Analysis of relationship between water temperature and catch for Pacific bluefin tuna and longtail tuna off Futaoi Island (western Sea of Japan) using the Jarque-Bera test

Masahiko Mohri *, Koich Fukada *, Tetsutaro Takikawa *, Tom Nishida **

and Mizuki Imamiya *

*National Fisheries University, Dept. of Fisheries Science and Technology,

Japan

**National Research Institute of Far Seas Fisheries, Fisheries Research Agency,

Japan

Abstract

The relationship between water temperature and number of two tuna species (Pacific bluefin tuna and longtail tuna) obtained by set-net fishery off Futaoi Island (western Sea of Japan) was examined using the Jarque-Bera test. In this study, the optimum water temperature ranges for catching the two species was 20-30°C for longtail tuna and 12-19°C for bluefin tuna. "Tennen kuromaguro (local Japanese name, natural bluefin tuna)" caught at 17.2°C were considered as Pacific bluefin tuna. "Yokowa" caught in the summer at a water temperature range of 20-30°C, which coincided with the optimum range for catching longtail tuna, were considered as longtail tuna. As temperatures in 2007 were higher than in normal years, longtail tuna were judged as being caught only in September (27.2°C) and October (24.1°C) during that year.

1 Introduction

Most tuna species caught in the Sea of Japan are Pacific bluefin tuna (*Thunnus orientalis*) and longtail tuna (*Thunnus tonggol*). At the Tottori Prefectural Fishery Experimental Station, this year (2009), the catch size for bluefin tuna was smaller than normal in the Sea of Japan due to a shortage of bait (Japanese common squid, *Todarodes pacificus*) and cold water temperatures (Japan Broadcasting Corporation, October 5, 2009). Concerns about the relationship between water temperature and tuna catch prompted an increased number of studies on bluefin tuna [1]-[4] and longtail tuna [5].

Since these tuna species resemble each other, longtail tuna are often mistaken for bluefin tuna. In relation to this error, we found the following three points through an examination of these studies in 2009: 1) It was not determined if the "Tennen kuromaguro (local Japanese name, natural bluefin tuna)" caught in May 2008 were Pacific bluefin tuna; 2) It was not elucidated whether the "Yokowa (local Japanese name, juvenile tuna species)" caught in the summer in the western Sea of Japan were bluefin tuna or longtail tuna.; and 3) The reason why longtail tuna were not caught during the fishing season (from June to August) in 2007 was not clarified.

Mohri *et al*.[6]-[8] examined the following six points for tuna species in the Sea of Japan: 1) The fishing season for longtail tuna runs from June to October; 2) Judging from the water temperatures obtained by NOAA satellite at juvenile tuna catch points, the optimum water temperature for adult longtail tuna was assumed to be about 24°C; 3) The optimum water temperature for catching longtail tuna was assumed to be about 25°C and bluefin tuna about 16°C; 4) The water temperature was the minimum value and it rose to the maximum value before longtail tuna were caught 24 h later. Subsequently, adult longtail tuna were caught in large numbers with a set net; 5) In most cases, longtail tuna were caught in the summer and bluefin tuna were caught in the winter; and 6) The optimum average water temperature for catching longtail tuna was 25.56°C.

However, these studies covering the above six points did not apply adequate statistical methods. Consequently, this paper aims to clarify the relationship between water temperature and catch size of the two tuna species using the Jarque-Bera test. This test is commonly used in the field of economics, but there is no example of its use in tuna fisheries science until now.

2 Materials and methods

2.1 materials

During the period from 1995- to 2008, we conducted fisheries oceanography research on longtail and bluefin tuna simultaneously through set-net operations performed by fishermen of Futaoi Island. Water temperature was observed at a depth of 5 m every 30 min. Three types of thermometers were used during the observation period: SBE 37 SM (Sea-Bird Electronics, USA), and AT-32K and ACTW-CMP (Alec Electronics, Japan).

Fig. 1 shows the location of Futaoi Island and the position of the set nets. Futaoi Island is located at 34°06'N 130°47'E and the set net was placed in the area northeast of the island.

