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First Report on the Use of the Larval Catcher Type Trawl Net for the Efficient Sampling of Juveniles of Two Tuna Species (*Thunnus orientalis* and *T. albacares*) in the Offshore Waters of the Nansei Islands, Japan

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Abstract
Establishing sampling techniques for juveniles of tuna species is essential for understanding their ecology and population dynamics because only individuals showing rapid growth during larval and juvenile stages are able to survive. This study is the first report on the successful sampling of juveniles of tuna species using the larva catcher (LC)-type trawl net, a pelagic trawl gear with a 10 × 10-m mouth opening, 40-m total length, and 5 × 5-mm mesh size. It was used in a research cruise in May-June 2009. The LC net was horizontally towed for 30 min at depths of 0 m-10 m at speeds of about 1.8 m/s. Overall, 66 and 163 juveniles of Pacific bluefin tuna (PBT) and yellowfin tuna (YFT) were collected; the standard length (SL) of the PBT and YFT ranged from 15.0 to 29.7 mm and 11.7 to 34.8 mm, respectively. The total operation time for the trawls of the LC-type net was much shorter than that of the usual trawls; therefore, a larger number of operations can be conducted in a day. We concluded that the LC-type trawl net can be used for collecting tuna juveniles because of its catchability and ease of operation.

Discipline: Fisheries
Additional key words: otolith daily increment, recruitment, sampling gear, spawning ground

Introduction

The Pacific bluefin tuna (PBT) (*Thunnus orientalis*) is the most commercially valuable tuna species in Japan; the yellowfin tuna (YFT) (*T. albacares*) is also an important species in the subtropical and tropical regions of the Pacific Ocean. Therefore, the population dynamics and stock status of these tuna species require accurate monitoring. The spawning grounds of PBT are known to be in the waters around Japan (Ashida et al. 2015; Okochi et al. 2016; Ohshimo et al. 2018a, 2018b; Shimose et al. 2016, 2017). The spawning grounds of YFT are widely distributed in the Pacific from the equatorial to the subtropical regions, including the offshore waters of the Nansei Islands in Japan (Schaefer 2001). The population dynamics of tuna species seem to be determined by the success or failure of recruitment; particularly for PBT, only individuals showing rapid growth during the larval and juvenile stages are able to survive (Ishihara et al. 2019; Tanaka et al. 2006; Watai et al. 2017, 2018), and the recruitment of PBT has also been shown to be dependent on environmental factors (Muhling et al. 2018).

Surveys for collecting larvae of *Thunnus* species have been conducted over 70 y since 1949 by research vessels (RV) and fisheries training ships belonging to the Japanese or prefectural governments, integrating administrative agency and fisheries high schools (Nishikawa et al. 1978, 1985; Satoh 2013; Tanabe 2002; Ueyanagi 1969; Yonemori 1989). From the 1950s to 1970s, large-scale research cruises in the Pacific, Indian, and Atlantic Oceans were conducted. During the 1980s, a concentrated sampling program for PBT larvae was conducted in the spawning grounds around Japan (Nishikawa et al. 1985, Yonemori 1989). From the

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1990s to 2010s, small-scale research cruises have been continued by the Japanese government, incorporating administrative agency, which conduct larval research cruises for collecting tuna species (Ohshimo et al. 2017, Tanaka & Suzuki 2016, Tawa et al. 2020). For larval tuna sampling, a 2-m mouth-opening ring net is usually used. With a one-time tow, hundreds of larvae are sometimes recorded and a sufficient number of sampling data are accumulated.

However, for juvenile tuna larger than 10 mm in standard length (SL), previous studies have collected only a limited number of specimens because of the swimming ability of juvenile tuna in relation to their growth. This has resulted in a lack of biological data on the early life history of each tuna species. In this study, individuals of 10 - 100 mm SL and 100-300 mm SL were classified into early and late juvenile, respectively. To forecast the recruitment level of PBT, surveys for collecting early juveniles, especially juveniles of 10-30 mm SL, are necessary, because the growth rate during the early juvenile period increases rapidly (Tanaka & Suzuki 2016), and late juveniles are usually caught by Japanese coastal fishing boats. In the past surveys, large-sized pelagic trawl nets with a mouth opening of 20 m × 20 m or more were used, and over 30-min or 1-h horizontal tows, tens of tuna juveniles were collected in the waters around the Nansei Islands in June and July (Tanaka & Suzuki 2016). In the Sea of Japan, large-sized trawl net surveys (30 m × 30 m mouth opening) were conducted in 1999 and 2004 (Tanaka et al. 2007), and a total of 186 PBT juveniles were caught. However, preparing, casting, and winding the large-sized trawl nets require a lot of time and effort. Because of this preparation time, the number of operations of large-sized trawls in a day is strongly limited; therefore, another simply operated gear for collecting juvenile tuna species should be developed. In this study, we applied a new type of towing net, the larva catcher (LC) net, in the offshore waters of the Nansei Islands. We also report the advantage of the LC-type net in comparison with the large-sized trawl net. Additionally, we also report the biological characteristics of juvenile tuna species.

