Comparison of catches and species composition for flounders caught using gillnets, gillnets with supporting lines, and trammel nets

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To compare the catches made using gillnets, trammel nets, and gillnets with supporting lines, several experiments were conducted with commercial vessels near Uljin and Pohang in Eastern Korea between July 2010 and May 2011. Two sets of 13 different nets were used, including 5 panels of gillnets and trammel nets each with stretched mesh sizes of 7.6, 9.1, 10.6, 12.1, and 13.6 cm and 3 panels of gillnets with a mesh size of 9.1 cm with supporting lines with different line spacing. The outer (stretched) mesh size of the trammel nets measured 51.5 cm. The target fishes of the fishing nets were various types of flounders. The catch rate of flounders was 50.7% of the total catch in weight. The total catch for all nets was 443.8 kg. The predominant species was pointhead flounder (*Cleisthenes pinetorum*). The total catch by trammel nets was 1.4 times that of the comparable gillnets. But more pointhead flounder were caught by gillnets than by trammel nets, though there was no significant difference. Fishermen catching the pointhead flounder in Korea said that there was no need to use trammel net to catch it; this was an unexpected finding compared to the findings of other flounder fisheries. The amounts of roughscale sole, brown sole, and blackfin flounder caught by trammel nets were greater than those caught by gillnets. The mean lengths (standard deviation) of blackfin flounder, pointhead flounder, brown sole, and roughscale sole were 21.0 (4.57), 22.9 (3.40), 24.7 (4.90), and 28.3 (5.43) cm, respectively; there were significant differences in mean length ($p < 0.00001$). Therefore, in order to catch flounder efficiently, the fishing nets and mesh size should be chosen according to the target species. One advantage of using supporting lines is that it prevents breakage by strengthening the material especially when utilized on a rough bottom. Catch by using gillnet with supporting lines was not greater than that by using trammel net for the conservation of fisheries resources.

Keywords : Species composition, Catch efficiency, Flounders, Gillnet, Trammel net

Introduction

Research on the catch of target species and bycatch with respect to various fishing gear is necessary to efficiently manage and protect the dwindling fishery resources, thus maintaining continuous fishing. The seabed of Eastern Korea

is rougher and deeper than that in other regions of Korea. Research on fishery resources as well as bycatch and discard in the coastal and offshore regions of Eastern Korea has been conducted using trawls, gillnets, and trammel nets (Park et al., 2007; Lee et al., 2008; Yoon et al., 2008; Bae et al., 2010).

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And comparison of gillnet and trammel net to assess fish community was done in a large river (Wanner et al., 2010). Gillnet and trammel net fisheries in Eastern Korea are some of the major types of coastal fisheries. Flounder, sandfish, Pacific sand eel, snow crab, Okhotsk Atka mackerel, Japanese flying squid, smooth lump sucker, and Tanaka's snailfish are caught using this equipment. In the past, flounder have been caught by bottom-trawling and 2 types of bottom seines. Nowadays, the use of gillnets and trammel nets has increased. Important flounder species for commercial fisheries in Eastern Korea include blackfin flounder, pothead flounder, roughscale sole, brown sole, and red halibut. Regulations on the length of fish that can be retained and mesh size have been adopted to reduce mortality of small fish.

It is permitted to use gillnets to catch fish throughout Korea; however, use of trammel nets is only allowed in special regions. Gillnets are more susceptible to tearing over a rough seabed; thus, it is essential that caution must be exercised to avoid destruction of a fishing gear. Three types of nets were used in the current study: gill nets, trammel nets, and gill nets with supporting lines suspended vertically to strengthen the gillnet to prevent it from tearing over a rough seabed (hereafter referred to as gillnet with supporting lines).

In this study, gillnets, trammel nets, and gillnets with supporting lines were constructed to target flounder, and the catch of the main target fish and bycatch using those gears in 2 regions of Korea were investigated between July 2010 and May 2011.

