Body length distributions and age compositions of the Pacific saury caught by the Chinese Taipei saury fishery in 2007-2018

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1. Introduction

In 2019, the SSC PS04 noted the need to share Pacific saury biological data, such as catch-at-age and catch-at-size data, for work towards the use of age-structured stock assessment models (SSC PS 2019). As a first step, it is essential to collect all available information for the estimation of the catch-at-age/size data from the saury fishing fleets in the Northwest Pacific Ocean (NWPO). This approach will allow for the development of a robust data set and will inform decisions for model construction based on data availability.

In the Pacific saury far sea fishery, such as the Chinese Taipei saury fishery (CTSF), saury is graded into several commercial size categories (by weight) on board. Six commercial size categories have been defined and used in the logbook of the CTSF since 2009, including *Extra large* (≤ 6 individuals/kg), *No.1* (7-9 individuals/kg), *No.2* (10-12 individuals/kg), *No.3* (13-15 individuals/kg), *No.4* (16-18 individuals/kg), and *No.5* (≥ 19 individuals/kg). Prior to 2009 only five commercial size categories were used; *No.5* was the last category to be added (Huang 2007). Immediately after being graded, saury is subsequently frozen and stored onboard in 10 kg capacity boxes. In this study, we modified the approach that Huang et al. (2019) reported in the SSC PS05 to refine the estimations of saury length-frequency distributions and age compositions. We use the knob lengths and body weights of saury samples from each commercial size category to investigate the size/age information of saury caught by the CTSF from 2007 - 2018.

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2. Materials and methods

Two datasets were used in this study:

(1) 2007-2018 landed saury catch data from the CTSF in the NWPO. This dataset was acquired from logbooks by the Overseas Fisheries Development Council (OFDC) and included records of daily catch (weight by commercial size categories), fishing effort (number of hauls), and fishing location (latitude and longitude).

(2) 2007-2018 saury knob length and body weight data for each commercial size category. Samples of saury caught in October, the highest catch and/or CPUE month, were obtained annually from the saury catch that was landed at the Kaohsiung Fishing Port. A random sample of 50-119 individuals was selected from the catch boxes for each commercial size category from 2007-2018, and their knob lengths and body weights were measured to the nearest 0.1 mm and 0.1 g, respectively (**Table 1**). The annual sample size ranged from 313-504.

Three steps were employed to estimate the length-frequency distributions and age compositions of saury caught by the CTSF each year:

(1) Estimation of the number of saury caught in each size category **(Figure 1)**: The number of individuals was estimated based on the amount of saury catch in weight, obtained from the OFDC, divided by the mean body weight of saury samples; this was assessed independently for each size category.

(2) Construction of a saury length-frequency distribution **(Figure 2)**: The knob length data for all fish in each size category was estimated through amplified replication of the knob length data from the saury samples measured in our study. The amplification factor was an integer estimated based on the number of saury caught in each size category divided by the number of saury samples assessed in our study. The length-frequency distribution of saury caught by the CTSF each year was composed by summarizing the knob length data from the six size categories and dividing at an interval of 1.0 cm.

(3) Composition of saury age **(Figure 3)**: For each 1.0 cm knob length interval, the number of saury was categorized as either *age-1* or *age-0*, based on an age-length key that was calculated annually according to the age/size data from saury samples. The

age-length key was based on percentages of annual age compositions for each 1.0 cm length interval as assessed by otoliths. The age composition of the saury caught by the CTSF each year was determined using the age-length key for individuals that ranged in size from 20-35cm.

Since the amount of saury catch in weight for each 1° x 1° grid can be obtained from the logbook data, the saury length-frequency distributions and age compositions for each 1° x 1° grid can be determined by applying the estimation techniques we have described.

In addition to the age-length keys derived from the CTSF's October samples, two seasonal age-length keys from 2001-2018 were provided by Dr. Suyama to adequately differentiate between saury growth rates in the early fishing season (May-July) and the main fishing season (August-December). To estimate the monthly length-frequency distributions and age compositions for the 1° x 1° grids throughout the fishing season, the age-length key derived from the CTSF and that shared by Dr. Suyama were used for the main fishing season and the early fishing season, respectively.