Materials and methods

1. The LC-type trawl net

To sample early tuna juveniles of *Thunnus* species, the LC-type trawl net (Model LC100 m^{2}R3, Nichimo Co. Ltd., Japan) was used (Fig. 1). The net was a type of pelagic trawl gear and equipped with a para-kite as a mouth-opening gear (cloth product, flexible structure, 9 m^2 area) at both side panels (Fig. 2). No otter board was attached to the LC net as used in the usual large-sized trawl nets; therefore, no attachment and detachment operations with mouth-opening gears were necessary during the casting and retrieval of the net, resulting in labor saving at each sampling. The net has the following dimension: mouth opening, 10 m × 10 m; total length, about 40 m; and mesh size of the body, 5 mm × 5 mm. The mouth opening for the top and bottom directions was achieved by the wing-kite (8 m^2 area) attached to the top and bottom panels of the mouth (Fig. 2). The body and cod-end of the net were constructed by square mesh panels and were made of high-tenacity polyethylene fibers.

2. Juvenile sampling

The research cruise for sampling juvenile tuna was conducted by the fisheries RV *Shunyo Maru* (887 ton) in the offshore waters between the west of Kume Island and south of the Yaeyama Islands of the Nansei Islands from May 31 to June 11, 2009. A total of 12 sampling stations were chosen in the survey area (Fig. 3, Table 1). The LC-type trawl net was horizontally towed for 30 min near the sea surface (depth: 0 m-10 m) at a speed of approximately 1.8 m/s (3.5 knots). Because early juvenile YFT are mainly collected at depths shallower than 60 m in the tropical Pacific (Tanabe 2002), we hypothesized that early juveniles of PBT and YFT in the Nansei Islands area are distributed in the shallower depth than those in the tropical area because of lower water temperature. We assumed that the LC-type trawl net should be towed at speeds of 1.5-2.1 m/s (3-4 knots) at night according to the results of the sampling of early juveniles of YFT and skipjack tuna (Tanabe 2002). At each station, three tows were made at nighttime between 20:00 and 24:00 Japan Standard Time. The direction of the RV was maintained during the entire duration of the three consecutive tows at each station; no backward movement to the original position of each station was carried out. The sample was weighed as the total wet weight after each towing operation and sorted into tuna juveniles and other major taxa. The tuna juveniles were counted and preserved in 99.5% ethanol. For the quantitative sampling of juvenile tuna, estimating the catch efficiency of the LC-type trawl net is necessary. In the framed trawl net sampling (Lu et al. 2018), the catch efficiency of the net was determined by combining the net sampling and acoustic data. Lu et al. (2018) described that the catch efficiency of a net is represented by the product of the efficiency of the volume of the water filtered, the ratio of juveniles collected and distributed in the sampling area, and the ratio of juveniles retained in the sampling gear and extruded from the gear. Because the LC-type trawl net does not have any frame at

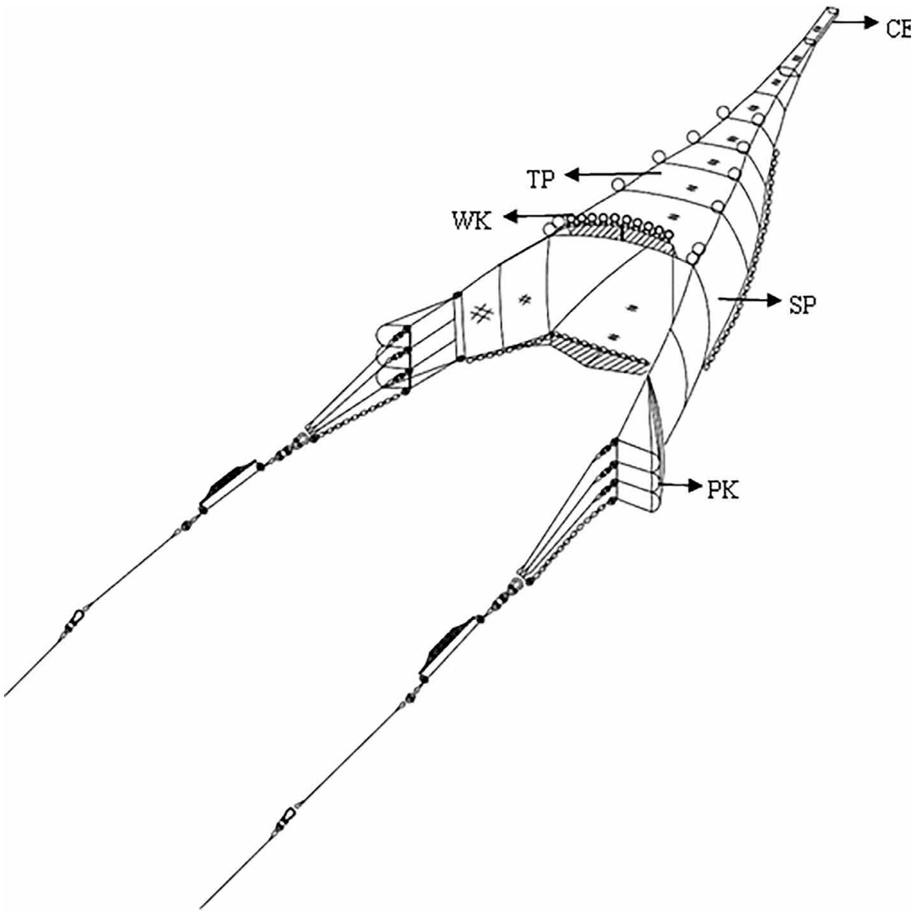

Fig. 1. A three-dimensional drawing of the larva catcher (LC)-type trawl net (LC100 m²R3) (Nichimo Co. Ltd., Japan) used for sampling tuna juveniles
PK and WK indicate para-kite and wing-kite, respectively. TP, SP, and CE indicate side panel, top panel, and cod-end, respectively.

