CCSBT-ESC/2008/32
(ESC Agenda Item 7)

Updated analysis for gonad samples of southern bluefin tuna collected by Taiwanese scientific observer program

Ching-Ping Lu[1], Hung-Hung Hsu[2], Sheng-Ping Wang[1],
Wei-Chuan Chiang[2], Ming-Hui Hish[3]

1. Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, Taiwan
2. Eastern Marine Biology Research Center, Fisheries Research Institute, Taiwan
3. Fisheries Agency, Council of Agriculture, Executive Yuan, Taiwan

ABSTRACT

A total of 745 gonad samples of southern bluefin tuna were collected during the period of April to September by Taiwanese scientific observer program from 2010 to 2019. The range of fork length were concentrated between 90 and 150 cm. For the monthly GSIs, the females' GSI showed the increasing trend from April to July and then revealed a decline. And the monthly GSIs of males reached the maximum value in May and then decreased gradually. For the sexual maturity stages determination, we analyzed 522 gonad samples in the collection period of 2010-2018 based on the histological sections. According to the results, most samples were designated as immature stage, and about 15.5% samples designated as mature. However, they were at reproductively inactive status. And most female samples were regressed or regenerating stages during April to June, and most of male samples were regenerating stages during June to August.

1. INTRODUCTION

Several reproductive biology researches have been studied for the southern bluefin tuna (SBT), *Thunnus maccoyii*. The reproductive information of SBT such as age-at-first-maturity, gonad index, ova size-frequency and fecundity had been investigated in the waters off the south eastern and southern Australia (Thorogood, 1986). And Farley and Davis (1998) investigated the spawning dynamics of SBT using ovaries obtained from the spawning ground in the northeast Indian Ocean and the main feeding ground in the south Indian Ocean. Also, the sexual maturity of SBT have been investigated using the morphological and histological observations of the gonad samples collected by Taiwanese observers program in the southwest Indian Ocean (Chen et al. 2013).

However, the guideline of the determination maturity stages for SBT was needed to be further improved. In order to improving the integrity of the reproductive research results, it is essential that developing an appropriate histological determination standard to classify the mature and immature females. Therefore, the scientific observers have conducted the observation program of SBT for collecting scientific information and biological samples including gonads, otoliths, and muscle tissues of SBT while deploying on board. Here, we presented the updated analysis for gonad samples of SBT collected by Taiwanese scientific observer program.

2. MATERIALS AND METHODS

All of the gonad samples of SBT were collected by scientific observers deployed on Taiwanese longline vessels operated in the Indian Ocean. The basic information including the fork length, body weight, sex, sampling date and location were recorded for each specimen.

Because the body weight of some samples were not recorded by observers, a length-based gonado-somatic index (Chen et al., 2013) was adopted in this paper:

$$GSI = \frac{GW}{L^3} \times 10^4$$

where *GSI* is the gonado-somatic index, *GW* is the weight of gonad and *L* is the fork length.

The sexual maturity stages were classified based on histological sections of gonad samples. The criteria of histological classification for gonadal developmental stages of SBT were needed further examined and discussed for SBT at this point time. Therefore, we still followed the criteria of Farley et al. (2013), which were used for albacore in the southern Pacific Ocean, and adopted to categorize the gonadal developmental stages for SBT in this study. The criteria of developmental stages were classified into the (1) immature stage, (2) developing stage, (3) spawning capable stage, (4) spawning stage, (5) regressing - potentially reproductive stage, (6) regressed stage, and (7) regenerating stage. Individuals were designated as mature if the most advanced oocytes were indicative of ≥ stage 3. Stages 3 and 4 are reproductively active stages, and stages1-2 and 5-7 are reproductively inactive stages (Table 1. adopted from Farley et al. 2013).

3. RESULTS AND DISCUSSION

There were a total of 745 gonad samples of SBT collected during April to September from 2010 to 2019 including 340 female and 405 male samples. The sampling area were located in the waters of the south Indian Ocean from 2010 to 2019, and distributed between 31°E-109°E in longitude and 29°S-40°S in latitude (Fig. 1). The range of fork length of female and male samples were from 80 to 178 cm and 60 to 191 cm, respectively. The majority of samples' fork length were concentrated between 90 and 150 cm in both female and male (Fig. 2).

The values of gonad weights increased with the growth pattern of fork lengths obviously in both sexes with the variation in larger specimens which were over 160 cm in fork length (Fig. 3). Generally, the patterns of the relationship between GSI and fork length revealed similar trends in both females and males, which the GSI obviously increased with fork length. However, the increasing patterns in the relationship between GSI and fork length were somehow unapparent in some samples (Fig. 4).

The monthly GSIs of females remained higher trend from April to July and then revealed decreasing trends; the monthly GSIs of males reached the maximum value in May and then decreased gradually with updated data of 2018. The monthly trends of GSI for females and males remained the unchanged trends as the past. Because the fishing season of Taiwanese SBT longliner fishery was limited, the samples were collected only from April to September, monthly trend of GSI would not be explored for the entire year (Fig. 5).

Due to frozen process in the preservation, some samples were not qualified for processing the histological sections. There were 522 gonad samples including 254 females and 268 males collected from 2010 to 2018 were successfully examined histological sections, and the sexual maturity stages were determined based on the criteria of developmental stages in Farley et al. 2013. According to the observations, the gonadal developmental stages of most samples were designated as immature stage and some samples were determined at developing stage. The majority of the samples were designated as immature. And there were about 15.5% of samples (20% for females and 11% for males) designated as mature but most of these samples were reproductively inactive (regressed or regenerating stages) (Figs. 6-8).

There was no mature specimen in newly updated information. The smallest fork length of mature females and males were 97 and 93 cm, respectively (Figs. 9-11). Although the gonad weights and GSIs generally increased with the fork lengths, most immature and mature samples overlapped in the ranges of the fork lengths, gonad weights and GSIs. And there was no overlapped for the samples with fork length less than about 90 cm (Figs. 10 and 11).

According to the proportion of gonadal developmental stages by months, more mature female samples were regressed or regenerating stages during April to August

than others, while most of mature male samples were regenerating stages during June to August (Fig. 12). The results of histological sections in this study indicated that mature fishes might migrate to the fishing ground of Taiwanese SBT fishery after reproductive activity.

REFERENCES

Chen, M.H., Chen, K.S., Chen, T.C., Sun, C.L., Chen, C.Y. 2013. Notes on the reproductive biology of southern bluefin tuna *Thunnus maccoyii* in the southwestern Indian Ocean. Indian J. Mar. Sci. 42, 419-424.

Farley, J.H., Davis, T.L.O., 1998. Reproductive dynamics of southern bluefin tuna, *Thunnus maccoyii*. Fish. Bull. 96, 223–236.

Farley J.H., Williams A.J., Hoyle S.D., Davies C.R., Nicol S.J. 2013. Reproductive Dynamics and Potential Annual Fecundity of South Pacific Albacore Tuna (*Thunnus alalunga*). PLOS ONE 8(4): e60577. doi.org/10.1371/journal.pone.0060577

Farley, J.H., Hoyle, S.D., Eveson, J.P., Williams, A.J., Davis, C.R., Nicol, S.J. 2014. Maturity ogives for south Pacific albacore tuna (*Thunnus alalunga*) that account for spatial and seasonal variation in the distributions of mature and immature Fish. PLoS ONE 9(1): e83017. doi:10.1371/journal.pone.0083017.