Materials and Methods

Fishing nets

Gillnet and trammel net have 1 and 3 sheets of netting, respectively. The simple structure of a trammel net and an ex-

ample of hauling trammel net are shown in Fig. 1. Trammel nets are composed of an inner panel with a small mesh size covered by 2 outer panels with large mesh sizes. Details of the experiments conducted with 3 types of fishing gear are described in Table 1. Gillnets catch fish by gilling them, whereas trammel nets do so by entangling and gilling fish. Three types of fishing nets, including gillnets, trammel nets, and gillnets with supporting lines, were constructed to investigate their ability to catch flounder. Five mesh sizes (7.6, 9.1, 10.6, 12.1, and 13.6 cm) of gillnet were used; the inner mesh sizes of the trammel nets were the same as those of the gillnets, while the outer mesh size was 51.5 cm. The mesh size of gillnets with supporting lines was 9.1 cm (stretched length). The 3 line spacings of 46, 92, and 184 cm were used from Jukbyeon and Daebo in 2010 and 92, 184, and 276 cm were used from Daebo port only in 2011. A total of 14 types of nets were constructed. The specifications of each fishing net (gillnet, trammel net and gillnet with supporting lines) relative to a mesh size of 9.1 cm are shown in Fig. 2.

Sea trials and analysis

Fig. 1. Panel structure of trammel net (left) and an example of hauling trammel net in the experiment at sea (right).

Table 1. Details of the experiments with gillnets, trammel nets and gillnets with supporting lines between 2010 and 2011

Experiment site	Uljin (Jukbyeon port)	Pohang (Daebo port)
Fishing gear	Gillnet, Trammel net, Gillnet with supporting lines	
Panels hauled per day	26	26
Mesh size	Gillnet, Trammel net: 7.6cm, 9.1cm, 10.6cm, 12.1cm, 13.6cm	
Line spacing	Gillnet with supporting lines (mesh size 9.1cm): 46cm, 92cm, 184cm 46cm, 92cm, 184cm (or 92cm, 184cm, 276cm)	
Depth (m)	40-55	53-70
Fishing vessel (gross tonnage)	No. 3 Kwangyong (7.93t)	No. 3 Donghae (5.19t)
Number of hauls	8	7

Fig. 2. Specification of the experimental (upper) gillnet, (middle) trammel net and (lower) gillnet with supporting lines. The figures of the specifications correspond to a mesh size of 9.1cm.

The experiment was conducted using a total of 26 panels each day with the 3 types of fishing nets mentioned above off the coasts of Uljin (Jukbyeon port) and Pohang (Daebo port)

between July 2010 and May 2011. Two commercial vessels (7.93 tons at Jukbyeon and 5.19 tons at Daebo) were chartered (1 vessel per port), and the experiments were repeated over 8

Table 2. Details of the daily experiment with gillnets, trammel nets and gillnets with supporting lines at Jukbyeon (Uljin) and Daebo (Pohang) sites between 2010 and 2011

No.	Date (2010-2011)	Depth (m)	Soaked day	Catch in number	Catch (g)	Experimental port
1	2010. 07. 22	51	1	319	76,814	Jukbyeon
2	07. 23	50~55	1	84	24,447	Jukbyeon
3	08. 31	56	1	58	8,979	Daebo
4	09. 01	53~55	1	47	8,889	Daebo
5	10. 14	40~52	1	321	43,048	Jukbyeon
6	10. 15	47~52	2	387	33,303	Jukbyeon
7	11. 18	42	1	175	25,131	Jukbyeon
8	11. 19	48	1	159	22,466	Jukbyeon
9	12. 21	60~70	2	343*	71,483	Daebo
10	2011. 03. 10	56.1	2	88	14,244	Daebo
11	03. 11	59~64	3	162	30,566	Daebo
12	03. 31	45~50	1	45	7,991	Jukbyeon
13	04. 01	52	2	95	12,289	Jukbyeon
14	05. 03	63	1	209	35,237	Daebo
15	05. 04	54~63	2	233	28,898	Daebo
Total				2,725	443,785	

* Japanese anchovy of 12kg was not counted.

days from Jukbyeon and 7 days from Daebo (Table 2). The sequence of nets cast was as follows: 5 panels of gillnets; 3 panels of gillnets with supporting lines; followed by 5 panels of trammel nets. The net was cast in the afternoon and hauled at dawn the next day or the day after that depending on sea conditions. Therefore, the soaking time was approximately 1 – 2 days. The lengths and weights of each species were measured to the nearest millimeter and gram, respectively.