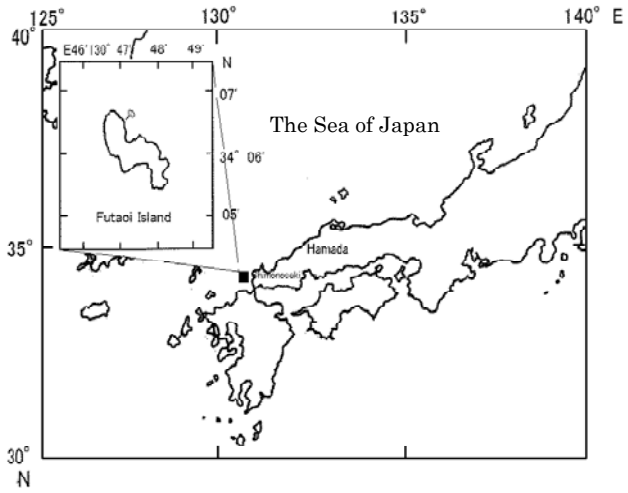

Fig.1 Location of Futaoi Island and set net position.

2.2 Analytical methods

2.2.1 Items analyzed

We analyzed the following items.

The Futaoi Island branch office of the Shimonoseki Hibiki Fishermen's Cooperative Association of Yamaguchi Prefecture recorded the data on adult tuna species caught with set nets during the period from 1995 to 2008. We used this catch data for our calculations.

First, we calculated the average water temperature on Day 1 with thermometers used for a set net on the day when tuna species were caught. A 1°C range was compiled per 0.0-0.9°C. In this study, we assessed the population for the average water temperature on the day when tuna species were caught.

Regarding the catch of "Yokowa", Mohri *et al*. considered them as longtail tuna in the summer and bluefin tuna in the winter [9]. Therefore, longtail tuna (longtail tuna and "Yokowa" caught in summer) and bluefin tuna ("Yokowa" caught in winter) were each calculated.

2.2.2 Jarque-Bera test

To confirm that the data conformed to a normal distribution [10][11], we referred to Konishi [12], for the conventional Jarque-Bera test, which uses *skewness* and *kurtosis*. A null hypothesis is assumed where "data obeys a normal distribution" and an alternative hypothesis where "data does not obey a normal distribution," and the following Eq. (1) is used:

$$JB = \frac{N}{6}\{skewness^{2} + \frac{1}{4}(kurtosis - 3)^{2}\} \tag{1}$$

where JB = statistical quantity of Jarque-Bera test

The Jarque-Bera test is one-sided with a chi-square test for degrees of freedom = 2 under a null hypothesis. *Skewness* (S) and *kurtosis* (K) are expressed in Eqs. (2) and (5).

$$Skewness = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{y_i - \bar{y}}{\hat{\sigma}}\right)^{3} \tag{2}$$

where N = number of samples, $\bar{y}$ = sample mean

When s = unbiased variance, Eqs. (3) and (4) are obtained:

$$s = \sqrt{\frac{\sum_{i=1}^{N}(y_i - \bar{y})^{2}}{N-1}} \tag{3}$$

$$\hat{\sigma} = s\sqrt{\frac{N-1}{N}} = \sqrt{\frac{\sum_{i=1}^{N}(y_i - \bar{y})^{2}}{N}} \tag{4}$$

When Eq. (4) is calculated, Eq. (5) is obtained:

$$Kurtosis = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{y_i - \bar{y}}{\hat{\sigma}}\right)^{4} \tag{5}$$

The value of *skewness* becomes 0 with a symmetric distribution. *Skewness* is biased to the right in the case of plus and left in the case of minus. *Kurtosis* becomes a normal distribution when the value is 3. *Kurtosis* has a peak in the case of values above 3, and is flat when the value is below 3.

3 Results

Fig. 2 shows the relationship between water temperature (horizontal axis) and catch size for longtail tuna (vertical axis). According to this figure, water temperature when longtail tuna were caught was within the range of 19-30°C, and the peak catch was at the temperature range of 24-26°C. When the highest number was caught (791), the water temperature was 26°C. When the second-highest number was caught (694), the water temperature was 24°C. In other words, the highest number was caught in the temperature range from 24°C to 26°C.

The relationship between water temperature and catch size of bluefin tuna is shown in Fig. 3. In this figure, the water temperature when bluefin tuna were caught ranged from 13°C to 18°C. When the highest number was caught (202), the water temperature was 14°C. A low number of bluefin tuna below 100 was caught in other water temperature ranges.