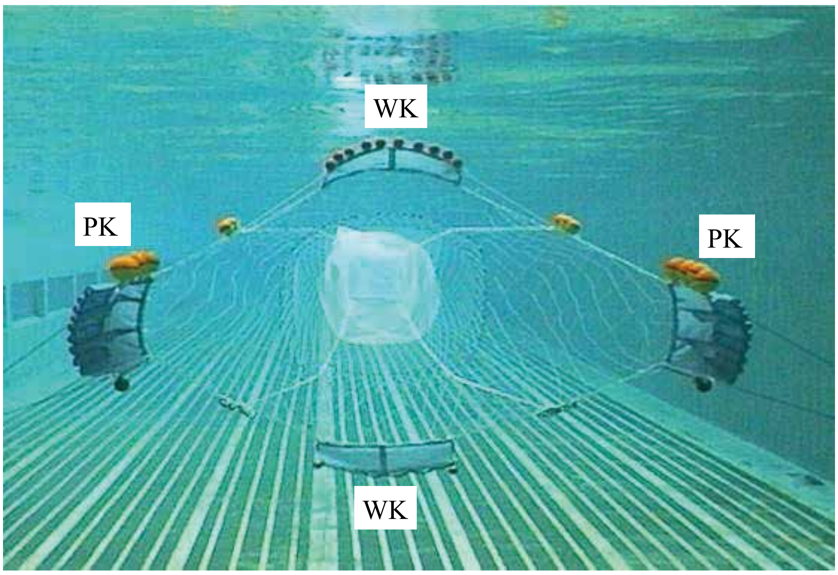

Fig. 2. Front view of a model of the larva catcher (LC)-type trawl net at the experimental tank of Nichimo Co. Ltd., at Shimonoseki, Japan
PK and WK indicate para-kite and wing-kite, respectively.

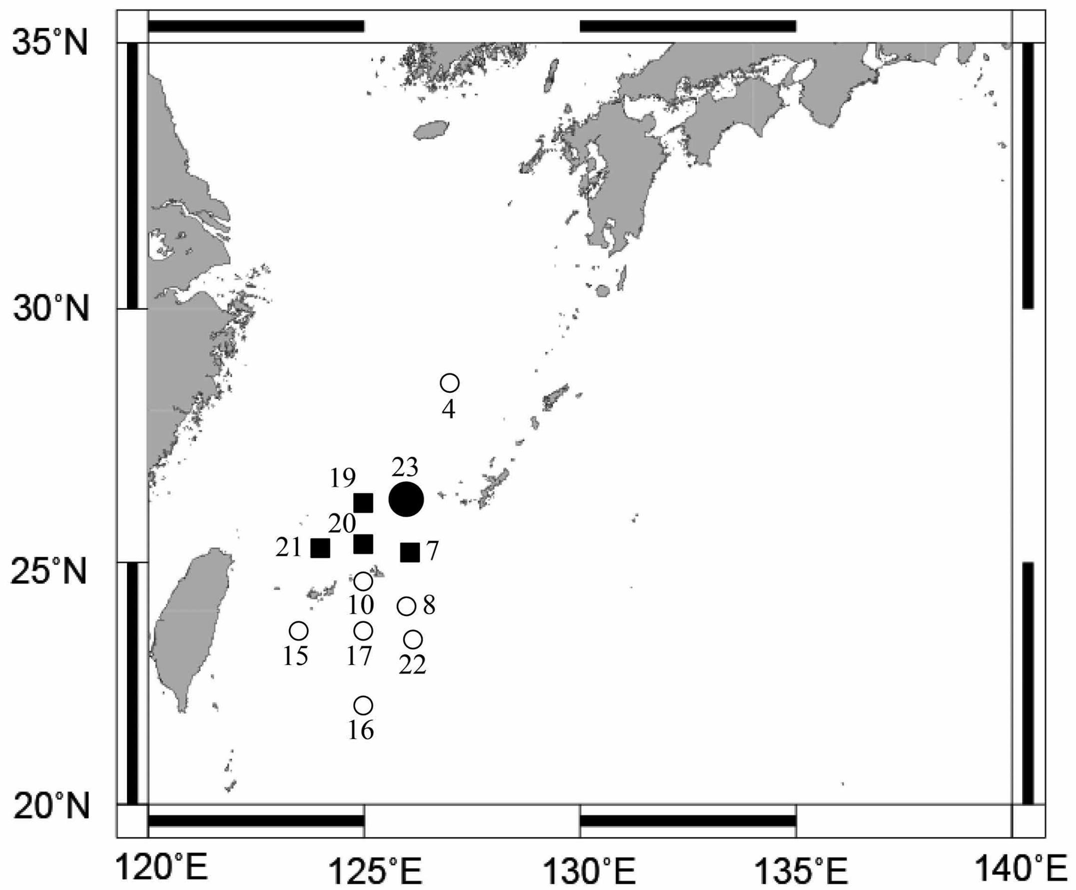

Fig. 3. Sampling locations for Pacific bluefin tuna (PBT) and yellowfin tuna (YFT) juveniles in the offshore waters of the Nansei Islands, Southwestern Japan

The solid circle, squares, and open circles with numbers indicate the sampling stations where a large number of tuna juveniles were collected, a few juveniles were collected, and no juvenile was collected, respectively.

