Monterey Bay Aquarium Seafood Watch®

Japanese flying squid

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China

Midwater trawls

July 6, 2020

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Disclaimer

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Seafood Watch Standard used in this assessment: Standard for Fisheries vF3

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About Seafood Watch

Monterey Bay Aquarium's Seafood Watch program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Watch Assessment. Each assessment synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices," "Good Alternatives" or "Avoid." This ethic is operationalized in the Seafood Watch standards, available on our website here. In producing the assessments, Seafood Watch seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying assessments will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Watch assessments in any way they find useful.

Guiding Principles

Seafood Watch defines sustainable seafood as originating from sources, whether fished[1] or farmed that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

The following guiding principles illustrate the qualities that fisheries must possess to be considered sustainable by the Seafood Watch program (these are explained further in the Seafood Watch Standard for Fisheries):

- Follow the principles of ecosystem-based fisheries management.
- Ensure all affected stocks are healthy and abundant.
- Fish all affected stocks at sustainable levels.
- Minimize bycatch.
- Have no more than a negligible impact on any threatened, endangered or protected species.
- Managed to sustain the long-term productivity of all affected species.
- Avoid negative impacts on the structure, function or associated biota of aquatic habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.

These guiding principles are operationalized in the four criteria in this standard. Each criterion includes:

- Factors to evaluate and score
- Guidelines for integrating these factors to produce a numerical score and rating

Once a rating has been assigned to each criterion, we develop an overall recommendation. Criteria ratings and the overall recommendation are color coded to correspond to the categories on the Seafood Watch pocket guide and online guide:

Best Choice/Green: Are well managed and caught in ways that cause little harm to habitats or other wildlife.

Good Alternative/Yellow: Buy, but be aware there are concerns with how they're caught.

Avoid/Red Take a pass on these for now. These items are overfished or caught in ways that harm other marine life or the environment.

[1] "Fish" is used throughout this document to refer to finfish, shellfish and other invertebrates

Summary

This report covers the Japanese flying squid (*Todarodes pacificus*) fishery in Chinese EEZ, which is mostly concentrated in north Yellow Sea. Chinese vessels also fish for JFS in the EEZs of Japan and South Korea under the bilateral agreements, but the fisheries in these areas are not evaluated in this report. JFS are harvested by multiple gear types, while paired trawler is identified to be the primary gear, which is evaluated in this report, with a small number of purse seiner and jigger also used by Chinese vessels.

There is no recent abundance assessment available for the Japanese flying squid stock around Chinese EEZ. Productivity-susceptibility analysis (PSA) suggests that the stock has a high susceptibility to the fishery, resulting in a high concern for abundance. Though there is no information on fishing mortality from the Chinese fleet, the stock assessment performed by Japan Fisheries Research and Education Agency (FRA) suggests that overfishing is occurring in the stock spawned in the East China Sea. As a result, a "High Concern" is assigned to fishing mortality.

Trawl are of high concern for the impacts on other species, and the majority of the influenced species by JFS trawl fishery are suffering a high concern for stock abundance and fishing mortality. Among them, smooth hammerhead shark (*Sphyrna zygaena*) is currently assessed as "Vulnerable" globally by IUCN.

The Criterion 3 is scored "red". Regulations and management plans for Japanese flying squid are lacking, with several general management measures in place. The implementation is undertaken at the local level, however there is not enough information available to evaluate the effectiveness. Bycatch strategy are insufficient to mitigate the impact on other species. Scientific research and monitoring need to be improved.

Paired trawlers are able to adjust the operating depth to avoid the contact with the bottom, but the incidence of demersal species in the catch indicates that the fishery has the possibility to contact the sea bed, with no known measures to mitigate it. Ecosystem based management is not implemented in this fishery.

Overall, the Japanese flying squid trawl fishery in Chinese EEZ is rated as "Avoid".

Final Seafood Recommendations

SPECIES | FISHERY	CRITERION 1: Impacts on the Species	CRITERION 2: Impacts on Other Species	CRITERION 3: Management Effectiveness	CRITERION 4: Habitat and Ecosystem	OVERALL RECOMMENDATION
Japanese flying squid | Winter cohort China | Midwater trawls	Red (1.000)	Red (1.000)	Red (1.000)	Red (2.000)	**Avoid (1.189)**

Scoring Guide

Scores range from zero to five where zero indicates very poor performance and five indicates the fishing operations have no significant impact.

Final Score = geometric mean of the four Scores (Criterion 1, Criterion 2, Criterion 3, Criterion 4).

- **Best Choice/Green** = Final Score >3.2, and no Red Criteria, and no Critical scores
- **Good Alternative/Yellow** = Final score >2.2-3.2, and neither Harvest Strategy (Factor 3.1) nor Bycatch Management Strategy (Factor 3.2) are Very High Concern2, and no more than one Red Criterion, and no Critical scores
- **Avoid/Red** = Final Score ≤2.2, or either Harvest Strategy (Factor 3.1) or Bycatch Management Strategy (Factor 3.2) is Very High Concern or two or more Red Criteria, or one or more Critical scores.

[2] Because effective management is an essential component of sustainable fisheries, Seafood Watch issues an Avoid recommendation for any fishery scored as a Very High Concern for either factor under Management (Criterion 3).

Introduction

Scope of the analysis and ensuing recommendation

This report analyzes the fishery targeting Japanese flying squid (*Todarodes pacificus*) by Chinese vessels in Chinese EEZ (mainly from Yellow Sea). Though a small percentage of jiggers and purse seiners are used to harvest this species, almost all Japanese flying squid are fished by trawlers in Chinese waters (FishSource 2016). Additionally, Chinese vessels also harvest JFS in co-managed waters with South Korea and Japan and within their EEZs under bilateral agreements, but these fisheries are not assessed in this report. The Chinese trawl fishery for JFS in the Yellow Sea is currently involved in fisheries improvement projects (FIPs).

Species Overview

T. pacificus has a 1-year life span, averaging a mantle length of 20–30 cm at maturity (Kidokoro H and Hiyama Y. 1996). It has a broad geographic distribution within the Northern and Western Pacific Ocean (Fig.1). Near China, it can be found in the South China Sea, East China Sea, and Yellow Sea. The stocks are usually defined by their spawning seasons: summer, fall and winter stocks, with the autumn and winter stocks being the largest (Arkhipkin AI et al. 2015). Winter stock is considered dominant in the East China Sea and Yellow Sea, accounting for 75 to 80% of annual landings in the Yellow Sea (Fang Q and Jocelyn D 2018). However, the stock structure of *T. pacificus* in China's coastal water has not been well studied, given the difficulty in observing their spawning and migration behaviors in the wild. It's a highly migratory species. The winter stock spawns in the offshore region of northern Eastern China Sea during winter. After hatching, squids migrate northward in spring along the Pacific side and separate into two branches. One branch of the larvae are carried to the Sea of Japan, the larvae in other branch move into the Yangtze River estuary with the Yellow Sea Warm Current and Taiwan Warm Current. The squids aggregate in the northern East China Sea during June and July, during the summer fishing moratorium in China. Then most of the stock migrates northward into Yellow Sea from August and stays until October, which creates most of the Chinese JFS production (Fang Z and Chen X 2018).

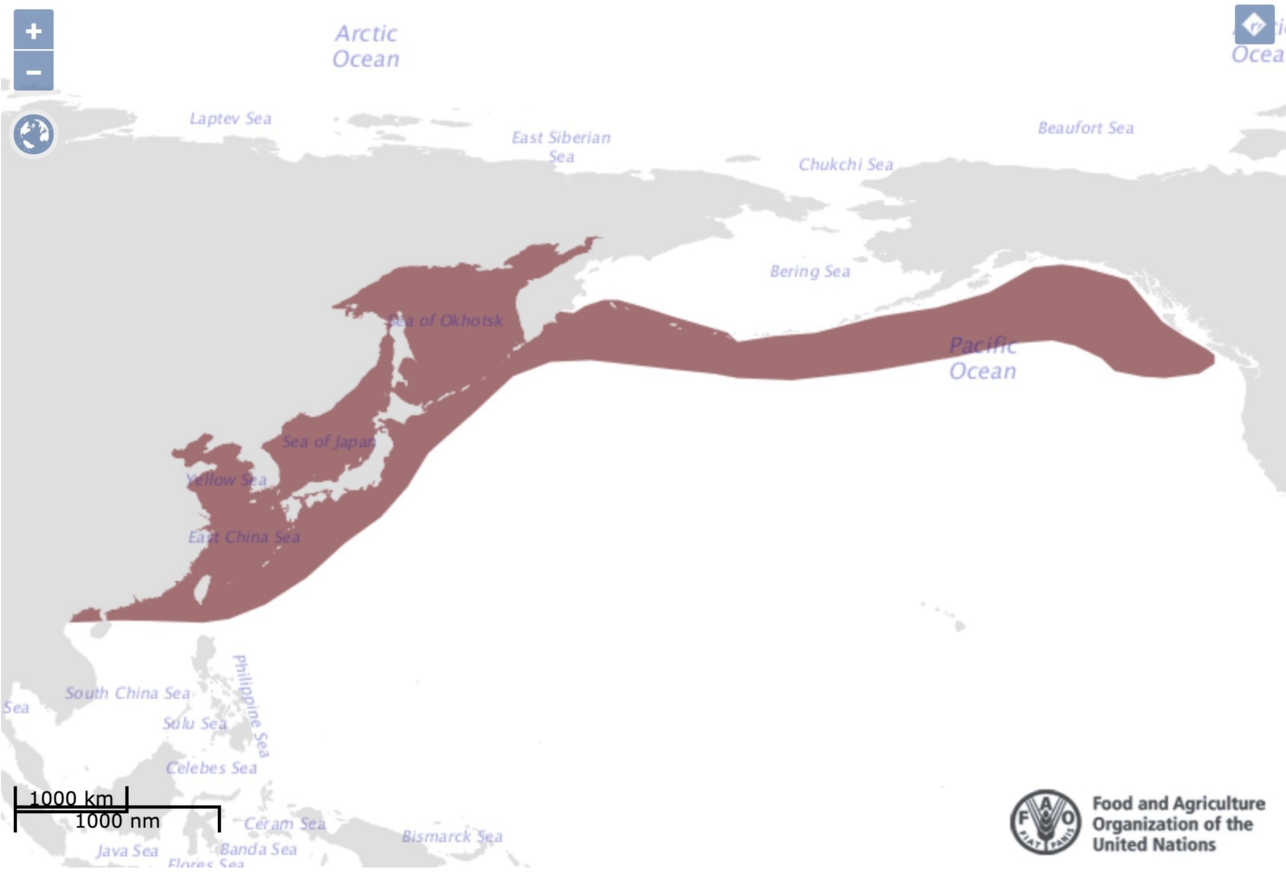

Figure 1 Distribution of T. pacificus around the world(FAO)

The resource in Chinese jurisdiction and fishing activities are managed by Ministry of Agriculture and Rural Affairs of the People's Republic of China (MOA). Currently, there is no specific regulation for JFS fishery or resource management plan for this species in China, except some general fisheries management measures in place, such as the summer fishing moratorium.

