Longline Fishing for Southern Bluefin Tuna in Mid-latitude South Indian Ocean areas in 2017

Masahiko Mohri*, Hideaki Tanoue*, Yuichiro Inoue*, Haruna Oidaira*, Setsuko Nagai*, Shun Yokota*, Yuji Kashino* Yoshiyasu Kobayashi, Kiyohiko Fukami**, ＆ Tadashi Kamano****

*** National Fisheries University, Dept. of Fishery Science and Technology, Japan**
**** National Fisheries University, Koyomaru, Japan**

Abstract

In 2017, longline fishing and oceanographic surveys were conducted for southern bluefin tuna (*Thunnus maccoyii*) to collect data in vertical direction. As a result, the water depth where the same species was caught ranged from 120 to 265 m, and its fork length and weight ranged from 142 to 173 cm and from 70 to 105 kg, respectively. The water temperature ranged from 12 to 15℃.

1 Introduction

Thunnus consists of eight species: Pacific bluefin tuna (*Thunnus orientalis*), Atlantic bluefin tuna (*T. thynnus*), southern bluefin tuna (*T. maccoyii*), bigeye tuna (*T. obesus*), yellowfin tuna (*T. albacares*), albacore (*T. alalunga*), longtail tuna (*T. tonggol*), and blackfin tuna (*T. atlanticus*). Southern bluefin tuna is found in temperate waters of the southern hemisphere, mainly in the Indian Ocean. This species sells as well at a high price as both Pacific bluefin tuna and Atlantic bluefin tuna inhabiting different temperate waters of the Northern Hemisphere Pacific and Atlantic, because the meat of these three species is superior.

After World War II, the abolition of the MacArthur line increased the number of fishing grounds for tuna longlining in the 1950s and the utilization of southern bluefin tuna started to gradually increase. Around that time, studies on this species have begun to go into full swing. Some findings of published studies are as follows: spawning as indicated by the occurrence of its larvae [1], distribution and migration [2], spawning activity and discoloration of meat and loss of weight [3], age and growth by use of scale

[4], fluctuations in amount and age composition of catch in longline fishery [5], preliminary evaluation of effect of the voluntary regulation on stock and the longline fishery [6], stock assessment [7], biology and resources [8], research fishing [9], which are listed in chronological order. As regard to the study findings shown by Fisheries Research Institutes, it was determined that the studies of these 50 years should be classified into one category, and therefore the findings include the data shown by the Far Seas Fisheries Research Laboratory (the predecessor of the National Research Institute of Far Seas Fisheries).

According to the latest available statistics, the catches of southern bluefin tuna by Japan amounted to 4,745 tons in 2015, which tended to increase for these five years: 2,678 tons in 2011, 2,953 tons in 2012, 2,747 tons in 2013, and 3,539 tons in 2014 [10]. Regarding such an increase, it is reported that the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) has contributed to the promotion of successful conservation management and optimum utilization of the resources [11]. The Commission consists of Japan, Australia, Indonesia, New Zealand, South Africa, South Korea, Taiwan, and EU.

Taking into consideration southern bluefin tuna as a target species of fisheries production, the most popular method in Japan to catch adult fish is longline fishing. This fishing has achieved significant results in catches of commercially important six species: Pacific bluefin tuna, Atlantic blackfin tuna, southern bluefin tuna, bigeye tuna, yellowfin tuna, and albacore tuna. Especially, the findings obtained by bigeye tuna longlining have clarified the followings in the vertical distribution: the fishing ground creation and inhabitancy [12], comparison of catches by regular and deep tuna longline gears [13], effect of oceanographic environment on the distribution [14], and vertical distribution [15]. However, studies on the vertical distribution of southern bluefin tuna by longline fishing are not sufficient at present.

Under such a situation, recently, the number of Japanese commercial tuna longline fishing boats has decreased and the tuna longline fishing by public research ships and high-school/university training ships has declined, resulting in a noticeable decrease in opportunities to collect the fish catch data. Consequently, this study aimed to obtain knowledge on the recent catches of southern bluefin tuna through longline fishing. In 2017, we conducted this fishing method and oceanographic surveys for the same species to collect data in vertical direction. In addition, sea surface height, water temperature in vertical direction, and salinity were examined together with the findings of the fishing operations. This paper discusses the results.

2 Materials and Methods

Survey was conducted under the 71st navigation of the Koyo Maru eight times during December 8-15, 2017. Figure 1 shows the surveyed areas, which started from 24° 51.9′ S latitude and 106° 53.8′ E longitude. The survey was conducted while heading the ship south and ended at 31° 00.0′ S latitude and 104° 23.5′ E longitude. The reason for targeting these areas is because of some good fishing spots for southern bluefin tuna [2] [8] and because of students' practical training schedule of entering and leaving the Fremantle Port in Australia without delay.

