Fork length body weight and stomach contents of longtail tuna Thunnus tonggol caught in the set net fishing off Futaoi Island (on the Japan Sea side of Yamaguchi Prefecture).

Fork length, body weight, and stomach contents of longtail tuna, *Thunnus tonggol*, caught in the set net fishing off Futaoi Island (on the Japan Sea side of Yamaguchi Prefecture)

Masahiko Mohri*, Takumi Terashima*, Junji Koga*, Katsuya Narutaki*,
Teru Taguchi and Hideaki Tanoue*
***National Fisheries University, Dept. of Fishery Science and Technology, Japan**

Abstract

The fork length, stomach contents, and lipid content percentage for each of longtail tunas caught in the set net off Futaoi Island (on the Japan Sea side of Yamaguchi Prefecture), were investigated and the following results were obtained. The number of longtail tunas caught for this study was 80, whose fork length and body weight ranged from 42.5 to 65.0 cm and from 1500 to 5000 g, respectively. In particular, fork lengths of the individuals within the 47.5– 57.5 cm range accounted for the largest number of 65 and exceeded 80% of the total. On the other hand, the body weights were 93% of the largest number of 74 longtail tuna individuals between 1500 and 3500 g. The stomach contents of 24 longtail tunas were checked and the result showed Japanese jack mackerel 58%, Japanese anchovy 17%, round herring 13%, Japanese sardine 8%, and chub mackerel 4%.

1 Introduction

Most tunas caught in the Japan Sea are either longtail tuna (*Thunnus tonggol*) or Pacific bluefin tuna (*T. orientaris*) (hereafter referred to as bluefin tuna). Of the two species of tunas, research results are currently less in the former and more in the latter.

Longtail tuna, which requires further research due to the current situation with few results, has a spindle-shaped species with characteristic long pectoral fins. The maximum length of this species is small, approximately one meter, and most of those that migrate to the seas around Japan are 60 cm or less in body length. Longtail tuna is sometimes confused with juvenile of other tuna species, especially juvenile bluefin tuna.

With regard to longtail tuna from the perspective of the fishing target [1], in Japan, the largest catch is in Nagasaki Prefecture, followed by Yamaguchi and Shimane Prefectures. For the purpose of verifying that Yamaguchi Prefecture is a suitable place for the study of longtail tuna, we plotted the changes in the number of this species caught by the set net off Futaoi Island (on Japan Sea side) in the same prefecture over years (1995 through 2019, the period currently available) on Fig. 1 with the vertical axis representing the number of individuals caught and the horizontal axis the year. This figure shows that approximately 1,700 individuals were caught in 2009, which was the maximum catch, and in the other years the number fluctuated between approximately 50 and 1,000 and never dropped to zero. As a result, we decided that Yamaguchi Prefecture was one of the prefectures suitable for the study because of its sufficiently large catch of longtail tuna and collected basic information on the ecology of this species caught in the set net off Futaoi Island (on Japan Sea side) in the same prefecture from the aspect of three factors, i.e., fork length, maturity, and stomach contents. This paper reports these results. Fig. 2 shows the location of Futaoi Island and the position of the set net.

In this study, in addition to the investigation of the above three factors using the accumulated data, the lipid content percentage of longtail tuna was focused as well. The lipid content percentage of fish is generally known to vary by sex and season, with large individual differences [2]-[5]. It is common knowledge among those involved in the fishing industry that the lipid content percentage of tunas becomes higher before and lower after spawning - that is, the maturation and spawning of this species act on the change in the lipid content percentage - and that this change influences the price of an individual fish from the perspective of a commodity. In particular, there is a high demand from wholesalers and distributors for information on the lipid content percentage of the target fishes discussed here because the commercial value as fresh fish varies greatly depending on the situation: the higher the lipid content percentage, the higher the value; the lower the lipid content percentage, the lower the value [6].