Production Statistics

As an important spawning ground, the annual production from East China Sea by Chinese vessels was about 48,000 tons during 1952 to 1966(Fang Z and Chen X 2018). However, the capture volume of this species in Yellow Sea was quite small before 1980s, which generally came from the bycatch of the gillnet, purse seine and trawl fisheries. The production increased sharply after 1980s, with the production of 5,335 tons from Yellow Sea in 1990 (Fang Z and Chen X 2018). Nowadays, *T. pacificus* is mainly fished from Zhejiang, Liaoning and Shandong Provinces (Fang Q and Jocelyn D 2018). However, there is no available data on capture from Yellow Sea since 1990s, as the officially published statistics provides only the total production of all squid species. Though it's widely distributed in Chinese EEZ, the current distribution of Chinese JFS fisheries appears to have shifted from the East China Sea and southern Yellow Sea more northerly to primarily the Yellow Sea, particularly the Shidao fishing ground (of Shandong province), as the summer fishery closure prohibits fishing during the available time of JFS in East China Sea (Fang Q and Jocelyn D 2018). As an important commercial species, there is also some capture from Korean and Japan EEZ under bilateral agreements, but the volume is considered relatively small, with no capture data published.
As a fast-growing species with short lifespan, Japanese flying squid can be greatly influenced by environmental factors, which can be seen from the fluctuations of the capture production. The global production began to decrease in 2000 (Fig. 2). In 2016, the global capture of Japanese flying squid was 194,921 tons, consisting of catches predominantly from Japan and the South Korea (FAO 2019a).

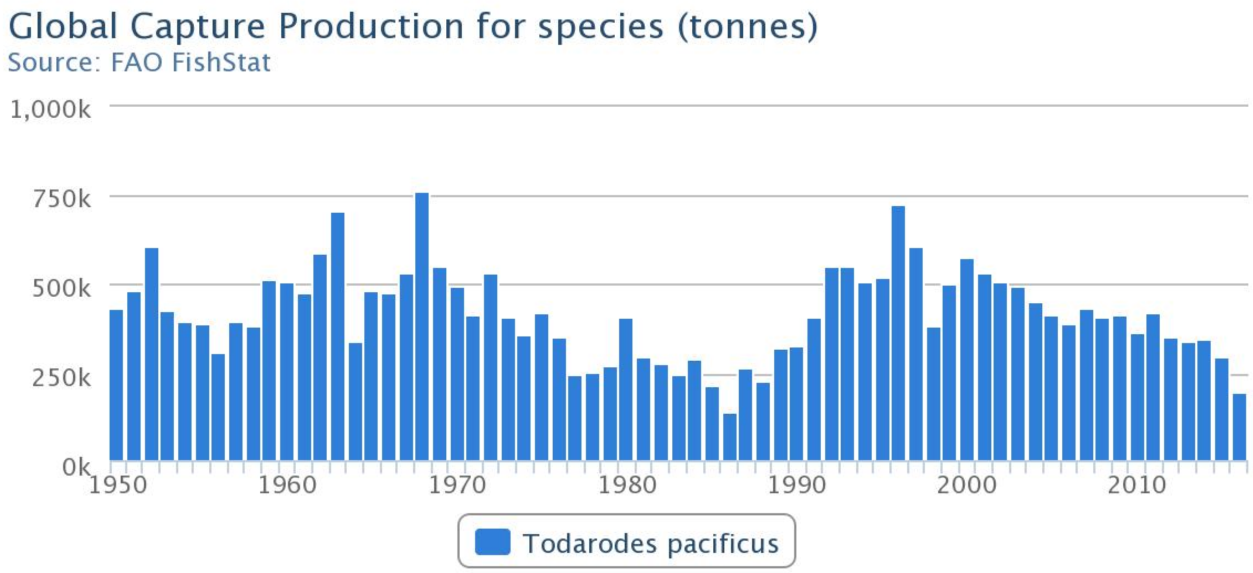

Figure 2 Global capture production for T. pacificus (FAO)

Importance to the US/North American market.

There are no data from both China and the US to understand the species-level trade volume. It's known that China has the highest export volume of squid products to US (Fig. 3), however since the statistics of U.S. imported squid products from China are not species-based, the import volume of JFS from China is not clear

(NOAA 2019). Figure 4 shows the categories of the imported squid products mainly including Loligo NSPF and squid NSPF, of which the squid NSPF accounts for more than half of the total volume, indicating the general squid species. Research conducted by O2 concluded that for several main U.S. orientated squid export provinces, the main export squid species is Japanese flying squid (Fang Q and Jocelyn D 2018). A conclusion is made that *T. pacificus* should be an importantly imported squid species for the U.S. from the China.

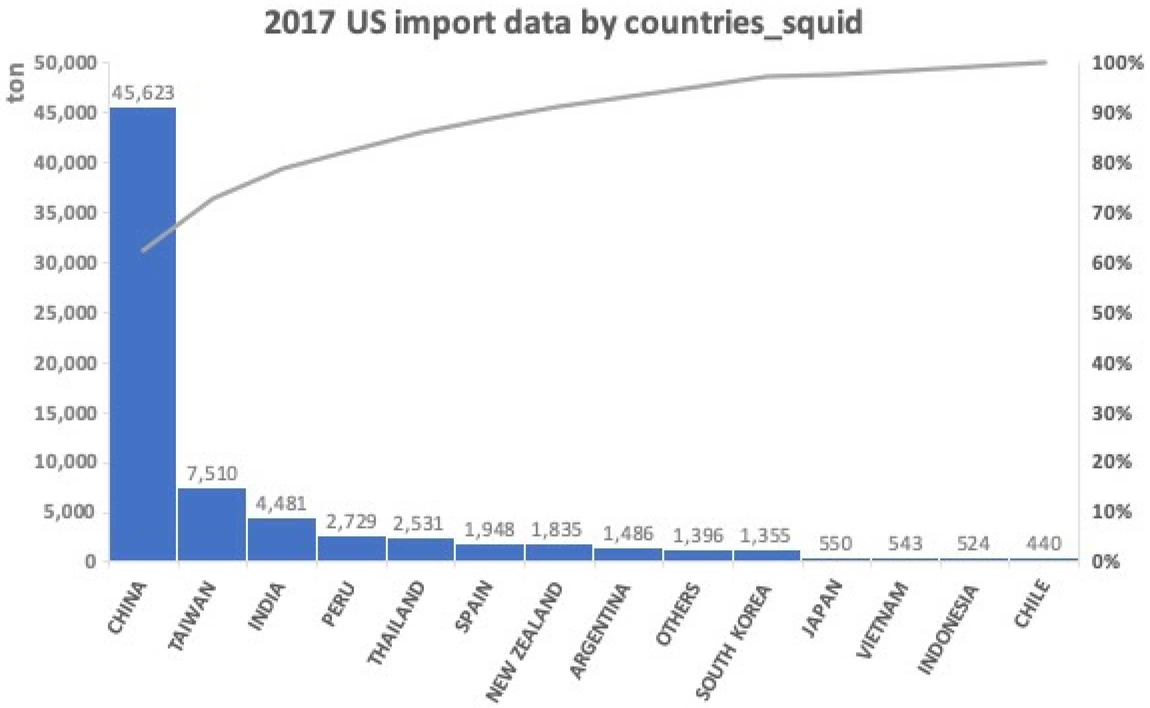

Figure 3 2017 US squid import volume by countries (NOAA, 2019)

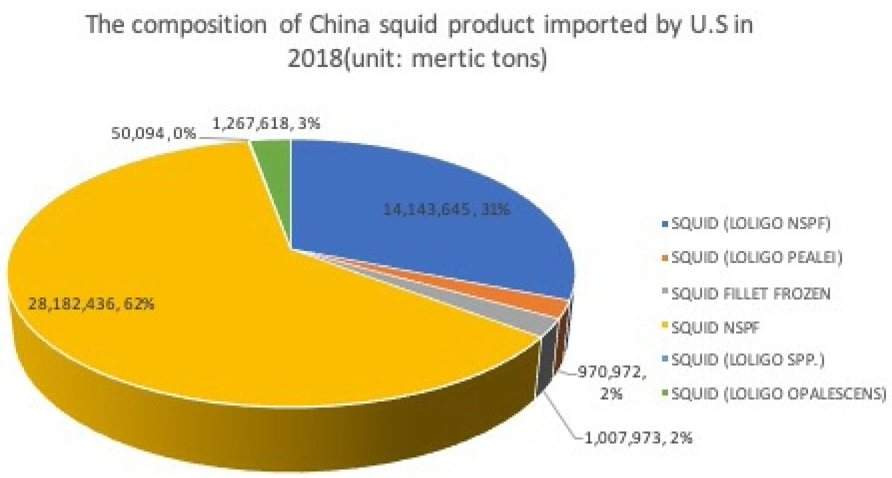

Figure 4 The composition of China squid product imported by U.S in 2018 (unit: mertic tons) (NOAA, 2019)

Common and market names.

The common name of *T. pacificus* is Japanese flying squid, but also is sometimes called Japanese common squid or Pacific flying squid. Its Chinese common names include Yellow-Sea squid, Rocket fish, North squid, Orient squid, Japan squid, and dark-skinned squid, with usually called "Tai ping yang zhe rou yu" in Chinese.

Primary product forms

Squid in China is consumed in various forms, including fresh, grilled, fried, or fermented products.

Assessment

This section assesses the sustainability of the fishery(s) relative to the Seafood Watch Standard for Fisheries, available at www.seafoodwatch.org. The specific standard used is referenced on the title page of all Seafood Watch assessments.