Figure 2 shows the construction of longline. In this study, the operation was conducted with 12 fishing hooks per pot. The fishing gear used during 8-day operation consisted of 420 pots and 5,040 hooks in total. During this operation, the computational depth and shortening rates were focused to set the hooks at the desired depth, as described in the paper by Tanoue *et al.* [16]. Taking into consideration the conventional studies [2] [8], the operation was conducted at some selected points with steep seafloor topography [17] where large variations in the oceanographic environment were expected with an increase in the depth (See Figure 1).

$$D = ha + hb + \ell \left\{ \sqrt{1+\cot^2\varphi_0} - \sqrt{\left(1-\frac{j}{n}\right)^2 + \cot^2\varphi_0} \right\} \qquad (1)$$

where D is the depth of hook, ha is the length of the branch line, hb is the length of the float line, ℓ is half the length of the main line, n is the number of branch lines in one basket, and j is the consecutive number of the branch line counted from one side of the basket. The angle of inclination φ_0 at the supporting point of the main line.

The depth where southern bluefin tuna was caught was measured by the small bathythermograph system SBT-500 (Murayama Denki Ltd.). At the end of the operation, the oceanographic survey in vertical direction was conducted by using the CTD (Sea-Bird Electronics). About CTD data, we use salinity value calibrated by expert of oceanography.

To precisely figure out the inhabitant environment of southern bluefin tuna, the sea surface height anomaly maps were created by using Ocean Data View, which is a program designed for graphical display of various oceanographic data, and the relationship between the maps and the environment was examined.

3 Results and Discussion

Table 1 shows the number of pots, length of float line, shortening rate, number of hooks, number of bates, depth of hook determined by SBT-500, number of tuna caught, and depth determined by a small water depth and temperature meter. To set hooks over a wide range in vertical direction, the float lines were constructed at depth of 80 m during December 8-11, 40 m and 80 m during December 12 to 14, 40 m on December 15. For the depth of the float line set on the last day, the results obtained during the preceding operations of December 12 to 14 showed that the target species was caught at the shallower depth, and therefore float lines at 40 m depth only were used.As shown in the table, the shortening rate (k) falls within $0.6 \leqq k < 0.8$. In addition, two different types of baits were used: 4,008 saury and 1,032 chub mackerel. Eight of the nine southern bluefin tuna caught in total took saury and the remaining one took chub mackerel.

The depth of hooks, measured by the SBT-500, ranged from 115 to 395 m, which covered the range of 280 m. Number of tuna caught and the catch depth were three at 120 m, one at 200 m, two at 240 m, one at 245 m, one at 250 m, and one at 265 m.

Table 2 shows the fish body sizes (weight, length, etc.) of all the southern bluefin tuna caught: the weight ranges from 70 to 105 kg and the fork length ranges from 142 to 173 cm. It is considered that the age of fish is around 4 to 10 [5] [8]. For the three female fish, their gonad weights ($G.I.= 10^4 \cdot W/L^3$, where W is ovary weight(g) and L is fork length(cm)) were 2.5, 2.6, and 2.6, which suggests that these fish are adult, according to the definition that fish with $G.I. \geqq 2.0$ is adult [2].

Figures 3-1～3-8 show the vertical profiles of water temperature and salinity measured by the CTD and the depth range of hooks during the operations respectively: the water temperature of successful catches ranges from 12 to 15℃ with the salinity of 35.2 to 35.7. The surface water temperature when southern bluefin tuna was caught in this survey areas ranges from 18 to 22℃, which is almost the same as that of the conventional studies reporting to be 17 to 21℃ [2]. According to Fig.3-7 (St.7) and Fig. 3-8 (St.8), salinity value reversed from 800 m to 890 m depth. There are a too few oceanographic observation to examine the cause of reversal of salinity value. On the other hand, we want to examine influence that floating substances give to the reading of CTD.

4 Future Prospects in this Study

Past studies for southern bluefin tuna fishing distribution are examined using surface temperature, salinity [3][8] and seafloor topography [17]. However, these studies cannot give a definite standard about southern bluefin tuna fishing distribution. On the other hand, Hanaoka [18] stated relation between water temperature and osmotic pressure. Characteristics of water masses in vertical distribution of southern bluefin tuna is not elucidated judging from T-S diagram. So, we discuss southern bluefin tuna fishing distribution as seen from information of ocean data.

According to the surface temperature map (See Figure 4), it is found that, in the area where the target species was caught, colder water layer is expanding in the southern ocean and isothermal stretches to the north. In addition, variations in the depth indicate that some shallow slopes sink steeply toward the deep seafloor. In such an area, it is considered that some currents might cause cold seawater of the deep layer to rise toward the upper layers.

Figure 5 shows the maps of sea surface height measured at the time of survey operations: The sea surface heights with no catches for December 8-11 indicate −0.5 m to ＋0.5 m (from plus to minus value) in a wide area. On the other hand, the sea surface heights with successful catches for December 12-14 indicate ＋0.5 m to ＋1.0 m (plus value), which covers a wide area. The results of the successful catches (Figure 5) and the survey areas (Figure 1) show that southern bluefin tuna was caught by the fishing hooks set in the areas where significant variation was observed at the sea surface height of ＋0.5 m to ＋1.0 m (plus value). Judging from low surface height in four stations (St.5, 6, 7 and 8) where target species were caught, we thought that equal density layer became shallow. At present, the sea surface height can be predicted for several ten-days in advance. Hence, it is expected that studies on a method for effectively catching southern bluefin tuna should be advanced based on the prediction of sea surface height as well as the sea surface temperature and the bathymetry feature.