Table 1. Number of Pacific bluefin tuna (PBT) and yellowfin tuna (YFT) juveniles collected using the larva catcher (LC)-type trawl net in the offshore waters of the Nansei Islands in 2009

Station No.	Date	Location		SST (°C)	Number of juvenile collected					
					First tow		Second tow		Third tow	
		Longitude	Latitude		PBT	YFT	PBT	YFT	PBT	YFT
16	May 31	125°00′E	22°00′N	26.8	0	0	0	0	0	0
17	June 1	125°00′E	23°30′N	26.9	0	0	0	0	0	0
19	June 2	125°00′E	26°05′N	27.0	0	1	0	0	0	0
20	June 3	125°00′E	25°15′N	26.5	0	0	0	0	2	0
10	June 4	125°00′E	24°30′N	27.3	0	0	0	0	0	0
15	June 5	123°30′E	23°30′N	28.2	0	0	0	0	0	0
21	June 6	124°00′E	25°10′N	27.2	1	0	0	0	0	1
8	June 7	126°00′E	24°00′N	27.5	0	0	0	0	0	0
7	June 8	126°05′E	25°05′N	26.4	0	2	0	1	0	0
22	June 9	126°09′E	23°20′N	27.4	0	0	0	0	0	0
23	June 10	126°00′E	26°09′N	27.5	30	73	21	64	12	21
4	June 11	127°00′E	28°30′N	25.7	0	0	0	0	0	0

the mouth of the net and the present research is the first attempt to use the LC-type trawl net for sampling early juvenile tuna, we calculated the number of juveniles in 1-h tows and the frequency of the occurrence of juveniles as indices of successful sampling.

3. Identification and measurement of juvenile tuna

After the research cruise, the total length (TL) and SL of juvenile tuna were measured to the nearest 0.01 mm using a digital caliper. The body weight (BW) of the specimen was measured to 0.01 mg using an electronic balance. A portion of muscle tissue was taken from the right side of the body using a dissecting knife, and crude DNA was extracted using the Gentra Puregene Tissue Kit (Qiagen, Netherlands). The PBTs were identified according to the method of Chow and Inoue (1993). The flanking region of ATCO between ATPase6 and cytochrome oxidase III (CO3) genes of mtDNA was amplified using the polymerase chain reaction (PCR) method. The PCR products were directly digested by the restriction enzyme Alu1, and the restriction fragment length polymorphism (RFLP) was analyzed. Additionally, the multiplex PCR method was used in this study to increase the precision of the identification (Suzuki et al. 2014). The YFTs were identified using the method of Chow et al. (2003). The CytB fragments of mtDNA were amplified using the PCR method. The PCR products were directly digested by the restriction enzyme EcoN1 and analyzed using the RFLP method.

4. Stomach contents and otolith daily increment examination

The stomach of juvenile tuna was removed, and the wet weight of the stomach contents was measured to the nearest 0.1 mg. The stomach contents were identified to the lowest possible taxa under a dissecting microscope, and the number of each taxon was recorded. The sagittal otoliths of the juvenile tuna were removed from the specimens under a dissecting microscope and cleaned using distilled water, dried, and preserved at ambient temperature. The left side of the otoliths was embedded in enamel resin, dried more than 36 h at ambient temperature, and polished with lapping films (Tanabe et al. 2003). The number of daily increments between the core and the edge of the otoliths was counted, and the increment widths were measured using an otolith measurement system (APR/W, Ratoc System Engineering, Japan). The otolith radius (OR) was measured as the maximum length between the core and the posterior edge. The first increment in the otolith of the PBT is formed around 4 d after hatching (Itoh et al. 2000); the daily age after hatching was determined according to Itoh et al. (2000). Based on the first increment formation of the YFT (Wexler et al. 2001), the age after hatching was determined.