Based on the above background, this study aimed to measure the lipid content percentage using a fish quality state distinction device (hereafter referred to as Fish Analyzer) and to understand a relationship between the maturity and the lipid content percentage. This result is also reported here.

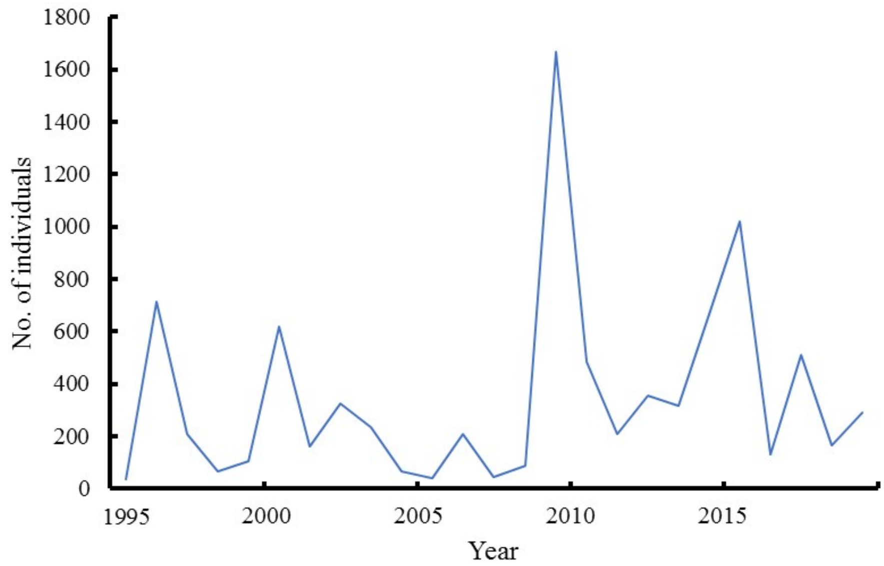

Fig.1 Changes in the number of longtail tunas caught by the set net off Futaoi Island (on Japan Sea side) over years (1995-2019).

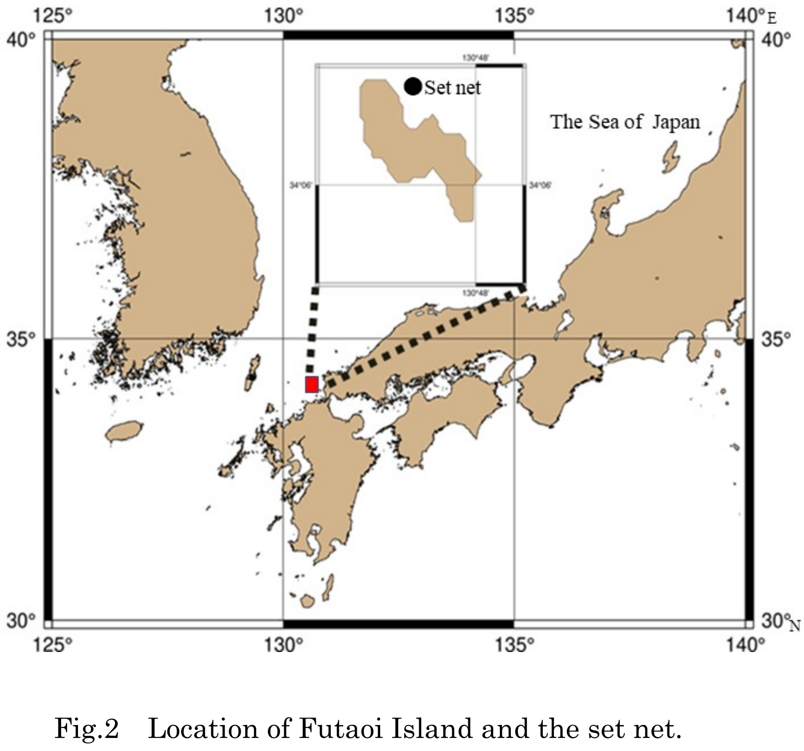

Fig.2 Location of Futaoi Island and the set net.