Criterion 1: Impacts on the Species Under Assessment

This criterion evaluates the impact of fishing mortality on the species, given its current abundance. When abundance is unknown, abundance is scored based on the species' inherent vulnerability, which is calculated using a Productivity-Susceptibility Analysis. The final Criterion 1 score is determined by taking the geometric mean of the abundance and fishing mortality scores. The Criterion 1 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and ≤3.2=Yellow or Moderate Concern*
- *Score ≤2.2=Red or High Concern*

Rating is Critical if Factor 1.3 (Fishing Mortality) is Critical

Guiding Principles

- *Ensure all affected stocks are healthy and abundant.*
- *Fish all affected stocks at sustainable level.*

Criterion 1 Summary

JAPANESE FLYING SQUID			
Region | Method	**Abundance**	**Fishing Mortality**	**Score**
China | Midwater trawls Winter cohort	1.00: High Concern	1.00: High Concern	Red (1.000)

Criterion 1 Assessment

SCORING GUIDELINES

Factor 1.1 - Abundance

Goal: Stock abundance and size structure of native species is maintained at a level that does not impair recruitment or productivity.

- *5 (Very Low Concern) — Strong evidence exists that the population is above an appropriate target abundance level (given the species' ecological role), or near virgin biomass.*
- *3.67 (Low Concern) — Population may be below target abundance level, but is at least 75% of the target level, OR data-limited assessments suggest population is healthy and species is not highly vulnerable.*
- *2.33 (Moderate Concern) — Population is not overfished but may be below 75% of the target abundance level, OR abundance is unknown and the species is not highly vulnerable.*

- *1 (High Concern) — Population is considered overfished/depleted, a species of concern, threatened or endangered, OR abundance is unknown and species is highly vulnerable.*

Factor 1.2 - Fishing Mortality

Goal: Fishing mortality is appropriate for current state of the stock.

- *5 (Low Concern) — Probable (>50%) that fishing mortality from all sources is at or below a sustainable level, given the species ecological role, OR fishery does not target species and fishing mortality is low enough to not adversely affect its population.*
- *3 (Moderate Concern) — Fishing mortality is fluctuating around sustainable levels, OR fishing mortality relative to a sustainable level is uncertain.*
- *1 (High Concern) — Probable that fishing mortality from all source is above a sustainable level.*

JAPANESE FLYING SQUID | WINTER COHORT

Factor 1.1 - Abundance

CHINA
Midwater Trawls | Winter Cohort

High Concern

The abundance of Japanese flying squid stocks in Chinese EEZ is uncertain. Generally, there is no recent published abundance estimation of the stock around Chinese waters since 2009. The productivity-susceptibility analysis (PSA) indicates that it has high productivity but is highly susceptible to the fishery activities. According to this, it is scored as "High Concern".

Justification:

The stock status of the cohorts around Japanese waters, which are the part of the branches derived from the East China Sea spawning ground as well, are monitored and assessed annually in Japan. The recent 2018 stock assessment estimated that both the winter and autumn cohorts are showing decreasing trends in the past 5 years. However, in general, there is a shortage of understanding on stock status in Chinese waters. Some researchers investigated the migration and potential biomass for *T. pacificus* stock in Yellow sea and East China Sea, such as the preliminary biomass was estimated to be 29,913 tons in East China Sea (Song H et al. 2009), but there is no update of the estimation since 2009. Given this situation, PSA was used to assess the production and susceptibility of this species.

The productivity attributes are scored with relatively low to medium risk. For susceptibility, its depth distribution typically ranges from surface waters to a depth of 100 m (Roper et al. 1984), and it has daily vertical migration, but the fishing gears used (mainly trawlers) are adapted to the squid migration. Additionally, the fishing areas highly overlap with squid distribution areas, leading to the high susceptibility to the fisheries. Based on this, this factor is considered "High Concern".

Productivity Attribute	Relevant Information	Score (1 = low risk, 2 = medium risk, 3 = high risk)
Average age at maturity	JFS is estimated to reach sexual maturity at the age approximately 6 months. (Takahara et al. 2016)	1 (<5 years.)

Average maximum age	One year. (Takahara et al. 2016)	1 (<10 years.)
Fecundity	300,000~500,000 eggs. (Fang Z and Chen X 2018)	1 (>20,000 eggs per year)
Reproductive strategy	*Todarodes pacificus* produces gelatinous, nearly neutrally buoyant egg masses that contain many small eggs. (Sakurai Y. 2006)	1 (Broadcast spawner)
Trophic level	3.3 (Tian Y et al. 2014)	3 (>3.25)
Density dependence (invertebrates only)	No density or compensatory dynamics demonstrated or likely	2 (No depensatory or compensatory dynamics demonstrated or likely)
Quality of Habitat	Habitat is considered to be robust to human activities	1 (Habitat is robust, no known degradation from non-fishery impacts)
Productivity		1.43

Susceptibility Attribute	**Relevant Information**	**Score (1 = low risk, 2 = medium risk, 3 = high risk)**
Areal overlap (Considers all fisheries)	No precise data available. Chinese JFS fishing grounds include Yellow Sea, northern East China Sea and part of waters in Sea of Japan, which highly likely cover more than 30% of the species concentration.	3 (Default score)
Vertical overlap (Considers all fisheries)	JFS is distributed in depths of 0-300 meters. It has the daily vertical migration, inhabiting mid to bottom depths during the day and moving up toward surface at night (Science L 2019). The fishing gears are adapted to it, for instance, bottom-oriented trawling during the day and pelagic trawling at night.	3 (High degree of overlap between fishing depths and depth range of species)
Selectivity of fishery (Specific to fishery under assessment)	JFS is targeted and both mature and immature squid are caught in Chinese JFS fishery.	3
Post-capture mortality (Specific to fishery under assessment)	All squids are retained, including other valuable by-catch species.	3 (Retained species)

Susceptibility		3.0

Factor 1.2 - Fishing Mortality

CHINA
Midwater Trawls | Winter Cohort

High Concern

At present, no quantitative data about fishing mortality for this species is available in China. No reference point such as Fmsy or any other alternatives have been defined for this species in China, causing the difficulty evaluating the current fishing mortality. While Japanese vessels are also catching the stock spawned in the East China Sea, the annual stock assessment performed by Japan Fisheries Research and Education Agency (FRA) suggests that overfishing is occurring to the stock spawned in the East China Sea. Considering the stock that Chinese vessels are catching could be in the similar condition, this factor receives a "High Concern".

Justification:

As a short-lived species, the catch of JFS has been found to have a variation pattern, which is related to both overfishing and North Pacific regime shifts(Rosa et al. 2011). For regime shifts, the impacts have been revealed on the spawning of the squid, which can also cause the uncertainty in the management and estimation of the fishing mortality.

The optimal JFS fishing season in Chinese waters is from May to October with key fishing grounds concentrated in the Changjiangkou, Shidao, Shidong, and Haiyangdao areas, which are mainly located in Zhejiang, Shandong and Liaoning province, the three provinces with highest squid production in China (Table 1). However, the summer moratorium stops the fishery from May to August precluding legal fishing by Chinese vessels in East China Sea and Yellow Sea coastal areas, which can have some positive impacts on reducing the fishing mortalit to this species.

No reference point is clearly defined for this fishery in China. Shandong Marine Resource and Environment Research Institute (SMRERI) has conducted the relevant research and suggests that JFS resources in China may still have potential capacity for further development with a hypothesized sustainable fishing volume around 8,00 tons per year (Fang Q and Jocelyn D 2018). However, only total catch of all squid species is available in Chinese fishery statistics, with no species-based data published. The difficulty of species-based data collection can be attributed to multiple reasons in China, including the non-selective fishing methods targeting multiple species, th misreporting from the fishermen, and the insufficient management plan and enforcement for data collection, etc The situation is similar for the number of vessels fishing *T. pacificus*, only the total numbers of each type of vessels are available.

Table 1. All species squid harvest of China's three key JFS provinces (tons) (production followed b the percentage of the total domestic squid harvest of respective year)

Province	Year					
	2012	2013	2014	2015	2016	2017
Liaoning	30,884(8.0%)	37,920(10.5%)	30,343(8.1%)	33,065(8.7%)	33,147(8.5%)	16,086(5.0%)
Zhejiang	82,163(21.3%)	87,747(24.3%)	83,412(22.3%)	84,044(22.1%)	88,180(22.7%)	79,133(24.7%

Shandong	106,531(27.6%)	71,119(19.7%)	79,506(21.2%)	72,824(19.2%)	75,757(19.5%)	47,317(14.8%
Total China domestic squid harvest	**385,845**	**361,058**	**374,727**	**380,105**	**388,634**	**320,199**

FRA suggests that overfishing is occurring to the stock spawned in the East China Sea, which is caught by Japanese vessels mainly in Pacific Ocean. The FRA has established an F_{MED} reference point for each stock, whic is the fishing level at which the stock is able to replace itself given the spawning-recruitment survival ratio (Cad and Mahon 1995). For this stock, the F_{MED} is 0.38 and current fishing mortality ($F_{CURRENT}$) is 0.39 (Kaga et al. 2018). The $F_{CURRENT}$ is cumulative for both the Japanese and Republic of Korea Japanese flying squid fisheries, because the FRA also collects catch statistics from the Republic of Korea. Based on simulation models, the FRA predicts that the biomass of this stock is below B_{LIMIT} and will keep declining if the current rate of fishing mortality continues for the next 5 years, and only 13% chance for this stock to be above the B_{LIMIT} 5 years later

Criterion 2: Impacts on Other Species

All main retained and bycatch species in the fishery are evaluated under Criterion 2. Seafood Watch defines bycatch as all fisheries-related mortality or injury to species other than the retained catch. Examples include discards, endangered or threatened species catch, and ghost fishing. Species are evaluated using the same guidelines as in Criterion 1. When information on other species caught in the fishery is unavailable, the fishery's potential impacts on other species is scored according to the Unknown Bycatch Matrices, which are based on a synthesis of peer-reviewed literature and expert opinion on the bycatch impacts of each gear type. The fishery is also scored for the amount of non-retained catch (discards) and bait use relative to the retained catch. To determine the final Criterion 2 score, the score for the lowest scoring retained/bycatch species is multiplied by the discard/bait score. The Criterion 2 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and ≤=3.2=Yellow or Moderate Concern*
- *Score ≤=2.2=Red or High Concern*

Rating is Critical if Factor 2.3 (Fishing Mortality) is Crtitical

Guiding Principles

- *Ensure all affected stocks are healthy and abundant.*
- *Fish all affected stocks at sustainable level.*
- *Minimize bycatch.*

Criterion 2 Summary

Only the lowest scoring main species is/are listed in the table and text in this Criterion 2 section; a full list and assessment of the main species can be found in Appendix A.