In the areas targeted in this study, eight longline fishing operations were carried out, resulting in catches of nine southern bluefin tuna in four days. We will aim to obtain more data and produce fruitful results, taking into consideration the prevention of decline in southern bluefin tuna resources. In addition, the Indian Ocean is affected by Monsoon and Ocean Dipole phenomena, and therefore it is necessary to research the relationship between these phenomena and southern bluefin tuna in further studies.

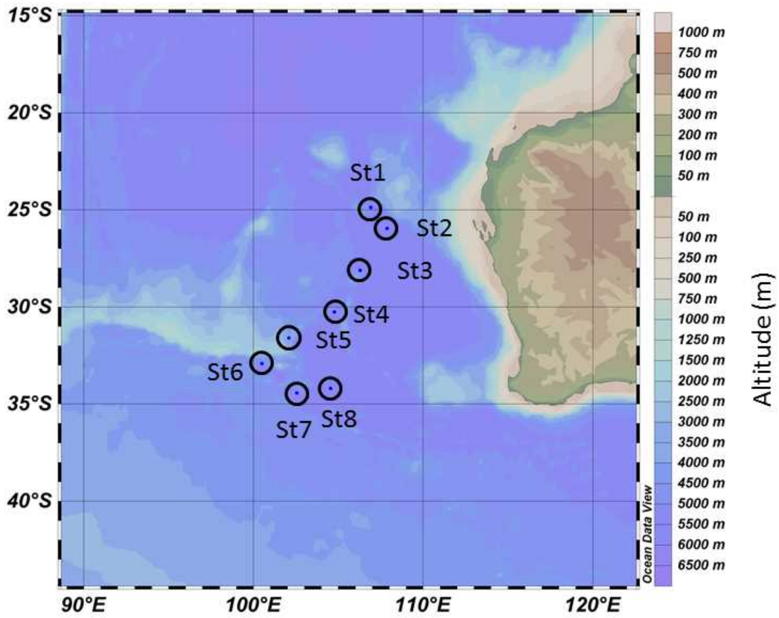

Figure 1 Longline fishing areas targeted for tuna.

The circles (○) indicate the areas St1 to St8 where longline fishing were conducted. These operations were conducted once a day between December 8 (St1: 26-19.6S、107-01.8E) to 15 (St8: 34-31.0S、104-23.5E) resulting in a total of eight operations.

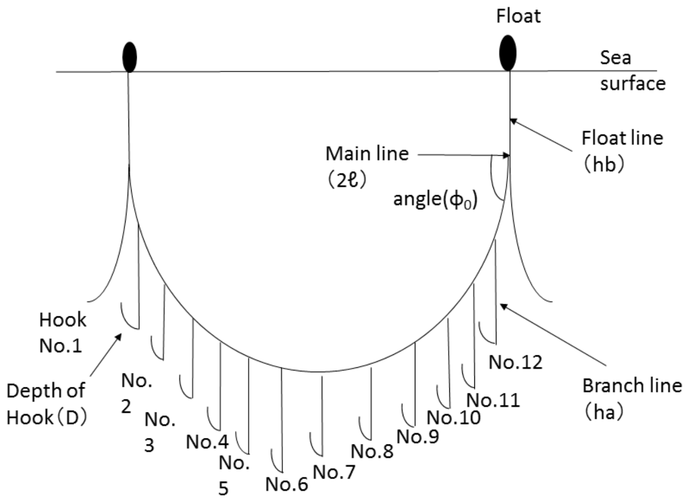

Figure 2 Construction of tuna longline with 12 hooks per pot.

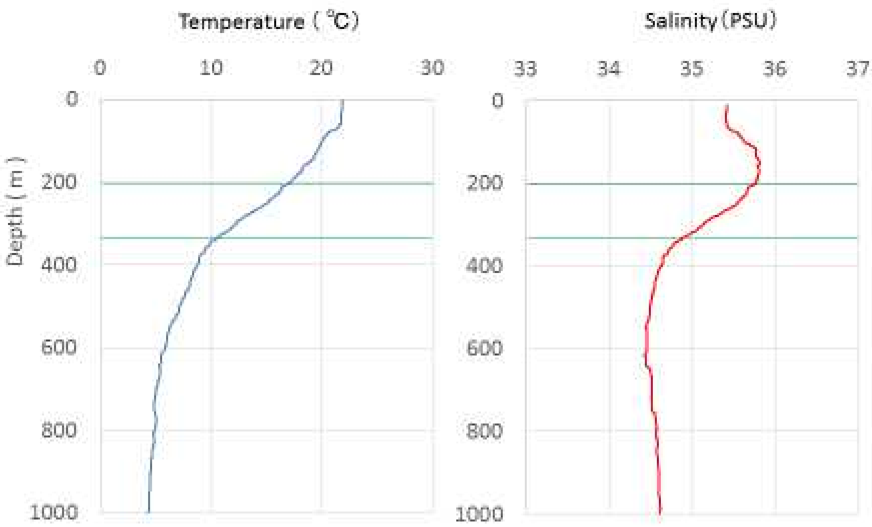

Figure 3-1 Vertical profile of water temperature and salinity based on the CTD data (December 8: St1) Green lines a to b indicate the depth zone where hooks were attached.

