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Republic of Korea

국립수산과학원
National Institute of Fisheries Science

KOREA ANNUAL REPORT ON FISHING, RESEARCH ACTIVITIES, AND OBSERVER IMPLEMENTAION IN THE SPRFMO CONVENTION AREA IN 2019

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National Institute of Fisheries Science NIFS

CONTENTS

1. Description of Fisheries

1.1 Trawl

Korea has been conducting trawl fishing targeting on *Trachurus murphyi* (jack mackerel) since 2003 when Korean research trawl vessel *Tamgu No.1* operated pristinely in the SPRFMO Convention Area. The number of active Korean trawl vessels has been changed from 1 to 3 in last 15 years (Table 1). In the present year, Korea conducted no trawl fishing in the Convention Area.

Table 1. Summary of the number and size of Korean trawler in the Convention Area.

Year	Number of vessels	Gross registered Tonnage (GT)			
		2,000-2,999	3,000-3,999	4,000-4,999	5000<
2004	3	1	1	1	-
2005	2	1	1	-	-
2006-2008	3	1	1	1	-
2009	2	-	1	1	-
2010-2012	2	-	1	-	1
2013-2014	1	-	1	-	-
2015-2016	2	-	1	-	1
2017	1	-	1	-	-
2018-2019	2	-	1	-	1
2020	0	-	-	-	-

1.2 Jigging

Korea jigging fishery targeting on jumbo flying squid (*Dosidicus gigas*) has been commercially operating in the Convention Area since 1990. The number of jigging vessels fluctuated in a range of 0-50 in the last 30 years (Figure 1). In the 1990s, the numbers of vessels peaked at 50 vessels in 1995 and decreased rapidly since then. Only the number of vessels remained smallest in the 2000s, and increased up to more than 15 in the recent two years.

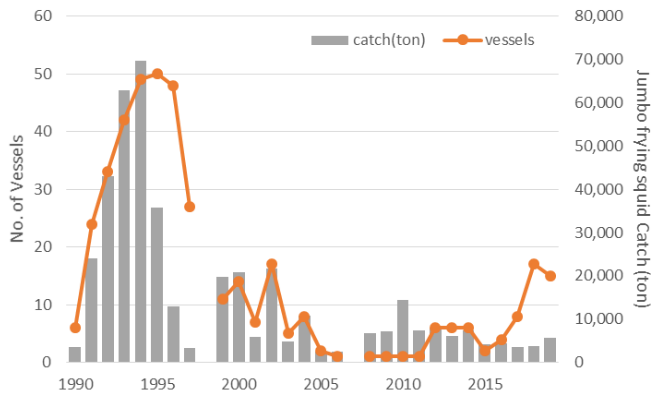

Figure 1. Trends in effort (the number of jigging vessels fishing) and total catch of *Dosidicus gigas* in the Convention Area from 1990.

2. Catch, Effort and CPUE Summaries

2.1 Pelagic trawl Fishery

The annual trawl fishing effort and catch by Korean vessels targeting on mainly jack mackerel (*Trachurus murphyi*) in the SPRFMO Convention Area is summarized in Table 2. The number of fishing days fluctuated between the range of 40-249, depending on the change of the number of vessels between 1 to 3 in last 16 years.

Jack mackerel (*T. murphyi*) is the main target species, and has made up more than 85% of the total catch with tonnages ranging from 1,235 to 13,759 tons. Chub mackerel (*Scomber japonicus*) is the second most dominant species in the catch which ranged from 21 to 1,460 tons. Other species that have been significant in the catch include blue fathead (*Cubiceps caeruleus*), Pacific pomfret (*Brama japonica*), and jumbo flying squid (*Dosidicus gigas*), and these species catches were included within "Other species" catch in Table 2.

The CPUE trend of jack mackerel is relatively stable in the range of 4 to 6 (ton/hour) except for 2009 when the highest CPUE (10.5 ton/hour) was reported (Figure 2). The total catch in 2019 increased substantially, and the catch of jack mackerel increased by more than twofold of the last year. However, the CPUE didn't increase as much as the catch.

Table 2. Annual fishing effort (number of vessels and tow) and fisher-reported catch (tonnes) of two main fishing species and others by weight (CJM: jack mackerel, MAS: chub mackerel) by Korean trawlers in the SPRFMO Convention Area from 2004.