3. Results

The mean body weights of saury samples from 2007-2018 for each commercial size category are shown in **Table 1**. The mean body weight in each category varied across years and its coefficient of variation was lowest (3.6 %) and largest (16.6 %) in the size category of *No.1* and *No.5*, respectively.

The estimated number of saury caught by the CTSF from 2007-2018 ranged from 730.7 million, the lowest in 2007, to 1870.7 million, the largest in 2014 (**Figure 4**). The estimated length-frequency distributions of saury caught by the CTSF from 2007-2018 is shown in **Figure 5**. Most of the minimum boundary of the length distributions in 2007-2018 was 25.0 cm, though the minimum boundary in 2009 was the smallest, 20.0 cm. The maximum boundary of the length distributions in 2007-2018 varied between 33.0 and 34.0 cm.

The age compositions of saury caught by the CTSF varied across 2007-2018 (**Figures 5 & 6**). In general, the majority of the saury caught across 2007-2018 were *age-1* (ranging from 50-80% of the total catch annually); 2009 had the smallest percentage of *age-1* individuals (18%), and 2010 and 2018 had the highest percentage of *age-1* individuals (92% and 88.3%, respectively) (**Figure 6**).

Comparisons of the age-length keys for saury in the main fishing season, August to November, between Chinese Taipei and Japan from 2007-2018 are shown in **Figure 7**. The S curves of the age-length keys from Chinese Taipei and Japan almost overlap in most years, although in 2009, 2011, 2013, and 2014, compared with Chinese Taipei, the S curve from Japan showed some right-shifted states. In general, the knob length of *age-1* fish derived from the Japanese age-length key was larger than that of Chinese Taipei in the main fishing season.

The estimations of monthly age compositions in the main fishing season for the 1° x 1° grids are shown in **Figure 8**, using the 2018 dataset as an example. The percentage of *age-1* fish in the 1° x 1° grids was more than 63% from August-November in 2018. The estimations of monthly age compositions for the 1° x 1° grids in the early fishing season are shown in **Figure 9**. The percentage of *age-1* fish in the 1° x 1° grids was more than 90% from May-July in 2018.

4. Discussions

4.1 Age-length keys

There were two sources of the age-length keys for saury: Chinese Taipei and Japan. In the main fishing season, the Chinese Taipei saury samples used for establishing the age-length key were collected from the high seas, while most saury samples that were used to construct the Japan age-length key were collected in nearshore waters. However, the age-length keys in the main fishing season showed consistent S curves in most years for both Chinese Taipei and Japan (**Figure 7**). Although differences between the age-length keys were found in 2009, 2011, 2013, and 2014, the differences were less than 1.0 cm. In order to cover all saury fishing grounds throughout the nearshore waters and high seas, and to enhance the sample size in the main fishing season, we suggest integrating the age-length data from Chinese Taipei and Japan (or potentially other fishing fleets) to develop a single age-length key. The age-length key for the early fishing season was only calculated by Japan, we encourage other saury fishing fleets to develop early fishing season age-length keys.

4.2 Sample sizes

The sample sizes of the saury knob lengths and body weights from all the six commercial size categories used for the estimations of the total catch number and body length-frequency ranged annually from 313 to 504. Although sample data was consistently collected each year mostly in October, this annual sampling frequency may impose limitations; specifically this approach did not allow for the incorporation of potential monthly and vessel variation. Additional sampling time points and vessels would help to resolve and assess temporal and vessel variations in our data, but such an approach would also impose substantial costs. To address this challenge, we are developing an image-based measurement approach that can be used easily across multiple months and vessels to measure the knob length of saury directly within commercial boxes. We hope that in the future this image-based measurement approach can be used to both enhance the quality of our datasets and also reduce the time and financial limitations currently hindering the acquisition of robust catch assessments.

5. References

SSC PS (Small Scientific Committee on Pacific Saury). 2019. *4th Meeting Report*. NPFC-2019-SSC PS04-Final Report. 48 pp. (Available at www.npfc.int)

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Huang WB, Chang YJ, Hsieh CH. 2019. Enumeration of commercial size category, body length distribution, and age composition of the Pacific saury caught by the Chinese Taipei's saury fishery in 2018. NPFC-2019-SSC PS05-WP03. 6 pp. (Available at www.npfc.int)

Table 1. Mean body weight (g) and sample size (in brackets) of saury measurements for the six commercial size categories within the Chinese Taipei saury fishing fleets from 2007-2018.

