (Fig. 2): The individual number and species number in most sites were greater in the CT than the CM method (Fig. 2a, b). These results indicate that sampling efficiency of the EM, based on the individual number is much better than that of the CM and that addition of EM to the conventional sampling gears will reflect actual abundance conditions of fish population or community

Statistical tests of the individual number, based on overall sites, are shown in the Table 2. The individual number was significantly (t = 8.520,

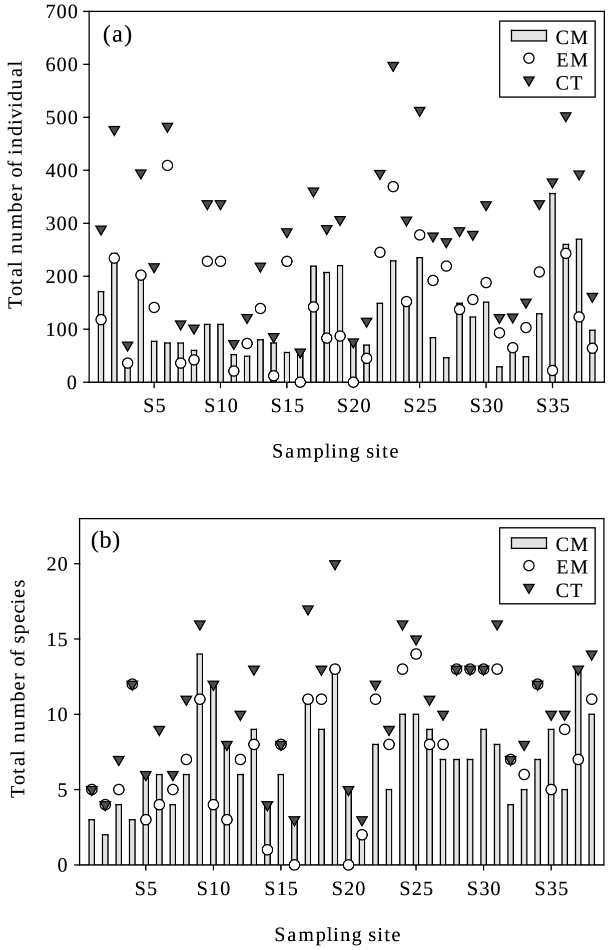

Fig. 2. The number of fish individual (a) and the species number (b) in the sampling sites by various sampling gears of the EM, CM, and CT. The abbreviations of EM, CM, and CT are the electrofishing method, conventional sampling method of casting net and hand net, and the combined technique of electrofishing and conventional sampling gear.

Table 2. Statistical analysis of t-tests, based on overall individual number (a) and species number (b) and CT vs. EM. The abbreviations of EM, CM, and CT are the electrofishing method, conventional sampling method of casting net and hand net, and the combined technique of electrofishing and conventional sampling gear (MD = Mean difference, SD = Standard deviation, DSE = Difference of standard error, C.I. = Confidence interval D.F. = Degree of freedom, *: $p<0.05$, **: $p<0.01$, †: Not significant)

(a) Statistical t-test based on the number of fish individual

Sampling gear	MD	SD	DSE	95% C.I.		t-value	D.F.	P value (Paired test)
				Lower limit	Upper limit			
EM vs CM	7.4	110.4	17.9	−28.8	43.7	0.414	37	0.681†
CT vs CM	137.0	99.1	16.0	104.4	169.6	8.520	37	0.0001**
CT vs EM	129.6	81.1	13.1	102.9	156.3	9.846	37	0.0001**

(b) Statistical t-test based on the species number

Sampling gear	MD	SD	DSE	95% C.I.		t-value	D.F.	P value (Paired test)
				Lower limit	Upper limit			
EM vs CM	0.5	3.6	0.5	−0.7	1.7	0.839	37	0.407†
CT vs CM	3.1	2.4	0.3	2.3	3.9	8.092	37	0.0001**
CT vs EM	2.6	2.3	0.3	1.9	3.4	7.078	37	0.0001**

D.F. = 37, $p<0.001$) greater in the CT than the CM and also the individual number was significantly ($t=9.846$, D.F. = 37, $p<0.001$) greater in the CT than in the EM. But there was no significant differences ($t=0.414$, $p=0.681$) in the individual number between the EM and CM.

Similarly, statistical comparisons of species number, based on overall sites, showed that species number was significantly ($t=8.092$, D.F.= 37, $p<0.001$) greater in the CT than the CM and was significantly ($t=7.078$, D.F.= 37, $p<0.001$) greater in the CT than in the EM. However, there was no significant differences ($t=0.839$, $p=0.407$) in the species number between the EM and CM technique.