Results

1. Collections of *Thunnus* juveniles

A total of 66 PBT and 163 YFT juveniles were collected throughout the 36 tows of the LC-type trawl net (Table 1). Most of PBT (95%) and YFT (97%) were caught at the station located offshore the west of Kume Island (Fig. 3). The sea surface temperature of the sampling station (26°09′N, 126°00′E) was 27.5°C (Table 1). The number of juveniles caught in the 1-h tows and the frequency of the occurrence of juveniles were 2-60 individuals and 13.9% for PBT and 2-146 individuals and 19.4% for YFT, respectively (Table 2). The mean wet weight of whole collections of the 1-h tows was 2.8 kg (Table 2). The dominant collections obtained from the LC-type trawl net, except for juvenile tuna, were lantern fish, flying fish, squids, and salps. The characteristics of the LC-type trawl net in comparison with the usual large-sized trawl net (NST-type trawl net) are shown in Table 2. In the collections of the LC-type trawl net, the ranges and means in the SL of the PBT were 15.0 mm-29.7 mm and 22.1 mm, respectively. Those of the YFT were 11.7 mm-34.8 mm and 19.3 mm, respectively. The mean SL of the PBT was significantly larger than that of YFT (Mann–Whitney U-test, $P < 0.001$). The mode in the SL of the PBT and YFT was observed at 20 mm-25 mm and 15 mm-20 mm classes, respectively (Fig. 4). The increased SL of the collected juveniles from the first to the second and third tow of the net was observed (Fig. 5). Significant differences of mean SL were recognized between the first and third tow of the PBT and between the first and second, and the first and third tow of the YFT (Mann–Whitney U-test, $P < 0.05$). The ranges and means in the BW of PBT were 23.2 mg-268.2 mg and 108.2 mg, respectively. Those of YFT were 4.7 mg-447.7 mg and 89.4 mg, respectively. The relationship between SL and BW in juveniles of PBT and YFT was represented by the following equations (Fig. 6):

$$BW_{PBT} = -2.234SL_{PBT}^{3.147}$$

$$BW_{YFT} = -2.311SL_{YFT}^{3.269}$$

The relationship between the TL and SL of the PBT and YFT was represented by the following equations:

$$TL_{PBT} = 1.0996SL_{PBT} + 1.317$$

$$TL_{YFT} = 1.1686SL_{YFT} - 0.0262$$

Table 2. Characteristics of two types of trawl nets, the LC-type, LC100m²R3 and the NST-type, NST99K1

		Type of net	
		LC100m²R3	NST99K1*
Size of mouth opening		10 m × 10 m	25 m × 25 m
Total length		40 m	90 m
Mesh size at cod-end		5 mm	17.5 mm
Towing speed		1.5-2.1 m/s	2.1-2.6 m/s
		(3.0-4.0 knots)	(4.0-5.0 knots)
Towing resistance		8 ton. at 3.0 knots	12 ton. at 4.5 knots
Mouth opening system		para-kite and wing-kite	a pair of otter board
Fitting operation at tow of the net		no operation necessary	attachment and dettachment
Number of crew on the deck		4 person	6 person
Time for casting and retrieval		11-21 min. (average 16 min.)	26-56 min. (average 34 min.)
Collections			
Number of tuna juveniles (except 0 catch)	PBT	2-60 inds.	1-15 inds.
	YFT	2-146 inds.	1-13 inds.
Frequency of occurrence of tuna juveniles			
	PBT	13.9%	50.0%
	YFT	19.4%	55.0%
Wet weight of whole collections		0.1-28.0 kg (average 2.8 kg)	1.1-24.2 kg (average 11.5 kg)

*Data of NST99K1 are obtained from Tanabe et al. (unpublished data).

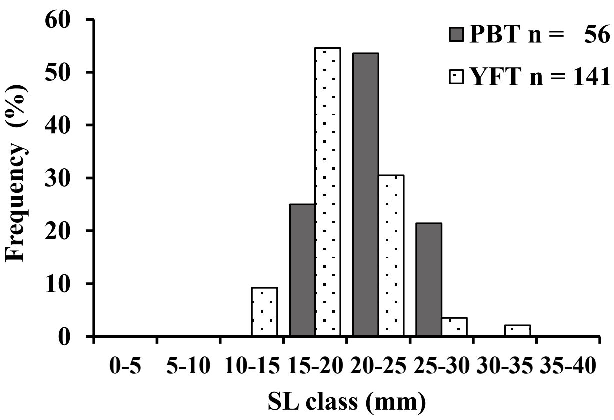

Fig. 4. Length frequency distribution of Pacific bluefin tuna (PBT) and yellowfin tuna (YFT) juveniles collected at the station (St. 23) located in the offshore waters west of Kume Island (26°09′N, 126°00′E)
SL indicates standard length.

2. Stomach contents

The ratios of empty stomachs to stomachs containing food, excluding damaged individuals, were 45% in the PBT and 44% in the YFT. Identifying the stomach contents was usually difficult because of the digestion of prey items. Larval fish of unidentified species were dominant in the PBT; 1-5 larvae were observed in each stomach. A few crustaceans were found in the PBT. In the stomachs of the YFT, unidentified larval fish, crustaceans, and appendicularians were found. The maximum wet weight of the stomach contents in the PBT and YFT juveniles was 12.9 mg (9.4% of BW) and 8.1 mg (7.4% of BW), respectively.

3. Daily age determination

The relationship between the SL and OR of the PBT and YFT juveniles was represented by the following equations, in which high correlation coefficients (approximately 0.9) were observed:

$$SL_{PBT} = 0.0849OR_{PBT} - 2.6587\ (R^2 = 0.885)$$

$$SL_{YFT} = 0.0937OR_{YFT} - 5.9285\ (R^2 = 0.922)$$

The determined age of 49 PBT juveniles ranged from 20 to 25 d (mean: 21.4 d) and that of 76 YFT juveniles ranged from 14 to 21 d (mean: 17.7 d). The mean age of PBT was higher than that of YFT (t-test, $P < 0.01$). The day of hatching estimated by daily age ranged from May 15 to 22 in the PBT and from May 19 to 26 in the YFT.