Year	Commercial size category						Sample size
	Ex large	*No. 1*	*No. 2*	*No. 3*	*No. 4*	*No. 5*	
2018	138.8 (80)	137.1 (100)	127.8 (80)	110.8 (80)	96.9 (80)	81.9 (80)	(500)
2017	150.6 (60)	135.9 (73)	119.7 (60)	97.0 (60)	80.6 (60)	83.8 (60)	(373)
2016	163.6 (60)	138.8 (65)	119.7 (65)	95.1 (65)	83.9 (65)	82.6 (65)	(385)
2015	146.5 (99)	131.5 (90)	116.8 (76)	100.0 (80)	73.2 (80)	66.0 (79)	(504)
2014	153.4 (99)	131.6 (74)	111.8 (68)	90.3 (70)	74.4 (80)	62.2 (69)	(460)
2013	158.8 (98)	136.3 (58)	110.6 (60)	78.4 (60)	77.2 (80)	57.0 (60)	(416)
2012	170.3 (90)	140.0 (80)	126.2 (71)	111.0 (78)	87.8 (76)	79.2 (76)	(471)
2011	176.2 (79)	130.5 (70)	120.3 (65)	105.4 (70)	96.4 (59)	75.9 (70)	(413)
2010	151.0 (73)	137.6 (69)	137.0 (68)	107.3 (75)	95.5 (70)	73.5 (72)	(427)
2009	173.7 (50)	141.5 (70)	123.9 (70)	94.3 (70)	70.9 (70)	50.0 (67)	(397)
2008	170.3 (68)	146.0 (63)	128.0 (62)	94.2 (60)	81.7 (60)	N/A	(313)
2007	151.0 (106)	144.4 (119)	120.6 (81)	101.7 (95)	87.1 (87)	N/A	(488)
Mean	158.7	137.6	121.9	98.8	83.8	71.2	(429)
CV (%)	7.6	3.6	6.0	9.5	10.9	16.6	
Range	138.8-176.2	130.5-146.0	110.6-137.0	78.4-111.0	70.9-96.9	50.0-83.8	(313-504)

CV: coefficient of variation

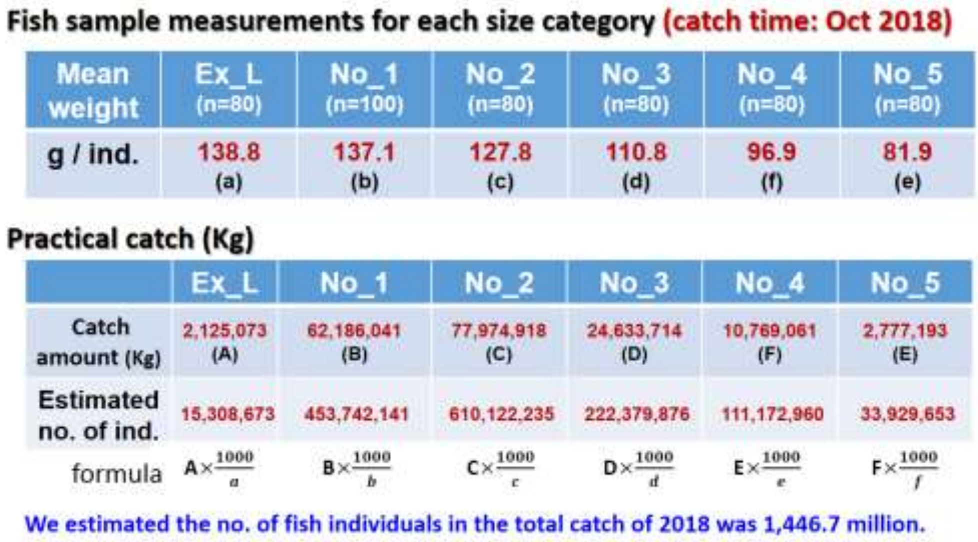

Figure 1. A schematic diagram for the estimation of saury caught in each size category, using data from 2018 as an example.