2 Material and Methods

A total of four items were examined in 80 longtail tunas caught between 2016 and 2021: Each fork length and weight were measured, and then gonadal sex determination and stomach contents analysis were performed for the same individuals.

For nine longtail tunas caught in 2021, in addition to the above four items, the lipid content percentage was measured and the maturation state was determined in order to examine the relationship between changes in the lipid content percentage and the maturity.

2.1 Measurement of lipid content percentage

Fish Analyzer (Yamato Scale Co., Ltd.), which was used for measuring the lipid content percentage, has a structure that measures differences in lipid content percentage based on high and low impedance values. Impedance value means the resistance value measured when electric current is passed through a fish body. This device takes advantage of the fact that, in general, electric current is difficult to pass through lipid and flows easily through muscle and moisture. In other words, measurement using impedance values means a method of deriving lipid content percentage based on whether or not current flows easily when it is applied to fish. That is, the higher the impedance value is, the higher the lipid content percentage of the fish body becomes, and the lower the impedance value, the lower the lipid content percentage.

Fish Analyzer cannot be used to measure fishes which have been frozen and thawed. The impossibility of such a measurement is due to the cell membrane damage induced during thawing. In order to prevent such a damage of cell membranes which are essential for lipid content measurement, in 2021 we asked a fisheries cooperative that owns the set net to send longtail tunas put in cold storage to us (although they are usually delivered frozen), and then measured the lipid contents percentage of these samples using Fish Analyzer.

Impedance values vary due to changes over time in fish body temperature after landing. The fishes for this study were put in cold storage as soon as they were caught to suppress changes in the fish bodies due to ambient temperature, and then only the fish which can be measured using Fish Analyzer within 24 hours of the catch was used as samples. For the lipid content percentage (%) measurement, the bluefin tuna mode was used because bluefin tuna is the same genus Thunnus as longtail tuna. For the calibration curve (Ω), the impedance value was measured in the same mode. The points of measurement using Fish Analyzer were three regions, i.e., dorsal, pelvic, and tail, for which the measurement was respectively performed three times according to the instructions, and then each average was calculated.

2.2 Determination of maturation state

A simple method below was applied to determine the maturation state of the longtail tunas whose lipid content percentage was measured. After the sex determination, both right and left gonads were eviscerated, weighed and recorded, respectively. After that, the gonad index (*GI*) was calculated by the following formula:

$$GI = W \cdot 10^4/L^3 \qquad (1)$$

where W is the gonadal weight (g) and L is the fork length (cm).

In general, the higher the *GI* value obtained by the above calculation is, the more mature the fish is, and the lower the value, the more immature it is [7]-[10].

3 Results

The distribution of the longtail tunas by fork length and body weight are shown in Fig. 3 and Fig.4, respectively. The number of longtail tunas caught for this study was 80, which ranged from 42.5 to 65.0 cm of fork length and from 1500 to 5000 g of body weight. In particular, those within the 47.5–57.5 cm range accounted for the largest number of 65 and exceeded 80% of the total (see Fig.3). On the other hand, the body weight was 93% of the largest number of 74 longtail tuna individuals between 1500 and 3500 g (see Fig.4).

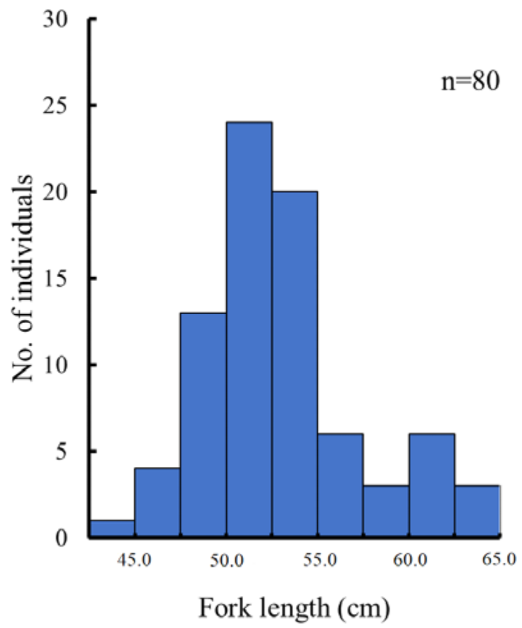

Fig.3 Distribution of longtail tunas by fork length.

