East China Sea and Yellow Sea Japanese Flying Squid (*Todarodes pacificus*) Fishery Improvement Project (FIP) Year 1 Report (September 2019 – January 2020)

Contents

1. Introduction

1.1 Current project purpose

The project described herein was conducted in support of implementing the East China and Yellow Seas JFS FIP during 2019, with the specific intent to:

(1) collect basic catch and biological information from the fishery to understand its current characteristics, proportional catch by species landed and an estimate of total Chinese JFS landings; and

(2) describe/review current approaches (if any) used by relevant authorities for estimating Chinese harvest of JFS and associated vessel effort (vessel fishing days) in the Yellow Sea, and identify any limitations of current efforts in providing accurate catch and effort data.

Some challenges were encountered in monitoring and collecting information from the fishery as originally planned, which are further described below.

1.2 Fishery and management in China Sea: context for 2020 monitoring

Japanese flying squid (JFS, *Todarodes pacificus*) is a typical temperate oceanic cephalopod, mainly composed of autumn and winter populations (Fang and Chen, 2018). The species has a broad geographic distribution within the Northern and Western Pacific Ocean. JFS is native to waters off Japan, mainland China, Taiwan, South Korea, North Korea, and Russia, and inhabits in both the open-ocean and coastal regions. At present, JFS is mainly distributed in the Japan Sea, the Pacific coast of Japan, and the East China Sea, and Yellow Sea of China. JFS is one of the important cephalopod fishery resources in Japan and South Korea (Dong, 1996).

The background of China's JFS resources and fisheries have previously been reviewed in the preassessment for the current fishery improvement project (Ocean Outcomes, 2016). We additionally provide a background of such key background information in Appendix to provide important context for these 2020 investigations.

The JFS resources in the Japan Sea and the Pacific coast have increased year by year and have become one of the potentially important species not only for Japan but also for China (Fang and Chen, 2018). JFS resources in the East China Sea are rich according to the investigation of related inshore fisheries. JFS has gradually replaced the traditional species of *Sepila maindroni*, which correspondingly has been an important commercial cephalopod in the East China Sea (Li and Yan, 2004). At the same time, the autumn and winter stocks support large-scale fisheries, while the summer spawning stock supports only small-scale fisheries. Fishery catches in autumn and winter are dominated by mature squid, whereas spring and summer catches are dominated by juvenile squid (Yang *et al.*, 2010). Recent harvests have mostly taken place in the autumn and winter due to the summer fishing moratorium, so catches are expected to be predominantly mature squid.

The world's cephalopod resources still have some potential for development. In the East China Sea and the Yellow Sea, China, South Korea, and Japan have overlapping exclusive economic zones (EEZs), which has caused great obstacles to the use of fishery resources in China's offshore waters, and various conflicts have occurred from time to time (Pan *et al*, 2015).To accurately identify and manage JFS stocks, it is necessary to understand their distribution, migration patterns, spawning behavior, and the extent of spatial overlap between adjacent stocks (Jacobsen and Hansen, 2005). Inshore and offshore groups of JFS do not function independently and should be managed as one unit stock or perhaps a stock complex with differing levels of exchange among stock components (Cadrin *et al*., 2013). We should continue to learn the successful experience of single stock management in the world, such as the use of spatial structure population models to improve the management of JFS fisheries in China (Thorrold *et al*., 2001). And to fully apply spatially structured concepts to fishery management, rates of exchange need to be quantified throughout the life cycle by a variety of approaches such as Lagrangian particle tracking, statolith microchemistry analysis, acoustic and radio telemetry (Cadrin *et al*., 2013).Additional needs include increased use of geostatistics in the analysis of distributions and life history of the JFS fisheries, and investigations on the impacts and mechanisms of changes in the marine environment on population dynamics of the JFS fishery resource, which likely will be increasingly influenced by climate change.

Building on the stock assessment and management examples provide by Argentine shortfin squid *Illex argentinus* fishery resources, a logical approach for the JFS fishery resource would be to establish a survey and assessment network, taking temporary closure measures to conserve replenishment of JFS, gradually improving the fishing strategy of JFS fishery in the off-season so that its resources can be continuously developed, strengthening fishing port supervision capacity, and building a comprehensive management data service platform for the development and utilization of marine fishery resources. To achieve the rational development and effective promotion of JFS resources management, it is important to use a combination of big data, spatial information, network technology, model development and other technologies, mainly based on the data of previous surveys. Moreover, for the JFS fishery, we should consider its early life history along with other stages of life history characteristics to view and manage it from the perspective of holistic analysis (Cadrin *et al*., 2013) and development of whole life cycle models to conduct research and management of JFS fishery resources, and ultimately achieve sustainable fishery development.

2. Materials and Methods

2.1. Sample collection

Samples were collected from commercial trawler landings in the Sea of Japan and the Yellow China Sea by cooperating with Shengyang Ocean Shipping Company located in Shidao, Weihai, Shandong Province. The Sea of Japan samples were collected in September 2019, while the Yellow China Sea samples were collected in November 2019. About 90-120 kg samples of JFS were collected each time. The samples were deep-frozen at sea and thawed in the laboratory.