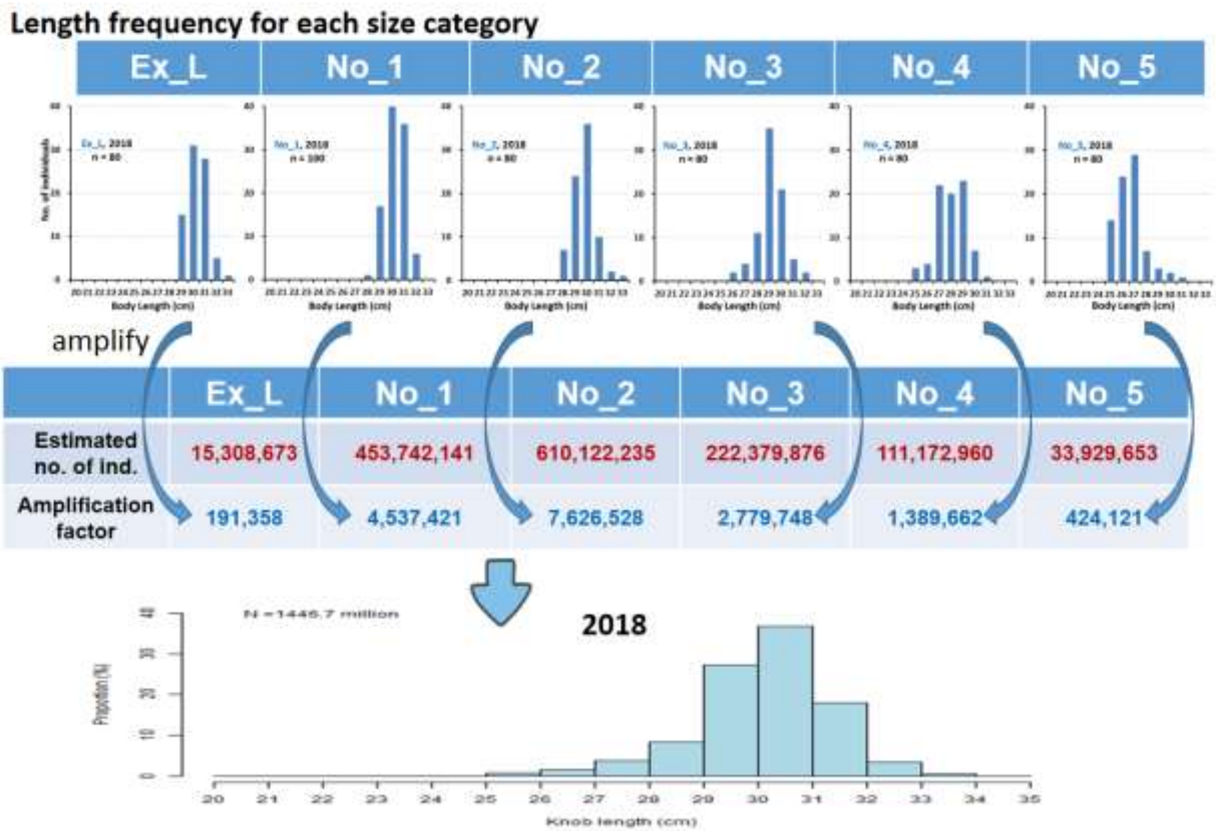

Figure 2. A schematic diagram for the determination of the saury length-frequency distribution, using data from 2018 as an example.