Also, we conducted t-tests on the types of sampling gear from various watersheds (Table 3). Statistical analyses in the remaining former four streams comprising more than 3 sampling sites, showed that total individual numbers and species number were significantly greater in the CT than the CM (Table 3). This phenomenon was shown in all Chogang, Yugu, Daejeon, and Gap streams (except for the species number in Gap Stream, so all p-values in the four streams ranged between 0.0001 and 0.039, indicating a statistically significant differences in the CT vs. CM dataset. The statistical differences (range of p values : 0.105−0.677, D.F = 4−13) of both individual number and species number in the EM vs. CM were not found in Yugu, Daejeon, and Gap streams.

Statistical t-tests on the types of sampling gear also showed that during the monsoon and postmonsoon seasons, total individual numbers and species number in the CT were significantly greater than the CM (Table 3). During the monsoon, the individual number was significantly ($t=3.411$, D.F. = 9, $p=0.008$) greater in the CT than the CM and also the individual number was significantly ($t=5.164$, D.F. = 9, $p\leq 0.001$) greater in the CT than in the EM. In the postmonsoon, individual number in the CT vs. CM and CT vs. EM also showed significant differences ($p<0.001$, $n=24$; Table 4a). In the mean time, statistical significance in the individual number CT vs. CM and EM vs. CM was not found during the premonsoon ($p\geq 0.100$) and this was attributed to low observed number (D.F. = 3) in the dataset. As shown in Table 4, statistical outcomes in the species number (Table 4a) were similar to the pattern of individual number (Table 4b). During the monsoon, the species number was significantly ($t=3.344$, $p=0.009$, $n=10$) greater in the CT than the CM, and also the species number was significantly ($t=3.500$, $p=0.007$, $n=10$) greater in the CT than in the EM. During the postmonsoon, species number in the CT vs. CM ($t=7.833$, $p<0.001$, $n=24$) and CT vs. EM ($t=5.062$, $p<0.001$, $n=24$) had similar statistical significance with the monsoon data (Table 4).

Statistical analyses on the overall dataset, spatial dataset of four streams, and the dataset

Table 3. Statistical analysis of t-test, based on the individual number (a) and species number (b) of various sampling watersheds, in the EM vs CM, CT vs CM, and CT vs EM (MD = Mean difference, SD = Standard deviation, DSE = Difference of standard error, C.I. = Confidence interval D.F. = Degree of freedom, *: $p < 0.05$, **: $p < 0.01$, †: Not significant)

(a) Statistical t-test based on the number of fish individual

Stream name	Sampling gear	MD	SD	DSE	95% C.I.		t-value	D.F.	P value (Paired test)
					Lower limit	Upper limit			
Chogang Stream	EM vs CM	37.5	31.9	12.0	8.0	67.1	3.110	6	0.021*
	CT vs CM	135.7	52.0	19.6	87.5	183.8	6.896	6	0.000**
	CT vs EM	98.1	51.4	19.4	50.5	145.6	5.051	6	0.002**
Yoogu Stream	EM vs CM	12.8	108.6	29.0	−49.8	75.5	0.443	13	0.665†
	CT vs CM	146.5	114.1	30.5	80.6	212.4	4.804	13	0.000**
	CT vs EM	133.7	75.3	20.1	90.2	177.2	6.639	13	0.000**
Daejeon Stream	EM vs CM	44.2	133.5	50.4	−79.2	167.7	0.877	6	0.414†
	CT vs CM	168.0	130.1	49.2	47.6	288.3	3.415	6	0.014*
	CT vs EM	123.7	77.9	29.4	51.6	195.7	4.200	6	0.006**
Gap Stream	EM vs CM	15.8	78.6	35.1	−81.8	113.4	0.449	4	0.677†
	CT vs CM	107.4	79.3	35.4	8.8	205.9	3.027	4	0.039*
	CT vs EM	91.6	48.0	21.4	31.9	151.2	4.267	4	0.013*

