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Overview of recent research cruises in the WCPO and Indonesian archipelagic water by the R/V Shunyo-Maru of NRIFSF

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Summary:

In this document, preliminary results of recent research cruises conducted by the R/V Shunyo-Maru of NRIFSF from 2012 and 2018 in the WCPO are summarized. The survey areas included the Indonesian archipelagic water (2017), EEZ of the U.S.A in the Northern Mariana (2015), the Republic of Palau (2015 and 2017) and the Federated States of Micronesia (2012 and 2013). The main objectives of this research cruises are to collect samples to describe spatial and vertical distributions of juvenile skipjack, albacore, bigeye and yellowfin tunas and their relation to environmental conditions as well as to understand species composition in the area. To collect juvenile of tunas, several mid-water trawl operations at night were conducted with oceanographic observations (CTD, water sampling for nutrients and chlorophyll-*a* and plankton sampling by a NORPAC net). Preliminary result of trawl survey in 2017 shows that collected samples consist of fish (87.3%) and squid (12.7%). Juvenile skipjack represents the majority of catch of tuna species. It should be noted that the juvenile skipjack were found in relatively deeper water compared to other tunas with high chlorophyll-*a* and such physical and biological characteristics may have affected and limited their vertical distributions.

Keywords: horizontal and vertical distribution, skipjack and tuna juvenile, ship surveys

Introduction

Understanding of early life history and survival is an essential to estimate stock variability of target fish (e.g. Pepin *et al.*, 2016), yet that of tuna species including skipjack has not been fully accomplished because of its difficulty in sampling due to the broad spatial and vertical distributions of these species.

Nishikawa *et al*. (1985) summarised spatial and seasonal tuna and skipjack larvae distribution in the Pacific, Atlantic and Indian Oceans based on samples collected in 26 years from 1956 to 1981 by surface plankton nets with 1.4–2.0 m in diameter. Reglero *et al*. (2014) showed global distributions of larval occurrence for 7 major oceanic tuna species to investigate environmental predictors of larval habitat and found that "regions of suitable larval habitats were most commonly in western boundary currents, where warm water masses coincide with intermediate eddy kinetic energy".

On the other hands, sampling of juvenile tunas, larger than larvae, were started in 1960s using trawl gears. At the beginning of the research survey in 1960s, Matsumoto (1961) used midwater trawl with approximately 10 m in diameter and collected 33 skipjack juveniles with length ranging 6–53mm. King and Iversen (1962) applied 4 types of trawl (beam trawl, IKMT with different diameters and ring net) and collected 6 skipjack and other tunas with length ranging 18–60 mm in the central Pacific Ocean. Recent development and advancement of surface and mid–water trawl, especially a skipjack-specific trawl net developed by Tanabe (2002) enables us to collect more samples to tow specified depth with faster speed, which can reduce rate of escaping from the net. There are many discussions focusing on horizontal and vertical distributions of tuna larvae (i.e., fish length approximately less than 1 cm) and their associations with temperature distribution (e.g. Nishikawa et al., 1985; Reglero et al., 2014; 2018). Tanabe *et al*. (2017) found that the most of juvenile skipjack collected by trawl surveys from 1992 to 1996 in the tropical western Pacific were sampled in depths between 40 and 120 m, which was near the thermocline in the area Several reports of juvenile skipjack collection exist, however discussions on their vertical distribution and its relation to environmental conditions still remain. Since 2000s, no ship surveys to collect juvenile and young stages of skipjack and other tuna species have been conducted in the WCPO, possibly due to taking too much time and efforts to obtain results which cannot be directly input into stock assessment framework.

Species caught during trawl surveys consist of not only skipjack or other tuna species but also other micronekton. Biomass distribution, community structure and species composition of the micronekton in the western tropical Pacific were summarized based on the samples collected by using a commercial midwater trawl (Hidaka et al., 2003). The results show that the peak of micronekton biomass in the distribution and the distribution of early stage of tuna larvae do not coincide in the western tropical and subtropical Pacific. It indicates that the separate distributions or different life strategy between micronecton and larvae/juvenile of tunas including skipjack, as the micronekton community shows diel vertical migration at relatively deeper water, while tuna species and skipjack stay at shallower depths.

The objectives of this research are (1) to describe spatial distributions of juvenile skipjack and other tuna species (albacore, yellowfin and bigeye tuna) in the WCPO and the Indonesian archipelagic water and their relation to environmental conditions, (2) to understand early life history of these species and (3) to understand species compositions to discuss about prey-predator relations in the research area. It is necessary to perform biological sampling and hydrographic observation in the North Equatorial Current and the adjacent waters including the EEZs in the Northern Mariana and the Republic of Palau. In this document, only preliminary results are provided.

