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Spawning Possibility and Growth of Longtail Tuna, *Thunnus tonggol*, in the Water around Japan

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The reproductive possibility of longtail tuna, *Thunnus tonggol*, in the water around Japan was examined based on the observation of gonad of fish ranged from 44 to 57 cm in fork length. Growth of this species caught in the water around Japan was also examined based on daily age estimation with otolith increment of fish ranged from 13 to 49 cm in fork length. Occurrence of a fish which had an ovary with hydrated eggs observed in catch landed in Japan suggested the possibility of spawning around Japan. However, examination of gonad index (GI) and histological observation of fish sampled in other times did not necessarily support the spawning activity nearby Japan. Small fish ranged from 13 to 33 cm in fork length caught around Japan were estimated to be ranged from 33 to 132 days old when assuming daily increment of otolith. This period seems too short to reach to the water around Japan from any known spawning sites. Estimated spawning seasons by GI and estimated birthdate of small fish determined by otolith increment coincided. These two facts also indirectly support the possibility of reproduction occurring in the water around Japan. Parameters for von Bertalanffy growth equation were estimated as L_∞ = 55.0 cm, t_0 = -0.089 year, and K = 1.70.

Key words: longtail tuna, reproduction, growth, otolith, around Japan

Introduction

Longtail tuna, *Thunnus tonggol*, is one of the commercially important species in the Southeast Asia and Arabian countries. The global catches in 1995 was about 115,000 tons (FAO, 1997). This species have been caught around Japan sporadically (Kishinouye, 1915, 1923; Nakamura, 1969; Fukusho and Fujita, 1972). The recent catch records, reviewed by Itoh et al. (1996), suggested that the occurrence of longtail tuna was much more common than previously thought especially in the west part of Japan.

The spawning area is known to be the water of the Southeast Asia (Wilson, 1981; Chen and Wei, 1981; Boonragsa, 1987; Chayakul and Chamchang, 1988; Nishikawa and Ueyanagi, 1991), and there is no record of spawning around Japan. The possibility of reproduction of longtail tuna in the water around Japan was examined. In addition, the growth of longtail tuna caught in the coastal water of Japan was also estimated using otolith increments.

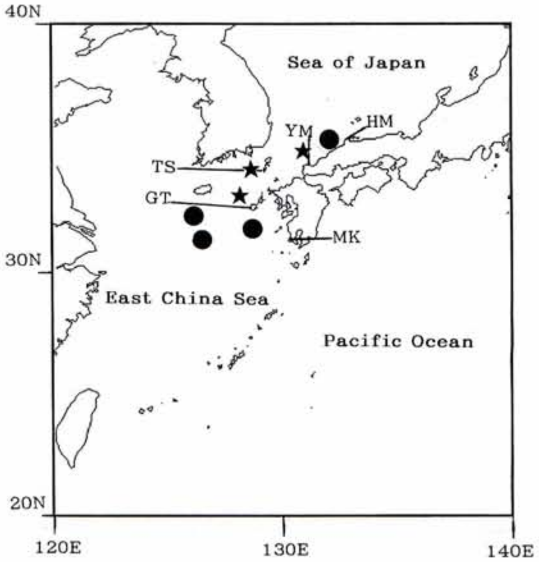

Fig. 1. Map of location where longtail tuna were sampled. ●: adult fish, ★: juvenile fish, HM: Hamada, YM: Yamaguchi, TS: Tsushima, GT: Goto, and MK: Makurazaki.

Table 1. Summary of samples of adult longtail tuna.

Date of capture	23-27 Aug., 1992	28 Aug., 1995	31 Jul.,1995	9 Jul., 1996	23 Jul., 1996	23 Jul., 1996	2 Aug., 1996	30 Aug., 1996	Total
Fishing gear	pole and line	pole and line	pole and line	set net	purse seine	set net	set net	set net	
Area of capture	East China Sea	East China Sea	East China Sea	Hamada	off Hamada	Hamada	Hamada	Hamada	
	31-32N, 126-127E	32N, 126E	32-33N, 128-130E						
Remarks	caught by R/V *Miyazaki maru*		landed at Makurazaki						
Total sample number	10	9	2	22	20	15	32	14	124
male:female	8:2	4:5	1:1	9:13	13:7	8:7	17:15	6:8	66:58
FL average (mm)	456	523	560	457	460	466	479	473	474
FL range (mm)	450-487	491-565	555-560	436-477	443-497	456-489	444-587	458-490	436-587
ovary sampled*1								8	8
otolith sampled*2	8								8

*1: number of fish its ovary used for histological observation.
*2: number of fish its otolith used for aging.