Year	No. Vessels	*No. Fishing days	No. Tows	Total tow hours	CJM (ton)	MAS (ton)	Other species (ton)	Total catch (ton)
2004	3	205			7,438	708	-	8,146
2005	2	170			9,126	381	-	9,507
2006	3	232			10,474	1,460	-	11,934
2007	3	237			10,940	1,240	-	12,180
2008	3	249			12,600	968	-	13,568
2009	2	182			13,759	716	59	14,534
2010	2	136			8,183	84	-	8,267
2011	2	205			9,253	24	100	9,377
2012	2	117			5,492	-	-	5,492
2013	1	140		975	5,267	111	-	5,378
2014	1	86		652	4,078	21	-	4,099
2015	2	104		900	5,749	82	3	5,834
2016	2	182		1,581	6,430	486	16	6,931
2017	1	40		225	1,235	191	3	1,429
2018	2	138	209	882	3,717	246	86	4,049
2019	2	111	249	1,427	7,444	82	96	7,622

* No. of fishing days: only days of fishing activity occurred.

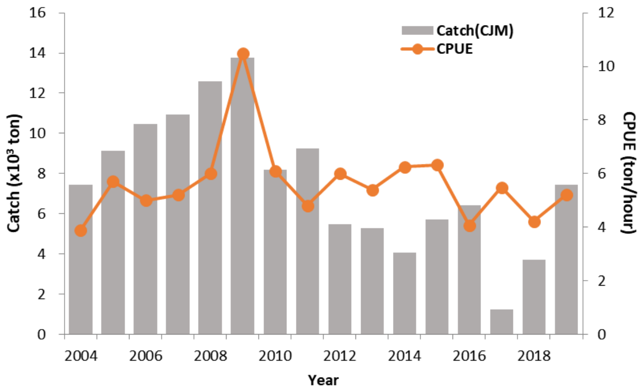

Figure 2. Annual catch and CPUE (ton/hour) of Jack mackerel.

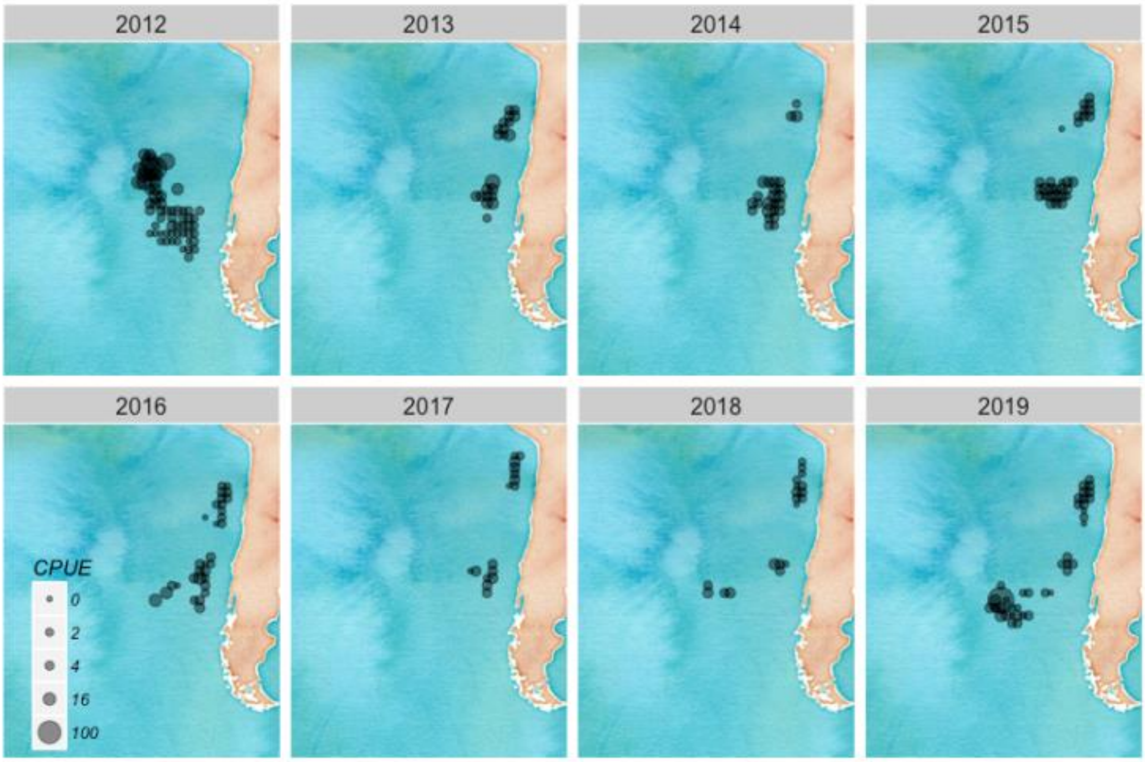

Figure 3. Distribution of CPUE (ton/hour) of *T. murphyi* in the SPRFMO Convention Area during 2012-2019