2.2. Species identification

Traditional cephalopod species identification relies on the identification of morphological features (Gebhardt and Knebelsberger, 2015).Taxonomic identification was carefully conducted based on anatomical characteristics (teeth shape on sucker ring in the arms) following Dong (1987) and Okutani (2015).

2.3. Sample measurement

Mantle length (ML, mm), body length (BL, mm), body weight (BW, g), and gutted weight (GW, g), gender and maturity of gonads were measured for each individual. The maturity of gonads is divided into five stages according to the standard of maturity of gonads of Jumbo flying squid (*Dosidicus gigas*) (Ehrhardt *et al.*, 1983) (Table 1), and the developmental stage of the gonads were determined by visual examination. Statoliths were extracted, cleaned with an ultrasonic cleaner, and preserved in 75% ethanol. The ML-BW relationships for females and males were estimated by a non-linear least square regression method (Froese, 2006; Froese *et al.*, 2014).

Table 1. Maturity of gonads for JFS (Ehrhardt *et al.*, 1983)

Maturity stage	Visual identification
I (immature)	Females have thin and transparent nidamental gland. Oviduct and eggs do not formed. Males have semitransparent and white fibrous testis. Spermatophoric sac is thin, transparent to semitransparent and empty
II (immature)	Ovary has a granular appearance. Gray and milky white **nidamental gland.** Barely obvious o**viduct.** Milky white testis. Spermatophoric sac have a few white flakes.
III (mature)	The gonadal structure has developed to a certain extent. Oviduct occupies 1/3 of the mantle cavity. Bright orange eggs. White nidamental gland, which is similar to the size of oviduct. Full spermatophoric sac is filled with **spermatophore. White and large testis.**
IV (mature)	Oviduct shrunk, with a few eggs inside. White nidamental gland shrunk. Soft and translucent spermatophoric sac with residual spermatophore.
V (mature)	Obviously atrophic gonads. Almost empty and decreased significantly nidamental gland.

3. Results

3.1 JFS sampled volume

In September 2019, a total of approximately 701 squids were collected from trawl landings, weighing a total 90 kg. In November 2019, a total of approximately 1231 squids were collected from trawl landings, with a total weight of 120 kg.

3.2 Size variation in JFS samples

The September samples ranged in size from 139 to 215 mm for ML, 293 to 492 mm for BL, 71.3 to 239.4 g for BW, and 59.8 to 196.4 g for GW. The distribution of ML and BW for males and females was scattered, and the maximum ML and BW of males was greater than that of females (Figs.1-2). In November, the samples ranged in size from 146 to 204 mm for ML, 274 to 417 mm for BL, 50.1 to 172.1 g for BW and 44.5 to 149.3 g for GW. The distribution of ML and BW for males and females was relatively unimodal, and most squids fell within the ranges of 160-170 mm for BL and 80-100 g for BW. The maximum ML and BW of females was greater than that of males (Fig. 1-2). The relationship between ML (mm) and BW (g) for females and males were as follows (Fig. 3). The slopes of the ML-BW relationship of females (b=3.2606) and males (b=3.2653) in November were greater than 3, indicating allometric growth. However, the slopes of the ML-BW relationship of females (b=2.9157) and males (b=2.3851) in September were less than 3, indicating slow growth. The coefficient of determination (R^2) values were high for the ML-BW relationships, indicating high correlation between ML and BW.

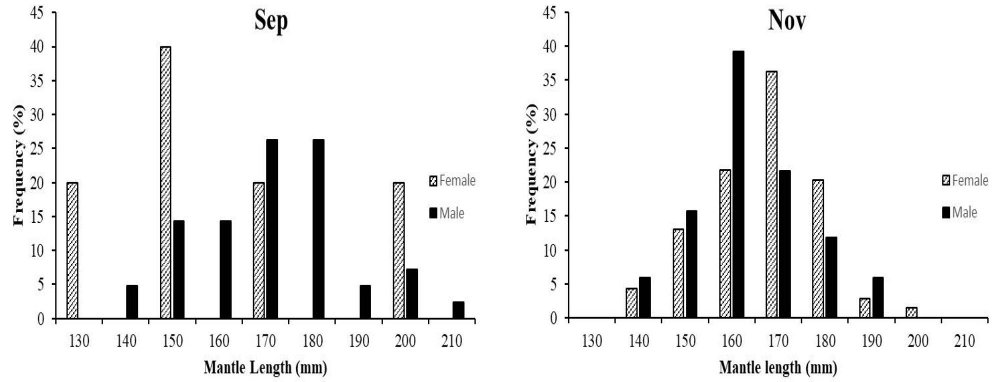

Fig.1 Frequency distribution of the mantle length of Japanese flying squid collected in different months.