Results

Species composition and catch

When the 2 sets of 13 panels, each including gill nets (5 panels), trammel nets (5 panels), and gillnets with supporting lines (3 panels), were used off Jukbyeon and Daebo ports on the eastern coast of Korea between July 2010 and May 2011, 15 replicates provided a total catch of 443.8 kg (Table 2). As shown in Table 3 the most dominant species caught was pointhead flounder (33.4%), followed by giant Pacific octopus (8.0%), roughscale sole (7.3%), Pacific cod (7.0%), sculpin (6.3%), brown sole (5.6%), cubed snailfish (4.5%), blackmouth angler (4.2%), Japanese anchovy (2.7%), black-

fin flounder (2.7%), and black edged sculpin (2.2%). Most individuals (93.0%) were of commercial value; only a small fraction (7.0%), including semiregular seastar, purple sea urchin, Ortmann's hermit crab, infant fish, and small and damaged individuals, was discarded.

Regarding the dominant species caught with the 3 types of nets as shown in Table 3, trammel nets caught more giant Pacific octopus, Pacific cod, blackfin flounder, blackmouth angler, sculpin, chum salmon, roughscale sole, brown sole, slime flounder, red halibut, and fat greenling than did the other nets. Gillnets caught more pointhead flounder, Japanese anchovy, Japanese flying squid, Okhotsk Atka mackerel, and Pacific herring. Lastly, gillnets with supporting lines caught more small cubed snailfish.

Total catch by net type and mesh size

The same mesh sizes were used for gillnets and trammel nets between July 22, 2010 and May 4, 2011. However, from Table 3 the catches by gillnets and trammel nets were 123.0 and 207.2 kg, respectively – the latter being 1.7 times the former. Interestingly, a trammel net caught a rather large giant

Table 3. Species composition and biomass caught with the 3 types of fishing nets (gillnets, trammel nets and gillnets with supporting lines) in the eastern coastal waters of Korea