The relationship between daily age and SL in the PBT and YFT juveniles was represented by the

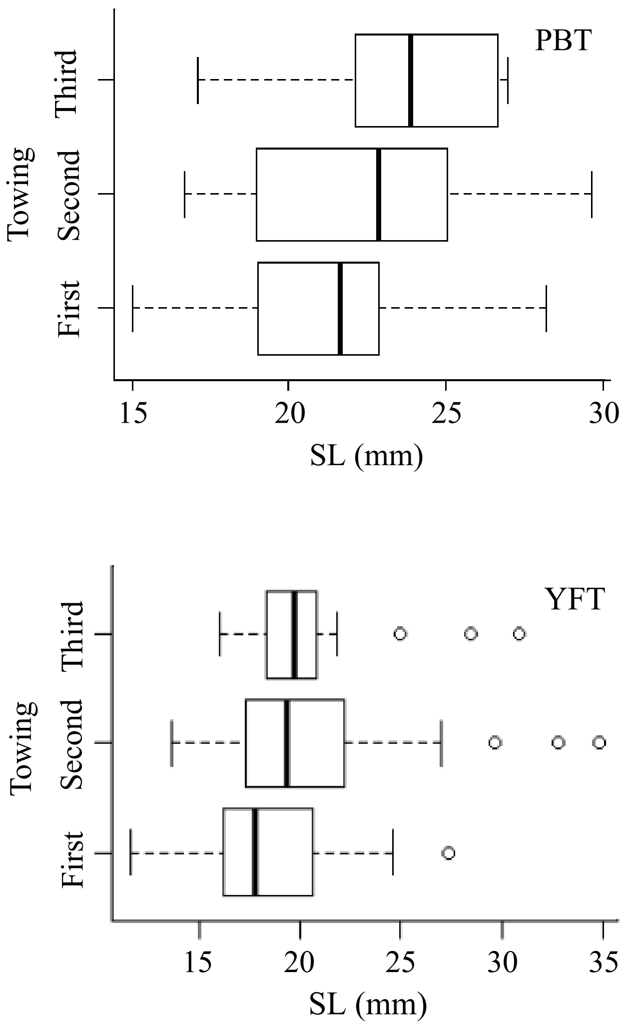

Fig. 5. Boxplots of the standard length (SL) of the Pacific bluefin tuna (PBT) and yellowfin tuna (YFT) juveniles caught using the larva catcher (LC)-type trawl net at the station (St. 23) (26°09′N, 126°00′E), where the largest number of tuna juveniles were collected

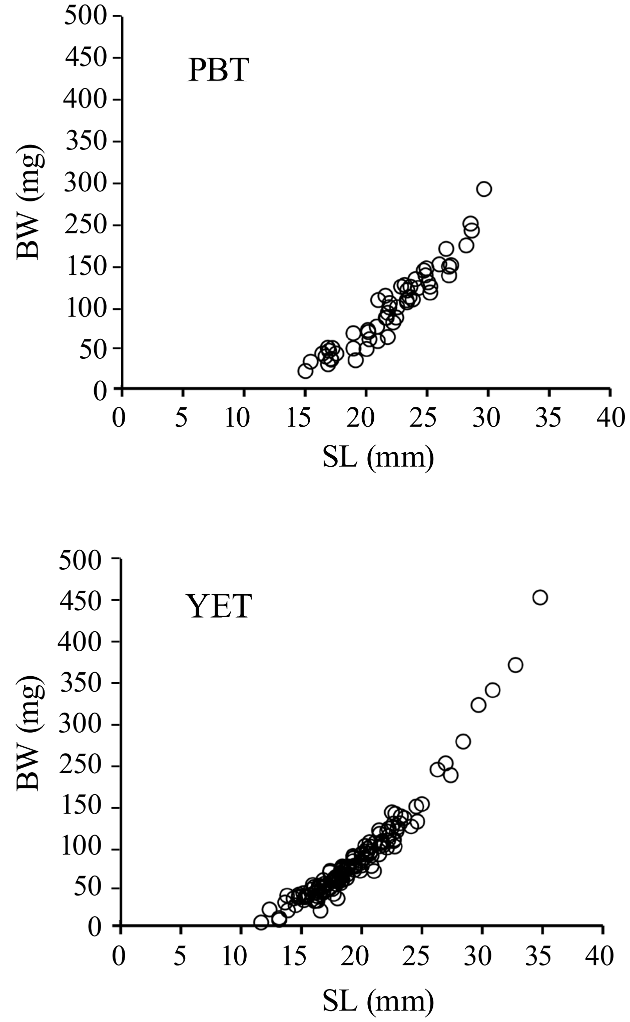

Fig. 6. Relationship between the standard length (SL) and body weight (BW) of the Pacific bluefin tuna (PBT) and yellowfin tuna (YFT) juveniles

following equations:

$$SL_{PBT} = 2.199D - 25.159\ (R^2 = 0.558)$$

$$SL_{YFT} = 1.681D - 9.725\ (R^2 = 0.340)$$

Daily growth rate until 3 weeks after hatching in both species of juveniles was estimated at approximately 2 mm/d (Fig. 7).