2.2 Bottom trawl Fishery

Korean bottom trawl fishery, mainly targeting on orange roughy (*Hoplostethus atlanticus*), stop fishing in the SPRFMO Convention Area since 2008 (Refer to SC6-Doc27).

2.3 Jigging Fishery

The annual fishing efforts (fishing days) and catches by Korean jigging vessels are summarized in Table 3. The fishery mainly targets on jumbo flying squid (*Dosidicus gigas*). The annual fishing effort and catch varied over time. The highest catch on jumbo flying squid was over 69 thousand tons in 1994, and the largest number of jigging vessels operated in 1995. The catch trend shows a continuous decrease since the highest catch was observed (Figure 1). The CPUE ranged from 3.6 to 28.2 ton/day in the recent 8 years. The lowest CPUE appeared in 2018 and the CPUE in 2019 increased slightly. The CPUE stayed low level since 1995 (Figure 4).

Table 3. Annual catch of Korean jigging fisheries in the SPRFMO Convention Area.

Year	No. Vessels	No. Fishing days	Avg. fishing days/vessel	Total catch (ton)
1990	6	?		3,465
1991	24	?		24,015
1992	33	?		43,022
1993	42	?		62,887
1994	49	?		69,664
1995	50	?		35,719
1996	48	?		12,896
1997	27	?		3,359
1998	-	-		-
1999	11	?		19,728
2000	14	?		20,822
2001	7	?		5,797
2002	17	?		21,759
2003	5	?		4,722
2004	8	?		10,787
2005	2	?		2,519
2006	1	?		2,485
2007	-	-		-
2008	1	?		6,775
2009	1	?		7,221
2010	1	?		14,506
2011	1	?		7,410
2012	6	580	97	7,991
2013	6	365	61	6,034
2014	6	397	66	7,261
2015	2	151	76	4,263
2016	4	409	102	4,388
2017	8	456	57	3,460
2018	17	1,003	59	3,651
2019	15	1,037	69	5,577

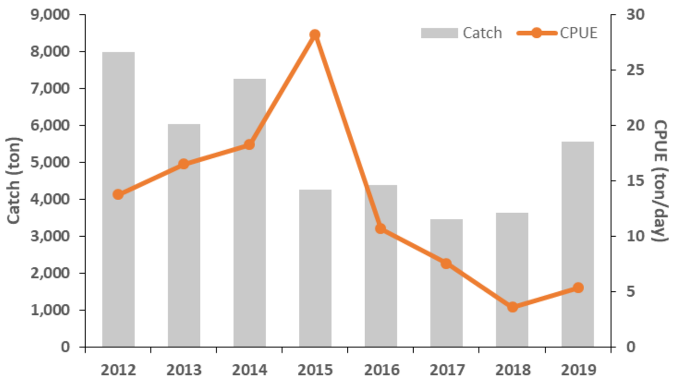

Figure 4. Annual catch and CPUE (catch/day) of jumbo flying squid

3. Fisheries Data Collection and Research Activities

3.1 Fisheries catch & effort data collection system

The data collection system implemented for Korean high seas fishing vessels has been changed since 2015.

Before 2015, the system was operated in a dualized manner: total catches of high seas fishing vessels were collected by Korea Overseas Fisheries Association (KOFA) while fishing logbook was collected and managed by National Institute of Fisheries Science (NIFS). Since September 2015, detailed tow-by-tow catch and effort data of all high seas fishing vessels is being reported through Electronic Reporting System (ERS) to Korea Fishery Monitoring Center (KFMC). The catch and effort data is submitted to the SPRFMO Secretariat in accordance with the data standards of SPRFMO.

3.2 Research Activities

Korea has worked on three research projects on jumbo flying squid caught in the Convention Area: 1) diet composition, 2) gene structure analysis, and 3) mercury concentration. The biological samples were collected by scientific observer dispatched on board Korean jigging vessels in 2018. A brief summary of each project is provided below.