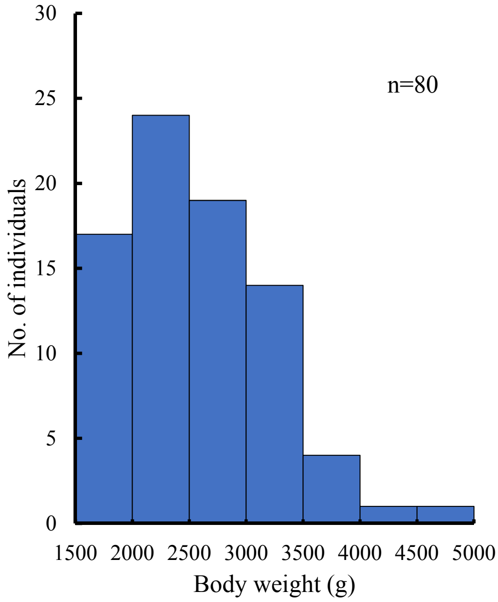

Fig.4 Distribution of longtail tunas by body weight.

Tables 1 to 6 show the catch date, sex, fork length (cm), weight (g), and stomach contents of the sample longtail tunas obtained over a six-year period from 2016 through 2021.

First, in 2016 (see Table 1), the samples were obtained over four days (July 8 and 22, September 6 and 7), with a total of 11 individuals (five males and six females), fork length of 49.8–55.0 cm, weight of 2,260–3,080 g, stomach contents of Japanese anchovy (*Engraulis japonicus*) in four individuals, Japanese jack mackerel (*Trachurus japonicus*) in two individuals, and no stomach contents in the other six individuals.

In 2017 (see Table 2), samples were obtained over four days (September 9 and 16, October 2, and November 2), with a total of 12 individuals (seven males and five females), fork length of 49.0–55.0 cm, weight of 2,300–3,800 g, stomach contents of Japanese jack mackerel in two individuals and no stomach contents in the other 10 individuals.

In 2018 (see Table 3), samples were obtained over four days (August 28, September 19, October 4, and November 15), with a total of 12 individuals (five males and seven females), fork length of 44.5–51.2 cm, weight of 1,540–2,540 g, stomach contents of Japanese jack mackerel in one individual, and no stomach contents in the other 11 individuals.

Table 1 Catch date, sex, fork length (cm), weight (g) and stomach contents of longtail tunas (2016).

No.	Date	Sex	Fork length (cm)	Body weight(g)	Stomach contents
1	Jul.8	male	55.0	3,080	*Trachurus japonicus*
2	Jul.8	female	52.5	2,780	*Trachurus japonicus* *Engraulis japonica*
3	Jul.8	female	53.5	2,740	*Engraulis japonica*
4	Jul.22	female	49.8	2,500	empty
5	Jul.22	male	50.5	2,560	empty
6	Jul.22	male	53.0	3,040	empty
7	Sep.6	male	54.6	2,780	empty
8	Sep.6	female	53.2	2,660	empty
9	Sep.6	female	52.4	2,540	empty
10	Sep.7	female	55.0	2,740	*Engraulis japonica*
11	Sep.7	male	50.0	2,260	*Engraulis japonica*

Table 2 Catch date, sex, fork length (cm), weight (g) and stomach contents of longtail tunas (2017)
(Fork lengths were measured a decimal by cutting off in 2017.)