JAPANESE FLYING SQUID China | Midwater Trawls | Winter Cohort					
Subscore:	**1.000**	**Discard Rate:**	**1.00**	**C2 Rate:**	**1.000**

Species | Stock	Abundance	Fishing Mortality	Subscore
Smooth hammerhead	1.00:High Concern	1.00:High Concern	Red (1.000)
Japanese anchovy	2.33:Moderate Concern	1.00:High Concern	Red (1.526)
Japanese seer	2.33:Moderate Concern	1.00:High Concern	Red (1.526)
Pacific chub mackerel	2.33:Moderate Concern	1.00:High Concern	Red (1.526)
Silver pomfret	2.33:Moderate Concern	3.00:Moderate Concern	Yellow (2.644)

Bycatch is a high concern in the trawl fishery due to the low selectivity of this fishing gear. Fishermen usually retain all economically valuable species, however generally there is no regular bycatch data collection in China. The fieldwork conducted by SMRERI in fall 2017 provided some qualitative information, which indicated that bycatch species of JFS trawl fishery in north Yellow Sea mainly consisted of Japanese Spanish mackerel (*Scomberomorus niphonius*), Japanese anchovy (*Engraulis japonicus*), Largehead hairtail (*Trichiurus lepturus*), and Pacific chub mackerel (*Scomber japonicus*), with some other species such as Silver pomfret (*Pampus argenteus*), Yellowtail amberjack (*Seriola lalandi*), Yellow goose fish (*Lophius litulon*), Alaska pollock (*Theragra* *chalcogramma*) also observed (Table 2) (Fang and Drugan 2018). Some of these bycatch species can be confirmed through some published studies, which indicate that the predominant species during the JFS harvesting time in north Yellow Sea including Japanese anchovy, Japanese Spanish mackerel and Pacific chub mackerel and Silver pomfret (Lv, Li et al. 2011, Chen 2017). Additionally, the incidence of ETP species such as smooth hammerhead shark (*Sphyrna zygaena*) has been confirmed (Fang and Drugan 2018). Therefore, the above 5 species are considered in the assessment.

Table 2. Bycatch species observed in Japanese flying squid landings monitored by SMRERI in fall 2017 in Shidao. (edited according to Fang and Drugan 2018)

中文名	**English Common Names**	**Scientific Name**	ETP species
蓝点马鲛	Japanese seer	*Scomberomorus niphonius*	No
日本鳀鱼	Japanese anchovy	*Engraulis japonicus*	No
带鱼	Largehead hairltail (or ribbon fish)	*Trichiurus lepturus*	No
日本鲐	Pacific chub mackerel	*Scomber japonicus*	No
银鲳鱼	Silver pomfret	*Pampus argenteus*	No
黄条鰤	Yellowtail amberjack	*Seriola lalandi (prev. S. aureovittata)*	No
鲯鳅鱼	Dolphinfish	*Coryphaena hippurus*	No
鮟鱇鱼	Yellow goose fish (or monkfish)	*Lophius litulon*	No
狭鳕鱼	Alaska pollock	*Theragra chalcogramma*	No
锤头双髻鲨	Smooth hammerhead shark	*Sphyrna zygaena*	Cites II

For most of the assessed species there is no available reference points to evaluate the stock abundance and fishing mortality, however, several affected stocks are generally not in good condition, which can be confirmed by related studies. The data-limited method PSA was applied to determine the scores for the several species stocks.

Criterion 2 Assessment

SCORING GUIDELINES

Factor 2.1 - Abundance

(same as Factor 1.1 above)

Factor 2.2 - Fishing Mortality

(same as Factor 1.2 above)

SMOOTH HAMMERHEAD

Factor 2.1 - Abundance

CHINA
Midwater Trawls

High Concern

Smooth hammerhead shark is currently assessed as Vulnerable globally by IUCN (IUCN 2005). There is no stock assessment for this species in the assessed region, and reliable species-specific data on the smooth hammerhead shark are extremely limited globally (Miller MH 2016). As this species is a highly vulnerable species according to SFW criteria, and studies suggest that the global population of smooth hammerhead sharks has likely experienced a decline, this factor of smooth hammerhead shark is of "High Concern" (Miller MH 2016).

Factor 2.2 - Fishing Mortality

CHINA
Midwater Trawls

High Concern

The fishing mortality of smooth hammerhead shark stock around Chinese waters is unknown because none reference points are available for this species (Miller MH 2016). Applied UBM suggests that the fishing mortality of bottom or midwater trawlers in Northwest Pacific is score with 1 for shark. Therefore this factor receives a score of "High Concern".

Factor 2.3 - Modifying Factor: Discards and Bait Use

Goal: Fishery optimizes the utilization of marine and freshwater resources by minimizing post-harvest loss. For fisheries that use bait, bait is used efficiently.

Scoring Guidelines: The discard rate is the sum of all dead discards (i.e. non-retained catch) plus bait use divided by the total retained catch.

RATIO OF BAIT + DISCARDS/LANDINGS	FACTOR 2.3 SCORE
<100%	1
>=100	0.75

CHINA
Midwater Trawls

< 100%

In order to protect juvenile fish, China has enacted a series of regulations prohibiting the juvenile fish of 15 species from being caught and landed (MOA 2018b). For this reason, part of the capture may be thrown away on the sea (Tang Y et al. 2009). There is no available data about the discards in JFS trawl fishery, but the discard rate of Chinese fishery is estimated to be 0.5%, which indicates that the low discards rate in Chinese fishery (FAO 2019b). According to the findings of Greenpeace, the low value feed fish, which is also called trash fish with small size, accounts for 49% of the total catch in Chinese trawl fishery (Greenpeace 2017) (Tang Y et al. 2009). This suggests that almost all species caught in Chinese trawl fishery are retained regardless of its economic value. Therefore, the discards of JFS trawl fishery is considered small percentage.

Criterion 3: Management Effectiveness

Five factors are evaluated in Criterion 3: Management Strategy and Implementation, Bycatch Strategy, Scientific Research/Monitoring, Enforcement of Regulations, and Inclusion of Stakeholders. Each is scored as either 'highly effective', 'moderately effective', 'ineffective,' or 'critical'. The final Criterion 3 score is determined as follows:

- *5 (Very Low Concern) — Meets the standards of 'highly effective' for all five factors considered.*
- *4 (Low Concern) — Meets the standards of 'highly effective' for 'management strategy and implementation' and at least 'moderately effective' for all other factors.*
- *3 (Moderate Concern) — Meets the standards for at least 'moderately effective' for all five factors.*
- *2 (High Concern) — At a minimum, meets standards for 'moderately effective' for Management Strategy and Implementation and Bycatch Strategy, but at least one other factor is rated 'ineffective.'*
- *1 (Very High Concern) — Management Strategy and Implementation and/or Bycatch Management are 'ineffective.'*
- *0 (Critical) — Management Strategy and Implementation is 'critical'.*

The Criterion 3 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and ≤3.2=Yellow or Moderate Concern*
- *Score ≤2.2 = Red or High Concern*

Rating is Critical if Management Strategy and Implementation is Critical.

GUIDING PRINCIPLE

- The fishery is managed to sustain the long-term productivity of all impacted species.

Criterion 3 Summary

Fishery	Management Strategy	Bycatch Strategy	Research and Monitoring	Enforcement	Stakeholder Inclusion	Score
Fishery 1: China | Midwater trawls	Ineffective	Ineffective				Red (1.000)

Criterion 3 Assessment

Factor 3.1 - Management Strategy and Implementation

Considerations: What type of management measures are in place? Are there appropriate management goals, and is there evidence that management goals are being met? Do manages follow scientific advice? To achieve a highly effective rating, there must be appropriately defined management goals, precautionary policies that are based on scientific advice, and evidence that the measures in place have been successful at maintaining/rebuilding species.

CHINA
Midwater Trawls

Ineffective

There is no specific regulation for JFS fishery operation or resource management plan established for the fishery of *T. pacificus*, however the domestic squid fisheries are subject to the general management strategies. The fishery is under Chinese jurisdiction and fishing activities are generally under the management of Ministry of Agriculture and Rural Affairs (MOA), while the fishery management strategies are mainly developed by the National Fishery Bureau of MOA, with local authorities at each level implementing and enforcing these strategies (Chinese Fisheries Law 2013). Some of the measures are implemented strictly in a large scale such as summer fishing moratorium, which covers the entire Chinese coastal waters including *T. pacificus* fishery, while the others such as marine protected areas, TACs are not implemented in the assessed fishery. Generally, the implementing status of management strategies are not regularly updated by the authorities, with some information available on the website occasionally.

Due to the shortage of specific management strategies for the assessed fisheries, and the insufficient information about the implementation of fisheries management strategies, this factor is assessed as ineffective.

Justification:

The general coastal fishery management system consists of several components, including fishing licensing system, fishing input controls, etc. Regular inspection is undertaken by fisheries enforcement to ensure that fishery operations run legally (Chinese Fisheries Law 2013). For resource conservation, a series of management measures are developed, such as the summer fishing moratorium (from May 1st to September 1st in north Yellow Sea), marine protected areas, minimum mesh size, fishing gear requirements, stock enhancement and total marine fisheries production restriction (MOA 2013). These strategies are developed generally for the whole coastal fishery, instead of any specific species. Some measures are defined specifically for some species, for example the minimum capture size limits are set for 15 economically valuable species (MOA 2018b), but currently there is no such limit for *T. pacificus*. TACs are under pilot stage for some species. Ecosystem based management is recognized and under development but has not been widely applied for instructing the fishery management in China.