Thorogood, J. 1986. Aspects of the reproductive biology of the southern bluefin tuna (*Thunnus maccoyii*). Fish. Res. 4, 297–315.

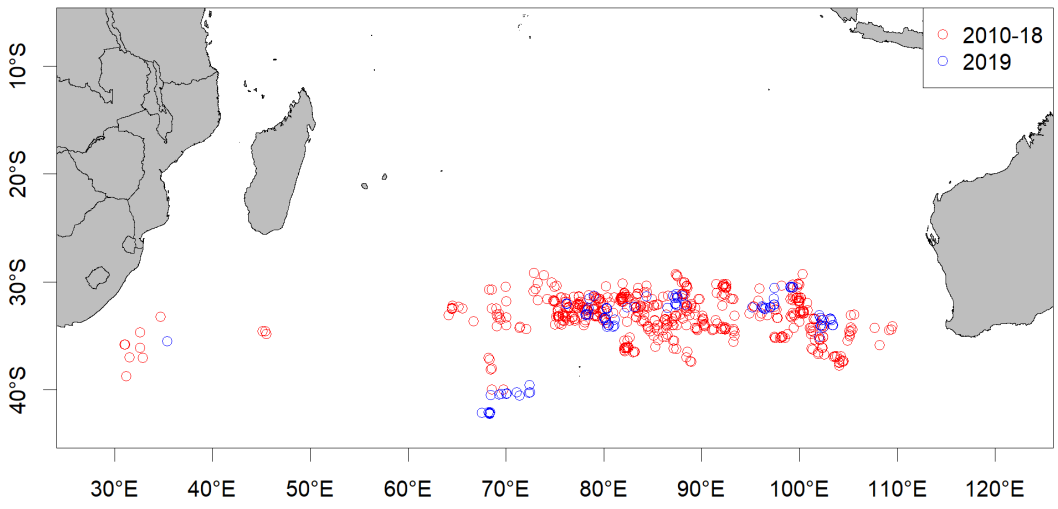


Fig. 1. Sampling locations of SBT gonad samples collected by Taiwanese scientific observer program during 2010-2019.

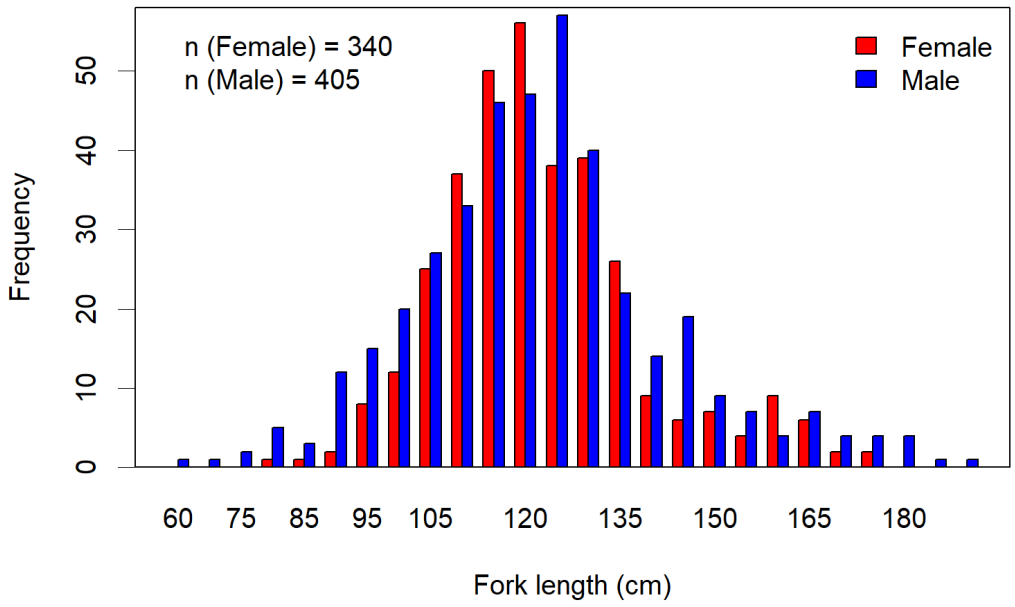


Fig. 2. Length frequency distributions with 5 cm intervals for SBT gonad samples collected by Taiwanese scientific observer program during 2010-2019.

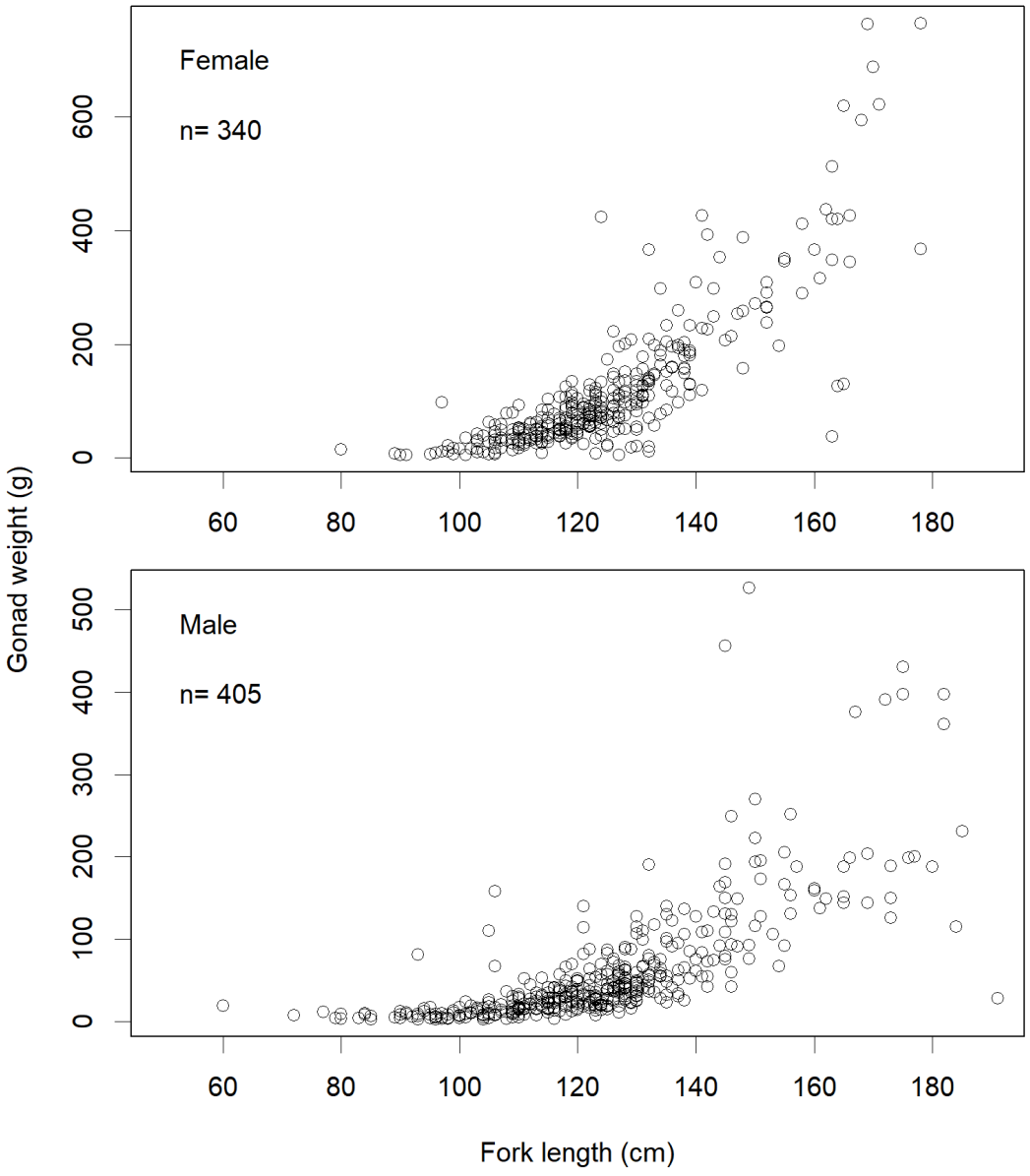


Fig. 3. Relationship between fork length and gonad weight for SBT gonad samples collected by Taiwanese scientific observer program during 2010-2019.