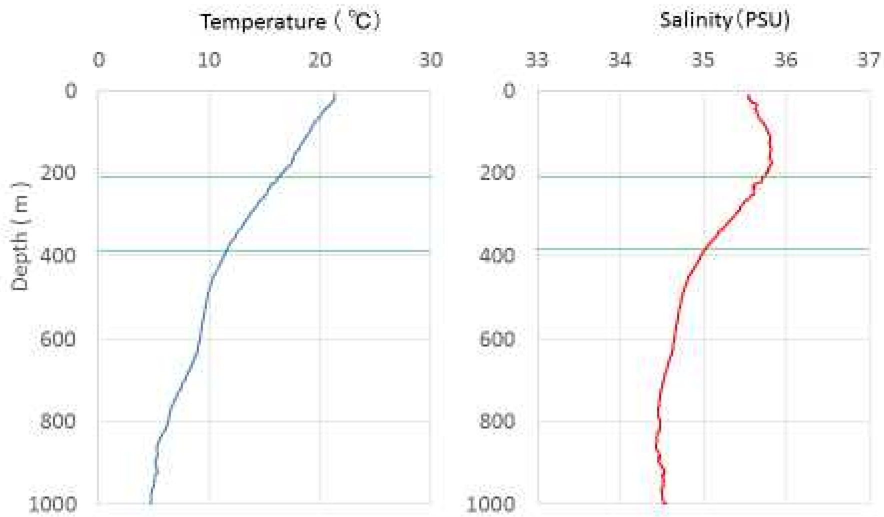

Figure 3-2 Vertical profile of water temperature and salinity based on the CTD data (December 9: St2) Green lines a to b indicate the depth zone where hooks were attached.

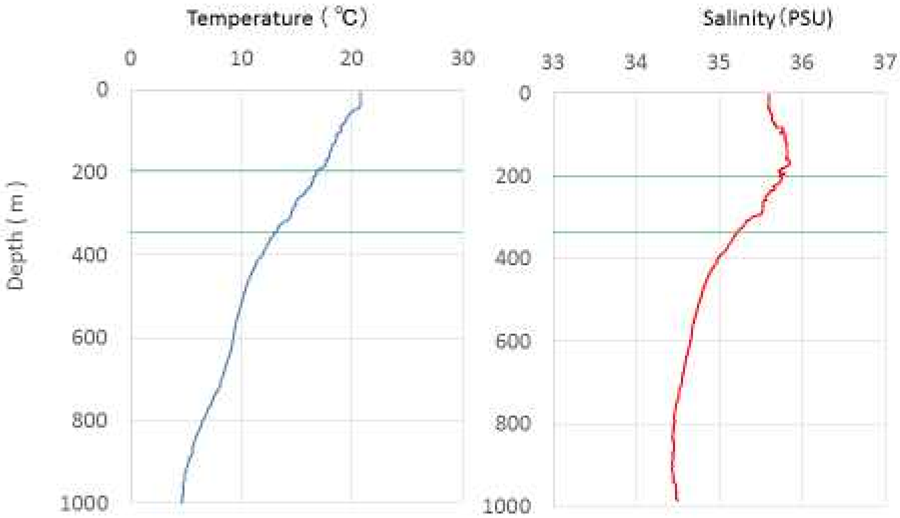

Figure 3-3 Vertical profile of water temperature and salinity based on the CTD data (December 10: St3) Green lines a to b indicate the depth zone where hooks were attached.

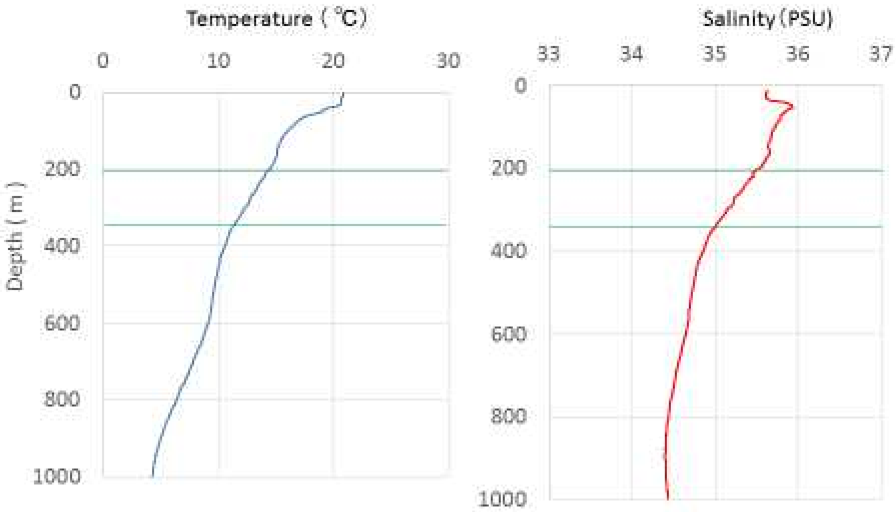

Figure 3-4 Vertical profile of water temperature and salinity based on the CTD data (December 11: St4) Green lines a to b indicate the depth zone where hooks were attached.