3.2.1 Diet composition of jumbo flying squid and pry gene structure analysis

The *D. gigas* samples used in this study were collected from October to December 2018 to determine the trophic ecology of *D. gigas* in the Convention Area of SPRFMO. In total, 92 *D. gigas* specimens ranging between 21.1 and 92.0 cm in mantle length were collected during the study period. Mollusks were the most common prey item for *D. gigas*, comprising 90.6% based on the ranking index. Among the three mollusks taxon consumed by *D. gigas*, cephalopods were the dominant taxon. Its diet also included small quantities of fishes, crustaceans, seaweeds, and vinyl. In this study, cephalopods were the dominant prey item in medium (50-80 cm, n=33) and large (>80 cm, n=28) size classes. Also, fishes were the dominant prey item in small size class (<50 cm, n=22). The proportion of cephalopods increased as body size of *D. gigas* increased, whereas the consumption of fishes decreased with greater size. The graphical method for feeding strategy revealed that *D. gigas* is a specialized predator on cephalopods and showed narrow niche width.

A total of 59 individuals of *D. gigas* were used for metabarcoding analysis. Based on the mantle length, squids were further divided into three groups: small (12 specimens smaller than 50 cm), medium (22 between 50 and 80 cm), and large (25 larger than 80 cm), respectively. After bioinformatic analysis of raw reads generated by MiSeq sequencer, a total of 29 representative haplotypes were obtained, which were composed of 3 phyla, 3 classes, 6 orders, 8 families, 13 genera. *D. gigas* occupied most of the reads, indicating its cannivalism as its feeding strategy. Besides own species, other cephalopods such as *Ommastrephes bartramii* and *Argonauta sp.* were identified as prey items. In the class Actinopterygii, there were two main groups of large fish, including 4 families (Serrivomeridae, Nomeidae, Scombridae, Bramidae) and lantern fish belonging to the family Myctophidae. Due to the lack of the reference sequences in the family Myctophidae, we were unable to identify several lantern fish species. qPCR results showed that proportions of cephalopods increase, while those of lantern fish species decreased.

3.2.2 Gene structure analysis (preliminary results)

A total of 45 *D. gigas* samples collected from October to December 2018 in the SPRFMO Convention Area were analyzed to invest genetic diversities. The samples grouped into 5 arbitrary locations: A (n=23, 15˚S 85˚W), B (n=1, 20˚S 85˚W), C (n= 15, 20˚S 80˚W), D (n= 6, 25˚S 75˚W) and unknown location (n=1). 46 samples were analyzed using mtDNA cytochrome c oxidase subunit I (COI), and a total of 15 haplotypes were identified from a 579 bp fragment of mtDNA analyzed. The numbers of identified haplotypes in each group are: 9 in group A, 6 in C, and 5 in D (Figure 5). The values for haplotype diversity (Hd) and nucleotide diversity (Pi) were 0.7546±0.062 and 0.002±0.001. Among the groups, D showed the highest values of both haplotype diversity and nucleotide diversity (Hd: 0.933±0.122, Pi: 0.003±0.002). The pairwise fixation index (F_{st}) of each group was in the range of -0.008 to 0.212 which was not statistically significant.

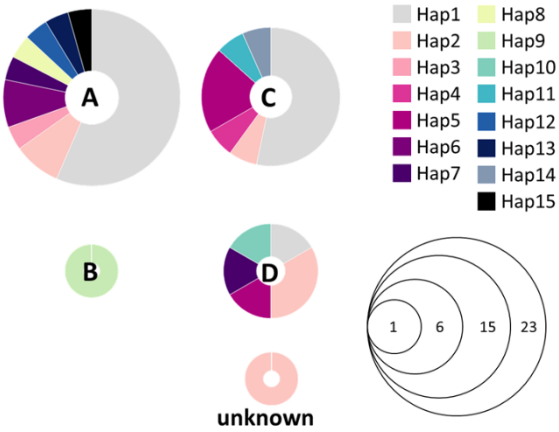

Figure 5. Haplotype distribution for the population of D. gigas

The analysis of haplotype network showed that the 15 haplotypes are connected by 1-2 nucleotide variations. Hap1 was the most common haplotype among the samples, and it appeared in 13 samples from A, 8 samples from B, and 1 sample from D. Other haplotypes are divided from Hap1 by a star-like topology in the haplotype network (Figure 6)