Materials and Methods

Collection of biological samples

Summary table of each research cruise by the R/V (Research vessel) Shunyo-Maru (NRIFSF) are shown in **Tab. 1(a)** and sampling locations are shown in **Fig. 1**. The research areas were subtropical and tropical including the EEZs (exclusive economic zones) of the Federated States of Micronesia (SHU1206 and SHU1305), the United States of America in the northern Mariana (SHU1505), the Republic of Palau (SHU1505 and SHU 1703), and the archipelagic waters of the Republic of Indonesia (SHU1703). Mid-water trawl operations were conducted at night at predetermined depth to collect juvenile skipjack and other tropical tuna (albacore, yellowfin and bigeye tuna). 2m-Ring net at surface were also operated to collect larvae at night and NORPAC was also conducted to collect zooplankton at depths from 0 to 150m. On board fish identification based on morphological characteristics and DNA identification after the cruise were done.

Oceanographic observations

A CTD (conductivity, temperature and depth profiler) mounted fluorometer was used to collect oceanographic data from surface to a depth of 1,500m. During the cruises, continuous acoustic Doppler current profiler (ADCP) and scientific echo sounder (Simrad EK60) continuously recorded water velocity and sound wave reflected from fish, respectively. Nutrients, chlorophyll-*a* pigment and salinity determinations from water samples collected during CTD operations were made determined in onshore laboratories after each cruise.

Preliminary results and further consideration

Skipjack juveniles represent the majority of catch in sampled tuna species (**Tab. 1(b)**). It should be noted that the juvenile skipjack were mainly found in relatively deeper water compared to other tunas where of high chlorophyll-*a* and temperate around 25°C were observed, and these characteristics may have affected and limited their vertical distributions (**Fig. 5**).

Tab. 2 shows lists of fish (a) and squid groups (b) and **Fig. 2** represents typical fish and squid collected by the trawl survey in SHU1703 as an example. Preliminary results of the trawl survey in 2017 shows that collected samples consists of fish (87.3%) and squid (12.7%), and families Myctophidae and Enoploteuthidae were the most dominant groups (**Fig. 3** and **4**).

Another interesting preliminary result shown in **Fig. 6** is that horizontal distributions of albacore and yellowfin tuna juveniles likely separated at the 10°N in latitude, as albacore appeared at the stations at latitude higher than 10°N and yellowfin occurred at lower latitudes. This indicates that these two species have different spawning areas. Further

sample collections are necessary to have conclusive evidences for what was indicated by the preliminary results, and spatial analysis taking environmental variables into consideration should be done as the next step.

Following summaries needed to be consider at the SC15;

1. It is recommended to conduct collaborative research among nations and organizations to collect larvae, juvenile and young stages of skipjack and other tuna species, which usually cannot be collected by fisheries.
2. To develop conceptual models particularly on the early life stage of skipjack and other tuna species based on the horizontal and vertical distribution analyses.
3. To develop a validated growth model incorporating the results obtained from otolith analysis and/or other age traits if possible.
4. To add new insights and update our understanding of ecosystem structures and functions in the WCPO based on species compositions and their relation to environmental conditions.

Supplemental information

Additional information on the pictures of R/V Shunyo-Maru of NRIFSF and examples of trawl operation.

Acknowledgements

Japan expressed our acknowledgements to the governments of the Federated States of Micronesia, the Republic of Indonesia, the Republic of Palau and the United States of America to enable us and allow to conduct surveys by the R/V Shunyo-Maru of National Research of Far Seas Fisheries, Japan Education and Research Agency.

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Table 1. (a) Summary of the mid-water trawl surveys and (b) number of skipjack and tuna species collected by the R/V Shunyo-Maru from 2012 to 2018.

(a)

Cruise Name	Year	Date	quarter	Observation items
SHU1206	2012	Dec. 12 – Dec. 17	4	• Trawl surveys to collect biological samples including juveniles of skipjack, albacore, yellowfin and bigeye • 2m-ring net for tuna and skipjack larvae • ocean observation and water sampling
SHU1305	2013	Nov. 17 – Dec. 16	4	
SHU1406	2015	Feb. 3 – Mar. 3	1	
SHU1505	2015	Nov. 6 – Dec. 21	4	
SHU1602	2016	May 17 – 28	2	
SHU1604	2016	Aug. 31 – Sep. 11	3	
SHU1703	2017	Nov. 9 – Dec. 15	4	
SHU1804	2018	Oct. 15 – Nov. 4	4	

(b)

Species	Number	Frequency
Skipjack tuna	2,088	0.919
Albacore	122	0.054
Bigeye tuna	4	0.002
Yellowfin tuna	32	0.014
Unidentified tuna	25	0.011

Table 2. Samples collected by the trawl survey in SHU1703 cruise as an example.