No.	Date	Sex	Fork length (cm)	Body weight (g)	Stomach contents
1	Sep.9	male	52.0	3,100	empty
2	Sep.9	male	53.0	3,200	empty
3	Sep.9	male	50.0	2,900	empty
4	Sep.16	male	51.0	2,800	empty
5	Sep.16	male	54.0	2,900	*Trachurus japonicus*
6	Sep.16	female	53.0	2,600	empty
7	Oct.2	male	55.0	3,600	*Trachurus japonicus*
8	Oct.2	female	49.0	3,500	empty
9	Oct.2	female	54.0	3,800	empty
10	Nov.2	female	50.0	2,300	empty
11	Nov.2	male	51.0	3,000	empty
12	Nov.2	female	49.0	2,700	empty

Table 3 Catch date, sex, fork length (cm), weight (g) and stomach contents of longtail tunas (2018)

No.	Date	Sex	Fork length (cm)	Body weight(g)	Stomach contents
1	Aug.28	male	49.1	1,958	empty
2	Aug.28	male	48.0	1,908	empty
3	Aug.28	male	44.5	1,634	empty
4	Sep.19	female	48.2	1,768	empty
5	Sep.19	female	45.2	1,569	empty
6	Sep.19	female	46.3	1,540	empty
7	Oct.4	female	49.4	1,962	empty
8	Oct.4	female	49.2	1,929	empty
9	Oct.4	female	48.6	2,046	empty
10	Nov.15	female	50.6	2,540	empty
11	Nov.15	male	51.2	2,320	empty
12	Nov.15	male	50.3	2,420	*Trachurus japonicus*

In 2019 (see Table 4), samples were obtained over eight days (June 5, 13, and 28, July 9 and 25, August 2 and 23, and October 25), with a total of 24 individuals (12 males and 12 females), fork length of 49.2–63.1 cm, weight of 1,720–3,660 g, stomach contents of Japanese jack mackerel in two individuals, Chub mackerel (*Scomber japonicus*) in one individual, one individual left a bone of unknown species, and no stomach contents in the other twenty individuals.

In 2020 (see Table 5), samples were obtained over four days (June 17 and 26, July 7 and 25), with a total of 12 individuals (10 males and 2 females), fork length of 46.8–56.0 cm, weight of 1,600–2,600 g, stomach contents of Japanese jack mackerel in three individuals, Round herring (*Etrumeus teres*) in two individuals, Japanese sardine (*Sardinops melanostictus*) in one individual, and both Japanese jack mackerel and Round herring in one individual, and no stomach contents in the other five individuals.

In 2021 (see Table 6), samples were obtained over three days (June 16 and 25, and July 7), with a total of nine individuals (four males and five females), fork length of 51.2–64.0 cm, weight of 2,180–4,760 g, stomach contents of Japanese jack mackerel in four individuals, Japanese sardine in one individual, and no stomach contents in the other four individuals.

Table 4 Catch date, sex, fork length (cm), weight (g) and stomach contents of longtail tunas (2019)

No.	Date	Sex	Fork length (cm)	Body weight (g)	Stomach contents
1	Jun.5	male	59.8	3,000	empty
2	Jun.5	female	63.1	3,480	empty
3	Jun.5	male	59.9	3,080	empty
4	Jun.13	female	49.7	2,140	unidentified
5	Jun.13	female	50.2	2,360	empty
6	Jun.13	male	53.4	2,580	*Scomber japonicus*
7	Jun.28	male	52.1	2,220	empty
8	Jun.28	male	53.2	2,320	empty
9	Jun.28	male	56.8	2,680	empty
10	Jul.9	female	53.8	2,180	empty
11	Jul.9	female	52.2	2,100	*Trachurus japonicus*
12	Jul.9	female	51.4	1,980	empty
13	Jul.25	male	57.4	2,680	empty
14	Jul.25	female	52.0	1,980	empty
15	Jul.25	female	53.8	2,260	empty
16	Aug.2	female	52.5	2,160	empty
17	Aug.2	female	53.8	2,320	empty
18	Aug.2	male	52.0	2,240	empty
19	Aug.23	male	54.0	2,380	*Trachurus japonicus*
20	Aug.23	female	51.0	1,980	empty
21	Aug.23	female	49.2	1,720	empty
22	Oct.25	male	60.0	3,020	empty
23	Oct.25	male	61.2	3,480	empty
24	Oct.25	male	61.8	3,660	empty