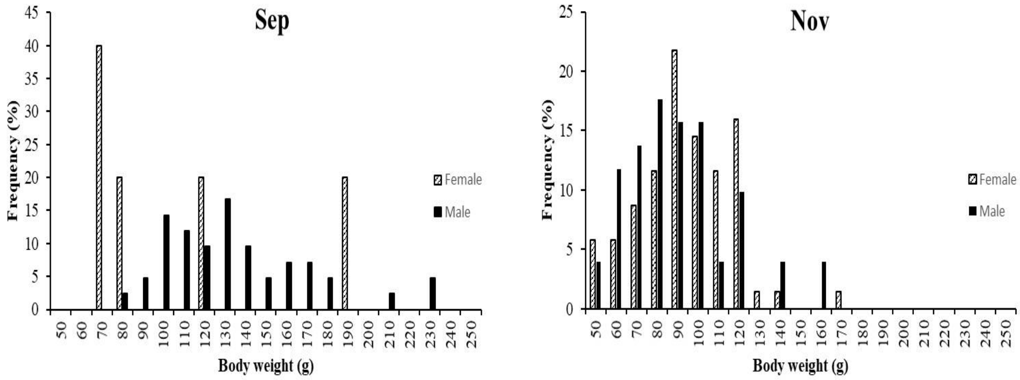

Fig. 2 Frequency distributionof the body weight of Japanese flying squid collected in different months.

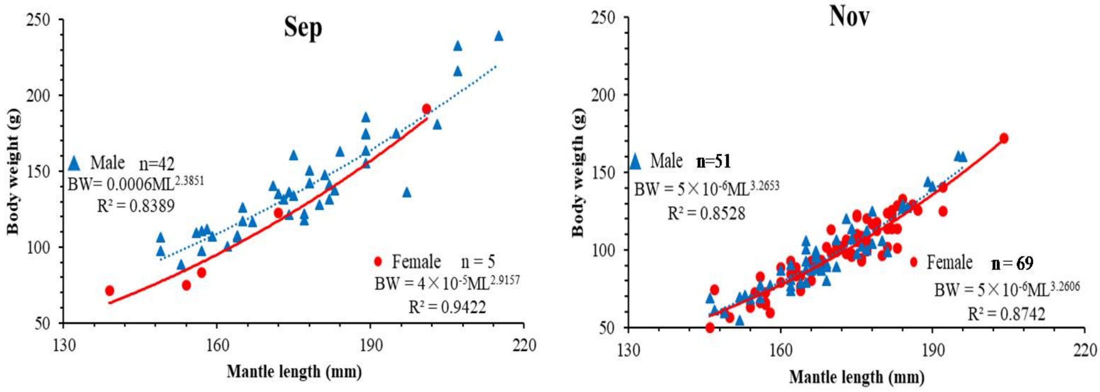

Fig. 3 Relationships between mantle length and body weight of mature female and maleJapanese flying squidwith the number (n), fitted equation, and coefficients of determination (R^2), for September and November samples.

3.3 Sex ratios

The sex ratio of female to male was 0.12 in September (42 males and 5 females).The sex ratio of female to male was 1.35:1 in November (51 males and 69 females).The female to male sex ratio in November was significantly higher than in September (Fig.4).

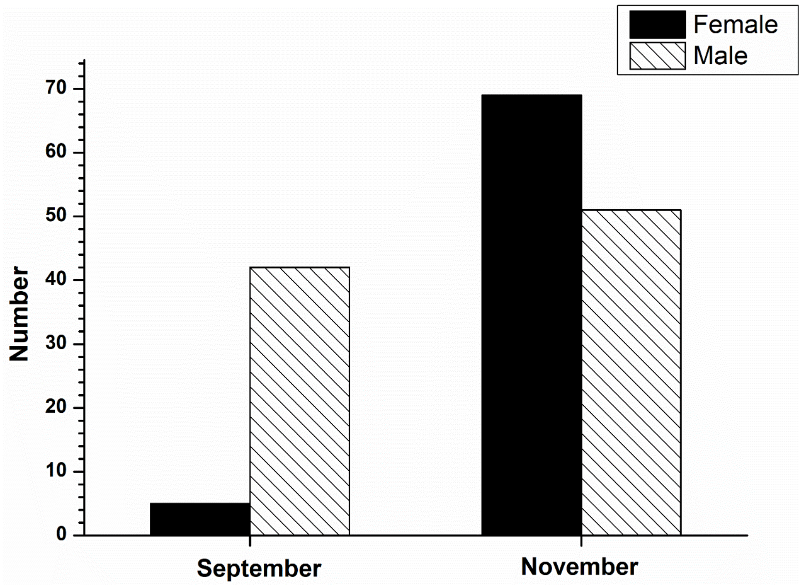

Fig. 4 Numbers of Japanese flying squid by gender in the September and November samples.