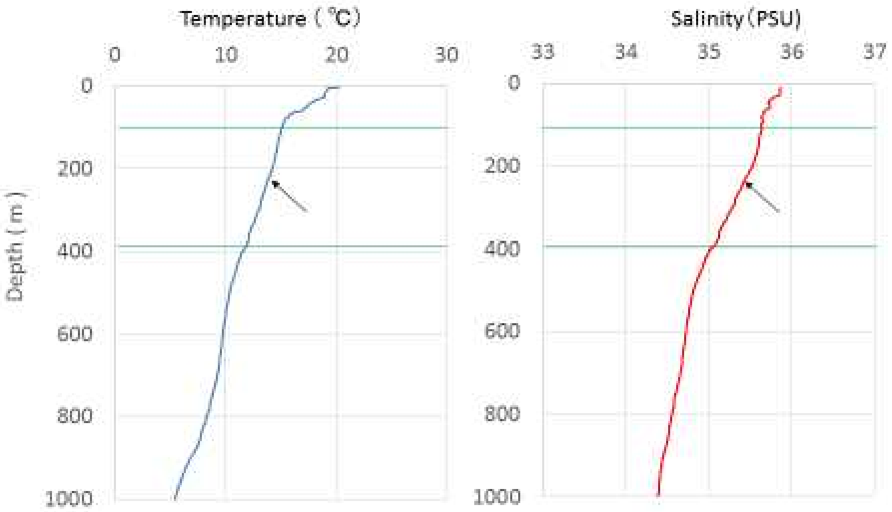

Figure 3-5　Vertical profile of water temperature and salinity based on the CTD data (December 12: St5) Green lines a to b indicate the depth zone where hooks were attached. Red arrows indicate the depth where southern bluefin tuna was caught.

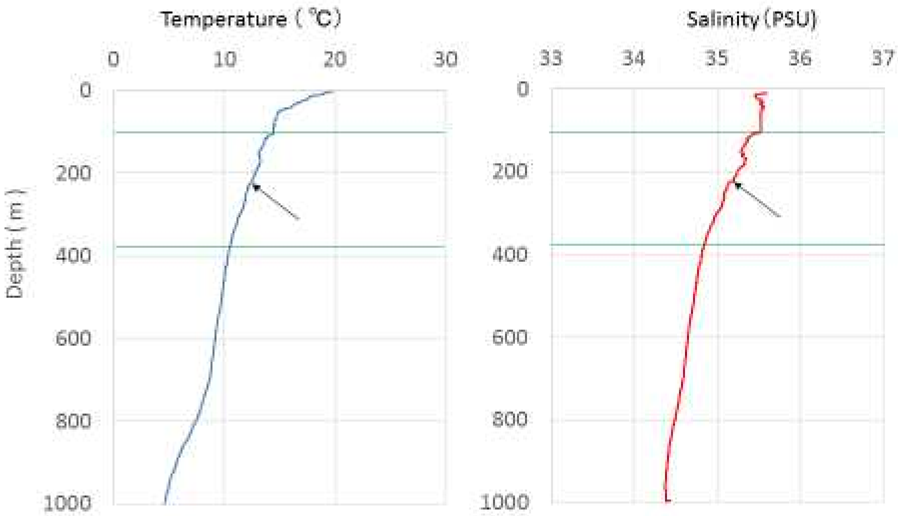

Figure 3-6　Vertical profile of water temperature and salinity based on the CTD data (December 13: St6) Green lines a to b indicate the depth zone where hooks were attached. Red arrows indicate the depth where southern bluefin tuna was caught.

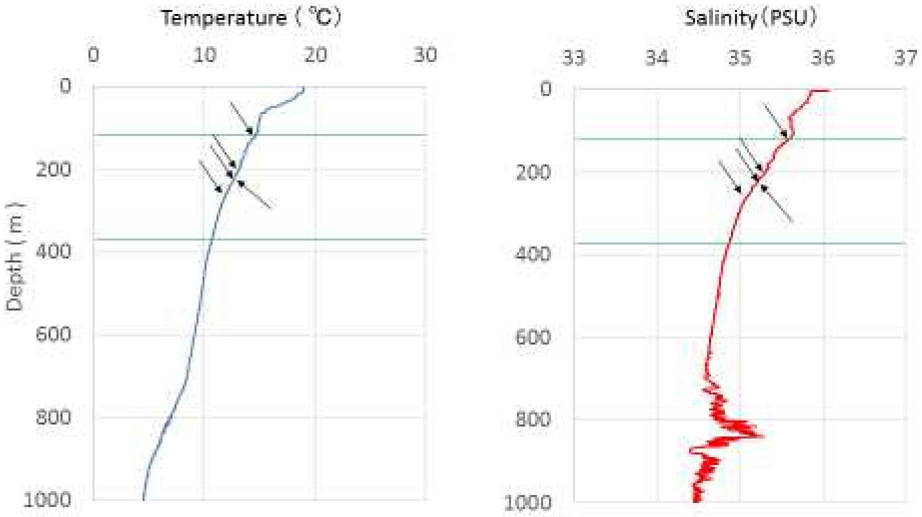

Figure 3-7 Vertical profile of water temperature and salinity based on the CTD data (December 14: St7) Green lines a to b indicate the depth zone where hooks were attached. Red arrows indicate the depth where southern bluefin tuna was caught.