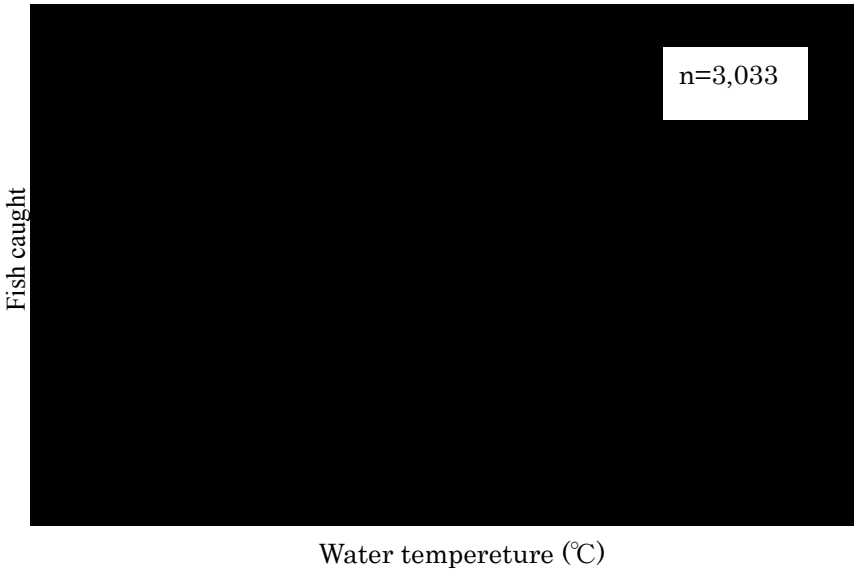

Fig. 2 Relation between water temperature and number of longtail tuna caught.

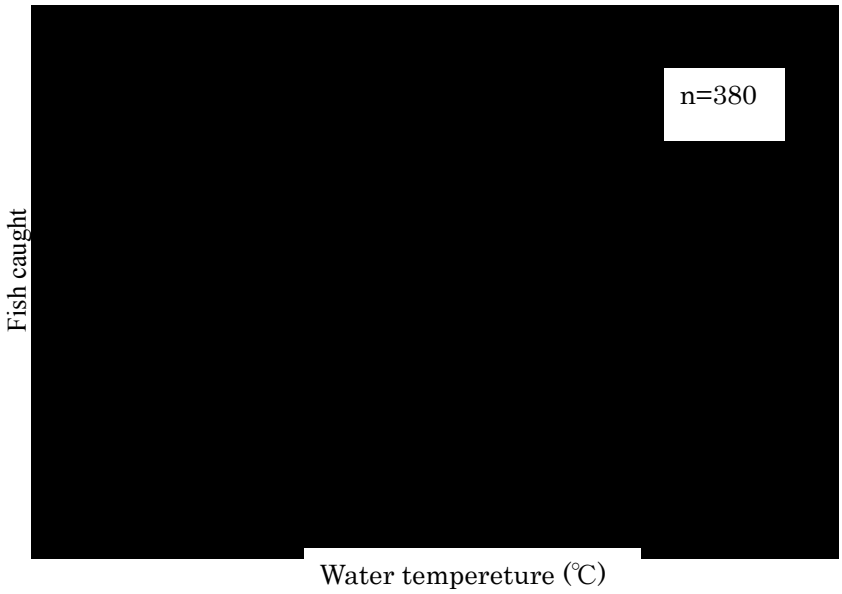

Fig. 3 Relationship between water temperature and number of bluefin tuna caught.

From Fig. 2 and Fig. 3, longtail tuna and bluefin tuna were distributed at the center of 25°C and 15°C, respectively. We examined the water temperature range using the Jarque-Bera test. For longtail tuna, the results of Eqs. (2) and (5) were S = 1.205 and K = 0.412, respectively. In the case of S = 1.205 and K = 0.412, the result of Eq. (1) was JB = 6.253. The Jarque-Bera test obeyed the chi-square test for degrees of freedom = 2. According to the chi-square distribution table, χ^2 = 5.991 for significance level = 0.05 and χ^2 = 9.210 for significance level = 0.01. Since the probability of a null hypothesis is above 1%, this hypothesis is not rejected. Therefore, we can judge that the "relationship between water temperature and catch size of longtail tuna" has a normal distribution.

On the other hand, for bluefin tuna, the results of Eqs. (2) and (5) were S = 2.043 and K = 4.388, respectively. In the case of S = 2.043 and K = 4.388, the result of Eq. (1) was JB = 4.656. According to the chi-square distribution table, χ^2 = 5.991 with significance level = 0.05 and χ^2 = 9.210 with significance level = 0.01. As the probability of a null hypothesis is above 5%, this hypothesis is not rejected. Ultimately, we consider that the "relationship between water temperature and catch size of bluefin tuna catch" has a normal distribution.