Discussion

In the present study, the LC-type trawl net was applied for collecting early juvenile tuna species in the offshore waters of the Nansei Islands, which is one of the spawning and nursery grounds for PBT (Uematsu et al. 2018, Wells et al. 2020). The larvae of PBT and YFT are abundantly distributed in the Kuroshio offshore waters (Tawa et al. 2020). The early juveniles of PBT and YFT collected in this study are found near the Kuroshio Current. Therefore, the larvae of PBT and YFT have been shown to be transported in the northeast direction by the Kuroshio Current (Fujioka et al. 2018) or to grow in the area around the Nansei Islands. Based on the results from the otolith microstructure analysis of PBT, individuals with rapid growth are able to survive during the larval and juvenile stages (Tanaka et al. 2006, Watai et al. 2017, 2018, Ishihara et al. 2019). There are some reports on the

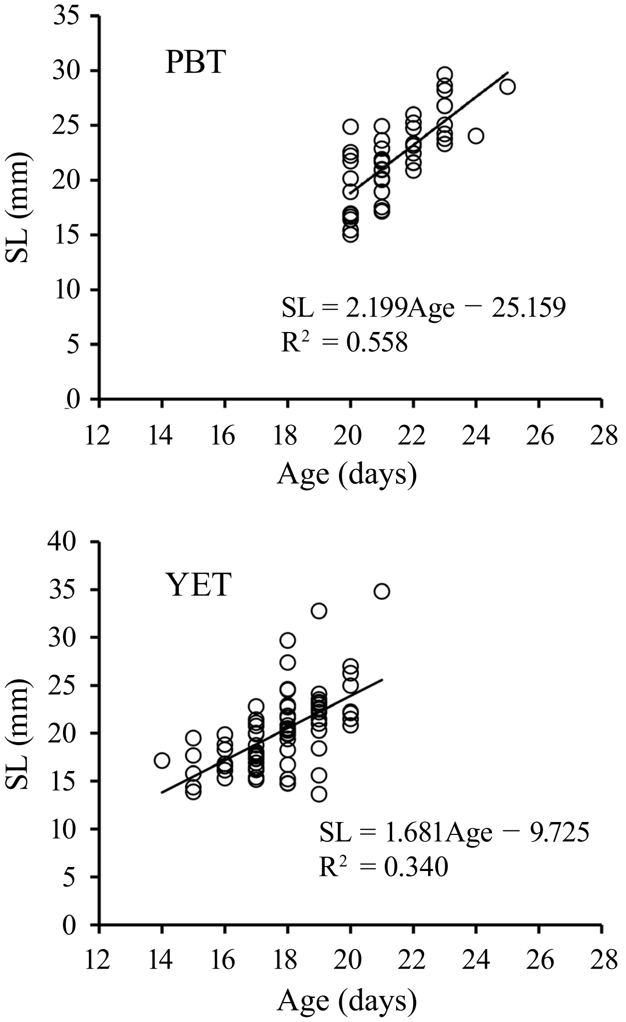

Fig. 7. Relationship between age in days and standard length (SL) of the Pacific bluefin tuna (PBT) and yellowfin tuna (YFT) juveniles

larval distribution of tuna species (Nishikawa et al. 1985, Satoh 2010, Tawa et al. 2020); however, reports on the distribution of juveniles are few because of their increased net avoidance ability. The main objective of this study was to show the efficiency of a new type of trawl net, LC net, for collecting early juvenile specimens of tuna species.

1. Efficiency of the LC-type trawl net

In previous studies of the 1990s and 2000s, commercial-sized mouth-opening trawl nets had been used for sampling tuna juveniles; however, only one record of a large number of early juveniles of tuna species has been obtained from the survey in the offshore waters of the Nansei Islands in June 1997 (Tanaka & Suzuki 2016). During the 1997 sampling, a total of 176 PBT (fork length [FL]: 20 mm-47 mm) and 7 YFT (FL: 26 mm-63 mm) juveniles were collected using the NST-type trawl net (30 × 30-m mouth opening, 86-m TL; Nichimo Co. Ltd., Japan) from seven tows during the day and night (Itoh et al. 1999). In the Sea of Japan, the NST-type trawl net was used from August to September 1999 and 2004, and 186 PBT late juveniles (FL: 108 mm-280 mm) were captured (Tanaka et al. 2007). Recently, in 2017 and 2018, hundreds of PBT late juveniles of lengths larger than 100 mm FL were collected in the northern part of the Sea of Japan (Tanaka et al. 2020). However, for early juveniles, especially of lengths between 10- and 30-mm SL, corresponding to the life stage shortly after the metamorphosis from larva to juvenile, collections remain limited. The reason for the limited number of early juvenile collections of 10 mm-30 mm SL seems to be the inadequate mesh sizes of the NST-type net or limited sampling area and period in the previous research cruises. We applied the LC-type trawl net for the first time for juvenile tuna sampling and carried out 36 tows at 12 stations at night in the offshore waters of the Nansei Islands. A total of 66 PBT (SL: 15 mm-30 mm) and 163 YFT (SL: 12 mm-35 mm) early juveniles were successfully collected in the present study. Around 95 % of the PBT juveniles and 97% of the YFT juveniles were caught at one sampling station located in the offshore waters to the west of Kume Island. The total number of tuna juveniles sampled by the LC net was similar to the number sampled by the NST net used in the past research. These specimens of tuna juveniles were enough for the analyses of biological studies. The mean operation time of casting and winding the LC and NST nets for tows was 16 min and 34 min, respectively (Table 2). The NST-type trawl needs the attachment and detachment operations with mouth-opening gears during the casting and retrieval of the net (usually six crews on the deck are necessary for each operation). This means that the LC net sampling has an advantage of saving time and effort compared with the NST trawling. This makes it possible for the LC trawl net to survey a wider area and to achieve a larger number of tows than the NST trawl net during the limited days available for sampling activities.