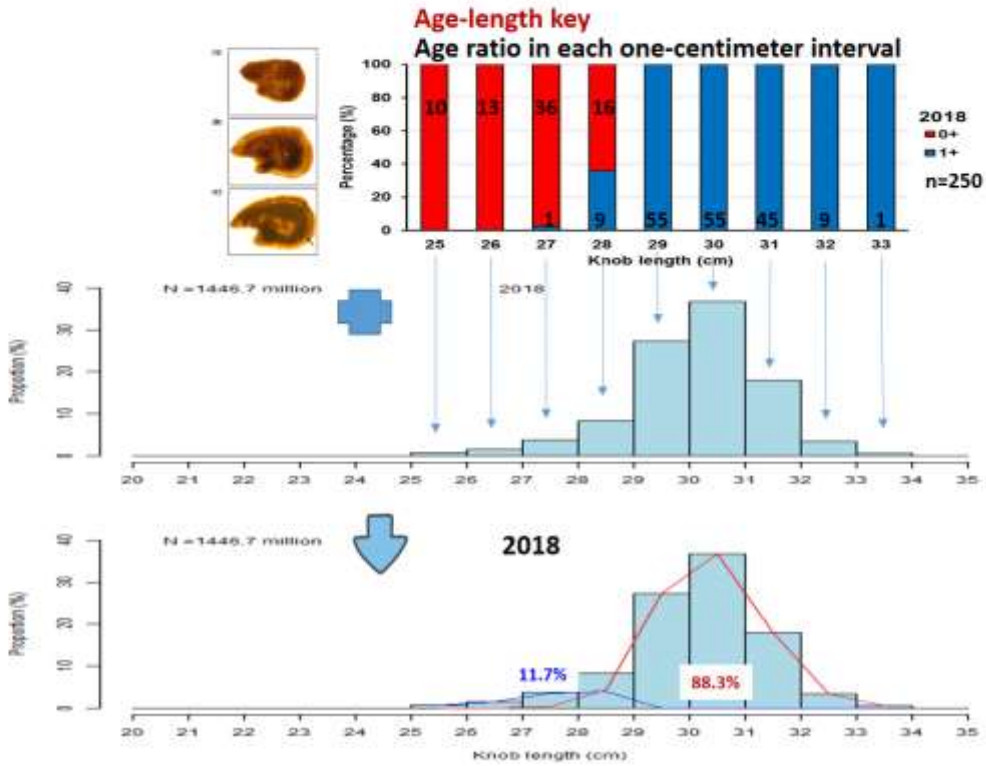

Figure 3. A schematic diagram for estimation of the composition of saury age, using data from 2018 as an example.

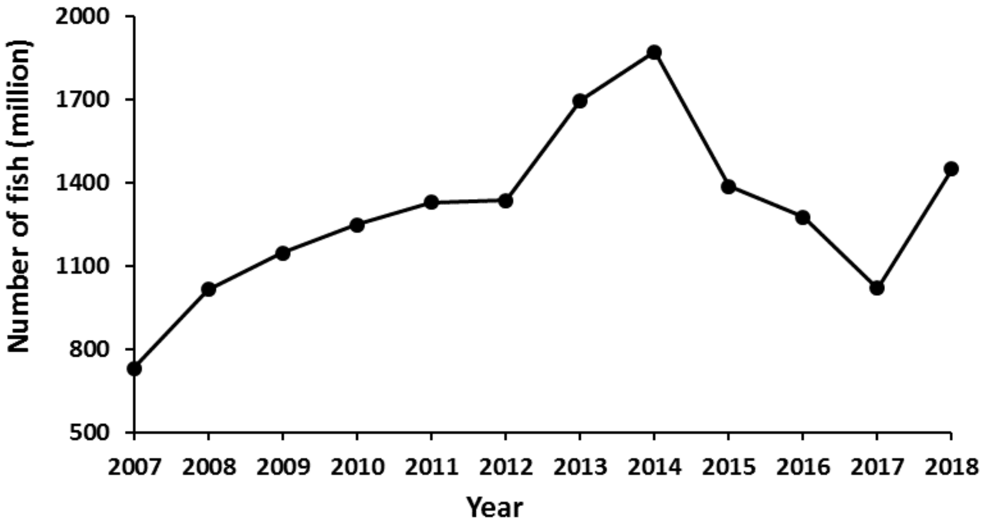

Figure 4. Variation in the estimated number of saury caught by the CTSF from 2007-2018.