For the assessed species, some of the above management measures are applied. The fishing gear type and mesh size is regulated, and some area on the migration routes of *T. pacificus* are protected, which can be confirmed from figure 9, where the left panel depicts the main Japanese flying squid fishing grounds in China, and the right panel shows the marine protected areas (The State Council 2011). Vessel monitoring system (VMS) is required to be installed for each overseas fishing vessel, and some regions also apply the system for coastal fishing vessels (MOA 2017a). Additionally, the fishery for *T. pacificus* also complies with the regulations of summer fishing moratorium, which requires a halt in all types of fishing gear except hook and line for three or four months with variations according to the location and type of fishing. The fishery targeting *T. pacificus* with trawl in Yellow Sea and East China Sea are banned for about four months (MOA 2017b). The summer fishing moratorium is believed to be effective to conserve the fishery resources in Chinese coastal waters, as it precludes the Chinese fishing vessels from legal fishery access in the spawning season of most of the economically important species. It should be noted that the time of summer fishing moratorium highly overlaps with the time of *T. pacificus* winter stock's northerly migration along the Chinese coastal waters (from May to October), which also precludes Chinese fishing vessels from access to *T. pacificus* during this period (Fang Q and Jocelyn D 2018). However, the fishing effort for *T. pacificus* after that is unknown, given the absence of catch limit for this species, with only a rough capture volume reported by each fishing vessel, leading to the uncertainty of the conservation measures. Even though some research institutes and local government, such as Shandong Marine Resource and Environment Research Institute (SMRERI), have started to conduct resource survey and data collection, there is no systematic research and data update for *T. pacificus* right now. In the published statistics, only a total number of all squid species is available (MOA 2012-2018). Harvest control rules and reference points are not defined for the resource management of this species. Fishing quota systems have been considered to provide output controls via development of TACs (total allowable catch), but these have not been implemented to squid fishery yet, and it's considered challenging for lacking fishery related data at current stage.

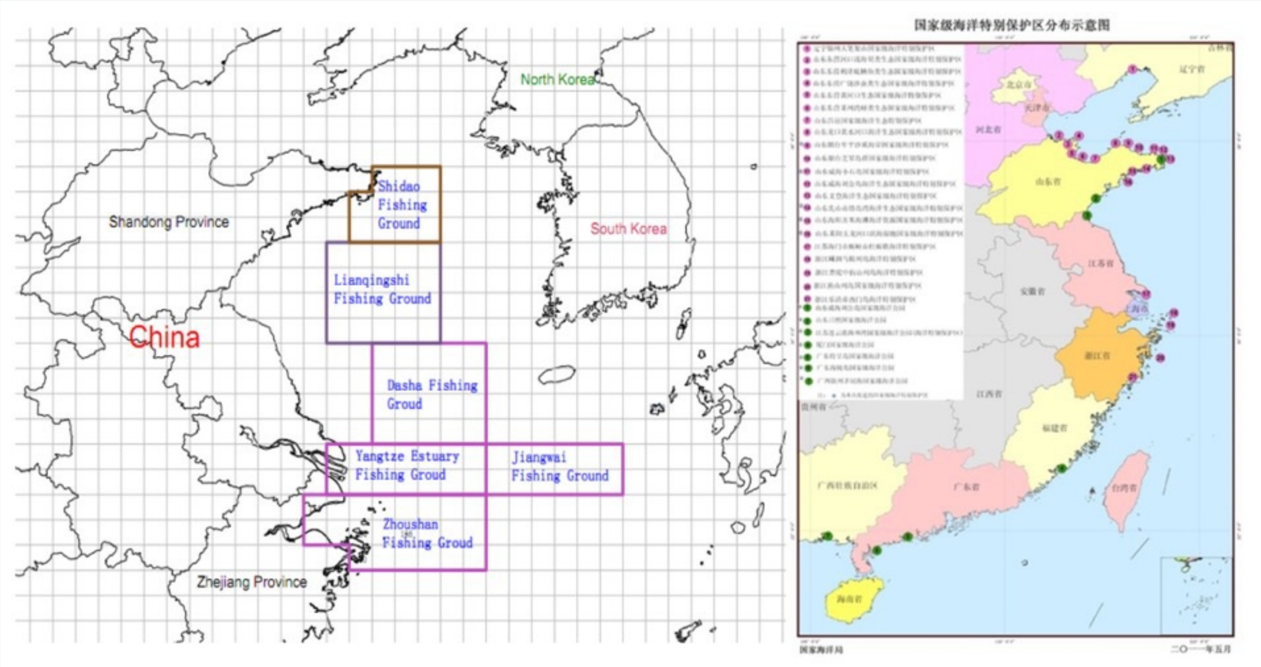

Figure 9 Main Japanese flying squid fishing grounds within China's EEZ (left panel) (Q. Fang & Jocelyn, 2018); Distribution of MPAs in China's coastal waters (right panel) (Council, 2011)

The implementation and enforcement are undertaken by local authorities at each level. Though the execution is improving in the past years, the implementation effectiveness varies by the region, and illegal fishing is still happening. Summer fishing moratorium is implemented strictly in entire Chinese coastal waters including *T. pacificus* fishery, and the government inputs a lot of efforts to make sure the effectiveness. However, the implementing status of management strategies are not regularly updated by the authorities, with some information available on the MOA website about the related activities at each local level. Illegal fishing is often published by the authorities, including illegal gear usage and catches of illegal or undersized species (Yu H and Yu Y. 2008), and illegal fishing during the fishing moratorium. According to the published information, we can draw a conclusion that some illegal, unreported and unregulated (IUU) fishing continues to occur. For example, 16 vessels were identified continuing to fish for squid during the first two months of summer fishing closure in Rongcheng in 2018, which is close to the main JFS fishing grounds in Shandong province (Sohu 2018). However, the detailed information such as the species targeted is usually not clearly described.

Given that the management measures are not sufficient and precautionary enough for Japanese flying squid fishery, and information regarding to the implementation status is not regularly updated, this factor is considered ineffective.

Factor 3.2 - Bycatch Strategy

Considerations: What type of management strategy/measures are in place to reduce the impacts of the fishery on bycatch species and when applicable, to minimize ghost fishing? How successful are these management measures? To achieve a Highly Effective rating, the fishery must have no or low bycatch, or if there are bycatch or ghost fishing concerns, there must be effective measures in place to minimize impacts.

CHINA
Midwater Trawls

Ineffective

Due to the insufficient strategy for avoiding contact with bycatch species and limited access to the information, the bycatch strategy of this fishery is considered "ineffective".

Justification:

As a non-selective fishing gear, the trawl fishery has a high risk of bycatch. However, management measures for the bycatch are generally missing in China, which indicates the insufficient management for the bycaught species.

Some measures are in place to mitigate the impact to resources caused by trawl fisheries such as the regulated mesh size, but there are no specific measures for Japanese flying squid fishery. According to the fishing licensing regulations published by MOA, bottom trawl fishery is not allowed within some coastal waters (MOA 2014), which should be useful to reduce the bycatch in shallow waters. Also the regulations for minimum catch size of some economically important species, such as Largehead hairtail (*Trichiurus lepturus*), Japanese Spanish mackerel (*Scomberomorus niphonius*), Silver pomfret (*Pampus argenteus*), which are found in the Japanese flying squid fishery landings in Shidao, Shandong Province (Fang Q and Jocelyn D 2018), are applied to reduce the capture of juveniles of these species (MOA 2018b). For ETP species, smooth hammerhead shark is confirmed to occur in the landings in this fishery. There are some regulations in place to protect ETP species (Chinese Fisheries Law 2013), which generally follow the international regulations. However, the protection measures in the coastal fisheries, especially trawl fisheries are considered insufficient to reduce the contact with these concerned species such as sharks. Additionally, the implementing information of these strategies is not regularly published by the responsible authorities.

Factor 3.3 - Scientific Research and Monitoring

Considerations: How much and what types of data are collected to evaluate the fishery's impact on the species? Is there adequate monitoring of bycatch? To achieve a Highly Effective rating, regular, robust population assessments must be conducted for target or retained species, and an adequate bycatch data collection program must be in place to ensure bycatch management goals are met.

Factor 3.4 - Enforcement of Management Regulations

Considerations: Do fishermen comply with regulations, and how is this monitored? To achieve a Highly Effective rating, there must be regular enforcement of regulations and verification of compliance.

Factor 3.5 - Stakeholder Inclusion

Considerations: Are stakeholders involved/included in the decision-making process? Stakeholders are individuals/groups/organizations that have an interest in the fishery or that may be affected by the management of the fishery (e.g., fishermen, conservation groups, etc.). A Highly Effective rating is given if the management process is transparent, if high participation by all stakeholders is encouraged, and if there a mechanism to effectively address user conflicts.

Criterion 4: Impacts on the Habitat and Ecosystem

This Criterion assesses the impact of the fishery on seafloor habitats, and increases that base score if there are measures in place to mitigate any impacts. The fishery's overall impact on the ecosystem and food web and the use of ecosystem-based fisheries management (EBFM) principles is also evaluated. Ecosystem Based Fisheries Management aims to consider the interconnections among species and all natural and human stressors on the environment. The final score is the geometric mean of the impact of fishing gear on habitat score (factor 4.1 + factor 4.2) and the Ecosystem Based Fishery Management score. The Criterion 4 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and ≤3.2=Yellow or Moderate Concern*
- *Score ≤2.2=Red or High Concern*

GUIDING PRINCIPLES

- Avoid negative impacts on the structure, function or associated biota of marine habitats where fishing occurs.
- Maintain the trophic role of all aquatic life.
- Do not result in harmful ecological changes such as reduction of dependent predator populations, trophic cascades, or phase shifts.
- Ensure that any enhancement activities and fishing activities on enhanced stocks do not negatively affect the diversity, abundance, productivity, or genetic integrity of wild stocks.
- Follow the principles of ecosystem-based fisheries management.

Rating cannot be Critical for Criterion 4.

Criterion 4 Summary

Region | Method	Gear Type and Substrate	Mitigation of Gear Impacts	EBFM	Score
China | Midwater trawls	2	0	High Concern	Red (2.000)

Criterion 4 Assessment

SCORING GUIDELINES

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate

Goal: The fishery does not adversely impact the physical structure of the ocean habitat, seafloor or associated biological communities.