3.4 Maturity of gonads

In September, the gonad maturity stages of females were mainly I, accounting for 80.0%, and the gonad maturity stages of male were mainly from I to II, accounting for 95.2%. In November, the gonad maturity stages of female were mainly I, accounting for 72.9%, and the gonad maturity stages of male were mainly I, accounting for 84.1%. This suggests that most JFS are immature in September and November. The number of females in stage I decreased from 80% in September to 72.9% in November.

4. Conclusions

4.1 Evaluation of the sample and processor data

Basis biological information (size, sex ratio and maturity) of JFS in the Sea of

Japan and the Yellow Sea was analyzed in this project that would benefit to JFS fishery improvement project. However, there are some limitations in the sampling process. Firstly, all individuals of samples were collected from commercial fishing vessels, and had been selected according to their size before landed. Therefore, the randomness of sampling was poor, thus the collected samples in this project could not well represent the whole population. Secondly, the sampling period was less than one year (only one time for each sea area), similarly, the collected individuals could not represent the population structure. Due to the above reasons, it is impossible to understand and evaluate the life history characteristics, population structure, and fishery resources of JFS fishery, which is not conducive to the management of the fish resources in the future.

4.2 Challenges in monitoring and collecting catches

At present, catches of fishery species are mainly collected from the official statistics. However, JFS has not been separately listed in the China Fishery Statistics Yearbook, thus it is more difficult to collect the JFS catch. In addition, lack of fishing effort information for JFS because China’s fishery management system does not regularly conduct species-specific monitoring for JFS, therefore, it is not possible to convert the overall catch based on the limited sampling vessels. Finally, the scientific survey data sharing among the fisheries research institutes is poor, that limits the monitoring and collecting fisheries data.

4.3 Future estimation of catch and effort in the fishery

Stock assessment for JFS needs to understand the monthly catch trend with stock structure information such as size and maturity level. In the first year of this report, we collect a limited number of samples and get some biological information in short-period for JSF. Therefore, the basic need to systematically collect fishery monitoring information is the highest priority in the future. One key biological parameter for ultimate assessment and management of the fishery is the size composition and maturation status of JFS in various fishing areas. The location and degree to which spawning is (or is not) occurs in Chinese fishing areas in the Yellow Sea could have considerable bearing on an approach to exploitation and escapement management for JFS population in the Pacifica.

In the future, frequency of sample collection should be once a month, at least in part, once a quarter, thus collected individuals can better reflect the population structure. Secondly, the selection of samples should always keep in randomness. The randomness of samples can be guaranteed by asking the captain or fishermen to provide unselected individuals considering that most of the samples are from commercial fishing vessels. Meanwhile, the basic parameters such as sampling location, time, ship speed, retention ratio, and landing during the sampling process should be provided by the company. Most importantly, it is necessary that catch and fishing effort of JFS should be separately listed in the Fishery Statistics Yearbook.

Acknowledgements

We would like to thank those who provided JFS samples and data for this report, as well as the researchers who analyzed and measured the samples.

References

Bower J R, Sakurai Y. 1996. Laboratory observations on *Todarodes pacificus* (Cephalopoda: Ommastrephidae) egg masses. American Malacological Bulletin, 13(1/2): 65-71.

Cadrin S X, Kerr L A, Mariani S. 2013. Stock identification methods: applications in fishery science. Elsevier, Amsterdam, pp. 346-355;398.

Dong Z Z. 1996. On the present status and exploratory problems of resource of *Todarodes pacificus*, in the Yellow Sea. Ocean Science, 6: 34-38.

Dong Z. 1987. Fauna Sinica, Phylum Mollusca, Class Cephalopoda. Beijing: Science Press.

Ehrardt N M, Jacquemin P S, Garcia F B, et al. 1983. On the fishery and biology of the giant squid Dosidicus gigas in the Gulf of California, Mexico. Advances in Assessment of World Cephalopod Resources. FAO Fisheries Technical Paper No. 231: 306–340.

Fang Z, Chen X J. 2018. Review on fishery of Japanese flying squid *Todarodes pacificus*. Marine Fisheries. 102-116.

Froese R. 2006. Cube law, condition factor and weight-length relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology, 22(4): 241-253.

Froese R, Thorson J T, Reyes J R B. 2014. A Bayesian approach for estimating length-weight relationships in fishes. Journal of Applied Ichthyology, 30(1): 78-85.

Goto T. 2002. Paralarval distribution of the Ommastrephid squid *Todarodes pacificus* during fall in the southern Sea of Japan, and its implication for locating spawning grounds. Bulletin of Marine Science, 71(1): 299-312.

Goto T, Kidokoro H, Kasahara S. 2002. Changes in the distribution and abundance of *Todarodes pacificus* (Cephalopoda, Ommastrephidae) paralarvae in the southwest Sea of Japan with changing stock levels. Fisheries Science, 68(supl): 198–201.

Gebhardt K, Knebelsberger T. 2015. Identification of cephalopod species from the North and Baltic Seas using morphology, COI and 18S rDNA sequences. Helgoland marine research, 69(3): 259-271.