Species		Catch (g)					Catch in number				
Scientific name	Common name	Gillnet ⁺	Tram-mel net ⁺	Gillnet-sl ⁺⁺	Total	Compo-sition (%)	Gillnet ⁺	Tram-mel net ⁺	Gillnet-sl ⁺⁺	Total	Compo-sition (%)
Pisces (Fish)											
<i>Cleisthenes pinetorum</i>	Pointhead flounder	53,966	38,942	55,390	148,298	33.42	488	350	602	1,440	52.84
<i>Clidoderma asperum</i>	Roughscale sole	1,126	26,219	5,014	32,359	7.29	5	71	17	93	3.41
<i>Pleuronectes herzensteini</i>	Brown sole	837	18,499	5,392	24,728	5.57	5	81	43	129	4.73
<i>Glyptocephalus stelleri</i>	Blackfin flounder	2,779	5,242	3,682	11,703	2.64	48	77	45	170	6.24
<i>Hippoglossoides dubius</i>	Red halibut	645	1,552	530	2,727	0.61	3	5	2	10	0.37
<i>Microstomus achne</i>	Slime flounder	534	1,607		2,141	0.48	1	4		5	0.18
<i>Eopsetta grigorjewi</i>	Shotted halibut	375	718	741	1,834	0.41	2	4	7	13	0.48
<i>Limanda schrenki</i>			203		203	0.05		1		1	0.04
<i>Tanakius kitaharai</i>	Willow flounder	58		83	141	0.03	1		2	3	0.11
<i>Pleuronectidae</i>		653	164		817	0.18	4	1		5	0.18
<i>Gadus macrocephalus</i>	Pacific cod	6,328	13,592	11,049	30,969	6.98	8	12	13	33	1.21
<i>Alcichthys elongatus</i>	Sculpin	10,193	13,536	4,204	27,933	6.29	61	94	33	188	6.90
<i>Liparis tessellatus</i>	Cubed snailfish	3,344	7,449	9,355	20,148	4.54	34	98	113	245	8.99
<i>Lophiomus setigerus</i>	Blackmouth angler	2,784	13,132	2,532	18,448	4.16	4	20	4	28	1.03
<i>Engraulis japonicus</i>	Japanese anchovy*	12,017		14	12,031	2.71	uncounted		1	uncounted	-
<i>Gymnocanthus herzensteini</i>	Black edged sculpin	1,428	5,594	2,609	9,631	2.17	9	42	20	71	2.61
<i>Hexagrammos otakii</i>	Fat greenling	2,047	2,871	1,562	6,480	1.46	6	7	4	17	0.62
<i>Oncorhynchus keta</i>	Chum salmon		5,500	870	6,370	1.44		1	1	2	0.07
<i>Pleurogrammus azonus</i>	Okhotsk atka mackerel	3,716	926	1,645	6,287	1.42	8	2	3	13	0.48
<i>Clupea pallasii</i>	Pacific herring	4,778	885	132	5,795	1.31	18	4	3	25	0.92
<i>Hemitripterus villosus</i>	Shaggy sea raven	456	2,110	1,490	4,056	0.91	2	9	7	18	0.66
<i>Thamnaconus modestus</i>	Black scraper		452	599	1,051	0.24		2	3	5	0.18
<i>Zoarces gillii</i>	Blotched eelpout	1,079			1,079	0.24	3			3	0.11
<i>Cookeolus japonicus</i>	Longfinned bullseye		910		910	0.21		1		1	0.04
<i>Hypodytes rubripinnis</i>	Racehorse		932		932	0.21		1		1	0.04
<i>Sebastes steindachneri</i>	Rockfish	636	129	157	922	0.21	4	1	1	6	0.22
<i>Takifugu xanthopterus</i>	Yellowfin puffer			940	940	0.21			2	2	0.07
<i>Scomber japonicus</i>	Chub mackerel	550	287		837	0.19	2	1		3	0.11
<i>Zenopsis nebulosa</i>	Mirror dory	808			808	0.18	2			2	0.07
<i>Pampus argenteus</i>	Silver pomfret	715			715	0.16	3			3	0.11
<i>Paralichthys olivaceus</i>	Bastard halibut		527		527	0.12		1		1	0.04
<i>Sebastes schlegeli</i>	Korean rockfish		526		526	0.12		2		2	0.07
<i>Takifugu chinensis</i>	Eyespot puffer		532		532	0.12		1		1	0.04
<i>Scombrops boops</i>	Gnomefish	434			434	0.10	1			1	0.04
<i>Sebastes taczanowskii</i>	White-edged rockfish	250		104	354	0.08	3		1	4	0.15
<i>Sebastes thompsoni</i>	Goldeye rockfish		354		354	0.08		2		2	0.07
<i>Zeus faber</i>	John dory	263			263	0.06	1			1	0.04
<i>Psenopsis anomala</i>	Butterfish	174			174	0.04	1			1	0.04
<i>Caelorinchus multispinosus</i>	Japanese grenadier	35	40	50	125	0.03	1	1	1	3	0.11
<i>Helicolenus hilgendorfi</i>	Rosefish	45	102		147	0.03	1	1		2	0.07
<i>Liparis tanakai</i>	Tanakas snailfish			115	115	0.03			1	1	0.04
<i>Sebastes owstoni</i>	Scorpion fish		131		131	0.03		1		1	0.04
<i>Arctoscopus japonicus</i>	Sailfin sandfish		110		110	0.02		2		2	0.07

Table 3. (continued)