- *5 - Fishing gear does not contact the bottom*
- *4 - Vertical line gear*
- *3 - Gears that contacts the bottom, but is not dragged along the bottom (e.g. gillnet, bottom longline, trap) and is not fished on sensitive habitats. Or bottom seine on resilient mud/sand habitats. Or midwater trawl that is known to contact bottom occasionally. Or purse seine known to commonly contact the bottom.*
- *2 - Bottom dragging gears (dredge, trawl) fished on resilient mud/sand habitats. Or gillnet, trap, or bottom longline fished on sensitive boulder or coral reef habitat. Or bottom seine except on mud/sand. Or there is known trampling of coral reef habitat.*

- *1 - Hydraulic clam dredge. Or dredge or trawl gear fished on moderately sensitive habitats (e.g., cobble or boulder)*
- *0 - Dredge or trawl fished on biogenic habitat, (e.g., deep-sea corals, eelgrass and maerl)*
  Note: When multiple habitat types are commonly encountered, and/or the habitat classification is uncertain, the score will be based on the most sensitive, plausible habitat type.

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts

Goal: Damage to the seafloor is mitigated through protection of sensitive or vulnerable seafloor habitats, and limits on the spatial footprint of fishing on fishing effort.

- *+1 —>50% of the habitat is protected from fishing with the gear type. Or fishing intensity is very low/limited and for trawled fisheries, expansion of fishery's footprint is prohibited. Or gear is specifically modified to reduce damage to seafloor and modifications have been shown to be effective at reducing damage. Or there is an effective combination of 'moderate' mitigation measures.*
- *+0.5 —At least 20% of all representative habitats are protected from fishing with the gear type and for trawl fisheries, expansion of the fishery's footprint is prohibited. Or gear modification measures or other measures are in place to limit fishing effort, fishing intensity, and spatial footprint of damage caused from fishing that are expected to be effective.*
- *0 —No effective measures are in place to limit gear impacts on habitats or not applicable because gear used is benign and received a score of 5 in factor 4.1*

Factor 4.3 - Ecosystem-Based Fisheries Management

Goal: All stocks are maintained at levels that allow them to fulfill their ecological role and to maintain a functioning ecosystem and food web. Fishing activities should not seriously reduce ecosystem services provided by any retained species or result in harmful changes such as trophic cascades, phase shifts or reduction of genetic diversity. Even non-native species should be considered with respect to ecosystem impacts. If a fishery is managed in order to eradicate a non-native, the potential impacts of that strategy on native species in the ecosystem should be considered and rated below.

- *5 — Policies that have been shown to be effective are in place to protect species' ecological roles and ecosystem functioning (e.g. catch limits that ensure species' abundance is maintained at sufficient levels to provide food to predators) and effective spatial management is used to protect spawning and foraging areas, and prevent localized depletion. Or it has been scientifically demonstrated that fishing practices do not have negative ecological effects.*
- *4 — Policies are in place to protect species' ecological roles and ecosystem functioning but have not proven to be effective and at least some spatial management is used.*
- *3 — Policies are not in place to protect species' ecological roles and ecosystem functioning but detrimental food web impacts are not likely or policies in place may not be sufficient to protect species' ecological roles and ecosystem functioning.*
- *2 — Policies are not in place to protect species' ecological roles and ecosystem functioning and the likelihood of detrimental food impacts are likely (e.g. trophic cascades, alternate stable states, etc.), but conclusive scientific evidence is not available for this fishery.*
- *1 — Scientifically demonstrated trophic cascades, alternate stable states or other detrimental food web impact are resulting from this fishery.*

Factor 4.1 - Physical Impact of Fishing Gear on the Habitat/Substrate

CHINA
Midwater Trawls

2

JFS demonstrates daily vertical migrations, inhabiting mid to bottom depths during the day and moving up toward surface depths at night (Science L 2019). The fishing behaviors are adapted to have higher efficiency by using bottom-oriented trawling during the daytime and pelagic trawling at nighttime. The paired trawlers are identified as the primary fishing gear for JFS in Yellow Sea (Fang Q and Jocelyn D 2018). The horizontal opening of paired trawler is maintained by the distance between the two towing vessels, while the vertical opening is obtained with the floats and weights on the groundrope (FAO 2019c). Therefore, the operating depth of paired trawler can be adjusted easily, which means it is able to avoid the contact with substrates. Additionally, trawls designed for squid fishing generally have a higher head rope than would be usual for finfish (FAO 2005). However, as JFS inhabits in deeper water during the day, the trawlers are considered to be demersally operated, which can still cause the risk of contact with the substrates. The average depth of Yellow Sea is only 44 meters on average, with a maximum of 152 meters, which is also of concern that the paired trawlers are likely to have contact with the bottom (You Z et al. 2017) (Wikipedia 2019d). Limited information is known about the impacts of JFS fishery has had on the substrates in Yellow Sea since the related research is generally lacking, but it's believed that trawler can cause more turbulence on the substrate comparing to the other fishing gears such as jigger, and potential bottom contact by the JFS fishery has been identified based on the incidence of some demersal species such as yellow goose fish (*Lophius litulon*) in the catch (Fang Q and Jocelyn D 2018). Therefore, it is considered likely that this fishery has direct contact with the benthos and causes some disturbance. For this reason, this factor receives a score of 2.

Factor 4.2 - Modifying Factor: Mitigation of Gear Impacts

CHINA
Midwater Trawls

0

In China, minimal mitigation is in place. Currently, 1.75% of Yellow Sea Large Marine Ecosystem (YSLME) is protected (Heileman S and Jiang Y 2019), which means fisheries are banned or regulated in the protected areas. The YSLME Project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Office for Project Services (UNOPS), is also actively supporting the creation of marine protected areas (MPAs) (UNDP/UNOPS 2018). However, the overlap of the MPAs and the JFS fishing grounds are not known. Fishing effort including vessel capacity and vessel number is controlled by the government, although overcapitalization is still present. Bottom trawlers are forbidden to operate in the nearshore waters (MOA 2018a). Gear modifications for mitigating the gear impacts on sea bed are generally lacking, while some studies about improving selectivity exist (You Z et al. 2017). Since there are no definitely effective mitigation measures, this factor is deemed a score of 0.

Factor 4.3 - Ecosystem-Based Fisheries Management

CHINA
Midwater Trawls

High Concern

The concept of ecosystem-based management is becoming well-known and in development in China. However, the poor data collection along with the insufficient scientific research and monitoring in Chinese fisheries makes it difficult to implement ecosystem-based fishery management (Wang G and Guo P 2014). For the assessed fishery, the assessment acknowledged that how varying levels of exploitation would impact the food web is unknown.

Japanese flying squid is one of the key prey for some species, including Pacific chub mackerel, Japanese amberjack (*Seriola quinqueradiata*), sharks and dolphins etc., and it is also an opportunistic feeders focusing upon Japanese anchovy, Pacific saury (*Cololabis saria*), pelagic crustaceans, etc. (Fang Z and Chen X 2018). As a result, the capture of JFS could have influence on the predation and population of these species. However currently there is no definite evidence demonstrates the fishery has detrimental impacts on the food web, given the lack of ecosystem-based studies, and the great fluctuations of its stock abundance over years. The management without sufficient consideration of the ecosystem impacts may cause the misunderstanding of the stock variation of other species, especially those who have links with Japanese flying squid in the food chain.

Given that the ecosystem perspective has not been included in the management of this fishery in China, and the uncertainty of this species' impacts on food web, ecosystem-based fisheries management is considered to be of "High Concern” for this fishery.

Acknowledgements

Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Seafood Watch would like to thank the consulting researcher and author of this report, Lu Fang, as well as Dr. Zhou Fang of Shangai Ocean University for graciously reviewing this report for scientific accuracy.

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Appendix A: Extra By Catch Species

SILVER POMFRET

Factor 2.1 - Abundance

CHINA
Midwater Trawls

Moderate Concern

According to the PSA score= 2.64, and combining the available information about the stock, this factor is scored as "Moderate Concern".

Justification:

There is no abundance estimation of silver pomfret stock in Yellow Sea, but some research indicates that the resource in 2007 has shrunk by more than half compared with 1984 (Xu Y et al. 2009). A PSA was used to determine the score.

Productivity Attribute	Relevant Information	Score (1 = low risk, 2 = medium risk, 3 = high risk)
Average age at maturity	1 year (Zeng L et al. 2005)	1 (<5 years.)
Average maximum age	6 years (Zheng Y et al. 2014)	1 (<10 years.)
Fecundity	Varies a lot among individuals, 18,000~240,000 eggs (Zeng L et al. 2005)	1 (>20,000 eggs per year)
Average maximum size	About 28 cm (Zheng Y et al. 2014)	1 (< 100 cm)
Average size at maturity	About 15 cm (Zheng Y et al. 2014)	1 (<40 cm)
Reproductive strategy	Broadcast spawner	1 (Broadcast spawner)
Trophic level	3.6 (Yang J 2001)	3 (>3.25)
Quality of Habitat	Habitat is considered to be robust to human activities	1 (Habitat no known degradation from non-fishery impacts
Productivity		1.25

Susceptibility Attribute	Relevant Information	Score (1 = low risk, 2 = medium risk, 3 = high risk)

Areal overlap (Considers all fisheries)	No precise data available. Chinese JFS fishing grounds include Yellow Sea, northern East China Sea and part of waters in Sea of Japan, which highly likely cover more than 30% of the species concentration.	3 (Default score)
Vertical overlap (Considers all fisheries)	Silver pomfret distributed in the depth between 5 – 110 meters (Fishbase 2019), which has high chance to encounter the JFS fishery.	3 (High degree of overlap between fishing depths and depth range of species)
Selectivity of fishery (Specific to fishery under assessment)	Trawl is not a selective gear and silver pomfret is one of the target species of Chinese trawl fishery in Yellow Sea. But it's not considered "high risk" in this fishery.	2
Post-capture mortality (Specific to fishery under assessment)	Almost all fish are retained	3 (Retained species)
Susceptibility		2.325

Factor 2.2 - Fishing Mortality

CHINA
Midwater Trawls

Moderate Concern

Silver pomfret is one of the main target species in the Chinese gillnet and stow net fishery, and trawlers can also harvest it as bycatch (Zheng Y et al. 2014). However, levels of fishing mortality are unknown for this species in Yellow Sea due to the limited information. Therefore a "Moderate Concern" is scored for this factor.