In the case of a normal distribution, $\bar{y}$ = sample mean and σ = standard deviation, 99.73% were included in $\bar{y} \pm 3\sigma$. As σ = 1.70, $\bar{y}$ = 25.5 $\bar{y} + 3\sigma$ = 30.4 and $\bar{y} - 3\sigma$ = 20.4 for longtail tuna, $\bar{y} \pm 3\sigma$ ranged from 20.4°C to 30.4°C. On the other hand σ = 1.22, $\bar{y}$ = 15.5, $\bar{y} + 3\sigma$ = 19.2 and $\bar{y} - 3\sigma$ = 11.8, so $\bar{y} \pm 3\sigma$ for bluefin tuna ranged from 11.8°C to 19.2°C. Accordingly, we considered that the optimum water temperature range for catching the two species was 20-30°C for longtail tuna and 12-19°C for bluefin tuna.

Fig. 4 and Fig. 5 show the relationship between water temperature and catch size for

the two species obtained by set net fishery using the expected value based on the null hypothesis for longtail tuna (Fig. 4) and bluefin tuna (Fig. 5), respectively. From Fig. 2 and Fig. 4, the expected value based on the null hypothesis resembled the observed values in distribution tendency. However, the observed values tend to become higher than expected based on the null hypothesis at the high-temperature side. As shown in Fig. 3 and Fig. 5, the number of bluefin tuna caught was higher at the observed value than at the expected value based on the null hypothesis at 14°C. We judged that this tendency of a higher observed value at 14°C was affected by the very large number of bluefin tuna caught at this temperature.

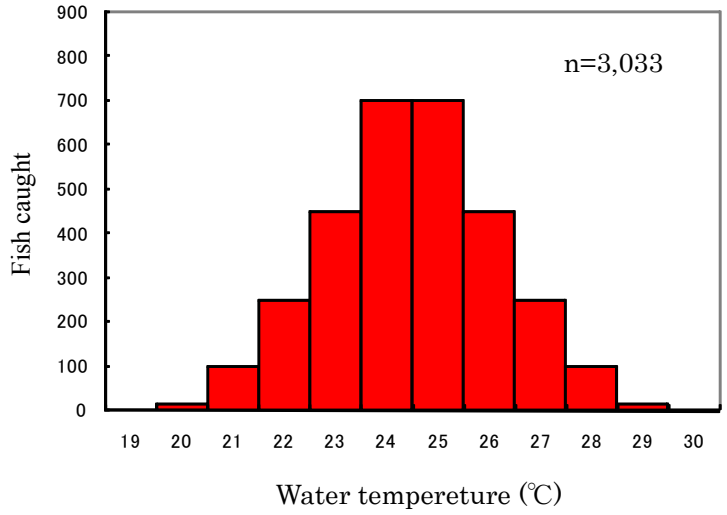

Fig. 4 Relation between water temperature and number of longtail tuna caught by set net fishery using expected value based on null hypothesis.

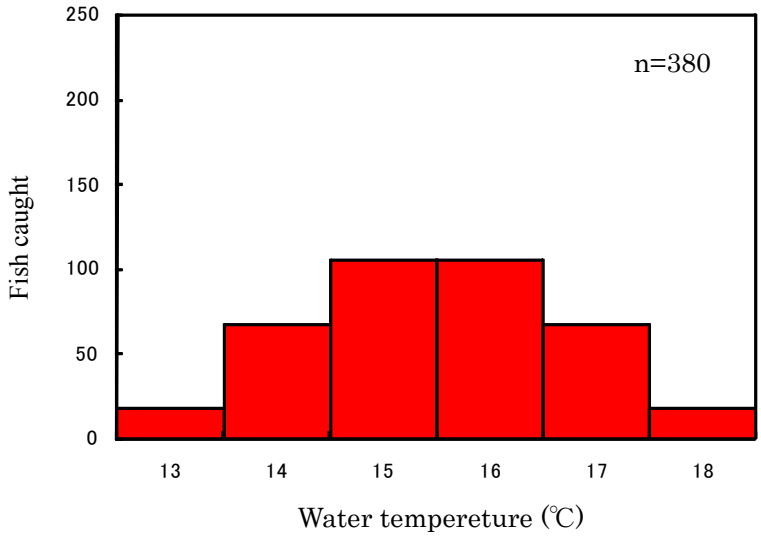

Fig. 5 Relation between water temperature and number of bluefin tuna caught by set net fishery using expected value based on null hypothesis.

4 Discussion

Here, we discuss the three points listed in the Introduction.