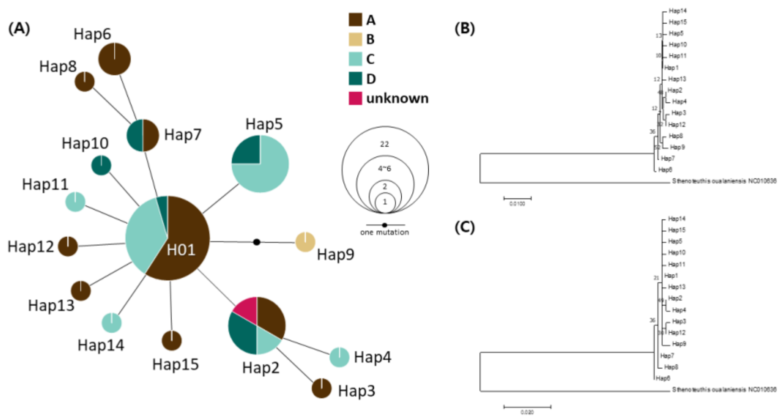

Figure 6. Haplotype network (A) and phylogenetic trees (B), (C) for 15 haplotypes of *D. gigas* based on COI region. (A) Each circle represents a haplotype and the area is proportional to the number of individuals. Each line represents one mutation step and black dot indicates the absence of haplotype in this study. Different colors denote each population; (B), (C) Numbers at the branches are the bootstrap support value for Neighbor-Joining (NJ) and Maximum Likelihood method, respectively.

The Tajima's D and Fu's Fu test showed statistically significant negative values (Table 4) which indicate recent demographic expansion of *D. gigas* (Sanchez, Tomano et al. 2016). A unimodal distribution of the samples (Figure 7) can be interpreted as that the sampled *D. gigas* are experiencing population bottleneck or demographic expansion. These results are in line with the previous studies that *D. gigas* are in population expansion and showing low genetic diversities (Sandoval-Castellanos, Uribe-Alcocer et al. 2009, Sandoval-Castellanos, Uribe-Alcocer et al. 2010, Ibáñez, Cubillos et al. 2011, Sanchez, Tomano eta al. 2016).

Table 4. Demographic parameters estimated for *D. gigas*

Population	Tajima's D	Fu's Fs
A	-1.277	**-5.547**
C	-1.201	**-2.841**

D	-0.676	**-2.711**
Mean	**-1.794**	**-12.186**

Significant values (P < 0.05) are indicated in bold.

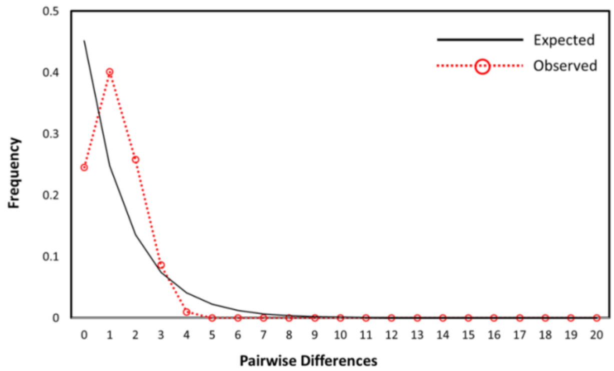

Figure 7. Mismatch distribution of the total *D. gigas* haplotypes

3.2.3 Tissue-specific mercury concentration on jumbo flying squid

An analysis was conducted to determine mercury concentrations in different organs of the jumbo flying squid (*D. gigas*) collected in the SPRFMO Convention Area. The order of mercury concentrations in different tissues was liver > fin, mantle, mouth > arms, tentacle > gill > ink sac (P<0.05). The results suggest that the mercury in liver (0.094 ± 0.035 mg/kg) is more considerable than the mercury concentrations in other tissues (below 0.065 mg/kg). Multivariate analysis revealed that the muscle tissues and organ tissues of the adult *D. gigas* group have high levels of mercury. All tissues had mercury levels below the limit specified by international guidelines (e.g. EC No. 1881/2006, 0.5 mg/kg). These results suggested that consumption of edible tissues (i.e. muscle tissues) of *D. gigas* present no health risk to humans.

The final papers of each project are planning to be submitted in the future SCs.

4. Observer Implementation Report

4.1 Observer program design and training

Korean scientific observer program for distant-water fisheries had in place since 2002. National Institute of Fisheries Science (NIFS) was responsible for implementing and developing the observer program, but the management of scientific observer program is transferred from NIFS to Korea Fisheries Resources Agency (FIRA) since Jun 2019.