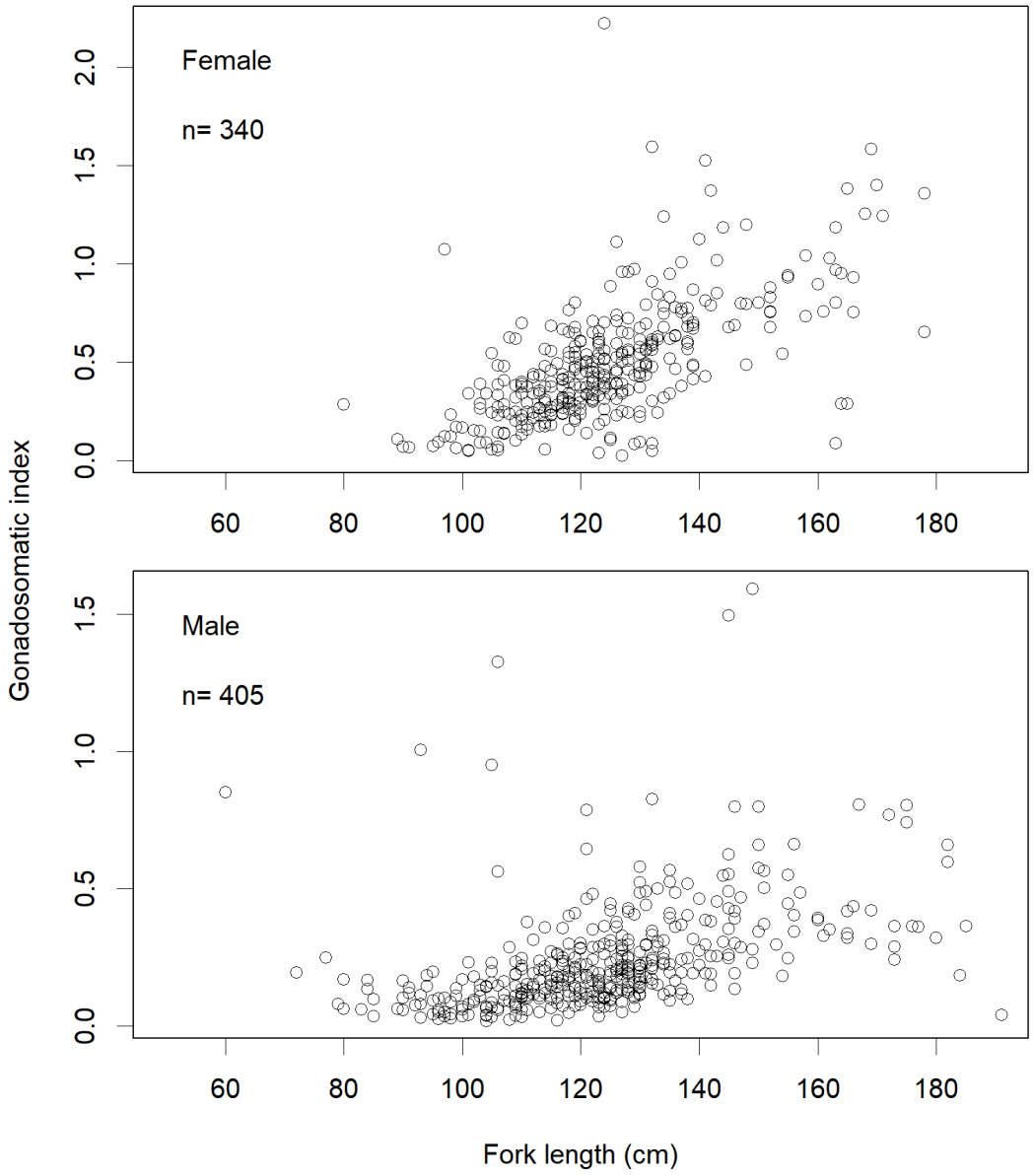


Fig. 4. Relationship between fork length and gonado-somatic index (GSI) for SBT gonad samples collected by Taiwanese scientific observer program during 2010-2019.