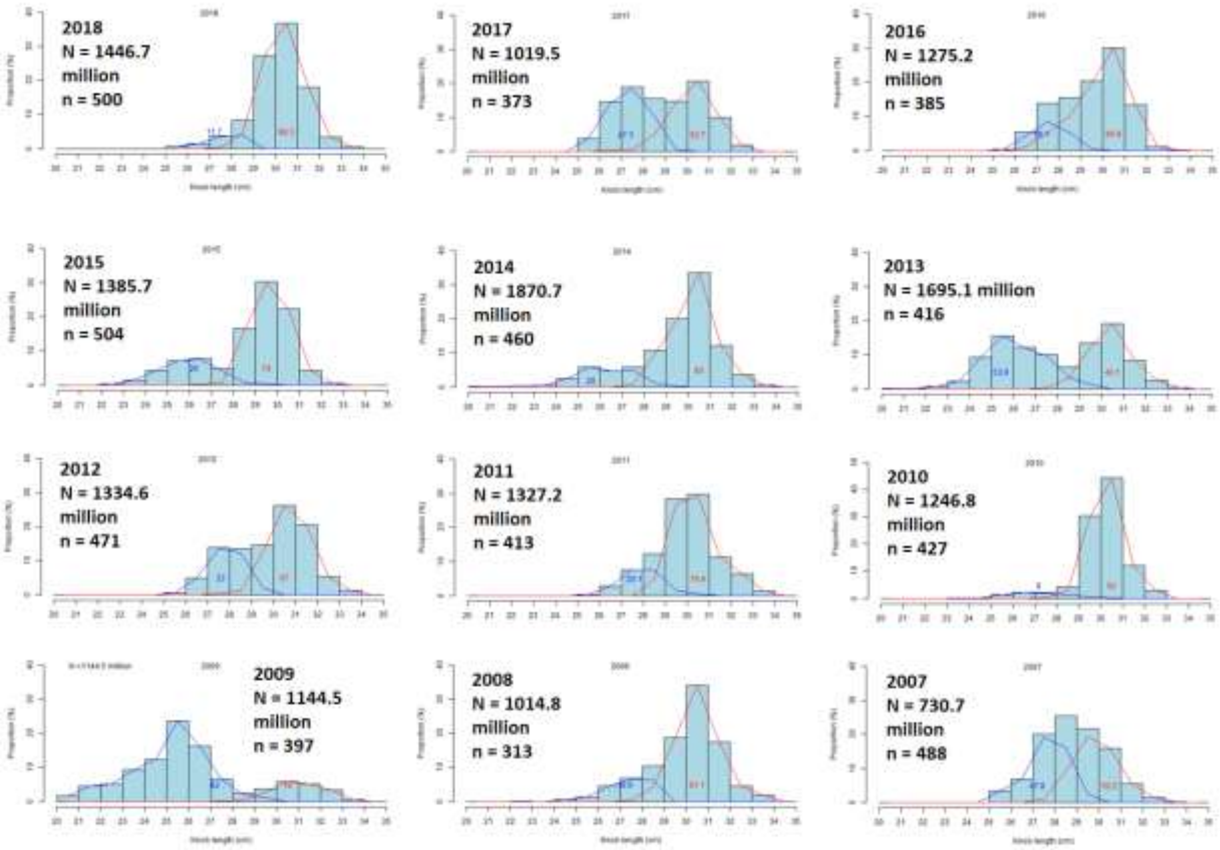

Figure 5. The estimated length frequency distributions and age compositions of the 2007-2018 saury catch. Blue and red lines represent proportions of the catch for *age-0* and *age-1* saury, respectively.

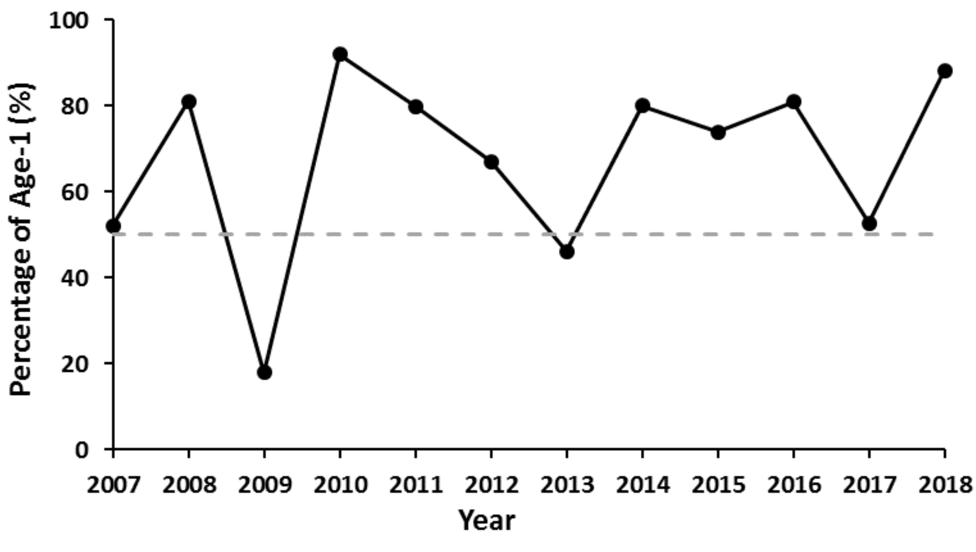

Figure 6. Percentage variation of the *age-1* saury caught by the CTSF from 2007-2018.