Jacobsen J A, Hansen L P. 2005. Internal and external tags. In: Cadrin, S.X., Friedland, K.D., Waldman, J.R. (Eds.), Stock Identification Methods. Application in Fisheries Science. Elsevier Academic Press, San Diego, pp. 415-433.

Katugin O N. 2002. Patterns of genetic variability and population structure in the North Pacific squids *Ommastrephes bartramii*, *Todarode spacificus*, and *Berryteuthis magister*. Bulletin of Marine Science, 71(1): 383-420.

Kidokoro H. 2010. Forecasting methods on the fishing conditions of Japanese common squid in the Sea of Japan[C]//Report of the 2009 Annual Meeting and Squid Resources. 3-12 (in Japanese).

Li J S, Yan L P. 2004. The numeric distribution of *Todarodes pacificus* and its relationship with the environment in East China Sea. Marine Fisheries, 26(3):

193-198.

Murata M. 1989. Population assessment, management and fishery forecasting for the Japanese common squid *Todarodes pacificus*. Marine invertebrate fisheries: their assessment and management, pp. 613- 636.

Ocean Outcomes (O2). 2016. Pre-assessment for the East China Sea and Yellow Sea offshore Japanese flying squid fishery. Unpubl. 58 p.

Okutani T. 2015. Cuttlefishes and squids of the world, new edition. National Cooperative Association of Squid Processors, Tokyo.

Pan P, Cheng J H, Li Y. 2015. Review of fisheries agreement of the people's Republic of China and Japan. Chinese Fisheries Economy, 33 (6) : 18-22.

Rosa A L, Yamamoto J, Sakurai Y. 2011. Effects of environmental variability on the spawning areas, catch, and recruitment of the Japanese common squid, *Todarodes pacificus* (Cephalopoda:Ommastrephidae), from the 1970s to the 2000s. ICES Journal of Marine Science, 68(6): 1114-1121.

Song H T, Yu K J. 1999. Distribution and migration of *Todarodes pacificus* in the East China Sea. Marine Science and Technology, (1): 9-14.

Sakaguchi K, Sawamura M. 2009. Commercial fishing of Japanese common squid, *Todarodes pacificus*, in the water of western Hokkaido during 1981 to 2007. Report of the 2008 Annual Meeteing on Squid Resources, 11-21 (in Japanese).

Sakurai Y, Kiyofuji H, Saitoh S, et al. 2000. Changes in inferred spawning areas of *Todarodes pacificus* (Cephalopoda: Ommastrephidae) due to changing environmental conditions. ICES Journal of Marine Science, 57(1): 24-30.

Sakurai Y, Kiyofuji H, SaitohS, et al.2002. Stock fluctuations of the Japanese common squid, *Todarodes pacificus*, related to recent climate changes. Fisheries Science, 68(sup1): 226-229.

Sakurai Y. 2006. How climate change might impact squid populations and ecosystems: a case study of the Japanese common squid, *Todarodes pacificus*. Global Ocean Ecosystem Dynamics,24: 33-34.

Thorrold S R, Latkoczy C, Swart P K, et al. 2001. Natal homing in a marine fish metapopulation. Science, 291(5502): 297-299.

Yang L L, Jiang Y Z, Cheng J Y. 2010. Spatial distribution of reproductive populations of Ommastrephes bartrami *Todarodes pacificus* in the East China Sea and its relationship with environmental factors. Acta Ecologica Sinica, 30 (7): 1825-1833.

Yamashita N, Fukuwaka M. 2011. Stock assessment and evaluation for winter spawning stock of Japanese common squid, Marine fisheries stock assessment and evaluation for Japanese waters (fiscal year 2010/2011), Fishery Agency and Fisheries Research Agency of Japan, 585-621 (in Japanese).

Yamashita N, Mori K. 2009. Changes in the fishing conditions of Japanese common squid in the coastal area of the Pacific Ocean. Report of the 2008 Annual Meeting on Squid Resources, 11-21 (in Japanese).

Appendix

Life history of JFS

JFS is highly migratory, moving to forage and reproduce, correspondingly this species is defined 3 subpopulations with different peak spawning seasons in summer, autumn and winter, and the latter two subpopulations are the largest and most important (Fig. A1) (Murata, 1989; Sakurai *et al*., 2000). Genetic analyses are limited but suggest the existence of two distinct breeding groups: 1) the fall stock and 2) the winter, summer and spring stocks combined (Katugin, 2002).The autumn spawning occurs mainly in the southern Sea of Japan, including Tsushima Strait between Japan and South Korea, while winter spawning is in the East China Sea off Kyushu Island south of Japan(Sakurai *et al*., 2002). JFS has a 1-year life cycle with the autumn spawned squid migrating to the northern Sea of Japan and then back again to spawn before dying. Some of the winter spawned JFS migrate to feed in the northern Sea of Japan while others migrate in the waters off eastern Japan to the Oyashio region where they feed during the summer and autumn (Kidokoro*et al*., 2010).