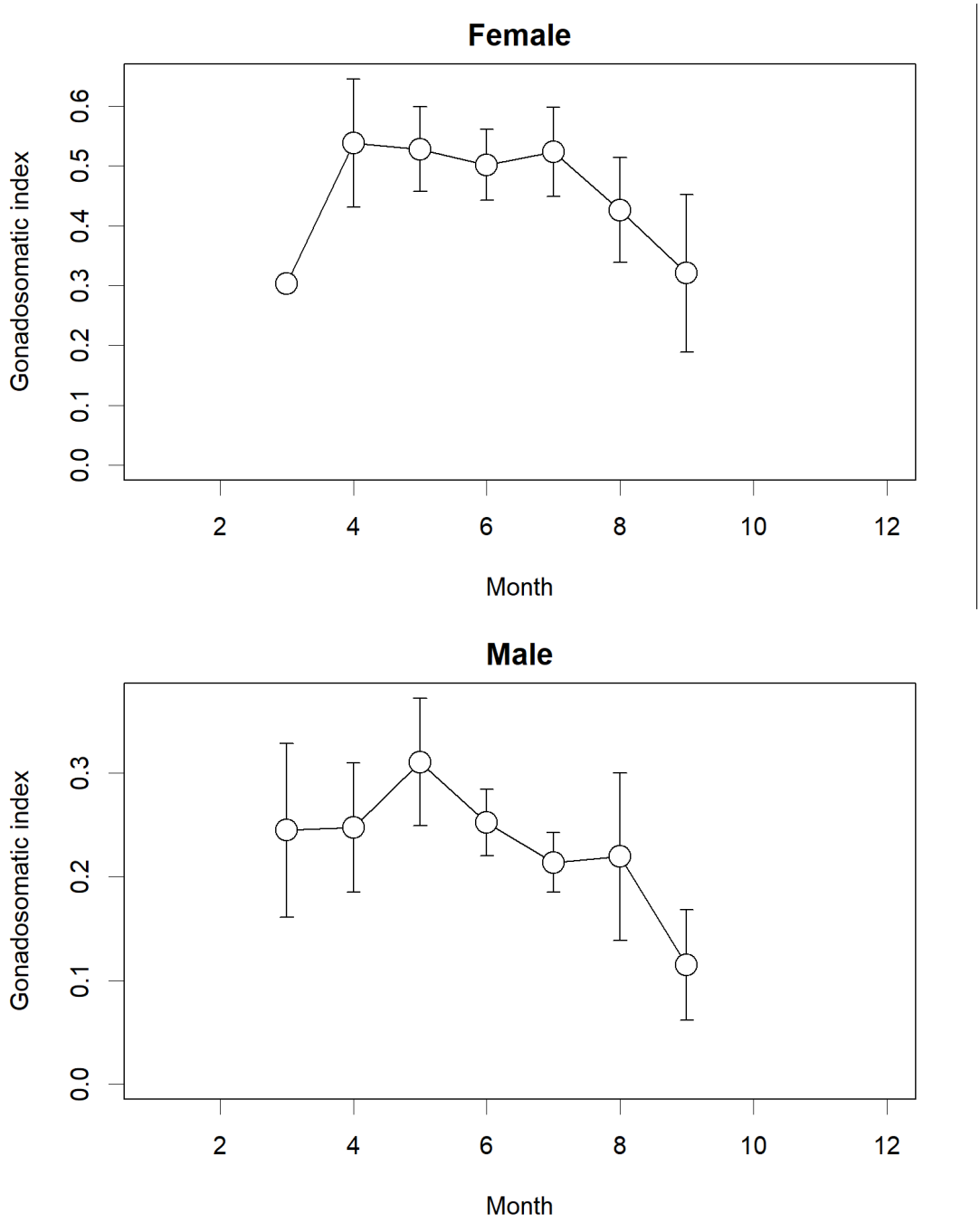


Fig. 5. Monthly trends of gonado-somatic index (GSI) for gonad samples of SBT collected by Taiwanese scientific observer program. Vertical bars represent the 95% confidence interval for means during 2010-2019.

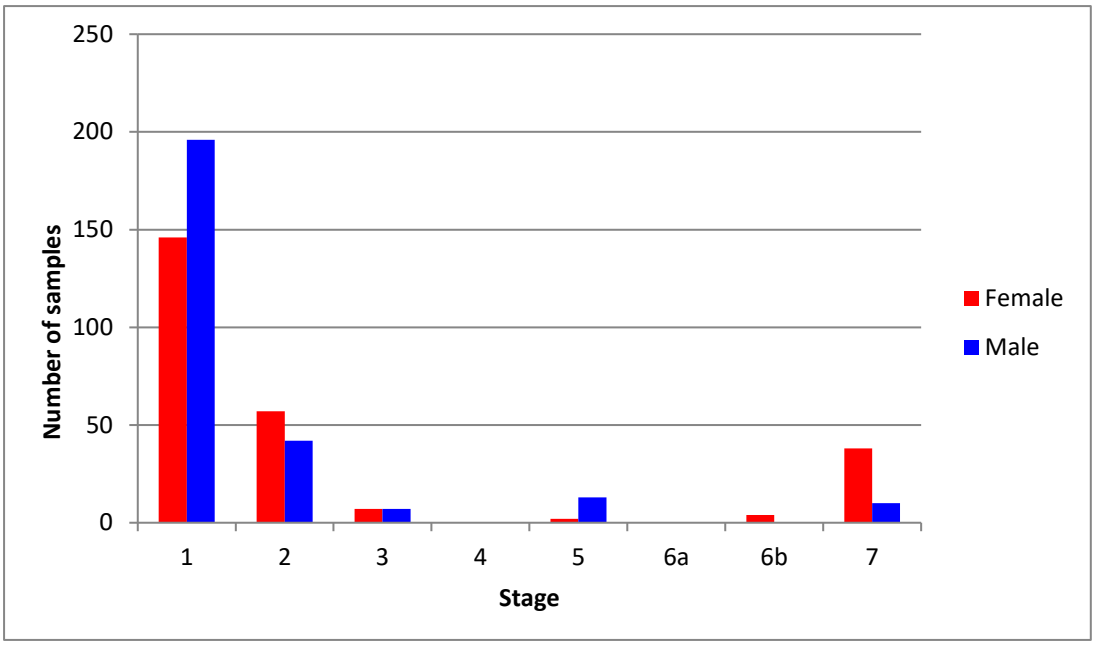
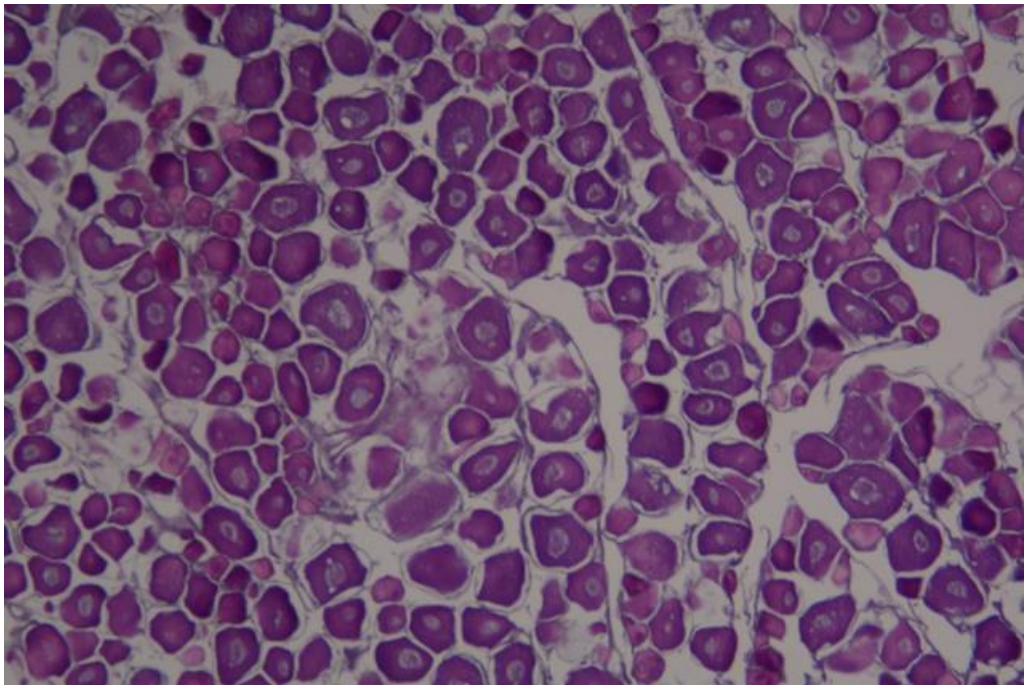
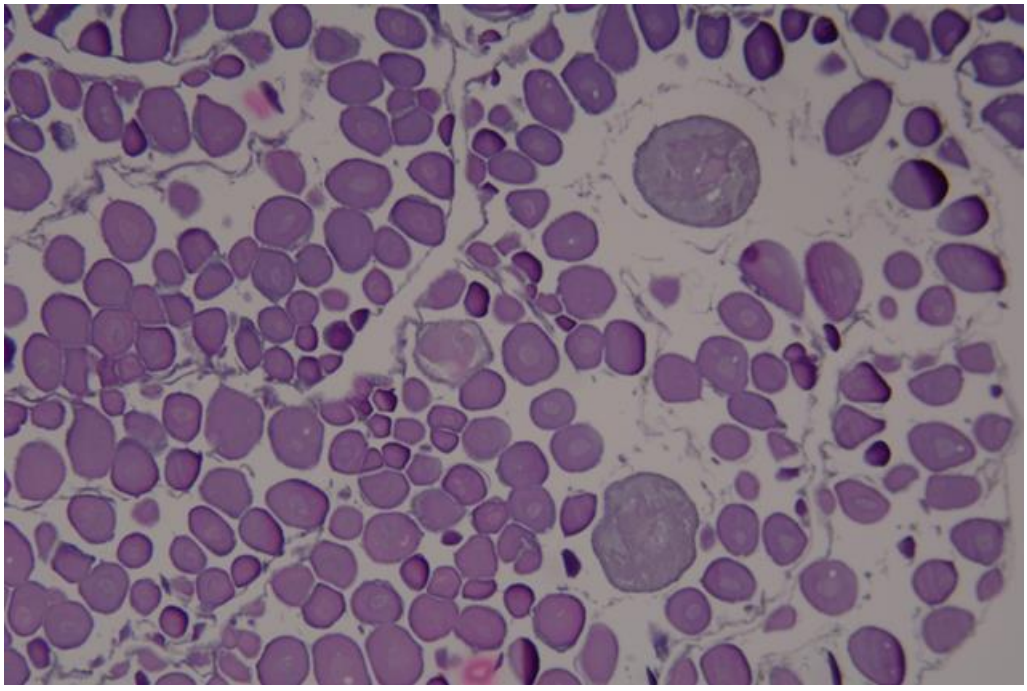