(a) Fish groups

Group name	Number	Frequency (%)
Acanthuridae	84	0.36
Acropomatidae	7	0.03
Astronesthidae	47	0.20
Balistidae	4	0.02
Berycidae	1	0.00
Bothidae	3	0.01
Bramidae	3	0.01
Bregmacerotidae	328	1.40
Carapidae	2	0.01
Chauliodontidae	57	0.24
Chiasmodontidae	23	0.10
Coryphaenidae	3	0.01
Dalatiidae	1	0.00
Engraulidae	59	0.25
Evermannellidae	1	0.00
Exocoetidae	20	0.09
Fistulariidae	1	0.00
Gempylidae	154	0.66
Gonostomatidae	52	0.22
Holocentridae	21	0.09
Howellidae	71	0.30
Idiacanthidae	2	0.01
Istiophoridae	10	0.04
Leptocephalus larvae	227	0.97
Malacanthidae	4	0.02
Malacosteidae	1	0.00
Melamphaidae	1	0.00
Melanostomiidae	118	0.50
Microstomatidae	14	0.06
Mullidae	6	0.03
Myctophidae	20860	89.25
Nemichthyidae	1	0.00
Nettastomatidae	1	0.00
Nomeidae	18	0.08
Notosudidae	48	0.21
Paralepididae	153	0.65
Phosichthyidae	7	0.03
Pomacanthidae	2	0.01
Scombridae	911	3.90
Scombrolabracidae	32	0.14
Serrivomeridae	3	0.01
Sternoptychidae	1	0.00
Stomiidae	7	0.03
Synodontidae	1	0.00
Tetragonuridae	2	0.01

(b) Squid groups

Group name	Number	Frequency (%)
Onychoteuthidae	78	2.29
Cranchidae	91	2.68
Pyroteuthidae	314	9.23
Ancistrocheiridae	27	0.79
Enoploteuthidae	2360	69.39
Histioteuthidae	7	0.21
Chiroteuthidae	3	0.09
Chtenopterygidae	37	1.09
Ommastrephidae	484	14.23