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Table 2. Summary of samples of juvenile longtail tuna.

Captured date	19 Sep., 1994	31 Oct., 1994	10 Nov., 1994	19 Dec., 1994	21 Aug., 1996	Total
Fishing gear	stick-held dipnet	stick-held dipnet	stick-held dipnet	trolling	-	
Area of capture	Sea of Japan off Yamaguchi	Sea of Japan off Yamaguchi	Sea of Japan off Yamaguchi	East China Sea off Goto	East China Sea off Tsushima	
Total sample number	10	7	4	3	1	25
FL average (mm)	189	241	248	305	130	
range (mm)	176-210	233-257	243-258	280-330		130-330

Material and Methods

Fish collected from various areas of the west part of the Sea of Japan and the East China Sea were used for analysis, which are summarized in Fig. 1 as well as Tables 1 and 2. Two groups of samples were identified. One was fish smaller than 33 cm in fork length (FL) caught by dipnet and trolling. The other was fish larger than 44 cm in FL caught by pole and line, purse seine and set net. The large and small fish examined were considered as adult and juvenile fish, respectively, based on the report on the minimum size of mature female as 40 or 43 cm in FL (Cheunpan 1984; Yesaki, 1994).

Twenty one adult fish were collected from the catch in the East China Sea (Table 1). Ten of them were collected from the catch of 3.9 tons in the area of 31°-32°N, 126°-127°E from 23 to 27 August, 1992, by pole and line with the *Miyazaki maru*, the research vessel of the Miyazaki Prefecture. Nine of them were collected from the catch of 118 fish in the area of 32°N, 126°E on 28 August, 1995, by the same vessel. Two fish were sampled from fish caught in the East China Sea in the area of 32°-33°N,128°-130°E by pole and line and landed at Makurazaki in Kagoshima Prefecture on 31 July, 1995, whose total landings were around 100 tons.

Adult fish were also sampled from the catch in the Sea of Japan by set net and purse seine landed to Hamada in Shimane Prefecture from July to September 1996. Total catch during the period was 22 tons. Among them, 109 fish were sampled through four samplings between 9 July and 30 August, 1996.

Juvenile fish were sampled from fish caught off Yamaguchi with stick-held dipnet (N=21, September-November 1994, FL=17.6-25.7cm), off Goto in Nagasaki Prefecture with trolling (N=3, December 1994, FL=28.0-33.0cm)(Itoh et al., 1996), and off Tsushima in Nagasaki Prefecture (N=1, 21 August, 1996, FL=13.0cm)(Table 2). The last one was fish which jumped into a trolling ship. All of them were caught as by-catch, not commercially targeted for the fisheries.

Sampled fish were measured its fork length and body weight. Sex was determined and gonad weight was measured for adult fish. Gonad index (GI) was calculated as GI = (gonad weight in gram)/(fork length in mm)$^3 \times 10^7$. Ovaries were sampled from 8 fish caught on 30 August in Hamada. These were preserved in buffered formalin and were prepared for histological examination with ordinary hematoxylin-eosin stain method.

Otoliths were removed for aging from all juvenile fish as well as 8 adult fish caught in the East China Sea in 1992. Otolith preparation was followed to the method described in Itoh and Tsuji (1996). At first, otolith increments were exposed by etching with 3N-HCl and 0.2 M EDTA along a path from core to postrostrum. The surface of otolith was examined with scanning electron microscope (SEM) magnified from 100 to 600 times after coated with gold. The photo of SEM image was also taken. Number of increments was counted three times on photo prints, and average number was used for the analysis.

Results

Among adult fish caught in Hamada in 1996, it was observed that a fish had an ovary with hydrated eggs, though the detailed data such as size of the fish and gonad weight was not recorded. This clearly suggests a possibility of spawning of longtail tuna around Japan.

All ovaries sampled on August 30, 1996, in Hamada were in the early yolk globule stage by histological observation. GI of female examined with histological observation were lower than 8.