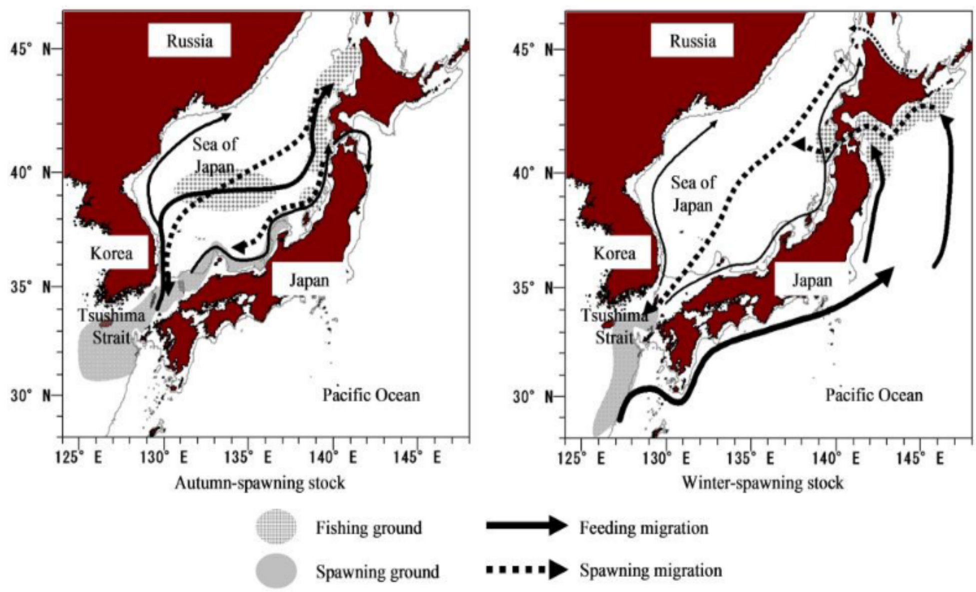

Fig. A1 The distribution range and migration pattern of Japanese flying squid. (From Kidokoro*et al*., 2010)

JFS paralarvae is mainly distributed in the southwest Sea of Japan, the East China Sea and pacific coast of Japan (Goto, 2002; Goto*et al*., 2002). Based on the laboratory studies, the spawning is assumed to occur above the continental shelf and slope around Japan (Bower and Sakurai, 1996). Sakurai *et al*. (2000) proposed the following reproduction process. After sitting on the bottom, the adult squids swim to an upper layer and spawn in surface water above thermocline. The spawned egg masses, due to differences in density, sink until reaching a buoyancy depth above thermocline. Once hatched the hatchlings will swim to the surface and be transported to the respective feeding grounds by the currents (Fig. A2).

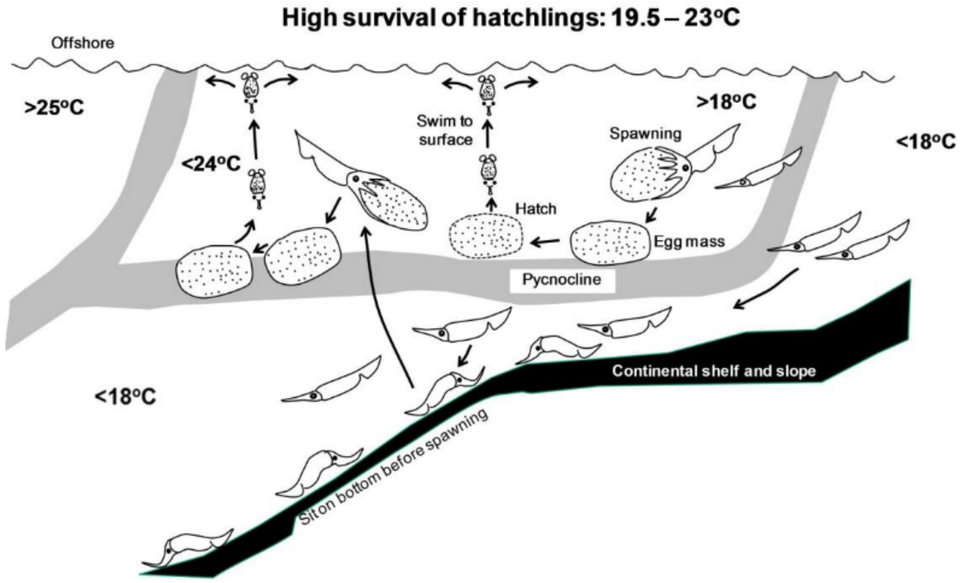

Fig. A2 Schematic view of reproductive processes of the Japanese flying squid.