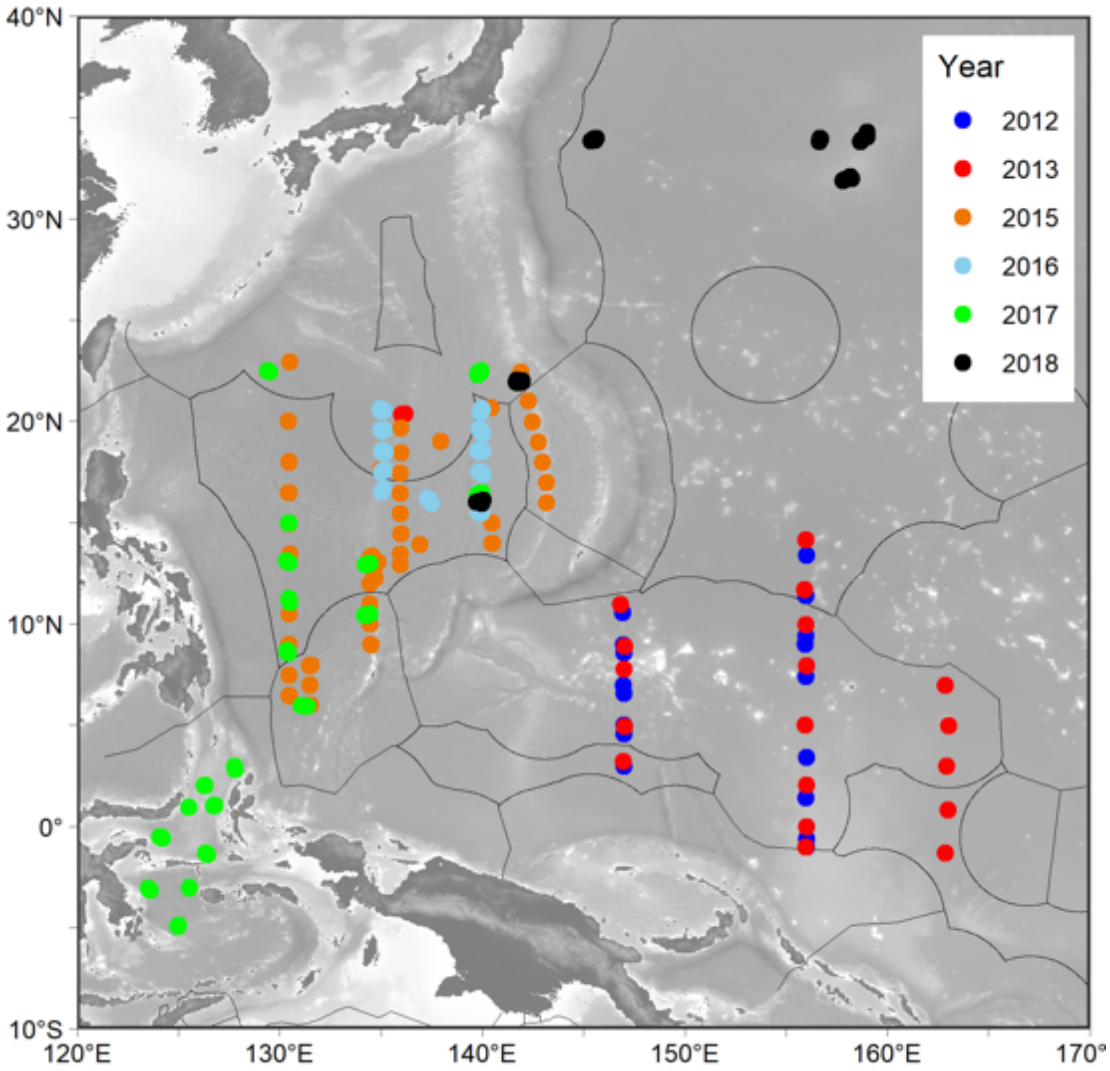


Figure 1. Sampling locations in cruises by the R/V Shunyo-Maru from 2012 to 2018.