Spawning possibility and spawning season was examined based on GI. No specific relationship was observed between GI and fork length for both male and female (Fig. 2). Therefore, no adjustment according to fish size was conducted. A fish caught on 28 August, 1995 in the East China Sea had the highest GI of female as 14.7 (Fig. 3). Since GI lower than 8 was judged to correspond to immature ovaries based on the histological observation, GI of mature female must be higher than this. When comparing samples obtained in Hamada in 1996, fish with GI higher than 10, were only caught on 9 July and 23 July. For samples from the East China Sea, GI higher than 10 were observed for female caught on 28 August, 1995, and for male caught on 23-27 August, 1992.

Numbers of otolith increments for fish of 13 to 49 cm in FL were from 33 to 434, increasing as fork length increased (Fig. 4). Coefficient of variation of three counting was ranged from 0.6 to 7.2% with 2.9% in average. These increments counted were assumed to be daily increments based on the similarity in structure

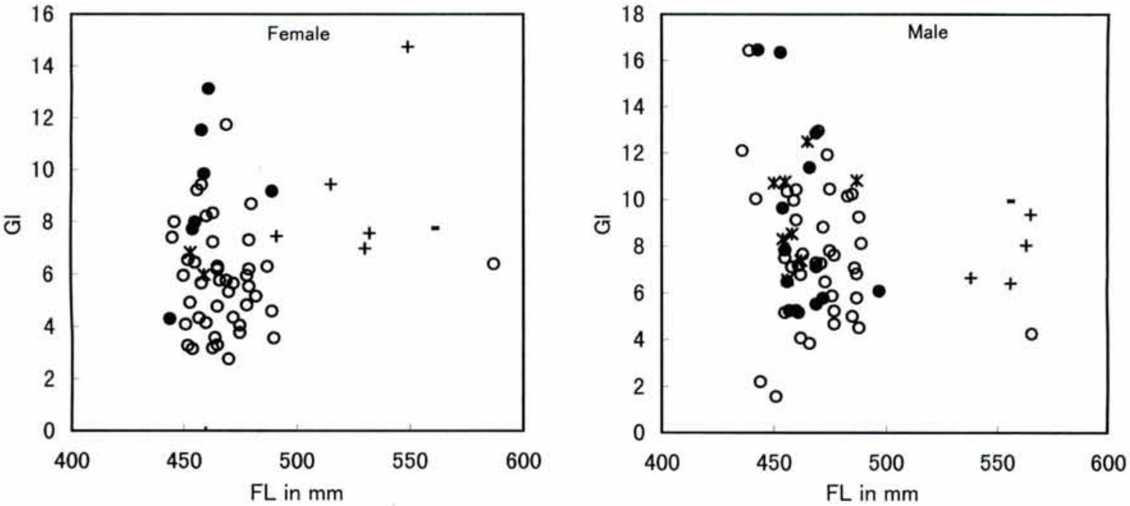

Fig. 2. Gonad index against fork length of female (left figure) and male (right figure). ○: fish caught by set net in Hamada from July to August 1996, ●: fish caught by purse seine in Hamada in July 1996, ∗: fish caught in the East China Sea in August 1992, +: fish caught in the East China Sea in August 1995, and —: fish caught in the East China Sea in July 1992.

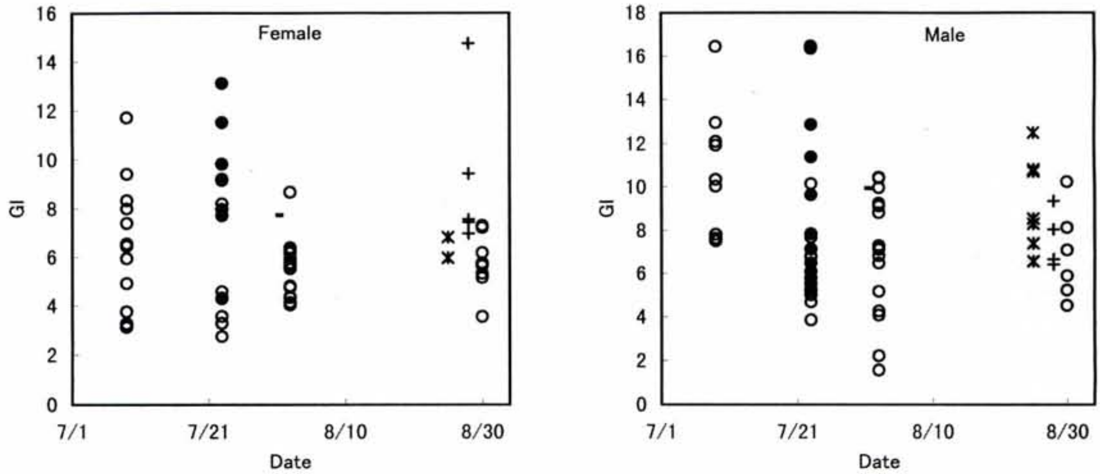

Fig. 3. Gonad index against catch date of female (left figure) and male (right figure). Symbols are the same as in Fig. 2.