Fig. 6. Number of samples by maturity classes for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2018.

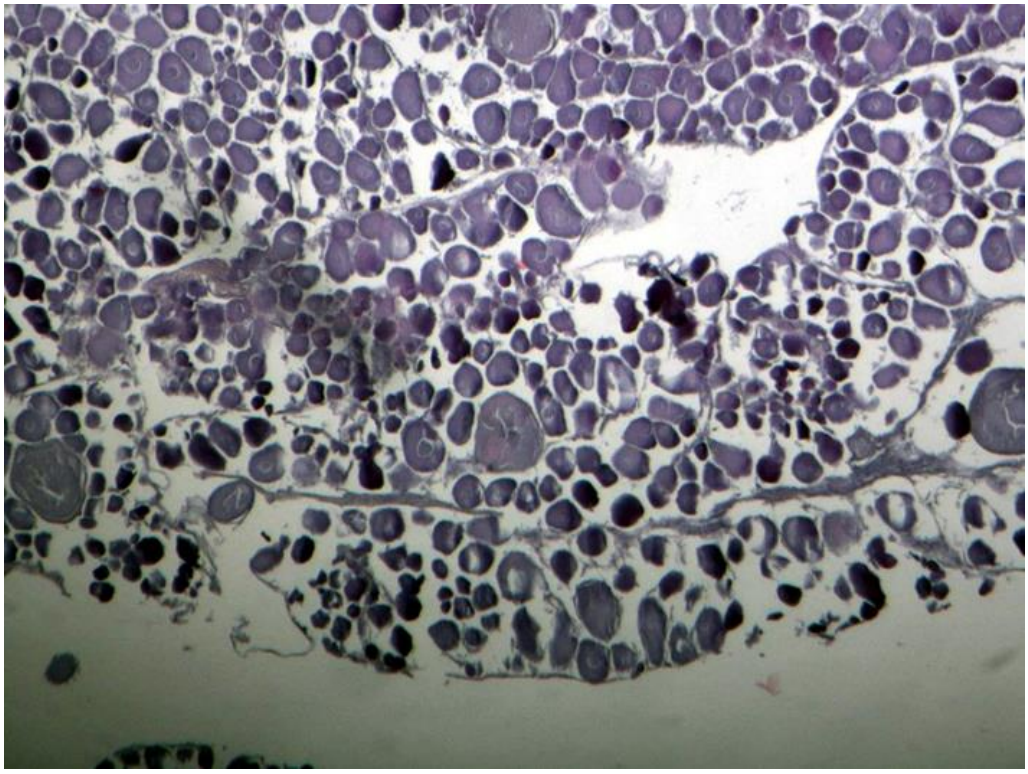


FL: 133cm, GW: 133.67g (Class 1, immature stage)

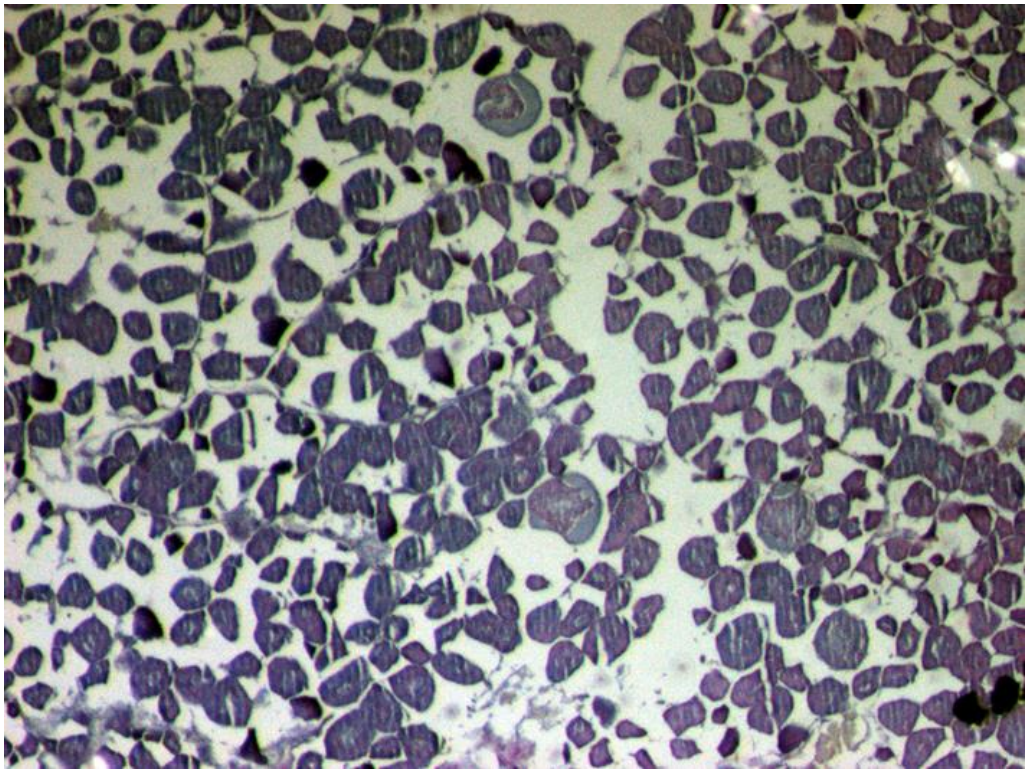


FL: 130cm, GW: 82.1g (Class2, developing stage)

Fig. 7. Histological sections and measurements of oocytes for gonad samples of female SBT collected by Taiwanese scientific observer program during 2010-2018.