The process to recruit observers is as follow. Candidates are selected by reviewing their applications and CVs based on the qualification criteria: a person who is a college graduate whose major field is nature science; or else, a high school specialized fisheries graduate who accompanies at least 1-year experience on board with having a certificate of qualification to deck officer. The candidates who pass the review process are subject to an in-person interview. In the interview, the candidates are asked their basic knowledge on fisheries, English speaking skill, availability to be on board, etc. The candidates who passed in-person interview can attend the training course. An outline of the observer training course is as follow.

• An overview of the observer program

• Introduction of distant-water fisheries

• Gear-specific observer duties (trawl, squid jigging, purse seine, longline, stick-held dip net, pot)

• Identification and measurement for target species

• Observation of sharks/whales/seabirds

• Observation of Vulnerable Marine Ecosystems (VMEs)

• Hand-on computer program (Excel) training

• Marine species identification

• Introduction of Regional Fisheries Management Organizations (RFMOs)

• Systematic management of fishing information

• Catch product processing

• Marine meteorology

• At-sea safety training

• Maritime English

• Everyday English

• Organizational structure and culture of a ship

• Fish dissection LAB

The trainees who pass the final test can be deployed to the vessels. FIRA provides biannual training for all selected observers. The training includes updated RFMOs' CMMs, safety trainings, and other subjects with scientific issues. Also, FIRA offers approximately $300/year to all observers who want to take courses to develope English skills, computer skills, and physical training.

NIFS trains observers before dispatching them to each RFMO area. The training includes the Conservation and Management Measure (CMM) of each RFMO, collecting the data and samples by specific tasks to be done.

4.2 Observer coverage and data collection

Korean observers collect a wide range of data from both target and bycatch species to inform scientific analyses. The lists of data collected by observers are based on SPRFMO CMM 02-2020 Annex 7.

The observer coverage of Korean vessels is summarized in Table 5. In 2008, two trawlers operated in the Convention Area, and one observer was deployed on two vessels for 9 days. No observer was dispatched in 2009-10. One observer was aboard in one trawler in 2011 and 2012, and the coverages were 6.8% and 58.1% respectively. The observer coverage for trawl fishing is 100% since 2013. The first scientific observers dispatching on commercial jigging vessels was in 2015. Since 2018, two observers embarked and collected scientific information on jigging vessels, and the coverage were 17-18% of the total fishing days.

Table 5. Scientific observer coverage on Korean vessels.

Year	Gear types	Vessel name	Observer onboard days	Coverage rate of the vessel (total coverage of the fishing method)
2008	Trawl	*Insungho*	3	4%
	Trawl	*Kwangjaho*	6	
2011	Trawl	*Kwangjaho*	14	6.8%
2012	Trawl	*Kwangjaho*	68	58.1%

2013	Trawl	*Kwangjaho*	140	100% (100%)
2014	Trawl	*Kwangjaho*	86	100% (100%)
2015	Trawl	*Kwangjaho*	120	100% (100%)
	Trawl	*Sejong*	10	100% (100%)
	Jigging	*No.705 Amor*	75	100% (50%)
2016	Trawl	*Kwangjaho*	179	100% (100%)
	Trawl	*Sejong*	28	100% (100%)
2017	Trawl	*Kwangjaho*	88	100% (100%)
2018	Trawl	*Kwangjaho*	134	100% (100%)
	Trawl	*Sejong*	37	100% (100%)
	Jigging	*No.703 Amor*	93	100% (17%)
	Jigging	*No.101 Agnes*	82	100% (17%)
2019	Trawl	*Kwangjaho*	194	100% (100%)
	Trawl	*Sejong*	17	100% (100%)
	Jigging	*No.705 Amor*	88	84% (18%)
	Jigging	*No.316Sunhae*	99	86% (18%)

4.3 Biological sampling and length composition of catches

The biological information of trawl target species, *T. murphyi*, are continuously collected by scientific observers. Yearly length frequencies and length-weight relationship of *T. murphyi* is shown in Figure 8 and 9. The ranges of annual sampling size are from 1,108 to 9,789 for the length measurement, and from 231 to 5920 for the length and weight measurement. A comparison among the range of the annual fork length measurements taken from 2012 to 2019 suggests that a trend having a single mode in the earlier part of the sampling year has been changed to have multiple modes in the later sampling period. In 2019, the strongest mode appeared around 23cm.