with those of validated daily increment of other *Thunnus* species (Wild and Foreman, 1980; Radtke, 1984; Foreman, 1996). The parameters of von Bertalanffy growth equation were estimated by least square method as L_∞= 54.99 cm (SD=2.73), t_0=-0.0893 year (SD = 0.0316), and K = 1.701 (SD = 0.2826).

Spawned dates were back-calculated from the captured date and number of otolith increment. Since the date of the first increment formation was estimated as 4 to 5 days after fertilization in bluefin tuna, *Thunnus thynnus*, by laboratory reared fish (Itoh et al., in preparation), the same condition for longtail tuna was assumed. Distribution of estimated spawned date of fish captured off Yamaguchi was concentrated in the short period from 18 July to 14 August, regardless of a wide range in the captured dates (Table 3). Spawned date of the smallest fish which was captured on 21 August, 1996, with 13 cm in FL was 14 July, 1996. Among 8

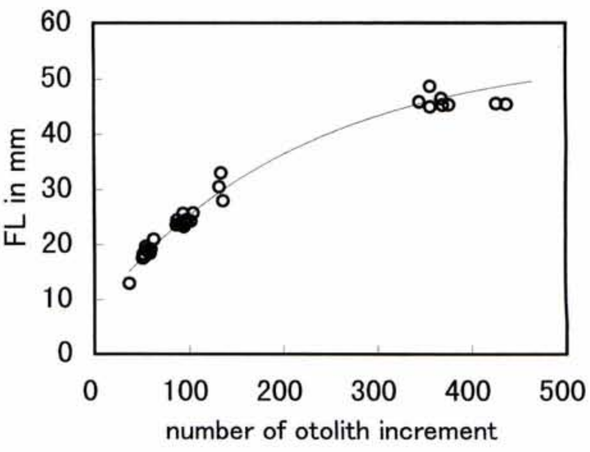

Fig. 4. Relationship between otolith increment number and fork length of longtail tuna (N=33). Curve of von Bartalanffy equation was fitted assuming the otolith increment formed daily.

Table 3. Back-calculated date of spawning estimated from otolith increment number assuming that the first otolith increment formed 4 days after spawning.

Date of capture	Back-calculated date of spawning											Total
	June			July			August			September		
	Early	Middle	Late	Early	Middle	Late	Early	Middle	Late	Early	Middle	
24 Aug., 1992		1	1					3		2	1	8
19 Sep., 1994					1	9						10
31 Oct., 1994						5	2					7
10 Nov., 1994						1	2	1				4
19 Dec., 1994							3					3
21 Aug., 1996					1							1
Total		1	1		2	15	7	4		2	1	33

adult fish, spawned dates of 6 fish caught in August 1992 ranged from the middle August to the middle September 1991, and those of 2 fish ranged from the middle to late June 1991. Therefore, overall spawning season for fish caught around Japan was estimated as the period from the middle June to the middle September. This period encompassed the period when the fish with high GI was caught.

Discussion

Spawning area of longtail tuna is known to be the water of the Southeast Asia. The larvae of longtail tuna have been collected in the Gulf of Thailand and off the west coast of Thailand (Chayakul and Chamchang, 1988; Nishikawa and Ueyanagi, 1991), as well as reported from Malacca Straits and South China Sea (Wilson, 1981; Chen and Wei, 1981Boonragsa, 1987). However, there has been no record of spawning around Japan.

The present study examined the spawning possibility of this species around Japan from several viewpoints. Observation of an ovary with hydrated eggs supported the spawning possibility in the nearby water where the fish captured. Occurrence of fish with GI higher than 10 seems to support the idea that these fish were on the way to or passed full matured stage, though, GI of female of late maturing stage in the Southeast Asia is reported to reach as high as 18 (Cheunpan, 1984). Histological observation was only conducted with one sample with 8 fish whose GI were lower than 8. These samples were at the early yolk globule stage, which did not provide a direct support on the hypothesis of spawning around Japan.