Table 5 Catch date, sex, fork length (cm), weight (g) and stomach contents of longtail tunas (2020)

No.	Date	Sex	Fork length (cm)	Body weight (g)	Stomach contents
1	Jun.17	male	49.9	2,020	*Trachurus japonicus*
2	Jun.17	male	54.8	2,560	*Trachurus japonicus*
3	Jun.17	male	50.0	1,920	empty
4	Jun.26	male	54.2	2,280	empty
5	Jun.26	male	56.0	2,600	empty
6	Jun.26	female	52.6	2,220	*Etrumeus teres*
7	Jul.7	male	50.1	1,920	*Etrumeus teres*
8	Jul.7	male	52.3	2,320	*Trachurus japonicus*, *Etrumeus teres*
9	Jul.7	male	52.9	2,160	*Trachurus japonicus*
10	Jul.25	female	46.8	1,720	empty
11	Jul.25	male	47.8	1,600	*Sardinops melanostictus*
12	Jul.25	female	47.0	1,700	empty

Table 6 Catch date, sex, fork length (cm), weight (g) and stomach contents of longtail tunas (2021)

No.	Date	Sex	Fork length (cm)	Body weight (g)	Stomach contents
1	Jun.16	female	51.2	2,220	*Trachurus japonicus*
2	Jun.16	male	52.4	2,180	*Trachurus japonicus*
3	Jun.16	female	61.2	3,380	empty
4	Jun.25	female	60.8	3,360	empty
5	Jun.25	male	51.8	2,220	*Trachurus japonicus*
6	Jun.25	female	62.0	3,460	empty
7	Jul.7	male	64.0	4,760	empty
8	Jul.7	male	64.0	4,000	*Trachurus japonicus*
9	Jul.7	female	59.0	3,460	*Sardinops melanostictus*

Fig. 5 shows the composition of the stomach contents of the sample longtail tunas. Out of all the samples included in this study, 25 longtail tunas were checked for the stomach contents. The stomach contents of No.4 were unidentified in 2019 (see Table 4). The result of the other 24 individuals were as follows: Japanese jack mackerel 58%, Japanese anchovy 17%, round herring 13%, Japanese sardine 8%, and chub mackerel 4%.

Table 7 shows the catch date, sex, *GI* of the longtail tunas caught in 2021 with the lipid content percentage (%) and the impedance value (Ω) of three regions (dorsal, pelvic, and tail). As we see from this table, the lipid percentage content was 1% in all the samples other than 5% in the pelvic of sample No. 3 and a large value of 18% in the pelvic of sample No. 6. The average impedance value increased from the anterior to the posterior regions of the fish body: 89.3 Ω in the range of 73–101 Ω for the dorsal, 94.7 Ω in the range of 72–136 Ω for the pelvic, and 131.3 Ω in the range of 107–157 Ω for the tail.

The *GI* of the samples measured ranged from 2.4 to 7.5 and the gonadal development for each sample was confirmed to be at an advanced stage by visual inspection. According to previous studies, mature individuals of tuna are reported to have $GI \geq 2.1$ [8] and $GI \geq 3.1$ [7] in the case of yellowfin (*Thunnus albacares*) and bigeye (*T. obesus*) females, respectively. In a study on observation of gonadal tissue sections of longtail tuna, it is reported that individuals identified as mature have higher *GI* [10]. With this fact, we conclude that the longtail tunas dealt with in this study are individuals in advanced stages of maturation.