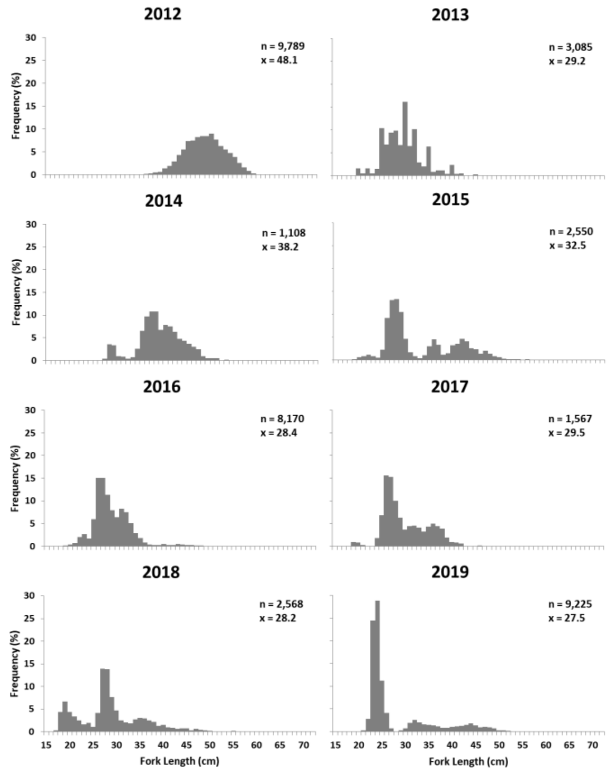

Figure 8. Length frequency distributions for *T. murphyi* from 2012 to 2019 collected by scientific observers aboard Korean trawl vessels fishing in the SPRFMO Convention Area.

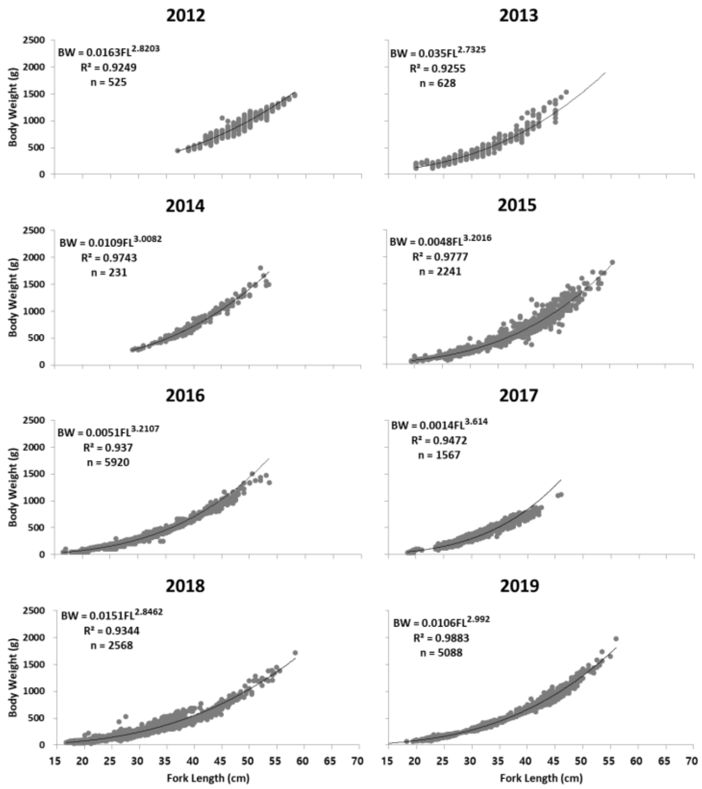

Figure 9. Length-weight relationships of *T. murphyi* from 2012 to 2019 collected by scientific observers aboard Korean trawl vessels fishing in the SPRFMO Convention Area.

5. Ecosystem Approach considerations

5.1 Seabird mitigation measures

Korean trawl vessels fishing in the SPRFMO Convention Area are required to comply with seabird mitigation methods specified in CMM09-2017. The requirements include deployment of streamer (tori) lines or bird bafflers where it is not operationally feasible to use streamer lines, and management of discharge of biological material. Trawl vessels are prohibited to discharge biological material during shooting and hauling. According to the observers deployed on board, all Korean trawl vessels complied with the CMM09-2017 for the seabird mitigation measure in 2019. Both vessels used bird bafflers whose boom lengths were longer than 4m and the distance between the dropper lines were less than 2m. The P.E and rubber materials were attached to the end of dropper lines and the distance between the materials and the surface was less than 0.5m.