(b) Statistical t-test based on the Species number

Stream name	Sampling gear	MD	SD	DSE	95% C.I.		t-value	D.F.	P value (Paired test)
					Lower limit	Upper limit			
Chogang Stream	EM vs CM	3.4	2.2	0.8	1.3	5.4	4.076	6	0.007**
	CT vs CM	4.1	2.5	0.9	1.7	6.4	4.307	6	0.005**
	CT vs EM	0.7	1.2	0.4	−0.4	1.8	1.508	6	0.182†
Yoogu Stream	EM vs CM	0.5	2.7	0.7	−1.0	2.0	0.690	13	0.502†
	CT vs CM	3.2	2.3	0.6	1.8	4.5	5.029	13	0.000**
	CT vs EM	2.7	2.0	0.5	1.5	3.9	4.944	13	0.000**
Daejeon Stream	EM vs CM	1.4	3.8	1.4	−2.1	5.0	0.977	6	0.366†
	CT vs CM	3.0	2.8	1.0	0.3	5.6	2.806	6	0.031*
	CT vs EM	1.5	1.9	0.7	−0.1	3.3	2.185	6	0.072†
Gap Stream	EM vs CM	−3.6	3.8	1.7	−8.3	1.1	−2.092	4	0.105†
	CT vs CM	2.0	2.0	0.8	−0.4	4.4	2.236	4	0.089†
	CT vs EM	5.6	2.1	0.9	2.8	8.3	5.715	4	0.005**

of three seasons suggested that there was no statistical difference in the individual number and species number between the conventional sampling methods and electrofishing methods and that new addition of electrofishing methods to conventional sampling gears of casting net and hand net resulted in statistically greater individual number and species number. So, if the electrofishing is not excluded from the sampling gears, it reduces the abundance of the real fish populations and communities.

DISCUSSIONS

In Korea, our reference searches for fish surveys showed that various sampling gears such as cast net (Choi *et al*., 1973; Ju and Jeon, 1977; Lee *et al*., 1980; Nam *et al*., 1998), kick net (Choi, 1972; Son, 1983; Hwang *et al*., 1995; Choi *et al*., 1997; Kim and Lee, 1998), seine net (Choi *et al*., 1977; Kim and Lee, 1984; Hwang *et al*., 1995), gill net (Choi, 1976; Son, 1983; An *et al*., 1992), and hooking (Choi, 1969; Lee and Kim, 1981) have been used for assessments of fish fauna and community abundance. The former two gears are

Table 4. Seasonal analysis of t-test in the EM vs CM, CT vs CM, and CT vs EM (MD = Mean difference, SD = Standard deviation, DSE = Difference of standard error, C.I. = Confidence interval D.F. = Degree of freedom, *: $p<0.05$, **: $p<0.01$, †: Not significant)

(a) Seasonal variation of species number

Season	Sampling gear	MD	SD	DSE	95% C.I.		t-value	D.F.	p value (Paired test)
					Lower limit	Upper limit			
Premonsoon	EM vs CM	−1.2	4.5	2.2	−8.5	6.0	−0.547	3	0.623†
	CT vs CM	2.7	2.7	1.3	−1.6	7.1	1.997	3	0.140†
	CT vs EM	4.0	1.8	0.9	1.0	6.9	4.382	3	0.022*
Monsoon	EM vs CM	−0.2	2.5	0.8	−2.0	1.6	−0.246	9	0.811†
	CT vs CM	2.6	2.4	0.7	0.8	4.3	3.344	9	0.009**
	CT vs EM	2.8	2.5	0.8	0.9	4.6	3.500	9	0.007**
Postmonsoon	EM vs CM	1.3	4.0	0.8	−0.3	3.0	1.621	23	0.119†
	CT vs CM	3.7	2.3	0.4	2.7	4.7	7.833	23	0.000**
	CT vs EM	2.4	2.3	0.4	1.4	3.4	5.062	23	0.000**

(b) Seasonal variation of individual number

Season	Sampling gear	MD	SD	DSE	95% C.I.		t-value	D.F.	p value (Paired test)
					Lower limit	Upper limit			
Premonsoon	EM vs CM	−133.0	145.8	72.9	−365.1	99.1	−1.823	3	0.166†
	CT vs CM	113.0	96.0	48.0	−39.8	265.8	2.353	3	0.100†
	CT vs EM	246.0	107.6	53.8	74.6	417.3	4.570	3	0.020*
Monsoon	EM vs CM	−41.70	86.2	27.2	−103.3	19.9	−1.529	9	0.161†
	CT vs CM	94.0	87.1	27.5	31.6	156.3	3.411	9	0.008**
	CT vs EM	135.7	83.0	26.2	76.2	195.1	5.164	9	0.001**
Postmonsoon	EM vs CM	51.7	85.9	17.5	15.4	88.0	2.952	23	0.007**
	CT vs CM	159.5	101.0	20.6	116.8	202.2	7.732	23	0.000**
	CT vs EM	107.7	59.2	12.1	82.7	132.7	8.904	23	0.000**