In the present study, the LC-type trawl net was horizontally towed for 30 min near the sea surface (depth: 0 m-10 m). Furukawa et al. (2017) reported the vertical distribution of late juvenile PBT in Tosa Bay using an electronic archival tag, and late juvenile PBT were distributed in the upper layers above the thermocline and sometimes dived to a deeper layer. Additionally, the mean depth of the late juvenile PBT at night was shallower than that during the daytime. The LC-type trawls were used only at night at shallow depths. Because Japanese longline boats operate during the daytime in the Nansei Islands, surveys with trawl operations during the daytime are restricted by fishing boats. Therefore, we conclude that the LC-type trawl net is more efficient than the NST-type trawl net under limited survey time.

2. Biological characteristics of *Thunnus* juveniles

In the present study, we observed the stomach contents of early juveniles of the PBT and YFT, and unidentified fish larvae were dominant. The results suggest the change in prey items from planktivores to piscivores during the early life stages from larva to juvenile of 10-30 mm SL (Tanaka et al. 1996, Uotani et al. 1990). Empty stomachs in the PBT and YFT juveniles (44%-45%) were also observed. In the present study, towing of the LC net was only conducted at nighttime; therefore, most of the prey items were digested because juveniles of PBT and YFT capture prey only during the daytime (Uotani et al. 1990, Young & Davis 1990). Hiraoka et al. (2019a) reported the stomach contents of late juvenile PBT (150 mm-299 mm) in Tosa Bay and concluded that small pelagic fish are the main prey items, but sometimes, crustaceans were observed in the stomach. The prey component in the PBT stomach has been shown to be affected by the environmental conditions (Hiraoka et al. 2019a). Kodama et al. (2017, 2020) developed metagenetic techniques to identify prey species in the stomach of PBT larvae. The morphological and metagenetic techniques for the identification of the prey species of PBT and YFT juveniles should be applied in further studies.

The estimated growth rates in the larvae of PBT and YFT ranged from 0.3 to 0.5 mm/d, which was observed using otolith daily increment analysis (Ishihara et al. 2019, Lang et al. 1994, Satoh et al. 2008, Tanaka et al. 2006, Watai et al. 2017, 2018). The growth rate of early juvenile tuna estimated in this study was approximately 2 mm/d, indicating the increased growth rate during the early life period from larva to juvenile. The rapid growth in the early juvenile period seems to play an important role for the survival of individuals (Ishihara et al. 2019, Tanaka et al. 2006, Watai et al. 2017, 2018); further detailed studies on the growth of juvenile tuna species are necessary with otolith increment analyses of large enough numbers of specimens. The analyses of feeding habits and nutritional condition in relation to the growth estimation during the juvenile stage of tuna species could be used for the assessment of the probability of survival of juvenile tuna. In the present study, the estimated day of hatching calculated from the daily age ranged from May 15 to 22 in PBT and from May 19 to 26 in YFT. The period for hatching of PBT juveniles corresponded with the spawning season of adult fish (Ashida et al. 2015, Shimose et al. 2017), and adult PBT and YFT are caught by longline boats during this period around the Nansei Islands (Furukawa 1961, Ohta & Yamada 2016).

Biological characteristics, such as growth, and prey items drastically change during the life stages from larva to juvenile in tuna species. Comparing the biological characteristics among each stage of tuna species is essential to understand population dynamics and recruitment processes. The present study reports the application of the LC-type trawl net for sampling early juvenile tuna (SL: 10 mm-30 mm) in a size range previously rarely collected in research surveys. An examination of biological characteristics of early stage juvenile tuna accompanied with effective sampling techniques is remarkably important. For example, comparative studies on the growth estimation and nutritional condition of early juveniles among different years may enable forecasts of year class strengths and subsequent improvement of stock management. In recent studies, the differences in nutritional condition (i.e., lipid contents and fatty acid composition) of PBT larvae and adults have been shown between the Nansei Islands area and the Sea of Japan (Matsumoto et al. 2018, Hiraoka et al. 2019b). This finding suggests a possibility of different survival strategies among habitats in PBT. Therefore, further surveys for sampling early tuna juveniles in the waters around Japan, such as the Sea of Japan and offshore of northeastern Japan, and comparative studies on the biological characteristics among different habitats are necessary.

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