（From Sakurai, 2006）

Fishing gear and Fishing Grounds

The peak of JFS catch is from June to September for the autumn cohort and October to January for the winter cohort (Rosa *et al*., 2011). JFS is fished by several fishing gear types, with the dominant gear varying by region around Japan (Fig. A3). JFSis mostly fished by coastal jiggers and offshore jiggers in the Sea of Japan. Along the Pacific side of Japanese waters, JFS is mainly taken by coastal jiggers, but more than a half of the total catch along the Pacific side is taken by other fisheries, i.e. offshore trawlers, large-and medium scale purse seiners and set nets (Yamashita and

Fukuwaka, 2011). In the Sea of Okhotsk and the Nemuro Strait, most of the catches are taken by set nets and coastal jiggers (Sakaguchi and Sawamura, 2009). In Korean waters, JFS is fished in the Sea of Japan, the Yellow Sea and the East China Sea by several fishing methods. Most of the catch is made by offshore jigging, large trawl in those areas. Outside of the East China Sea EEZ, offshore trawlers harvest JFS in the East China Sea Yellow Sea, and Sea of Japan, in areas co-managed with Japan and South Korea through bilateral agreements and also through sanctioned business to business arrangements between Chinese and North Korean entities. Although not a part of the FIP, JFS are also commonly caught using stow nets close to shore (Table A1). JFS fishery resources of the Yellow Sea are mainly caught by trawl, gillnet, and stow net (Table A2).

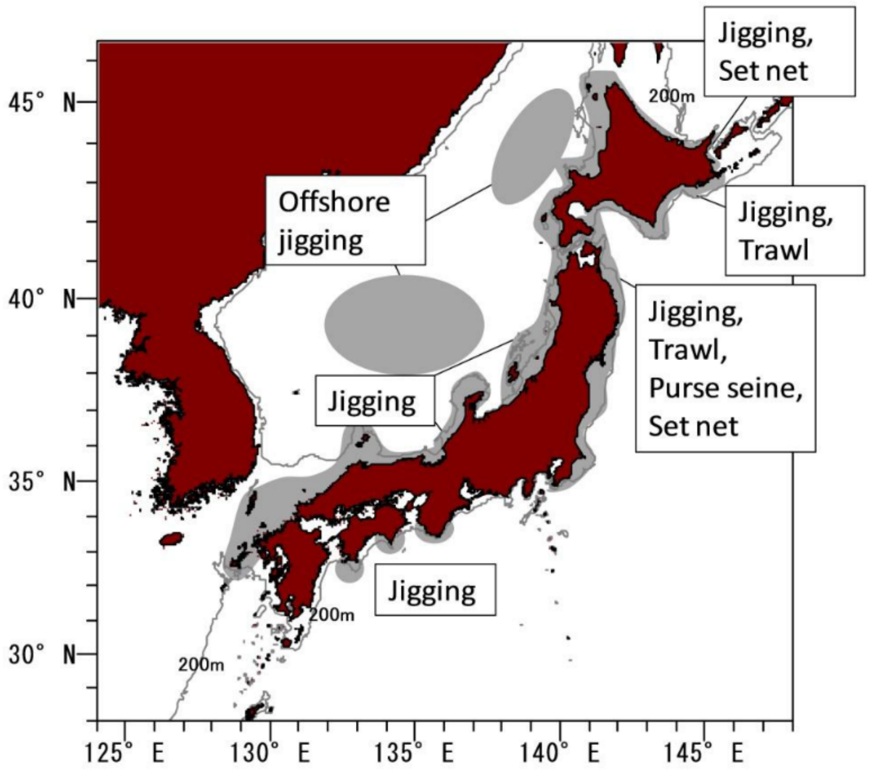

Fig. A3 Major fishing grounds and fishing methods for Japanese flying squid around the Japanese waters. (Figure from Yamashita and Mori, 2009)

According to the distribution of different cohorts, there are two main types of fishing grounds for Japanese flying squid: Offshore fishing grounds and nearshore fishing grounds. In addition, a fishing ground is located in the southeast sea area of

Shidao, Shandong Province, China. In the cold water areas of the Yellow Sea, the fishing ground is slightly tongue-shaped, ranging from 123°E to 125°E, 34°N to 38°N (Fang and Chen, 2018). In recent years, the output of the East China Sea has also been high.

Table A1. Numbers of vessels (No.) registered to Zhoushan ports and their total power (in megawatts; MW), separated by gear type. Source: Fishery Statistics Yearbook of Zhejiang Province by Zhejiang Ocean and Fishery Bureau.

Year	Trawler		Purse Seine		Gill Net		Stow Net		Line		Others		Overseas	
	No.	MW	No.	MW	No.	MW	No.	MW	No.	MW	No.	MW	No.	MW
2010	2345	485	267	66	956	108	2475	317	685	136	740	69	251	134
2011	2125	448	290	73	1134	115	2536	345	689	166	782	66	335	206
2012	2110	452	336	85	1235	76	2543	354	676	226	673	51	383	247
2013	2123	473	327	81	1107	114	2362	330	763	250	740	55	406	284
2014	1954	412	342	87	1215	127	2204	319	522	279	599	69	419	302

Table A2. Numbers of vessels (No.) registered to Shandong Province and their total power (in megawatts; MW), separated by gear type. Source: Fishery Statistics Yearbook of Shandong Province by Shandong Ocean and Fishery Bureau in 2010