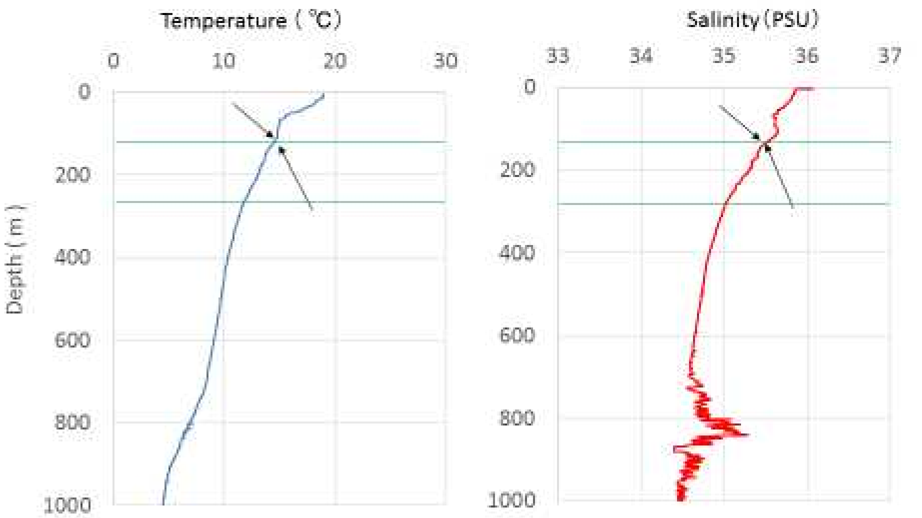

Figure 3-8 Vertical profile of water temperature and salinity based on the CTD data (December 15: St8) Green lines a to b indicate the depth zone where hooks were attached. Red arrows indicate the depth where southern bluefin tuna was caught.

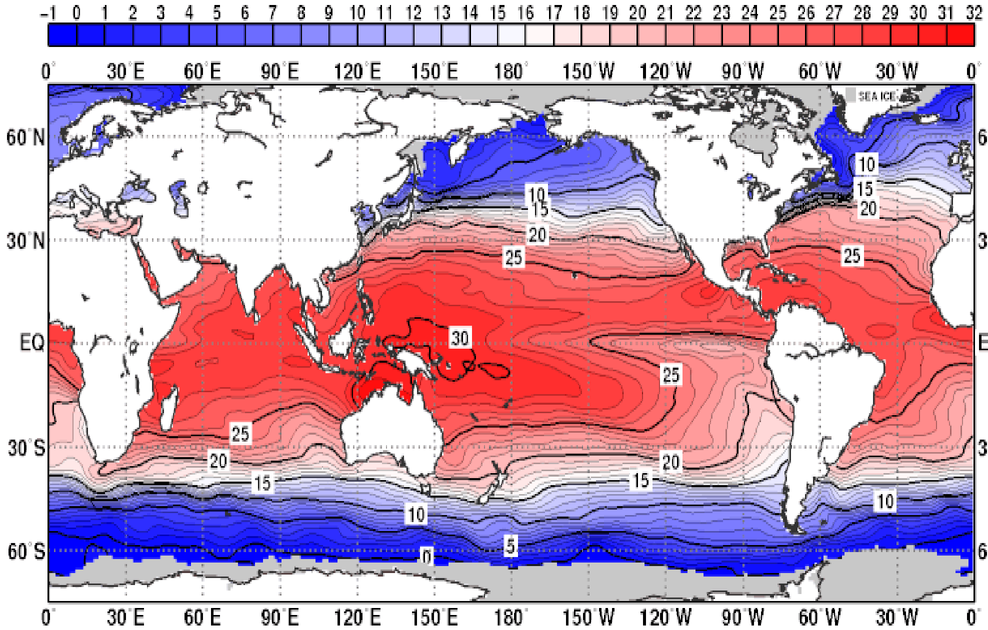

Figure 4　Sea surface temperature (monthly average) in December 2017, cited from Japan Meteorological Agency.