5.2 Observed interactions with other species of concern

All scientific observers executed daily observation of seabirds at least once every set or haul for more than 15 minutes. Observers were instructed to observe whether the seabirds were dipping their beak or head into the water near the net to feed on during fishing. The quantitative information on seabird observation was submitted by observers. Total of 24 species of seabirds were observed on trawl vessels in the last 7 years, and 8 species were observed on jigging vessels in the last 2 years (Table 6). There were no injured, struck or dead seabirds observed or reported in the last 7 years. In 2019, the most abundant four species by trawl fishing were southern black browed albatross (DIM, 21%), white-chinned petrel (PRO, 19%), prions nei (PWX, 17%), and cape petrel (DAC, 12%).

Table 6. A list of observed seabirds in the SPRFMO Convention Area by trawl and jigging vessels.

Observed fishing vessel	FAO species code	Scientific name	English name
Trawl	CSK	*Catharacta skua*	Great skua
Trawl, Jigging	DAC	*Daption capense*	Cape petrel
Jigging	DAQ	*Phoebastria albatrus*	Short-tailed Albatross
Trawl	DCR	*Thalassarche chlororhynchos*	Yellow-nosed Albatross
Trawl	DIB	*Thalassarche bulleri*	Buller's albatross
Trawl	DIC	*Thalassarche chrysostoma*	Grey-headed albatross
Trawl, Jigging	DIM	*Thalassarche melanophrys*	Black-browed albatross
Trawl	DIU	*Thalassarche cauta*	Shy albatross
Trawl, Jigging	DIX	*Diomedea exulans*	Wandering albatross
Trawl	DMP	*Diomedea melanophris*	Black browed albatross
Trawl	DSL	*Thalassarche salvini*	Salvin's albatross
Trawl	DSQ	*Sula dactylatra*	Masked Booby
Trawl, Jigging	FGZ	*Fregetta spp*	Storm petrels nei
Trawl	FUG	*Fulmarus glacialoides*	Southern fulmar
Trawl	MAH	*Macronectes halli*	Hall's giant petrel
Trawl	MAI	*Macronectes giganteus*	Southern giant petrel
Trawl	OCO	*Oceanites oceanicus*	Wilson's storm petrel
Trawl	PCI	*Procellaria cinerea*	Grey petrel
Trawl	PFG	*Puffinus griseus*	Sooty shearwater
Trawl	PHE	*Phoebetria palpebrata*	Light-mantled albatross
Trawl	PHE	*Phoebetria palpebrata*	Light-mantled Sooty Albatross
Trawl, Jigging	PRO	*Procellaria aequinoctialis*	White-chinned petrel
Jigging	PRX	Procellariidae	Petrels nei
Trawl	PWX	*Pachyptila spp*	Prions nei
Jigging	SZV	*Sula variegata*	Peruvian booby
Trawl	-	*Phaethon spp*	Tropicbird
Trawl	-	*Pteroderma externa*	Juan Fernandez petrel

Korea has reported 17 events of species of concern catches by trawl fisheries from 2015 to 2017; all reported species were porbeagle sharks (*Lamna nasus*) (SC6-Doc09). Over 3 discontinuous years (2015, 2018-2019), two shark species captures have been observed on Korean jigging vessels: six blue sharks (*Prionace glauca*) and one porbeagle shark (*Lamna nasus*) (Table 7). To encourage reporting on incidental captures of species of concern and non-target species (CMM02-2020) by commercial jigging fishing vessels, a bycatch species identification poster will be developed based on the previous catch of species of concern, and the poster will be distributed before the next fishing season.

Table 7. Summary of species of concern from the Korean jigging vessels

Year	Species	Amount caught	Datasets
Dec 2015	Blue shark	1 evnet (150cm/17kg)	Observer report
Nov 2018	Porbeagle shark	1 event (no info)	Observer report
Nov 2018	Blue shark	1 event (234cm/55.9kg)	Observer report
Dec 2018	Blue shark	1 event (222.2cm/45.7kg)	Observer report

July 2019	Blue shark	1 event (210cm/28.5kg)	Observer report
December 2019	Blue shark	2 event (191.5cm/22kg) (188cm/20kg)	Observer report

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