Region	Trawler		Purse Seine		Gill Net		Stow Net		Line		Others		Overseas	
	No.	MW	No.	MW	No.	MW	No.	MW	No.	MW	No.	MW	No.	MW
Shandong Province	8567	1123192	66	9141	10323	242289	3499	38477	1056	73234	241	9403	162	86653
Jinan	0	0	0	0	0	0	0	0	0	0	0	0	24	22140
Qingdao	593	50489	16	499	2667	73426	949	9351	713	9163	20	200	24	16906
Dongying	64	16558	0	0	979	19569	134	1741	0	0	0	0	0	0
Yantai	918	89996	4	397	4477	81496	532	6883	114	20892	4	16	12	10074
Weifang	519	99867	0	0	447	18230	0	0	0	0	0	0	101	36504
Weihai	4008	577794	1	199	937	8784	715	5323	258	56071	36	5856	0	0
Rizhao	1679	167154	39	1467	175	3363	900	11916	6	76	44	1130	0	0
Binzhou	77	14950	0	0	635	24970	62	1957	1	63	12	98	0	0
Linyi	0	0	0	0	0	0	0	0	0	0	0	0	1	1029

Catches in China

Annual catches of the JFS winter cohort from 1979 to 2017 by country is shown in Fig. A4. Data were obtained from China, Japan, South Korea and Russia. Annual catches of the JFS winter cohort by Chinese fisheries were approximately 500-3,000 t between 2013 and 2016, but the catch decreased significantly in 2016 (Fig. A5).

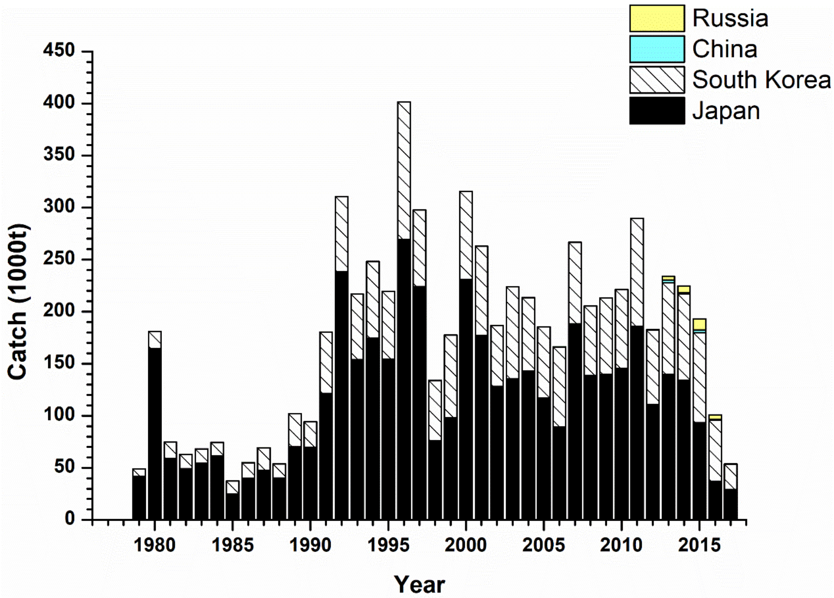

Fig. A4 Annual catch of winter cohort of Japanese flying squid from 1979 to 2017 by country. (Data from Japanese Fisheries Agency; http://abchan.fra.go.jp)

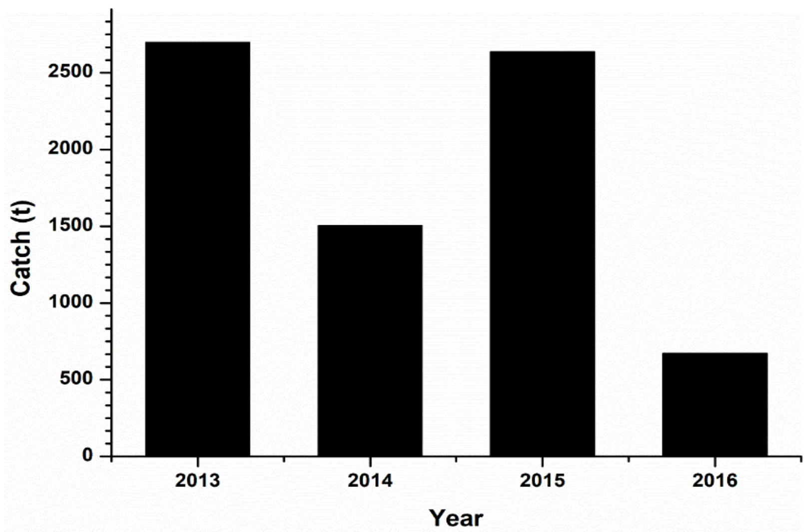

Fig. A5 Annual catch of Japanese flying squid by Chinese fisheries from 2013 to 2016. (Data from Japanese Fisheries Agency; http://abchan.fra.go.jp)