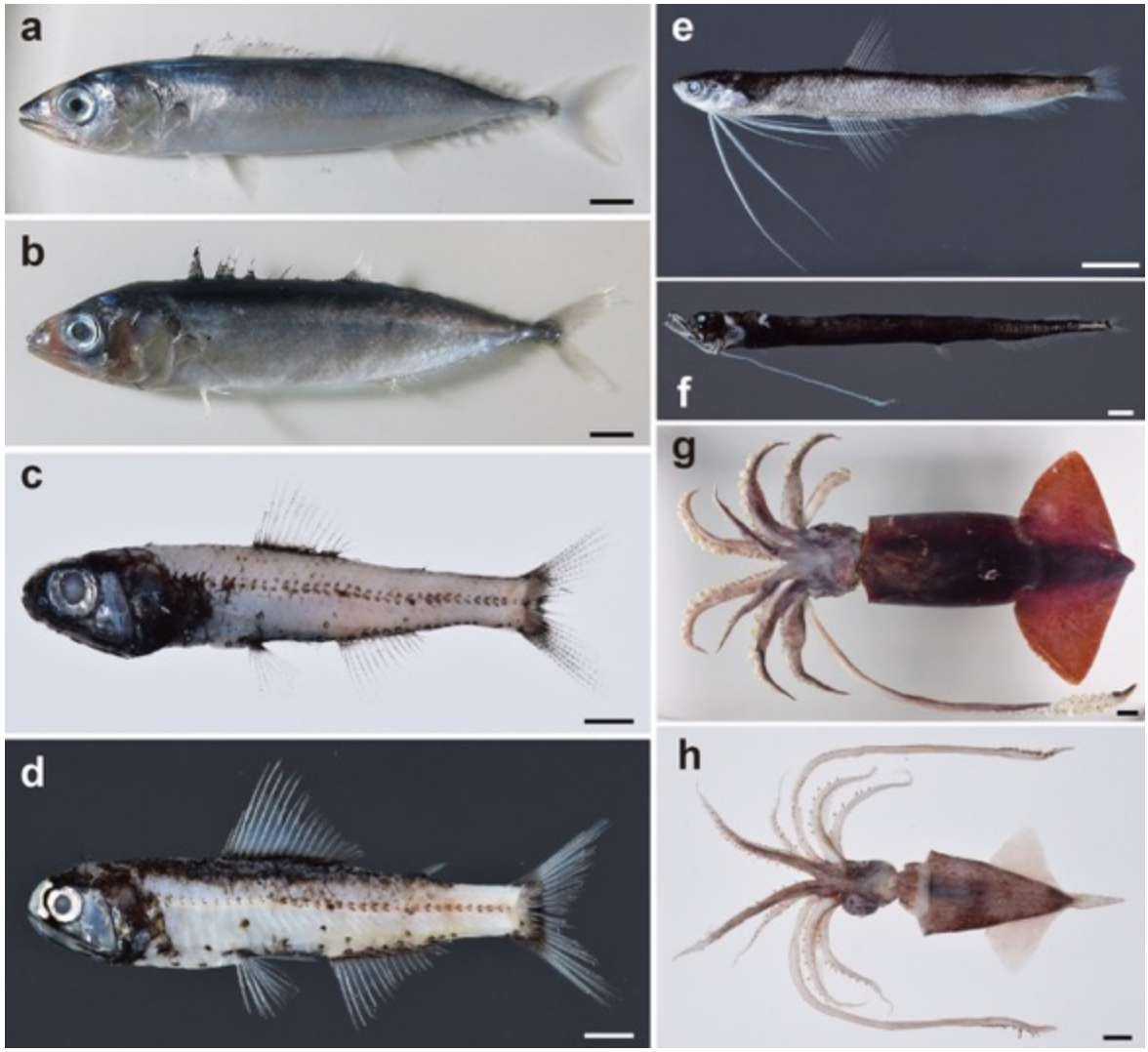


Figure 2. Examples of typical fishes and squids collected by mid-water trawling in SHU1703 Cruise. a) juvenile of skipjack tuna *Katsuwonus pelamis* (6.1 cm SL); b) juvenile of albacore *Thunnus alalunga* (5.0 cm SL); c) myctophid fish *Ceratoscopelus warmingii* (5.3 cm SL); d) myctophid fish *Diaphus fragilis* (4.5 cm SL); e) Bregmacerotid fish *Bregmaceros japonicus*(4.5 cm SL); f) Melanostomiid fish *Eustomias* sp. (13.1 cm SL); g) purpleback flying squid *Sthenoteuthis oualaniensis* (26.0 cm ML); g) firefly squid *Enoploteuthis* sp. (5.3 cm ML). In a)–f), and h) bar = 5 mm; in h) bar = 20 mm.