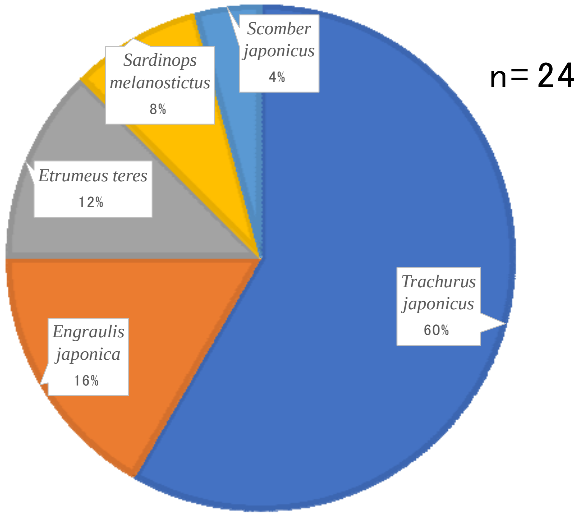

Fig.5 Composition of stomach contents of longtail tunas (Japanese jack mackerel (*Trachurus japonicus*), Japanese anchovy (*Engraulis japonicus*), round herring (*Etrumeus teres*), Japanese sardine (*Sardinops melanostictus*) and chub mackerel (*Scomber japonicus*))

Table 7 Sex, and *GI* of the longtail tunas caught in 2021 with the lipid content percentage (%) and the calibration curve (Ω) of three regions (dorsal, pelvic and tail) of the longtail tunas caught (2021)

No.	Sex	GI	Lipid percentage Dorsal / Pelvic / Tail (%)	Calibration curve Dorsal / Pelvic / Tail (Ω)
1	female	3.4	1%/1%/1%	90Ω / 81Ω / 107Ω
2	male	6.5	1%/1%/1%	73Ω / 82Ω / 144Ω
3	female	3.7	1%/5%/1%	74Ω / 72Ω / 116Ω
4	female	4.3	1%/1%/1%	99Ω / 103Ω / 155Ω
5	male	7.5	1%/1%/1%	101Ω / 136Ω /157Ω
6	female	2.4	1%/18%/1%	99Ω / 94Ω /109Ω

4 Discussion

First, we will discuss the sex, fork length (cm), weight (g), and stomach contents which were examined for all the samples. For the sex, the catch was almost half male and half female in the five years although there was skewed population ratio (10 males and 2 females) in 2020. As a whole, there was no significant difference between males and females in number.

The fork length ranged between the smallest of 44.5-51.2 cm in 2018 and the largest of 49.2-63.1 cm in 2019. Over the course of one year from 2018 to 2019, there was a marked increase in the size of longtail tuna body. This may have been caused by more advantageous habitat factors for longtail tuna such as water temperature and prey in 2019 than in 2018, or by ambient conditions that facilitated the migration of large individuals to the area around the set net off Futaoi Island.

The difference within each fork length range was 5.2 cm in 2016, 6.0 cm in 2017, 6.7 cm in 2018, 13.9 cm in 2019, 9.2 cm in 2020, and 12.8 cm in 2021, with 2019 being the widest. This difference exceeded 10 cm and became wider in the latter three years of the 6-year study period.

There was no significant difference between the number of months per year spent on this study: two months in 2016, three months in 2017, four months in 2018, four months in 2019, two months in 2020, and two months in 2021. As a result, the reason for the difference between the first half and the second half is unknown at the present stage. This cause needs to be investigated in details.

In general, it is known that longtail tuna with fork length of 60 cm ≤ migrates to the waters around Japan. Even in the set net used for this study, such longtail tunas were caught through all the periods except for three individuals in 2019 and five in 2021.