Factor 2.3 - Discard Rate

CHINA
Midwater Trawls

< 100%

In order to protect juvenile fish, China has enacted a series of regulations prohibiting the juvenile fish of 15 species from being caught and landed (MOA 2018b). For this reason, part of the capture may be thrown away on the sea (Tang Y et al. 2009). There is no available data about the discards in JFS trawl fishery, but the discard rate of Chinese fishery is estimated to be 0.5%, which indicates that the low discards rate in Chinese fishery (FAO 2019b). According to the findings of Greenpeace, the low value feed fish, which is also called trash fish with small size, accounts for 49% of the total catch in Chinese trawl fishery (Greenpeace 2017)

(Tang Y et al. 2009). This suggests that almost all species caught in Chinese trawl fishery are retained regardless of its economic value. Therefore, the discards of JFS trawl fishery is considered small percentage.

JAPANESE ANCHOVY

Factor 2.1 - Abundance

CHINA
Midwater Trawls

Moderate Concern

PSA score = 2.70, leading to "Moderate Concern" of this factor, which is appropriate according to the available information.

Justification:

Iversen et al. has studied about population dynamics and biomass estimation for Japanese anchovy stock in Yellow Sea based on the surveys during the period January 1985 to January 1990 (Iversen S et al. 1993). The winter stock biomass was estimated to be 400,000 tons in 2000/2001, while the stock declined to 110,000 tons in 2003, indicating the downsizing of the population (Fig.7) (Zhao X 2006). The estimation of its biomass using acoustic data conducted in 2010 concluded that the stock is at low-age state, implying the accelerated growth rate, and the results showed that the stock abundance is at low level (Zhang J 2011). However, there is no recent abundance estimation available, and no evidence suggests that reference points are currently used for Japanese anchovy resource management, causing the difficulty evaluating the current stock abundance. Therefore the PSA was used to assess the vulnerability and susceptibility of this species to fishery.

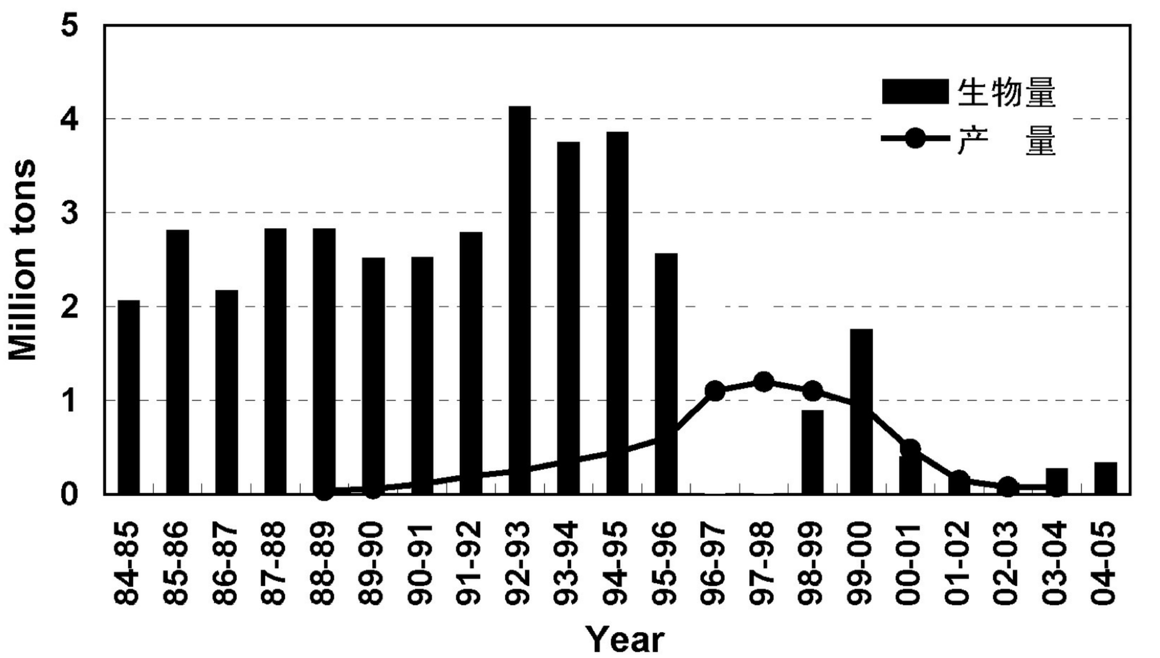

Figure 5 Biomass and capture of Japanese anchovy.(Zhao, 2006)

Productivity Attribute	Relevant Information	Score (1 = low risk, 2 = medium risk, 3 = high risk)

Average age at maturity	1 year (Zheng Y et al. 2014)	1 (<5 years.)
Average maximum age	4 years (Zheng Y et al. 2014)	1 (<10 years.)
Fecundity	7,500~14,800 eggs (Zheng Y et al. 2014)	2 (100-20,000 eggs per year)
Average maximum size	17 cm (Zhang J 2011)	1 (< 100 cm)
Average size at maturity	About 6 cm (Zheng Y et al. 2014)	1(<40 cm)
Reproductive strategy	Broadcast spawner (59baike 2019)	1 (Broadcast spawner)
Trophic level	3.38 (Lin Q 2012)	3 (>3.25)
Quality of Habitat	Habitat is considered to be robust to human activities	1 (Habitat no known degradation from non-fishery impacts
Productivity		1.375

Susceptibility Attribute	**Relevant Information**	**Score (1 = low risk, 2 = medium risk, 3 = high risk)**
Areal overlap (Considers all fisheries)	No precise data available. Chinese JFS fishing grounds include Yellow Sea, northern East China Sea and part of waters in Sea of Japan, which highly likely cover more than 30% of the species concentration. Additionally, as one of the main prey of JFS, Japanese anchovy is considered easily caught by JFS trawl fishery (Fang Z and Chen X 2018).	3 (Default score)
Vertical overlap (Considers all fisheries)	Japanese anchovy is distributed in the depth between 0 – 200 meters (Wikipedia 2019a), which has high chance to encounter the JFS fishery.	3 (High degree of overlap between fishing depths and depth range of species)
Selectivity of fishery (Specific to fishery under assessment)	Trawl is not a selective gear and Japanese anchovy is one of the main target species of Chinese paired trawl fishery in Yellow Sea.	2

Post-capture mortality (Specific to fishery under assessment)	Almost all fish are retained.	3 (Retained species)
Susceptibility		2.325

Factor 2.2 - Fishing Mortality

CHINA
Midwater Trawls

High Concern

Catch data are available but the fishing mortality of recent years is unknown. Since the stock abundance is at a low level, but the capture since 2009 show upward trends (Fig. 8), overfishing is considered happening. Therefore, the fishing mortality is of high concern.

Justification:

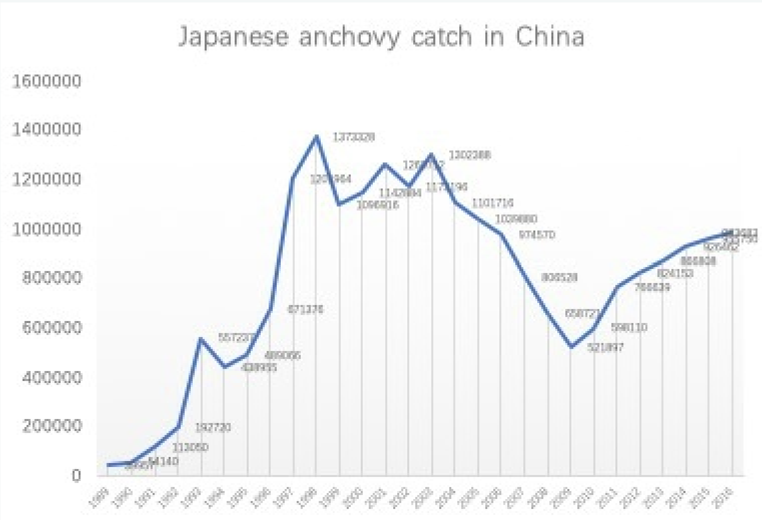

Figure 6 Annual catch of Japanese anchovy (FAO, FishstatJ.)

Factor 2.3 - Discard Rate

CHINA
Midwater Trawls

< 100%

In order to protect juvenile fish, China has enacted a series of regulations prohibiting the juvenile fish of 15 species from being caught and landed (MOA 2018b). For this reason, part of the capture may be thrown away on the sea (Tang Y et al. 2009). There is no available data about the discards in JFS trawl fishery, but the discard rate of Chinese fishery is estimated to be 0.5%, which indicates that the low discards rate in Chinese fishery (FAO 2019b). According to the findings of Greenpeace, the low value feed fish, which is also called trash fish with small size, accounts for 49% of the total catch in Chinese trawl fishery (Greenpeace 2017) (Tang Y et al. 2009). This suggests that almost all species caught in Chinese trawl fishery are retained regardless of its economic value. Therefore, the discards of JFS trawl fishery is considered small percentage.

JAPANESE SEER

Factor 2.1 - Abundance

CHINA
Midwater Trawls

Moderate Concern

PSA score=2.70, so the abundance is of "Moderate Concern", which is considered appropriate according to the available information.

Justification:

No recent stock assessment for Japanese seer exists. Though the recruitment showed upward trends according to the research of its spawning-recruitment relationship (Fig. 5), the information have not been updated since 2009 (Sun B 2009). Additionally, some changes of biological characteristics appear, such as earlier sexual maturity, smaller maturity size, which imply the stock status is of concern. As the current stock abundance is unknown, PSA was used to assess this factor.