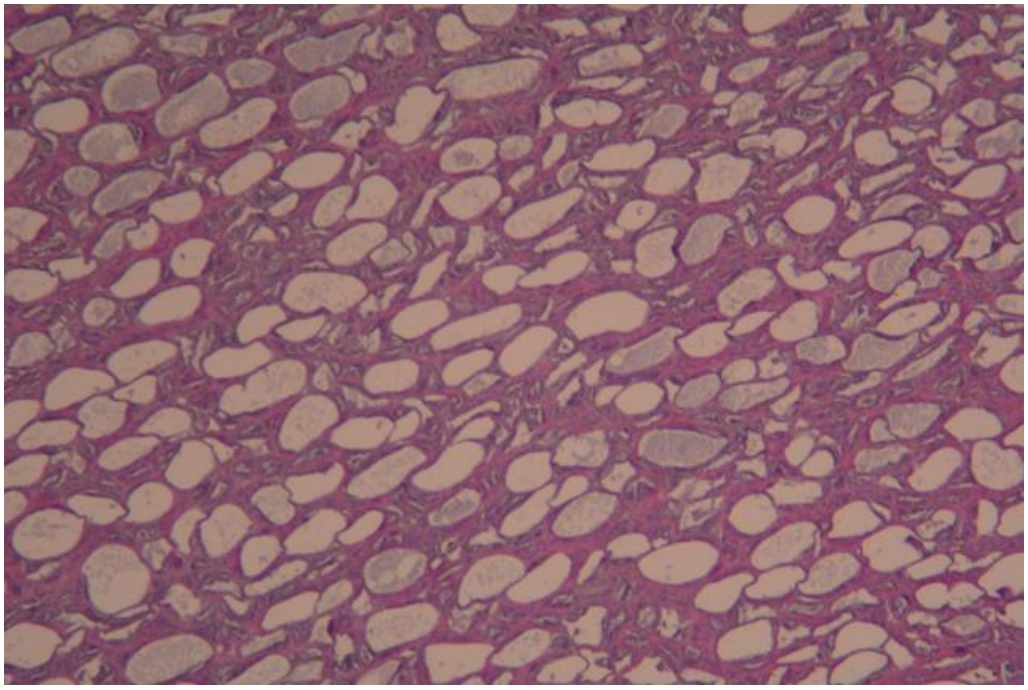


FL: 130cm, GW: 54.51g (Class 6b, regressed2 stage)

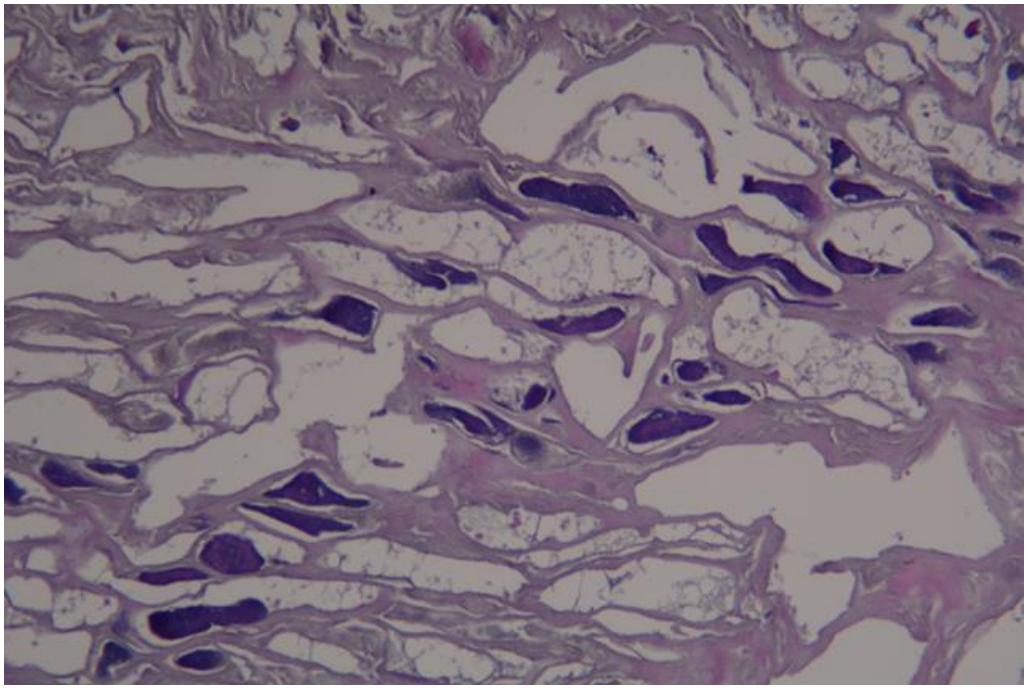


FL: 169cm, GW: 764.15g (Class 7, regenerating stage)

Fig. 7. (continued).



FL: 125cm, GW: 18.94g (immature stage)



FL: 127cm, GW: 17.87g (spent stage)

Fig. 8. Histological sections and measurements of oocytes for gonad samples of male SBT collected by Taiwanese scientific observer program during 2010-2018.