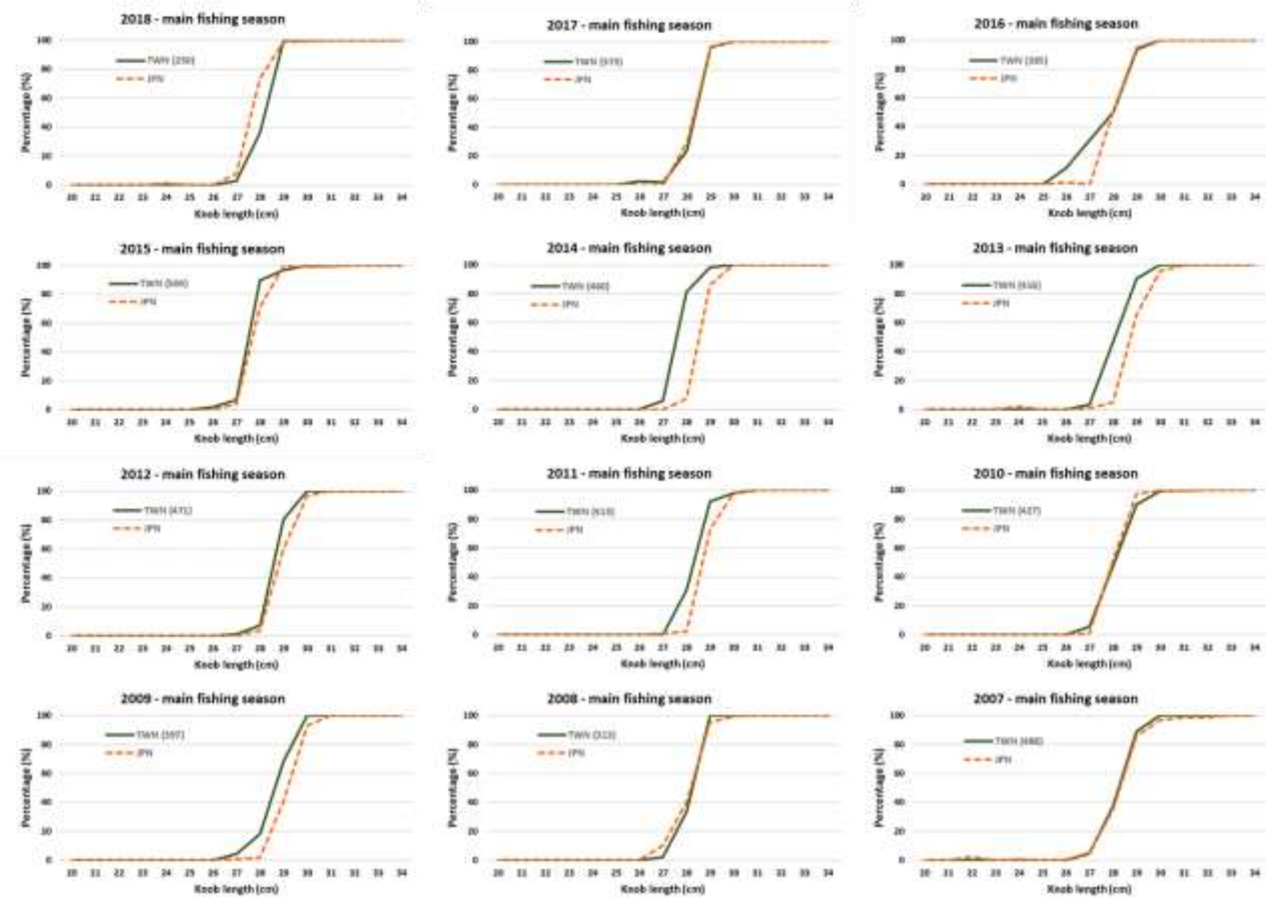

Figure 7. Comparison of the age-length keys for saury in the main fishing season, August to November, between Chinese Taipei and Japan in 2007-2018. Green solid lines and orange dotted lines represent percentages of the *age-1* fish by an interval of 1.0 cm estimated by Chinese Taipei and Japan, respectively. The number in the brackets is the otolith sample size for the age determination.