Species		Catch (g)				Catch in number				
Scientific name	Common name	Gillnet [†]	Trammel net [†]	Gillnet _{sl} ^{††}	Total	Composition (%)	Gillnet [†]	Trammel net [†]	Gillnet _{sl} ^{††}	Total
Echinoderms										
<i>Stichopus japonicus</i>		348	583		931	0.21	2	8		10
<i>Anthocidaris crassispina</i>	Purple sea urchin		36	274	310	0.07		1	3	4
<i>Asterias amurensis</i> Lütken	North Pacific seastar	4,010	2,823	2,057	8,890	2.00	15	21	7	43
<i>Centonardoa semiregularis</i>	Semiregular seastar	29	115	248	392	0.09	1	1	1	3
<i>Stelloridea</i>	Spinulosa		38		38	0.01		1		1
Crustacea										
<i>Charybdis bimaculata</i>			353		353	0.08		4		4
<i>Paguristes ortmanni</i>	Ortmanns hermit crab	66	141	26	233	0.05	3	9	2	14
<i>unus trituberculatus</i>	Swimming blue crab			28	28	0.01			1	1
<i>Erimacrus isenbeckii</i>				16	16	0.00			1	1
<i>Other crab</i>			2		2	0.00		1		1
Mollusca										
<i>Paroctopus dofleini</i>	Giant Pacific octopus		35,000		35,000	7.89		1		1
<i>Octopus vulgaris</i>	Common octopus	338		167	505	0.11	1		1	2
<i>Todarodes pacificus</i>	Japanese flying squid	3,615	848	1,112	5,575	1.26	11	2	3	16
<i>Fusitriton galea</i>		407	1,158	54	2,019	0.45	4	12	5	21
<i>Neptunea cumingi</i>	Arthritic neptune	62	1,102	528	1,692	0.38	1	12	5	18
<i>Buccinum opisoplectum</i>		205	26	192	423	0.10	1	1	2	4
<i>Buccinum striatissimum</i>	Finely-striate buccinum		45		45	0.01		1		1
<i>Turbinidae</i>		327			327	0.07	3			3
<i>Halocynthia roretzi</i>	Korean common sea squirt	562	948	16	1,526	0.34	4	10	1	15
Other invertebrates			205	190	395	0.09		1	1	2
TOTAL		123,022	207,196	113,567	443,785	100	777	986	962	2,725

* Japanese anchovy of 12kg was not counted.

† : 5 panels of mesh size of 7.6cm, 9.1cm, 10.6cm, 12.1cm and 13.6cm were used.

††: Gillnet_sl indicates Gillnet with suping lines. 3 panels of mesh size of 9.1cm only with different line spacing were used.

Pacific octopus (35 kg); excluding this octopus, the ratio of catch by trammel nets to that by gillnets was about 1.4. The catches in number by trammel nets and gillnets were 986 and 777 individuals, respectively. As the main target species were flounder and sole, the total percentile catches of flounders by gillnets and trammel nets were 50.7%; therefore, the bycatch was 49.3% by weight.

Comparison of the catch by gillnets with that by trammel nets according to mesh size revealed that the catch by gillnets with the smallest mesh size (7.6 cm) was greater than that by trammel nets with the same mesh size. The catches by trammel nets with the mesh sizes from 9.1 – 13.6 cm were greater than those by gillnets (Fig. 3). With a mesh size of 9.1 cm, the total catches of the gillnet, trammel net, and gillnet with

Fig. 3. Comparison of the catch of gillnets and trammel nets by mesh size.

supporting lines were 19.7, 64.7, and 37.9 kg, respectively (Table 4). One giant Pacific octopus (35 kg) was caught with a trammel net of mesh size 9.1 cm. The total catch by the trammel net including the octopus was 3.3 times that of the gillnet; however, excluding the octopus lowers the ratio to only 1.5 times. In addition, the catch by the gillnet with supporting lines was 1.9 times greater than that by the gillnet. The catches of pointhead flounder, which was the main target, with the gillnet and trammel net were 54.0 and 39.0 kg, respectively (Table 5). Therefore, the catch efficiency of the trammel net for pointhead flounder was only 0.7 times that of the gillnet. It was generally believed that catch by trammel net was greater than that by gillnet. But this did not fit to the log-transformed catch of pointhead flounder in the present experiment. (Null hypothesis: There is no difference in catch by fishing gear). The p-value of 0.15 was from a mixed-effects

analysis that incorporated random effects of haul and year. The power analysis on the hypothesis of no difference between catch by gillnet and that by trammel net gave $p = 0.107$. Therefore, there is no difference between the two catches. Even if the null hypothesis by power analysis on the II type error was not correct, it was supposed to be taken that the catch by gill net was greater than that by trammel net. In the consequence, it meant lack on the knowledge that the catch of pointhead flounder by trammel net would be larger. Some patches of fish happened to appear when gillnets and gillnets with supporting lines were used on December 21 and October 15, 2010, respectively (Table 5).