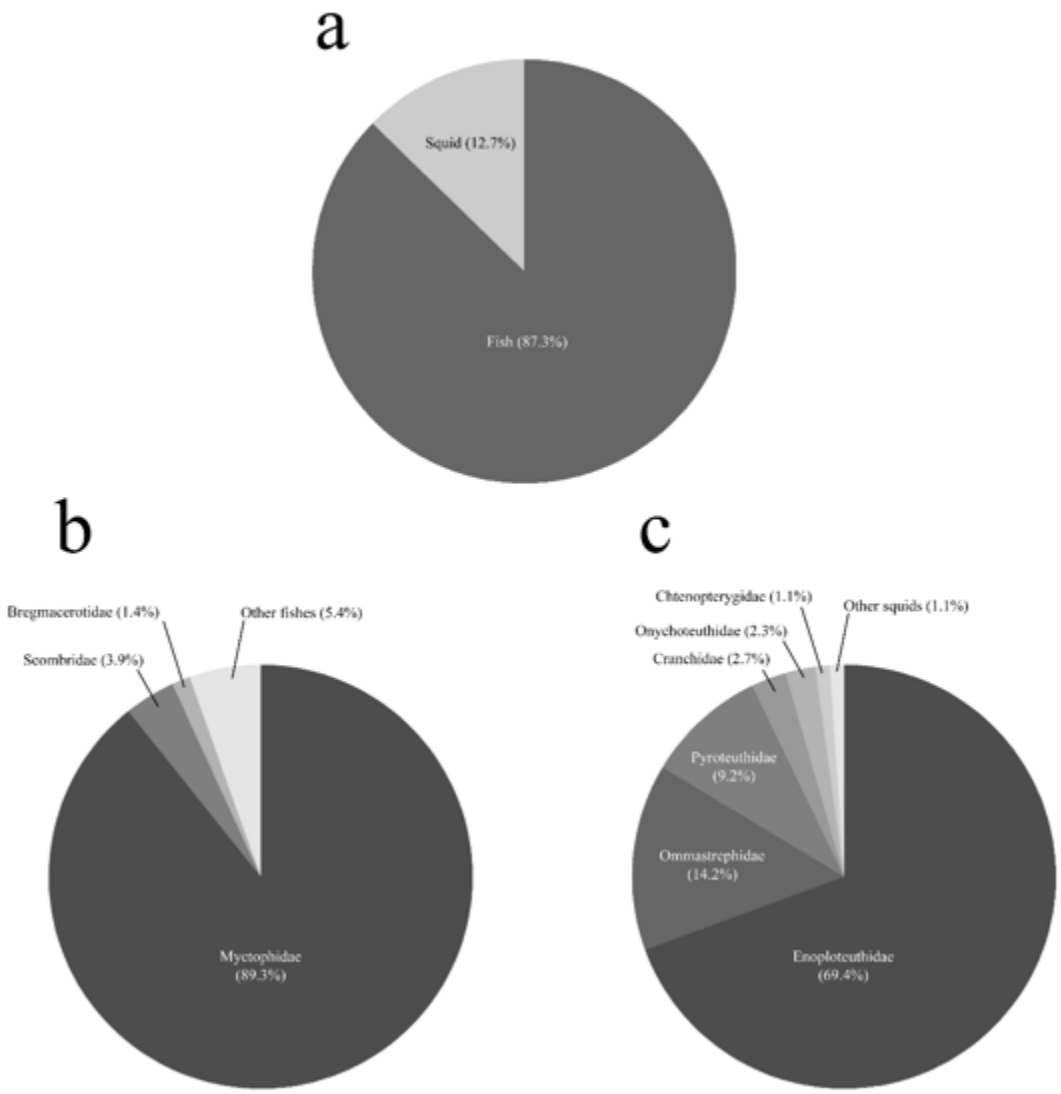


Figure 3. Proportions of samples collected by mid-water trawling in SHU1703 Cruise. a) proportion of fish species versus squid samples, b) proportion of fish groups, and c) proportions of squid groups. Other fishes/squids of b and c include groups which proportions are less than 1% (see **Tables 2**).