The top three species of the stomach contents of the longtail tuna were Japanese jack mackerel, Japanese anchovy, and round herring in descending order. This result is similar to that reported in a past study [11] and supports it. There have been no previous cases, including the present study, of longtail tunas feeding on squids (which are preferred by many species of tuna). Therefore, it is inferred that longtail tuna actively feeds on fish and does not feed on squids. When we checked the degree of digestion in the stomach contents of the longtail tunas obtained in this study, there was a case where the soft-bodied sardines were not digested well. This suggests one of the following possibilities: 1. the individual fed while entering the set net; or 2. the individual fed in the waters around the net and immediately entered it. This case will need to be examined in detail.

Next, we will discuss the relationship between changes in the lipid content percentage and the maturity for six longtail tunas. The measurement result of the lipid content percentage (%) of pelvics showed that the individual No. 3 is 5% and the individual No. 6 a large value of 18%, while all other individuals were 1%. For this lipid content percentage measurement, we had no other alternative but to adopt an approach to measurement for bluefin tuna because of the only tuna species having the precedents. In the future, it will be necessary to investigate whether there is a more suitable method for measuring the lipid content percentage in longtail tunas.

The measurement result of the calibration curve (Ω) showed that the average impedance values increased from the anterior to the posterior regions of fish body: 89.3 Ω in the range of 73-101 Ω for the dorsal, 94.7 Ω in the range of 72-136 Ω for the pelvic, and 131.3 Ω in the range of 107-157 Ω for the tail. The reason why the tail had the lowest value of 107 Ω and the highest average value of 131.3 Ω was thought to be one of the following: 1. Fish Analyzer reacted to an insulating part such as bone; or 2. The tail had higher lipid content percentage. The examination by touching each individual showed that the tail did not always have higher lipid content percentage. Therefore, it is inferred that the device reacted to an insulating part such as bone.

As explained in the section “Results”, the longtail tunas dealt with in this study were judged to be advanced in maturity from the *GI* values and the gonadal state by visual inspection.

The pelvic is generally focused as a part of fish body influenced by high and low lipid. The *GI* and abdominal impedance values in Table 7 is as follows in ascending order: No.1 was 3.4 at 81 Ω, No.2 was 6.5 at 82 Ω, No.3 was 3.7 at 72 Ω, No.4 was 4.3 at 103 Ω, No.5 was 7.5 at 136 Ω, and No.6 was 2.4 at 94 Ω. The fact that the *GI* was higher in the individual Nos. 4 and 5 with impedance values of more than 100 suggests that there is a relationship between lipid and maturity. On the other hand, there was a case where the *GI* was as high as 6.5 even though the impedance value was 82 Ω as in the individual No. 2.

Consequently, it is essential to increase the number of longtail tunas to accurately understand a relationship between lipid and maturation. In addition, the gonadal tissue sections must be analyzed in depth as did by the authors [10] and the lipid content percentage measurement must be examined taking into consideration of other methods to accurately understand a relationship between lipid and maturation to in the future.

One species of tuna, longtail tuna, is classified as a highly migratory fish. Therefore, investigations must be conducted not only for longtail tunas caught by the set net fishery applied for this study, but also for those caught by other fishing methods performed by other fisheries cooperatives in Yamaguchi Prefecture and those caught in other prefectures such as Nagasaki.

5 Acknowledgements

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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

Takumi Terashima:

04/2016 – 03/2020	Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2020 – present	Master’s course of Graduate School of National Fisheries University, Shimonoseki, Japan
Research field:	Fisheries information analysis

Jyunji Koga :

04/1984 – 03/1989	Tokyo University of Fisheries, Tokyo, Japan
04/1989 – 03/1990	Advanced course of Tokyo University of Fisheries, Tokyo, Japan
04/1990 – 03/2021	Fisheries Agency
04/2021 – present	Department of Fishery Science and Technology, National Fisheries University, Shimonoseki, Japan
Research field:	Fishing vessel operation

Katsuya Narutaki:

04/2016 – 03/2021	Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2021 – present	Advanced course of Graduate School of National Fisheries University, Shimonoseki, Japan
Research field:	Fisheries information analysis

Teru Taguchi:

04/2017 – 03/2022	Undergraduate course of Department of Fishery Science and Technology of 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