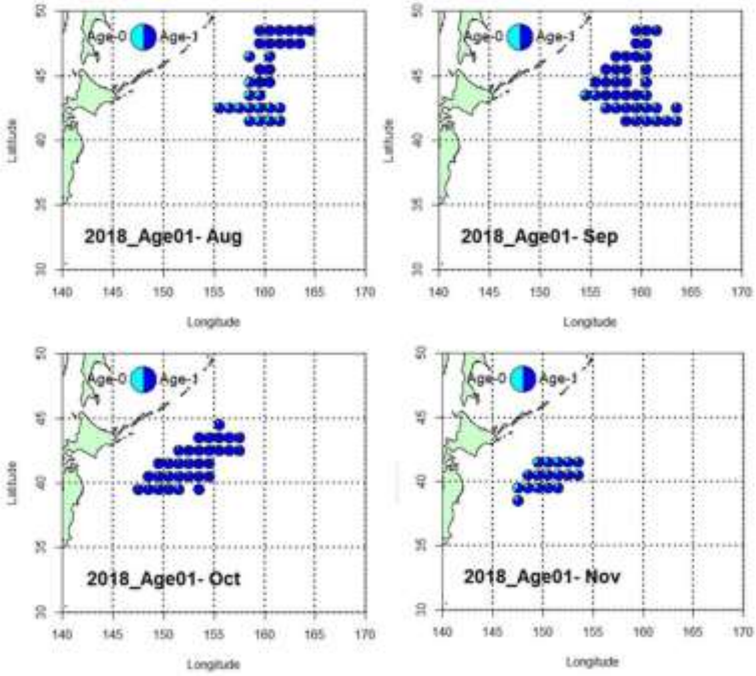

Figure 8. Pie plots of the age composition estimations within 1° x 1° grids in the main fishing season, August to November, for the *age-0* and *age-1* saury caught by the CTSF in 2018; using the Chinese Taipei age-length key .

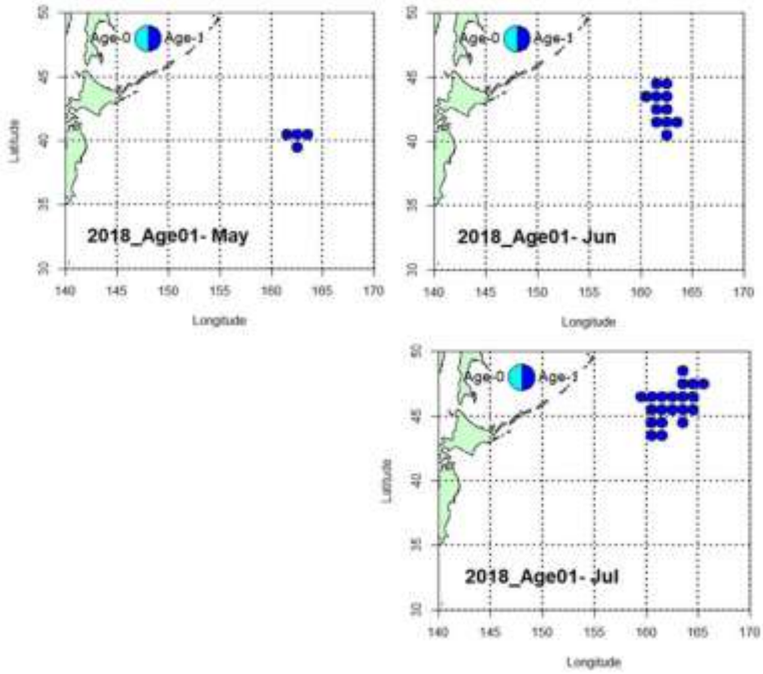

Figure 9. Pie plots of the age composition estimations within 1° x 1° grids in the early fishing season, May to July, for the *age-0* and *age-1* saury caught by the CTSF in 2018; using the Japan age-length key.