1. Are the "Tennen kuromaguro (local Japanese name, natural bluefin tuna)" caught in May 2008 actually Pacific bluefin tuna?

"Tennen kuromaguro" were caught on May 15, 2008, so we examined the average water temperature on that day and obtained a value of 17.2°C. This 17.2°C was within the optimum water temperature range for catching bluefin tuna, as shown in Fig. 5. Therefore, we considered the "Tennen kuromaguro" caught on May 15, 2008 to be Pacific bluefin tuna.

2. Are the "Yokowa (local Japanese name, juvenile tuna species)" caught in the summer in the western Sea of Japan bluefin tuna or longtail tuna?

Table 1 gives the dates when "Yokowa" were caught and the average water temperature during the period 1995-2008, except in winter. Average water temperature from 1995 to 2008 ranges from about 20-30°C in this table. As this 20-30°C coincided with the optimum water temperature ranges for catching longtail tuna, we considered "Yokowa" to be longtail tuna.

Table 1 Date of "Yokowa (Japanese local name, juvenile tuna species)" caught and average water temperature during the period 1995－2008, except winter.

Date	Average water temperature (℃)	Date	Average water temperature (℃)
28/07/1995	23.4	25/07/2000	21.2
31/07/1995	26.3	28/07/2000	26.8
02/08/1995	26.3	29/08/2000	30.5
11/10/1995	22.9	22/09/2000	29.8
23/10/1995	27.7	18/09/2001	24.3
01/09/1998	26.3	26/10/2001	22.9
07/09/1998	26.5	07/06/2006	19.0
		11/07/2006	20.7

3. Why were longtail tuna not caught during the fishing season (from June to August) in 2007 ?

The main fishing season for longtail tuna is from June to August, but this tuna species was caught only in September and October in 2007. On the other hand, longtail tuna were caught in the period from June to August in 2006 and 2008 because these two years had a normal sized catch of this tuna species. So, we examined the differences in average water temperature in 2006, 2007 and 2008.

Table 2 shows the average water temperatures (°C) from June to October in 2006, 2007, and 2008. From this table, we compared average water temperatures for these three years. In the case of September and October, we found that the average water temperature in 2007 was higher than that in 2006 and 2008. In 2007, it was 27.2°C in September and 24.1°C in October, and both months were 2°C higher than in 2006 and 2008. As 2007 had higher temperatures than in normal years, we judged that longtail tuna were caught only in September and October of that year. Average water temperatures from June to August in 2007 resembled normal years, but longtail tuna were not caught during this period. We cannot provide the reason why longtail tuna were not caught during this period.

Table 2 Average water temperature (℃) from June to October in 2006, 2007, and 2008.

Year / Month	2006	2007	2008
June	19.9	20.6	20.1
July	23.9	23.5	24.9
August	26.7	26.8	27.9
September	25.4	27.2	25.3
October	22.3	24.1	22.4

5 Future prospects

Our next task is to forecast the change in tuna catch size using the characteristics of water temperature distribution.

In this study, we examined the catch size of two tuna species only in relation to water temperature. We would like to analyze the relationship between catch size and other factors such as salinity and dissolved oxygen.

We could not elucidate the reason why longtail tuna were not caught during the 2007

fishing season from June to August in this study. We need to increase the volume of data in the future and further examine the relationship between water temperature and catch size of these two tuna species.

6 Acknowledgements

We express our gratitude to Toshiyuki Sakaki, head of the Futaoi Island branch office of the Shimonoseki Hibiki Fishermen's Cooperative Association of Yamaguchi Prefecture, for his valuable suggestions about adult longtail tuna and water temperature at the fishing grounds.

References

[1] T. Kitagawa, H. Nakata, S. Kimura, T. Itoh, S. Tsuji and A. Nitta: Effect of ambient temperature on the vertical distribution and movement of Pacific bluefin tuna (*Thunnus thynnus orientalis*), *Marine Ecology Progress Series*, **206**(2000), 251-260.

[2] T. Kitagawa, H. Nakata, S. Kimura and S. Tsuji: Thermoconservation mechanism inferred from peritoneal cavity temperature recorded in free swimming Pacific bluefin tuna (*Thunnus thynnus orientalis*), *Marine Ecology Progress Series*, **220**(2001),253-263.

[3] T. Kitagawa, S. Kimura, H. Nakata, H. Yamada Thermal adaptation of Pacific bluefin tuna *Thunnus orientalis* to temperate waters, *Fisheries Science*, **72**(2006), 149－156.