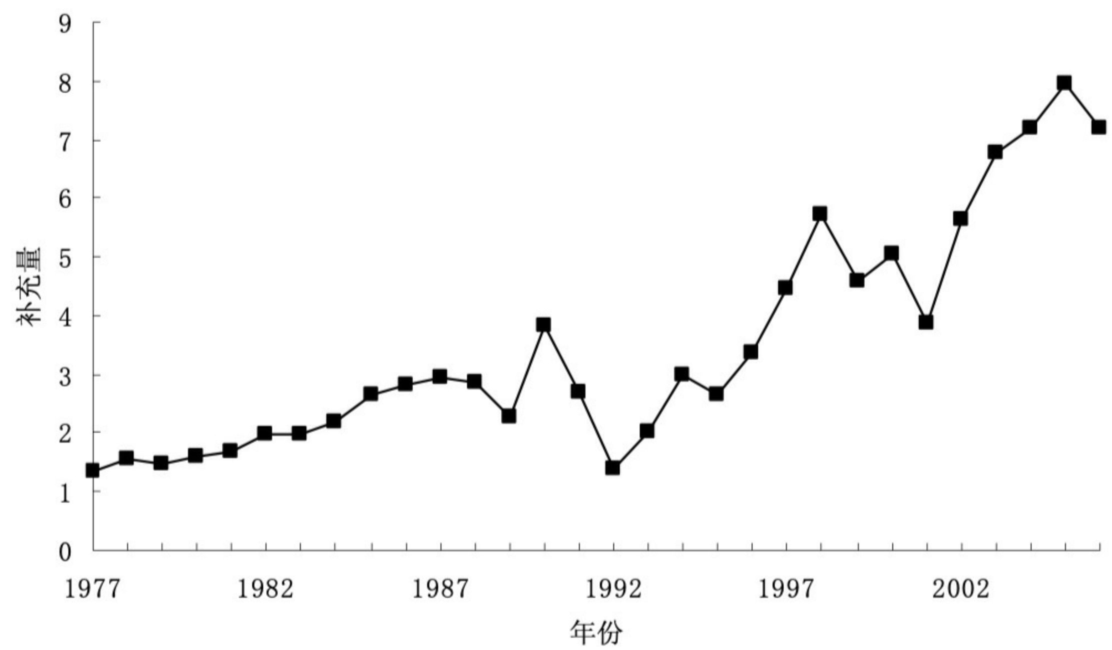

Figure 7 The recruitment of Japanese Spanish mackerel.(Sun, 2009)

Productivity Attribute	Relevant Information	Score (1 = low risk, 2 = medium risk, 3 = high risk)

Average age at maturity	2 year (Zheng Y et al. 2014)	1 (<5 years.)
Average maximum age	6 years (Zheng Y et al. 2014)	1 (<10 years.)
Fecundity	Varies a lot among individuals, 45,000~5,257,000 eggs (Zheng Y et al. 2014)	1 (>20,000 eggs per year)
Average maximum size	71 cm (Zheng Y et al. 2014)	1 (< 100 cm)
Average size at maturity	About 41 cm (Zheng Y et al. 2014)	2 (40 -200 cm)
Reproductive strategy	Broadcast spawner (Zhihuisannong 2019)	1 (Broadcast spawner)
Trophic level	3.82 (Lin Q 2012)	3 (>3.25)
Quality of Habitat	Habitat is considered to be robust to human activities	1 (Habitat no known degradation from non-fishery impacts
Productivity		1.375

Susceptibility Attribute	**Relevant Information**	**Score (1 = low risk, 2 = medium risk, 3 = high risk)**
Areal overlap (Considers all fisheries)	No precise data available. Chinese JFS fishing grounds include Yellow Sea, northern East China Sea and part of waters in Sea of Japan, which highly likely cover more than 30% of the species concentration.	3 (Default score)
Vertical overlap (Considers all fisheries)	Japanese seer is distributed in the depth between 5 – 50 meters (Wikipedia 2019b), which has high chance to encounter the JFS fishery.	3 (High degree of overlap between fishing depths and depth range of species)
Selectivity of fishery (Specific to fishery under assessment)	Trawl is not a selective gear and Japanese seer is one of the main target species of Chinese trawl fishery in Yellow Sea (Sun B 2009).	2

Post-capture mortality (Specific to fishery under assessment)	Almost all fish are retained.	3 (Retained species)
Susceptibility		2.325

Factor 2.2 - Fishing Mortality

CHINA
Midwater Trawls

High Concern

Even though the catch has been increasing since 1950s (Fig. 6 left panel), it's widely believed that the overfishing is happening (Mu X et al. 2018)(Qiu S 1995), as there is evidence show that the biological characteristics are changing to adapt itself to the continuously increasing fishing pressure, such as faster growth, earlier sexual maturity and smaller maturity size (Fig. 6 right panel). Therefore the fishing mortality is considered "High Concern".

Justification:

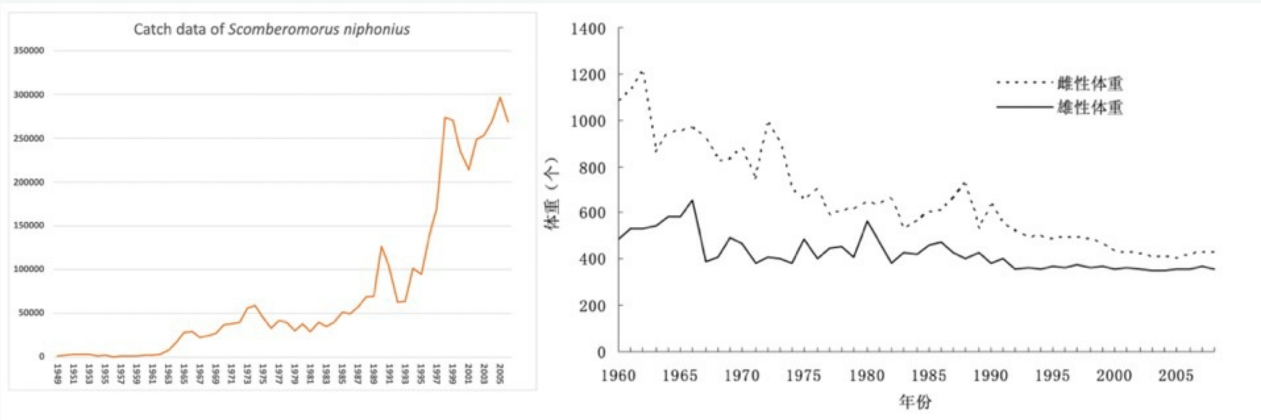

Figure 8 Catch data of Japanese Spanish mackerel (left panel); individual weight of male and female varying over time (right panel) (Sun, 2009).

Factor 2.3 - Discard Rate

CHINA
Midwater Trawls

< 100%

In order to protect juvenile fish, China has enacted a series of regulations prohibiting the juvenile fish of 15 species from being caught and landed (MOA 2018b). For this reason, part of the capture may be thrown away on the sea (Tang Y et al. 2009). There is no available data about the discards in JFS trawl fishery, but the discard rate of Chinese fishery is estimated to be 0.5%, which indicates that the low discards rate in Chinese fishery (FAO 2019b). According to the findings of Greenpeace, the low value feed fish, which is also called trash fish with small size, accounts for 49% of the total catch in Chinese trawl fishery (Greenpeace 2017) (Tang Y et al. 2009). This suggests that almost all species caught in Chinese trawl fishery are retained regardless of its economic value. Therefore, the discards of JFS trawl fishery is considered small percentage.

PACIFIC CHUB MACKEREL

Factor 2.1 - Abundance

CHINA
Midwater Trawls

Moderate Concern

PSA score = 2.6397, which leads to a low vulnerability. However, considering the uncertain stock status indicated by the studies, Pacific chub mackerel receives a score of "Moderate Concern".

Justification:

There are two chub mackerel stocks around Chinese waters, one stock is from Jeju Island, the other is from the spawning stock of central East China Sea; individuals caught in north Yellow Sea can be from either of them (Chen Q et al. 1983). Several studies assessed the total stock abundance in East China sea (Zheng Y et al. 2014), indicating the poor stock status and juvenile-dominant age structure (Zheng X et al. 2010), while the abundance of Yellow Sea stock has not been studied. Therefore the PSA was used for assessing this factor for the Yellow Sea stock.

Productivity Attribute	Relevant Information	Score (1 = low risk, 2 = medium risk, 3 = high risk)
Average age at maturity	2 year (Zheng Y et al. 2014)	1 (<5 years.)
Average maximum age	4 years (Zheng Y et al. 2014)	1 (<10 years.)
Fecundity	200,000~1,100,000 eggs (Zheng Y et al. 2014)	1 (>20,000 eggs per year)
Average maximum size	36 cm (Wikipedia 2019c)	1 (< 100 cm)
Average size at maturity	About 25 cm (Zheng Y et al. 2014)	1(<40 cm)
Reproductive strategy	Broadcast spawner (Kishida S 2019)	1 (Broadcast spawner)
Trophic level	3.38 (Lin Q 2012)	3 (>3.25)
Quality of Habitat	Habitat is considered to be robust to human activities	1 (Habitat no known degradation from non-fishery impacts
Productivity		1.25

Susceptibility Attribute	Relevant Information	Score (1 = low risk, 2 = medium risk, 3 = high risk)
Areal overlap (Considers all fisheries)	No precise data available. Chinese JFS fishing grounds include Yellow Sea, northern East China Sea and part of waters in Sea of Japan, which highly likely cover more than 30% of the species concentration. Additionally, JFS is an important food source for Pacific chub mackerel, so Pacific chub mackerel should be easily attracted to JFS fishing ground (Fang Z and Chen X 2018).	3 (Default score)
Vertical overlap (Considers all fisheries)	Pacific chub mackerel is distributed in the depth between 0 – 300 meters (Wikipedia 2019c), which has high chance to encounter the JFS fishery.	3 (High degree of overlap between fishing depths and depth range of species)
Selectivity of fishery (Specific to fishery under assessment)	Trawl is not a selective gear and Pacific chub mackerel is one of the main target species of Chinese trawl fishery in Yellow Sea.	2
Post-capture mortality (Specific to fishery under assessment)	Almost all fish are retained.	3 (Retained species)
Susceptibility		2.325

Factor 2.2 - Fishing Mortality

CHINA
Midwater Trawls

High Concern

Quantitative information of fishing mortality is not found, but the study about the relationship between biomass estimation and sea surface temperature indicated that the fishing effort has overexploited the resources and caused the decline of the abundance (Li GZ et al. 2011). For this reason, "High Concern" is assigned to the fishing mortality.

Factor 2.3 - Discard Rate

CHINA
Midwater Trawls

< 100%

In order to protect juvenile fish, China has enacted a series of regulations prohibiting the juvenile fish of 15 species from being caught and landed (MOA 2018b). For this reason, part of the capture may be thrown away on the sea (Tang Y et al. 2009). There is no available data about the discards in JFS trawl fishery, but the discard rate of Chinese fishery is estimated to be 0.5%, which indicates that the low discards rate in Chinese fishery (FAO 2019b). According to the findings of Greenpeace, the low value feed fish, which is also called trash fish with small size, accounts for 49% of the total catch in Chinese trawl fishery (Greenpeace 2017) (Tang Y et al. 2009). This suggests that almost all species caught in Chinese trawl fishery are retained regardless of its economic value. Therefore, the discards of JFS trawl fishery is considered small percentage.