（https://www.data.jma.go.jp/gmd/cpd/data/elnino/clmrep/sst-global.html）

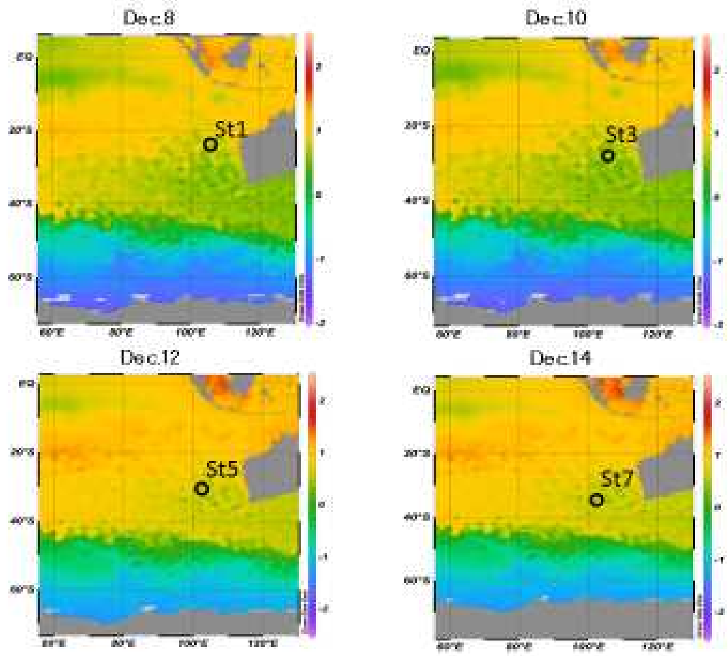

Figure 5　Sea surface height (December 8, 10, 12, and 14, 2017 cited from Schlitzer, R., Ocean Data View, odv.awi.de, 2018. https://odv.awi.de/).

The circles (○) indicate the areas St1, St3, St5, and St7 where longline fishing were conducted.

Table 1 Number of pots (w/ float line length), shortening rate, number of hooks, number of baits, depth range of hooks measured by the SBT, number of catches, and catch depth.

Number of pot (Float line)	Shortening rates	Number of hook Feed (Pacifick saury:Mackerel)	Depth range of hooks (m) by SBT	Southern bulefin tuna Number of catch	Depth of cathch (m)
12/8 30 (80m)	0.6	360 (300:60)	205～355	0	-
12/9 30(80m)	0.61	360 (300:60)	200～385	0	-
12/10 50 (80m)	0.64	600 (480:120)	200～350	0	-
12/11 50 (80m)	0.69	600 (480:120)	205～350	0	-
12/12 30 (40m),30 (80m)	0.67 (80m) 0.76(40m)	720 (540:180)	120～395	1	250
12/13 30 (40m),30 (80m)	0.72 (80m) 0.70 (40m)	720 (540:180)	115～380	1	245
12/14 40 (40m),30 (80m)	0.77	840 (660:180)	120～350	5	120, 200, 240, 240, 265
12/15 70 (40m)	0.77	840 (708:132)	120～275	2	120, 120

Table 2 Body sizes of southern bluefin tuna caught (weight, fork length, sex, and gonad weight).

	Weight (kg)	Fork length (cm)	Female (F) / Male (M)	Gonad weight (kg)
Dec.12	105	173	F	1.29
Dec.13	90	166	M	1.59
Dec.14	98	167	M	1.32
	79	154	M	1.08
	100	170	M	0.37
	85	158	M	0.83
	70	142	F	0.73
Dec.15	72	156	M	0.39
	103	171	F	1.30

4 Acknowledgements

We thank the crew of the training vessel "Koyomaru" from National Fisheries University.

References

[1]S.Ueyanagi: The spawning of the southern bluefin tuna (*Thunnus maccoyii*) as indicated by the occurrence of its larvae, *Bull. Far Seas Fish. Res. Lab.,* **1**(1969), 1-4.

[2]C.Shingu: Studies relevant to distribution and migration of the southern bluefin tuna, *Bull. Far Seas Fish. Res. Lab.,* **3**(1970), 57-113.

[3]I. Warashina and K. Hisada: Spawning Activity and Discoloration of meat and loss of weight in the southern bluefin tuna, *Bull. Far Seas Fish. Res. Lab.,* **3** (1970), 147-167.

[4]M. Yukinawa: Age and growth of southern bluefin tuna *Thunnus maccoyii* (CASTELNAU) by use of scale, *Bull. Far Seas Fish. Res. Lab*., **3** (1970), 229-257.

[5]C. Shingu and K. Hisada: Fluctuations in amount and age composition of catch of southern bluefin tuna in longline fishery, 1957-1969, *Bull. Far Seas Fish. Res. Lab.,* **5**(1971), 195-218.

[6]Y. Warashina and K. Hisada: Preliminary evaluation of effect of the voluntary regulation on stock of southern bluefin tuna and the longline fishery, *Bull. Far Seas Fish. Res. Lab.,* **10** (1971), 193-220.

[7]S.Hayashi: Stock assessment of southern bluefin tuna based on information up to September 1973—its conclusions and problems, *Bull. Far Seas Fish. Res. Lab.*, **11** (1974), 51-65.

[8]C. Shingu: Biology and resources of southern bluefin tuna, Fishery Research Series 31, Japan Fisheries Resource Conservation Association, 1978.