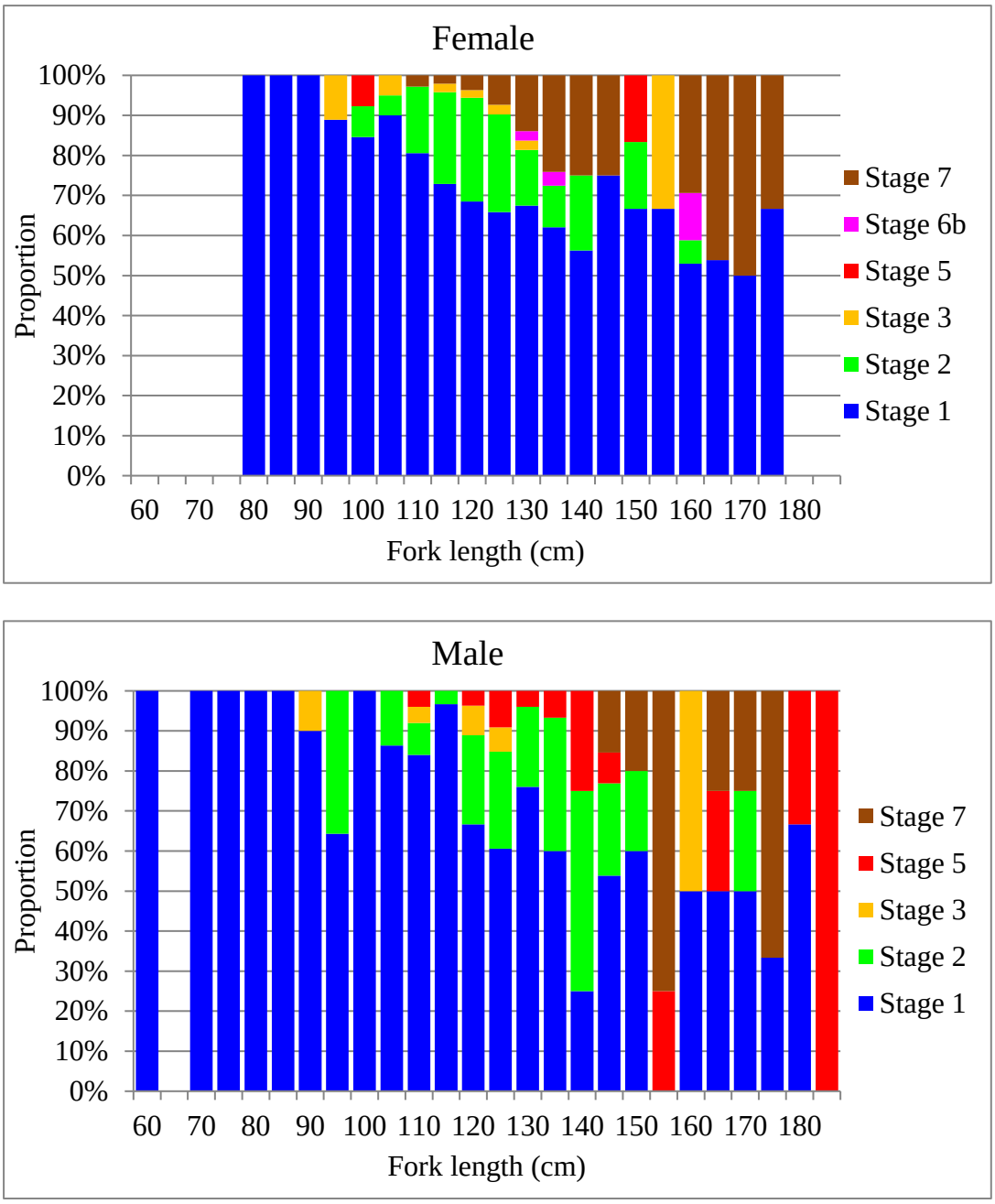


Fig. 91. Proportion of maturity stages by fork lengths with 5 cm intervals for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2018.

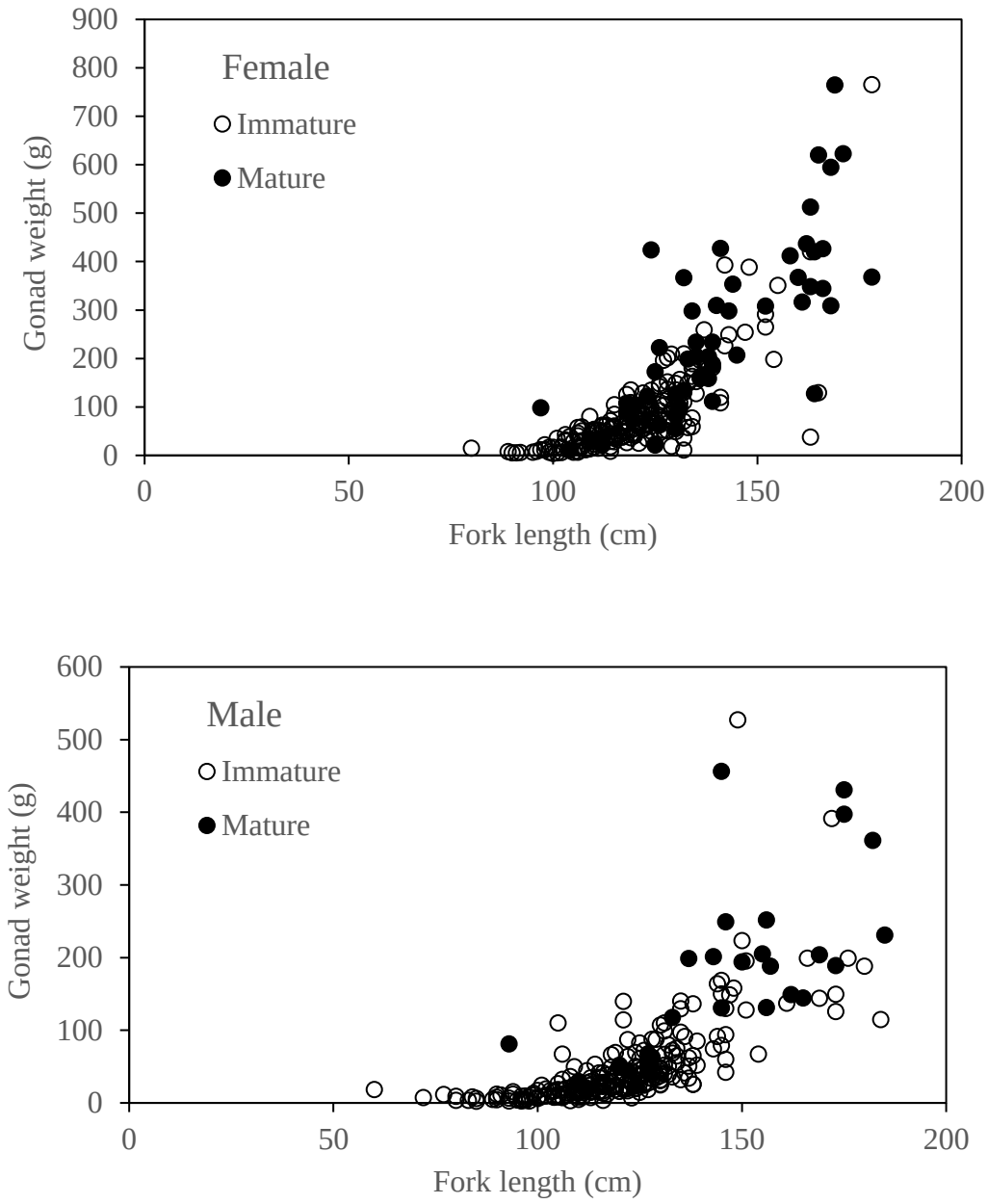


Fig. 10. Relationship between fork length and gonad weight by mature status for female and male gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2018.