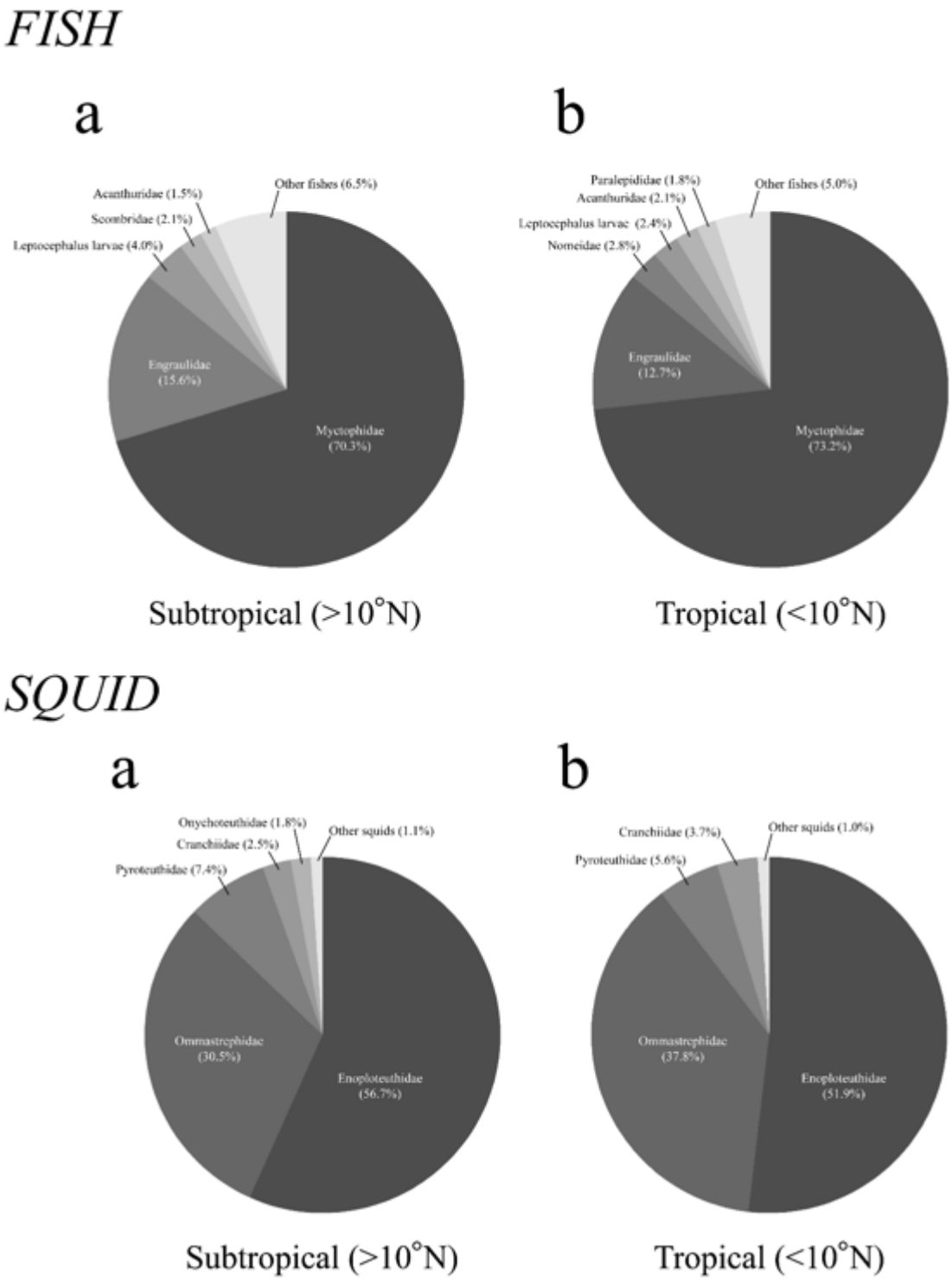


Figure 4. Proportions of samples collected from subtropical (a) and tropical areas (b) by mid-water trawling in SHU1505 and 1703 cruises. Upper pie charts for fish, and lower one for squid.

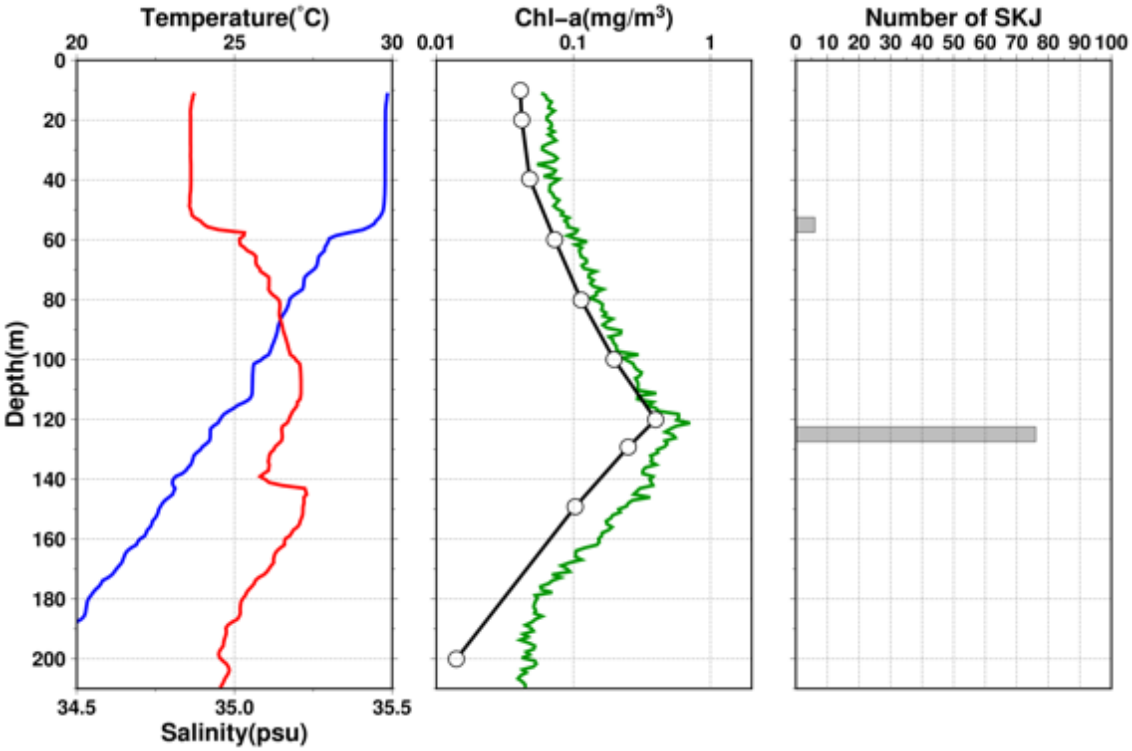


Figure 5. Vertical structure of temperature (left: blue), salinity (left; red), measured chlorophyll-a (mid: black with white circle) and fluorescence measured by fluorometer attached to CTD (mid: green), and the number of juvenile skipjack collected by trawl sampling at station 5 (139.9°E, 18.5°N) in SHU1604 (May 2016).