[9]S. Tsuji: Situations over the research fishing of southern bluefin tuna, Enyo, **106**(2000) , 9-12,

[10]The Editorial Committee of the Yearbook of fisheries: Yearbook of fisheries 2017, Suisansha Press, 2018.

[11]M. Ichinokawa: Evaluation and management goal of fishery resources. *Fra News*, **56** (2018), 4-9.

[12]A. Suda, S. Kume and T. Shiohama: An indicative note on a role of permanent thermocline as a factor controlling the longline fishing ground for bigeye tuna, *Bull. Far Seas Fish. Res. Lab.,* **1**(1968), 99-114.

[13]Z. Suzuki, Y. Warashina and M. Kishida: The comparison of catches by regular and

deep tuna longline gears in the Western and Central Equatorial Pacific, *Bull. Far Seas Fish. Res. Lab.,* **15**(1971), 51-89.

[14]E. Hanamoto: Effect of oceanographic environment on bigeye tuna distribution, *Paper published by Kanagawa Prefectural Fisheries Experiment Station,* **2** (1986), 1-61.

[15]M. Mohri, E. Hanamoto and S. Takeuchi: Optimum water temperatures for bigeye tuna in the Indian Ocean as seen from tuna longline catches, *Nippon Suisan Gakkaishi,* **62**(1996), 761-764.

[16]H. Tanoue, M. Mohri, T. Itoh, M. Kokatsu, H. Gotoh, T. Enoshima, K. Hata, Y. Kawato, M. Niitani, Y. Okita, S. Omi, K. Fukami, T. Kamano. Y. Gotoh and W. Miyashita Depths of fish catches using shortening rates of tuna longline on board training ship Tenyo maru in 2015, *Mathematical and Physical Fisheries Science*, **14**(2017), 17-26.

[17]T. Nishida: Japan-Australia cooperative studies on southern bluefin tuna resources, *Bulletin of the Japanese Society of Fisheries Oceanography,* **58**(1994), 171-178.

[18]T. Hanaoka: Relation between bodily fluids osmotic pressure and migration-maturity about marine products fish (*In* S. Kawamoto: Fish physiology), Kouseisya-Kouseikaku Press 1977. 587-596..

Received : November 7, 2018
Accepted : March 11 2 019

Academic backgrounds:

Masahiko Mohri:

04/1983 – 03/1987	Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1987 – 03/1988	Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1988 – 03/1990	Master's course of Graduate School of Tokyo University of Fisheries, Tokyo, Japan
04/1990 – 03/1991	Doctor's course of Graduate School of Tokyo University of Fisheries, Tokyo, Japan
04/1991 – present	Department of Fishery Science and Technology, National Fisheries University, Shimonoseki, Japan
Research field:	Fisheries information analysis

Hideaki Tanoue:

04/1997 – 03/2001	Undergraduate course of Department of Fishery Science and Technology of National Fisheries

	University, Shimonoseki, Japan
04/2002 – 03/2004	Master's course of Graduate School of National Fisheries University, Shimonoseki, Japan
04/2005 – 03/2009	Doctor's course of Graduate School of The University of Tokyo, Tokyo, Japan
04/2009 – 03/2010	Ocean Research Institute, The University of Tokyo, Japan
04/2010 – 03/2011	Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan
04/2011 – 03/2013	Policy Research, Ocean Policy Research Foundation, Tokyo, Japan
04/2013 – present	Department of Fishery Science and Technology, National Fisheries University, Shimonoseki, Japan
Research field:	Behaviour, Ecology and Observation systems, Fisheries resources management, Integrated Coastal Management

Yuichiro Inoue:

04/2015 – present	Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan

Haruna Oidaira:

04/2015 – present	Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan

Setsuko Nagai:

04/2014 – present	Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2018 – present	Master's course of Graduate School of National Fisheries University, Shimonoseki, Japan

Shun Yokota:

04/2013 – 03/2017	Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2017 – present	Master's course of Graduate School of National Fisheries University, Shimonoseki, Japan

Yuji Kashino:

04/1982 – 03/1986	Undergraduate course of Department of Science of Hokkaido University, Sapporo, Japan
04/1986 – 03/1988	Master's course of Graduate School of Science of Hokkaido University, Sapporo, Japan
04/1988 – 03/1991	Fujitsu co., Tokyo, Japan
04/1991 – 03/2017	Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan
09/2000	PhD from Hokkaido University

04/2017 – present Department of Fishery Science and Technology, National Fisheries University, Shimonoseki, Japan
Research field: Oceanography

Yoshiyasu Kobayashi :
04/1997－03/2001 Undergraduate course of Department of Fisheries Tokyo University of Fisheries, Tokyo, Japan
04/2001－03/2002 Advanced course of Tokyo University of Fisheries,Tokyo, Japan
04/2002– present Fisheries Agency

Kiyohiko Fukami:
04/1986－03/1990 Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1990－03/1991 Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1991– present Fisheries Agency
Research field: Navigation

Tadashi Kamano:
04/1980－03/1984 Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1984－03/1985 Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1996 – present Fisheries Agency
Research field: Navigation