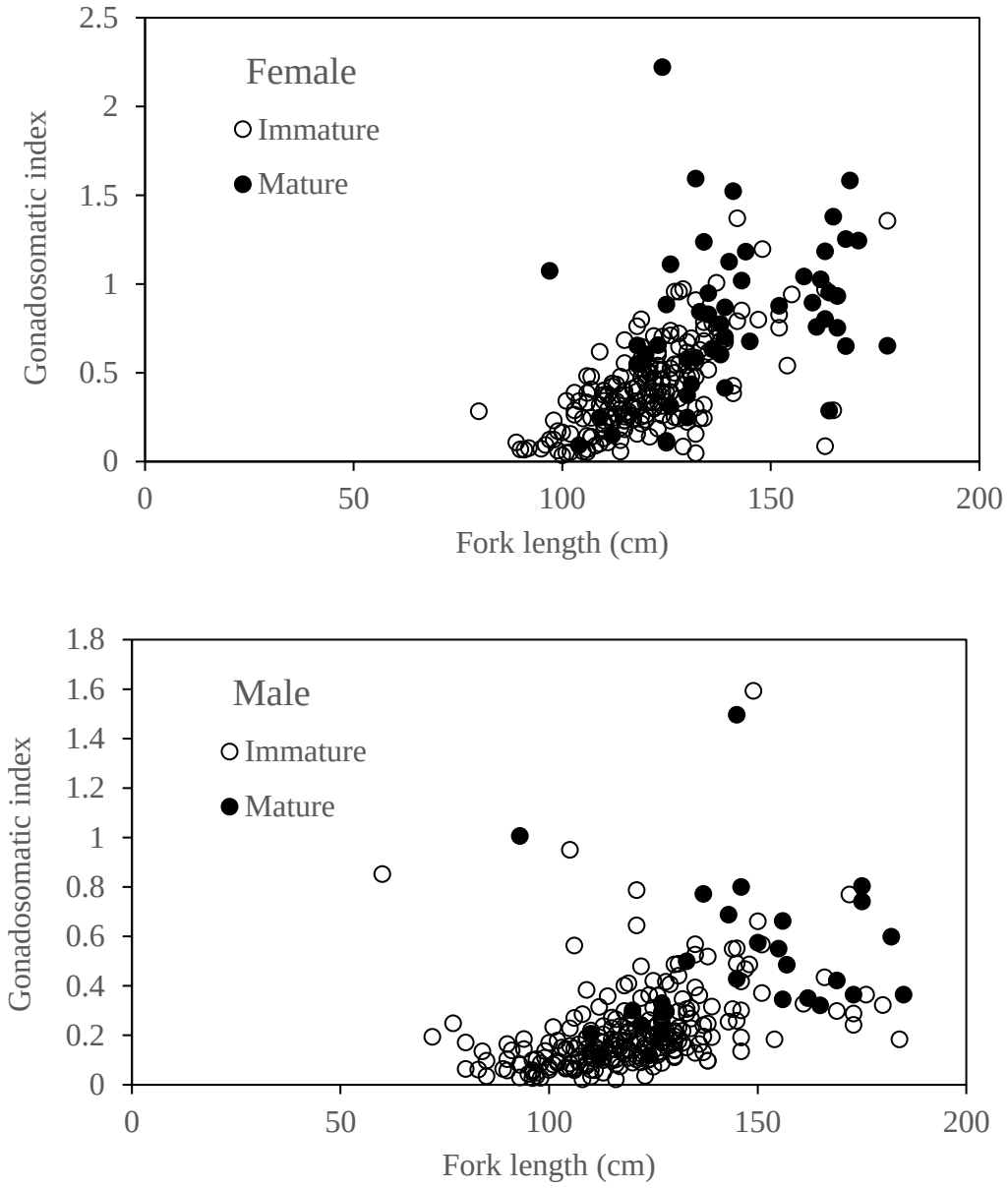
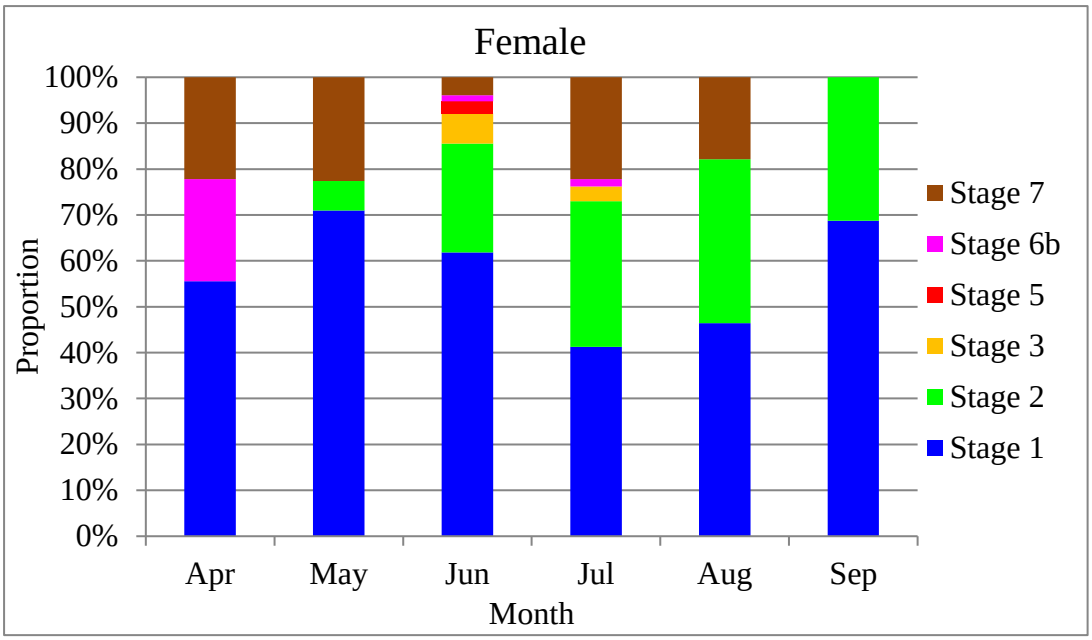


Fig. 11. Relationship between fork length and gonado-somatic index (GSI) by mature status for female and male gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2018.



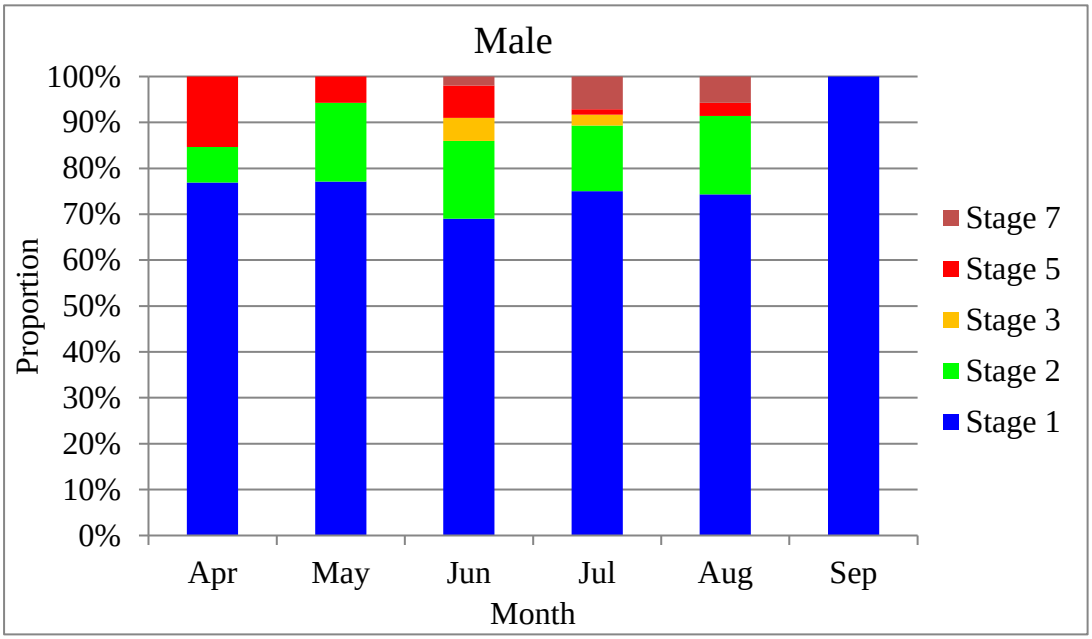


Fig. 12. Proportion of maturity stages by monthly category for female and male gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2018.

Table 1. The criteria of gonadal developmental stages for albacore in the south Pacific Ocean (Adopted from Farley et al., 2013).

Class	Maturity status	Activity	Development class	MAGO and POF stage	α and βatresia of yolked oocytes
1	Immature	lnactive	Immature	Unyolked,no POFs	Absent
2	Immature	lnactive	Developing	Early yolked,no POFs	Absent
3	Mature	Active	Spawning capable	Advanced yolked,no POFs	<50% αand βatresia may be present
4	Mature	Active	Spawning	Migratory nucieus or hydrated and/or POFs	<50% αand βatresia may be present
5	Mature	lnactive	Regressing-potentially reproductive	Advanced yolked,no POFs	≧50% αand βatresia present
6a	Mature	lnactive	Regressed 1	Unyolked or early yolked, no POFs	100%αand βatresia may be present
6b	Mature	lnactive	Regressed 2	Unyolked or early yolked, no POFs	No αand βatresia present
7	Mature	lnactive	Regenerating	Unyolked or early yolked, no POFs	Absent