Catch based on the line spacing of gillnets with supporting lines

As shown in Table 6, the mean catch per day by gillnets (mesh size 9.1 cm) having supporting lines with 46, 92, 184, and 276 cm spacing was 2.2, 2.9, 2.7, and 1.5 kg, respectively; Although the biggest catch was with a line spacing of 92 cm, the difference was not significant ($p = 0.57$). For the pointhead flounder, which was the main target of the experiment, the catches per day with 46, 92, 184, and 276 cm line spacing were 1.1, 1.2, 1.5, and 1.0 kg, respectively; although the best catch was obtained with a line spacing of 184 cm, the difference was not significant ($p = 0.58$). When the line spac-

Table 4. Comparison of the catches with gillnets, trammel nets and gillnets with supporting lines with a mesh size of 9.1 cm

	Gillnet	Trammel net	Gillnet with suping lines
Catch in total including one big octopus (kg) and catch ratio ( )	19.7 (1)	64.7 (3.3)	37.9 (1.9)
Catch in total except one big octopus (kg) and catch ratio ( )	19.7 (1)	29.7 (1.5)	37.9 (1.9)

Table 5. Daily catch of pointhead flounder with gillnets, trammel nets and gillnets with supporting lines between 2010 and 2011

Date	Gillnet (5 panels)	Trammel net (5 panels)	Gillnet with supporting lines (3 panels)	Total	(units: g)
					Experimental area
2010-07-22	2,678	1,713	2,689	7,080	Jukbyeon
2010-07-23	260	1,133	875	2,268	Jukbyeon
2010-08-31	368	1,014	3,020	4,402	Daebo
2010-09-01	824	216	793	1,833	Daebo
2010-10-14	10,108	4,218	11,048	25,374	Jukbyeon
2010-10-15	4,591	5,142	12,123	21,856	Jukbyeon
2010-11-18	2,719	2,622	4,422	9,763	Jukbyeon
2010-11-19	2,059	4,935	4,815	11,809	Jukbyeon
2010-12-21	21,226	2,793	2,858	26,877	Daebo
2011-03-10	1,594	3,091	1,837	6,522	Daebo
2011-03-11	1,675	6,100	3,313	11,088	Daebo
2011-03-31			148	148	Jukbyeon
2011-04-01	191		112	303	Jukbyeon
2011-05-03	2,590	3,532	3,001	9,123	Daebo
2011-05-04	3,083	2,433	4,336	9,852	Daebo
Total (g)	53,966	38,942	55,390	148,298	

Table 6. Catch per day by gillnets with supporting lines by line spacing
(unit: g)

	Line spacing (cm)			
	46	92	184	276
Catch per day	2,161	2,901	2,683	1,510
Pointhead flounder	1,050	1,198	1,462	982

ing is only 46 cm and the current is weak, the close spacing between lines relative to the net height might make it difficult for fish to approach the net, thus acting as a barrier.

Catch of flounders by net type and mesh size

The catch of the predominant flounder species such as pointhead flounder, roughscale sole, brown sole, blackfin flounder, and red halibut by gillnets and trammel nets are shown in Table 7. The catch of pointhead flounder by gillnets was 1.4 times that by trammel nets. Meanwhile, roughscale sole and brown sole were caught mostly by trammel nets. The trammel nets caught 1.9 times the blackfin flounder caught by gillnets. As shown in Fig. 4, the catches of point-head flounder using smaller mesh sizes (7.6 – 10.6 cm) were

Table 7. Comparison of catch and relative catch rate of dominant flatfish with gillnets, trammel nets, and gillnets with supporting lines
(unit: g)

	Pointhead flounder	Roughscale sole	Brown sole	Blackfin flounder
Gillnet	53,966 (1.4)	1,126 (1)	837 (1)	2,779 (1)
Trammel net	38,942 (1)	26,219 (23.3)	18,499 (22.1)	5,242 (1.9)

greater than those for roughscale sole, brown sole, and blackfin flounder. The roughscale sole and brown sole were caught more often with the relatively larger mesh sizes. Therefore, the type of fishing net should be chosen considering the target. The daily catch of pointhead flounder, which was a predominant species (except Japanese anchovy), is shown in Table 3 and 5. Although 4 of our 15 experiments showed that the use of trammel nets resulted in a bigger catch for the pointhead flounder compared to gillnets, the total catch was relatively small. In five experiments, the total catch using gillnets was greater than that using the trammel nets. This was particularly evident at Jukbyeon area in October 2010 and Daebos area in December 2010. These results indi-

Fig. 4. Comparison of the catches of pointhead flounder, roughscale sole, brown sole and blackfin flounder by gillnets and trammel nets according to mesh size.