[4] Y. Tanaka, M. Mohri and H.Yamada: Distribution, growth and hatch date of juvenile Pacific bluefin tuna *Thunnus orientalis* in the coastal area of the Sea of Japan, *Fisheries Science*, **73**(2007), 534－542.

[5] T. Kobayashi and T Watanabe: Longtail tuna migrating along the Sea of Japan off the coast of Yamaguchi Prefecture, *Bull. Seikai Brock Fishing and Oceanic Condition*, **10**(2003), 15-20.

[6]M. Mohri, K. Fukada, H.Yamada and H. Inoue: Relationship between Longtail Tuna Catches and Water Temperature on the Sea of Japan off the Coast of Yamaguchi Prefecture, *Memories of the faculty of agriculture of Kinki University*, **38**(2005), 68-75.

[7]M. Mohri, K. Fukada, T. Takikawa, D. Yamamoto and T. Yamane: Relation between Water Temperature Range and Longtail Tuna Caught by the Set-net off the Futaoi Island, *Mathematical and Physical Fisheries Science*, **4**(2006), 51-62.

[8]M. Mohri, K. Fukada, T. Takikawa and M. Miura: Relation between Water

Temperature and Longtail Tuna Caught by a Set-net Fishery off Futaoi Island, *Mathematical and Physical Fisheries Science*, **6**(2008), 58-67.

[9]M. Mohri, K. Fukada, T. Takikawa, H. Nozaki: Consideration on differences among catches of tuna species caught by a set-net fishery off Futaoi Island, Yamaguchi Prefecture (western Japan Sea) as seen from seasonal changes, Abstracts for the Annual Meeting of the Japanese Society of Fisheries Science (2008), 16.

[10] Y. Nagata: Mechanism of statistical methods, Nikkagiren Press, 2005.

[11] T. Matsui: Statistical analysis, Nihonjitsugyou Press, 2009.

[12] Y.Konishi: http://www.ier.hit-u.ac.jp/~konishi/.

Received September 11, 2009

Accepted October 15, 2009

Academic backgrounds:

Masahiko Mohri:

04/1983－03/1987	Department of Fishery Science and Technology of Shimonoseki University of Fisheries, Shimonoseki, Japan
04/1987－03/1988	Advanced course of Fishery Science and Technology of Shimonoseki University of Fisheries, 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

Koich Fukada:

04/1966－03/1970	Department of Fishery Science and Technology of Shimonoseki University of Fisheries, Shimonoseki, Japan
04/1970－03/1971	Advanced course of Fishery Science and Technology of Shimonoseki University of Fisheries, Shimonoseki, Japan
06/1971－03/1986	Research Associate of Shimonoseki University of Fisheries, Shimonoseki, Japan
04/1986－03/1991	Lecturer of Shimonoseki University of Fisheries, Shimonoseki, Japan
04/1991－present	Associate professor of National Fisheries University, Shimonoseki, Japan
Research field:	Fishing techniques, Fisheries data processing

Tetsutaro Takikawa:

04/1993－03/1997	Department of Earth and Planetary Sciences, Faculty of Sciences, Kyushu University, Fukuoka, Japan
04/1997－03/1999	Department of Earth System Science and Technology, Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Fukuoka, Japan (Master of Science)
04/1999－03/2003	Department of Earth System Science and Technology, Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Fukuoka, Japan (Doctor of Science).
04/2003－06/2004	Frontier Observational Research System for Global Change, Japan Marine Science and Technology Center (Postdoctoral Fellow)
07/2004－present	Department of Fishery Science and Technology, National Fisheries University, Shimonoseki, Japan (Research Associate)
Research field:	Physical oceanography

Tom Nishida

04/1973 － 03/1977	Faculty of Fisheries, Hokkaido University, Hokkaido, Japan. (Bachelor of Science)
04/1977 － 03/1979	Fisheries Science. University of Washington, Washington, USA. (Bachelor of Science)
04/1979 － 03/1983	Quantitative Ecology, University of Washington Washington, USA. (Master of Science)
04/1983 － 03/1991	Fisheries managements, University of Tokyo, Tokyo, Japan. (Doctor of Agriculture)
04/1992 － present	Research scientist, National Research Institute of Far Seas Fisheries, Fisheries Research Agency, Japan
Research field:	Fish stock assessment, Fisheries statistics, Integrated spatial analyses for fisheries and marine ecosystem information using GIS.

Mizuki Imamiya:

04/2004－03/2009	Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2008－present	Maruhachi Securities CO.,LTD., Japan
Research field:	Fisheries information analysis