widely used for rapid bioassessments in shallow-moderate streams, while the latter three are more time consumming sampling gear and more frequently used for surveys of deep lakes and reservoirs than streams. In the mean time, electrofishing methodology in Korea had been used for fish sampling along with cast net, deep net, and seine net by early 1995 from 1960s, but after that not any more till now based on reference searches. Numerous field studies of fish fauna and community in North America and European streams (Ohio EPA, 1989; US EPA, 1993; Barbour *et al.*, 1999) suggested that electrofishing is most recommended sampling gear in streams of order 6 or less because of its easy applicability and high sampling efficiency and that electrofishing produce scientific standardization of catch per unit of effort than any other sampling gears (US EPA, 1993). For these reasons, electrofishing has been widely applied for surveys of fish fauna, community abundance and bioassessments (Rapid Bioassessment Protocol; Barbour *et al.*, 1999) in many developed countries. Also, our investigation from Korean streams showed that the combined use of electrofishing equipment and the conventional methods resulted in greatest abundance in the species number and individual numbers. Also, we found that some species of benthic fishes such as *Misgurnus mizolepis* showed gear selectivity by electrofishing due to differences in the compositions of bottom substrate. This means that if the eletrofishing is not added to the conventional gears, the abundance of fish population and community can be underestimated and some species may be excluded from the analysis, resulting in overall errors including field sampling, fish fauna, and the final judgement of community or population abundance. In conclusion, overall our results strongly suggest that new application of electrofishing methods along with conventional sampling gears reduce sampling bias on underestimation of the real fish populations and communities. For the scientific data collections of fish abundance and fish bioassessments, an official permission or introduction of electrofishing to fish survey for research purpose should be reconsidered by the Ministry of Environment, Korea and the Ministry of Marine Affairs and Fisheries, Korea.

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<국문적요>

우리나라의 수계에서 어류채집 효율성을 위한 전기충격기의 도입

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본 연구의 목적은 2005년 6-9월까지 38개 조사지점을 대상으로 하여 채집된 어류의 종 수 및 개체 수 풍부도에 대한 전통적 채집방법(주로, 투망 및 족대 이용) 및 전기충격기를 이용하는 방법의 조사 효율성을 평가하는 것이었다. 채집도구는 전기충격기를 이용하는 방법(EM), 전통적인 조사법(CM) 및 이 두 가지 방법을 조합하는 기법(CT)의 3가지로 구분하여 통계적 유의성 차이를 비교·검토하였다. CM기법과 EM기법사이의 어종 구성도에 있어서 뚜렷한 차이는 미꾸라지 및 참종개와 같은 저서어종(Benthic species) 및 돌로 된 하상을 선호하는 꺽지와 같은 종에서 나타났다. 이런 종들의 출현빈도는 CM기법 보다는 EM기법에 의해 통계적 유의성이 높게 나타나 기존의 조사기법을 그대로 이용할 경우 저서성 어류 혹은 돌을 선호하는 종(Lithophilic species)의 풍부도 산정 시 과소평가되는 것으로 나타났다. 한편, 피라미와 갈겨니 같은 수층종(Water column species)은 CM기법 이용 시 개체 수 증가가 뚜렷하여 이런 종류의 개체군은 과대평가 될 수 있는 것으로 나타났다. 초강천, 유구천, 대전천 및 갑천 수계의 통계적 t-검정 결과에 따르면, 이들 모든 하천에서 종 수 및 개체 수는 CM기법보다는 CT기법에 의하여 통계적으로 높게 나타났다(t 값 = 2.806-6.896, p 값 $<$ 0.05, n = 5-14). 마찬가지로 계절별 통계 분석에서도 두 가지 기법 사이에 통계적 유의성이 크게 나타났다(p 값 $<$ 0.001, n = 10-24). 이러한 연구 결과는 전기충격기를 이용한 어류채집방법이 기존의 방법에 추가되지 않는다면 실제 수환경내의 어류 개체군 및 군집분석은 과소평가되며, 저서성종 혹은 돌이나 암반을 선호하는 종은 분석에서 배제되는 것으로 나타났다. 즉, 이러한 결과는 궁극적으로 채집오류는 물론이고 어류상, 개체군 및 군집풍부도 산정 시 큰 오류를 가져오는 것으로 나타났다. 결론적으로, 우리나라에서 어류조사 시 기존의 방법과 함께 전기충격기 방법의 새로운 도입은 실제 어류개체군 및 군집에 대한 과소평가의 분석오류를 감소시킬 것으로 사료되는 바, 북미 및 유럽에서 가장 보편적으로 사용하는 전기충격 채집법은 환경부 혹은 해양수산부의 어류 현장 지침서에 추가되어야 할 것으로 사료된다.