Table 8. The number of species caught with the 3 types of fishing nets

	Gillnet	Trammel net	Gillnet with suping lines
Number of species	41	48	37

cate that pointhead flounder other than roughscale sole, brown sole or blackfin flounder was more likely to be caught by gillnets, although there might have been a patch of schools in the experiment. The catch of roughscale sole and brown sole by gillnets was very small; however, the catches of these fishes by trammel nets and gillnets with supporting lines were larger. Therefore, gillnets caught pointhead flounder, which was the main target, most effectively even though the total catch, including other species, by trammel nets was greater.

With increasing mesh size of trammel nets a significantly higher number of larger roughscale sole and brown sole were caught ($p < 0.00001$), whereas larger mesh sizes were less effective in catching the pointhead flounder, and ineffective in catching the blackfin flounder. Gillnets seem to be advantageous for catching numerous fish of similar size, such as sand fish and Pacific sand eel, whereas trammel nets are advantageous for catching various sizes of fish (Jeong et al., 2009). The number of fish species caught using trammel net is shown in Table 8. Trammel nets cannot catch all fish species and selecting a larger inner mesh size allows juvenile fish to escape through the net (Cho et al., 2000; Kim and Lee, 2002; Park et al., 2011).

Dominant species and length distribution

Fig. 5 shows the length frequency distribution of the predominant species such as pointhead flounder, roughscale sole, brown sole, and blackfin flounder. The mean lengths (standard deviation) of blackfin flounder, pointhead flounder, brown sole, and roughscale sole were 21.0 (4.57), 22.9 (3.40), 24.7 (4.90), and 28.3 (5.43) cm in ascending order, respectively; there were significant differences in mean length ($p < 0.00001$). The total length of the pointhead flounder ranged from 12.5 to 35.1 cm (mean, 22.9 cm; SD 3.4 cm). The dominant species caught using three kinds of fishing gears according to weight by study site are shown in Fig. 6. The pointhead flounder was the dominant species at both

Fig. 5. Length frequency distribution of pointhead flounder, roughscale sole, brown sole and blackfin flounder. The mean lengths (standard deviation) of blackfin flounder, pointhead flounder, brown sole, and roughscale sole were 21.0 (4.57), 22.9 (3.40), 24.7 (4.90), and 28.3 (5.43) cm in ascending order, respectively.

Fig. 6. Dominant species in Jukbyeon and Daebo fishing grounds. The figure: %.

Jukbyeon and Daebo sites. Special catches included a large giant Pacific octopus, which was the second species by weight in Jukbyeon area, followed by Pacific cod, brown sole, cubed snailfish, roughscale sole, and blackmouth angler. At Daebo, the second largest catch was sculpin followed by roughscale sole, Japanese anchovy, blackfin flounder, blackmouth angler, Japanese flying squid and others in descending order. Although the main target fish catch by weight was similar, the bycatch differed in both areas.

Remarks

Trammel nets are preferred for use over rough seabed since gillnets are more susceptible to tearing. In addition, trammel nets are superior in keeping fish alive. In general, trammel nets are actively used on rough seabed in Korea, while gillnets are primarily used on smoother seabed and for catching various species with similar sizes near the surface or seabed. As the experiment was conducted to determine the catches of 3 types of fishing nets, the main finding was that the total catch using trammel nets was higher than that using gillnets, as expected. However, more of the main target fish, pointhead flounder, was caught by gillnets than by trammel nets. This result was unexpected considering the results of other similar experiments that investigated fishing equipment for catching flounder. One reason for this result may depend on the shape of the pointhead flounder, which has an outward-projecting mouth compared to the flatfish. Therefore, this might allow them to move forward or backward rather easily if they notice the net before being caught in it.