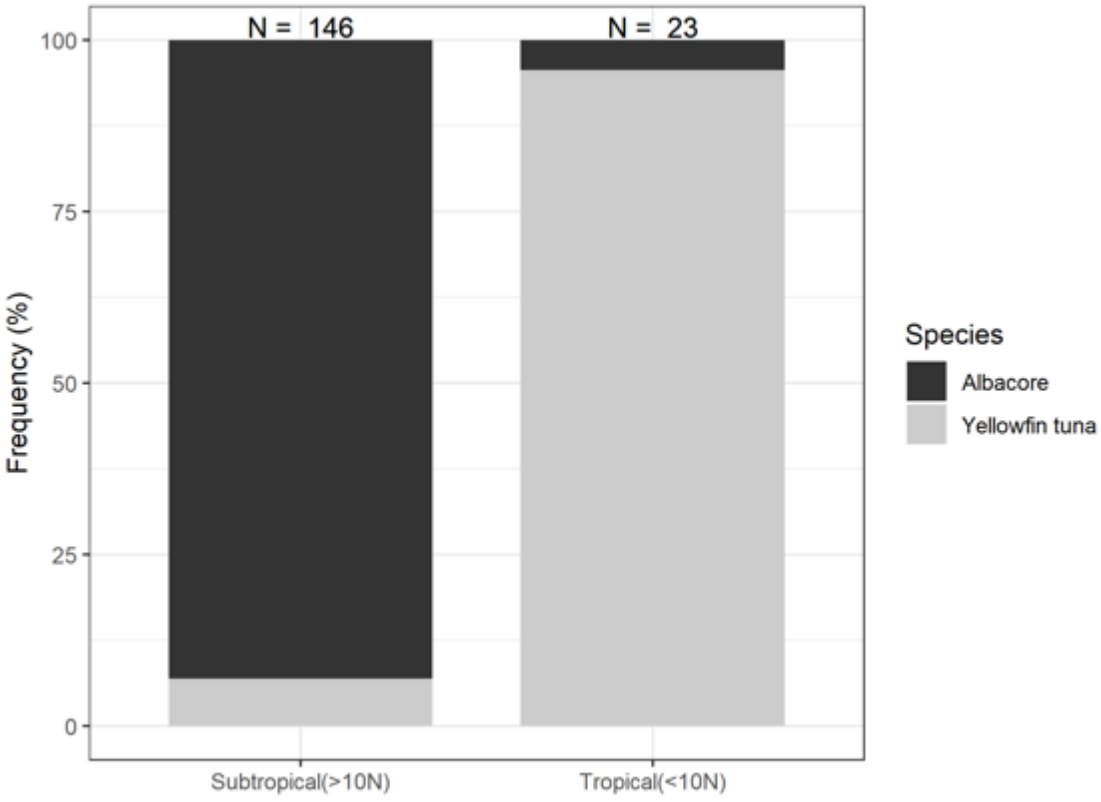
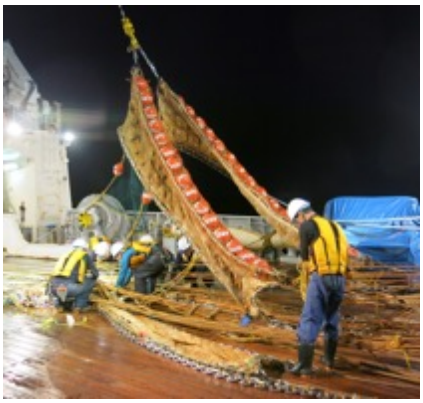


Figure 6. Ratios of the collected juvenile albacore and yellowfin tuna by mid-water trawling in SHU1406-1804 Cruises.

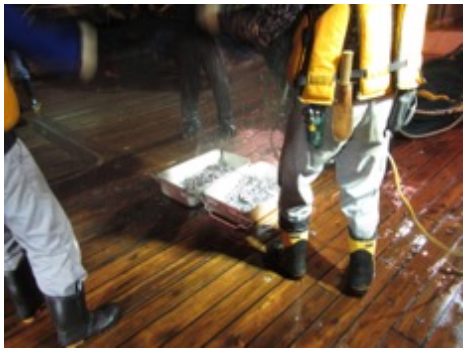
(a)

(b)



(c)

(d)



(e)

Figure S1. (a) R/V Shunyo-Maru of the NRFSF (length: 60.39m; Gross register tonnage: 887 tons), (b) and (c) setting mid-water trawl gear, (d) and (e) collected samples after trawl operation.