Longtail tuna is identified as a neritic species (Yesaki, 1987). Juveniles stay inner-neritic area and move to outer-neritic area by 40 cm in FL in Thailand (Yesaki, 1994). The juveniles caught in the coastal water of Japan were ranged from 13 to 33 cm in FL. The estimated age of the fish smaller than 30 cm in FL was 33 to 132 days old. These days would be too short for small juveniles to reach to the water around Japan from any known spawning sites. In the other words, the juvenile catch of from 33 to 132 days old indicated an existence of spawning area other than already known sites and closer to Japan.

The spawning season of longtail tuna seems to vary according to areas. There are two distinct spawning seasons observed in the west coast of Thailand as January-April and August-September (Yesaki, 1982), and in the Gulf of Thailand as March-May and July-December (Cheunpan, 1984). The spawning season is in summer in southern hemisphere in Papua New Guinea and New South Wales in Australia (Serventy, 1956; Wilson, 1981). The present study indicated that spawning might occur in the

Table 4. Summary table for studies which estimated parameters of von Bertalanffy growth equation of longtail tuna.

Author	Method	K	L-max	t_0	Length at 6 month	Length at 1 year
Wilson (1981)	Modal progress	0.41	122.9	-0.032	24.1	42.4
Wilson (1981)	otolith increments	0.395	131.8	-0.035	25.1	44.3
Silas et al. (1985)	ELEFAN*	0.49	93	-0.24	28.3	42.4
Supongpan and Saikliang (1987)	Modal progress	1.44	58.2	-0.027	31.0	44.9
Prabhakar and Dudley (1989)	ELEFAN	0.228	133.6		14.4	27.3
Yesaki (1989)	Modal progress	0.55	108		26.0	45.7
Khorshidian and Carrara (1993)	Modal progress	0.3	149.5	-0.06	23.1	40.7
Present study	otolith increments	1.70	55.0	-0.08934	34.8	46.4

*ELEFAN: Electronic Length-Frequency Analysis summer around Japan. Japan is considered as the northeastern extent of distribution of longtail tuna (Yesaki, 1994). If spawning occurs around Japan, it is expected to be in summer when the water temperature is high, in the similar way that the spawning is observed in summer in New South Wales which is considered as the southern extent of the distribution.

Age and growth of longtail tuna has been examined (Wilson, 1981; Silas et al., 1985; Supongan and Saikliang, 1987; Prabhakar and Dudley, 1989; Yesaki, 1989: Khorshidian and Carrara, 1993)(Table 4). However, most of studies were based on modal progression of fork length of catch. Wilson (1981) used otolith but examined only fish larger than 40 cm in FL. The present study is the first example of direct aging of fish younger than 1 year old, although no validation for the cycle of otolith increment formation was made.

Length at 1 year old was similar in all studies ranged from 40 to 46 cm in FL including the result of present study except Prabhakar and Dudley (1989), though length younger than 1 year old was larger in the present study comparing to the result of previous studies. The present study supports the estimated length at 1 year old in the previous studies.

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日本周辺海域におけるコシナガ*Thunnus tonggol*の産卵の可能性と成長

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摘　要

日本近海におけるコシナガ*Thunnus tonggol*の再生産の可能性を，尾叉長44～57cmの魚の生殖腺の観察から検討した．また，尾叉長13～49cmの成長を耳石輪紋による日齢査定から検討した．日本周辺で漁獲された魚の1尾に水子卵を持つ卵巣が観察されたことから，日本周辺での産卵が示唆された．しかし，他の魚の生殖腺指数からは日本周辺での産卵の可能性は必ずしも支持されなかった．一方，尾叉長13～33cmの小型魚の日齢は耳石輪紋を日輪と仮定した場合，33～132日齢と推定されたが，この期間は既知の産卵場から来遊するには短すぎると思われる．また，生殖腺指数から推定された産卵期と，耳石輪紋から推定された発生日とは一致していた．これらの2つのことも日本近海での再生産の可能性を支持している．バータランフィー成長式の係数は，L_∞ = 55.0cm, t_0 = -0.089year，K = 1.70と推定された．

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