Fishermen at Ulsan have previously reported that trammel nets ineffective in catching pointhead flounder. However, they said that more roughscale sole, brown sole, and blackfin flounder were caught by trammel nets than by gillnets. Therefore, different types of flatfish should be caught using various fishing nets. The catches by gillnets with supporting lines 46, 92, and 184 cm apart at Jukbyeon and Daebo port in 2010 and with supporting lines 92, 184, and 276 cm apart at Daebo only in 2011 were not significantly different ($p = 0.57$), although the total catch was the greatest with a spacing of 92 cm, and the catch of pointhead flounder was most efficient with a spacing of 184 cm. If the spacing between lines is very close, it might prevent fish from approaching the net, especially when the current is weak. The total catch by gillnets with supporting lines was greater than that by gillnets but less than that by trammel nets. However, as the catch by gillnets with supporting lines was only done with a mesh size of 9.1 cm, the catch might differ with other mesh sizes with respect to fish size. In addition to gillnets, trammel nets also exhibit mesh selectivity with respect to fish size. Furthermore, the larger inner mesh sizes allow small fish to escape

through the net. Fishermen in Eastern Korea use trammel nets because some flatfish such as roughscale sole and brown sole are rarely caught by gillnets. Moreover, trammel nets keep fish alive better, increasing the profit of the fishermen. Trammel nets yield greater total catches than gillnets; however, it is less selective and therefore not as conservative as gillnets. Constructing gillnets with supporting lines is labor intensive and expensive. One advantage of using supporting lines is that it prevents breakage by strengthening the material especially when utilized on the rough bottom. Therefore, the benefits and drawbacks of different types of nets should be considered while simultaneously considering both the conservation of fishery resources and economics.

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References

Bae BS, An HC, Park HH, Park CD and Yang YS. 2010. Catch characteristic and present condition of by-catch & discard of trammel nets fishery in the East Sea. J Kor Soc Fish Tech 46, 103-114. (DOI:10.3796/KSFT.2010.46.2.103)

Cho YB, Park CD and Lee JH. 2000. A study on the selectivity of the mesh size in trammel net for Cynoglossidae. Bull. Korean Soc Fish Tech 36, 89–95.

Jeong EC, Park HH, Bae BS, Chang DS, Kim CS, Choi SH and Cha

HK. 2009. Size Selectivity of Gill Net for Male Japanese Sandfish (*Arctoscopus japonicus*) off Gangwon in winter. J Kor Fish Soc 42, 78–82.

Kim SH and Lee JH. 2002. Mesh selectivity in trammel net for flat fish. Bull Kor Soc Fish Technol 38, 91–100.

Lee SI, Hwang SJ, Yang JH and Shim JM. 2008. Seasonal variation in Species Composition of Gill Net and Trammel Net Catches in the Coastal Waters off Wangdol-cho, Korea. Kor J Chthology 20, 291–302.

NFRDI (National Fisheries Research & Development Institute). 2007. The report for examination of regulation of catch prohibition by fisheries resources. Busan, Korea, 1–327.

Park HH, Jeong EC, Bae BS, Yang YS, Hwang SJ, Park JH, Kim YS, Lee SI and Choi SH. 2007. Fishing investigation and species composition of the catches caught by a bottom trawl in the deep East Sea. J Kor Soc Fish Tech 43, 183–191.

Park HH, Millar RB, Bae BC, An HC, Chun YY, Yang JH and Yoon SC. 2011. Selectivity of Korean flounder (*Glyptocephalus stelleri*) by gillnets and trammel nets using an extension of SELECT for experiments with differing mesh sizes. Fish Res 107, 196–200.

Wanner GA, Klumb RA, Shuman DA, Steffensen K and Stukel S. 2010. Comparison of green and white mesh trammel nets and gill nets to assess the fish community was done in a large river. North Am J Fish Management 30, 12–25.

Yoon SC, Cha HK, Lee SI, Chang DS, Hwang SJ and Yang JH. 2008. Variations in species composition of demersal organisms caught by trawl survey in the East Sea. J Kor Soc Fish Tech 44, 323–344.

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