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

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ABSTRACT

From 2010 to 2018, we collected a total of 590 gonad samples of southern bluefin tuna during the period of April to September by Taiwanese scientific observer program. The fork length of samples concentrated between 90 and 150 cm. The GSIs of females showed the increasing trend from April to July and then revealed a decline. And the GSIs of males reached the maximum value in May and then decreased gradually. The sexual maturity stages were determined based on the developmental stages of histological sections of 502 gonad samples collected in 2010-2017. Most samples were designated as immature stage, and about 16% samples designated as mature but they were reproductively inactive. More mature 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

There are several researches have been studied for the reproductive biology of southern bluefin tuna (SBT), *Thunnus maccoyii*. The information related development of SBT gonads such as age-at-first-maturity, gonad index, ova size-frequency and fecundity of SBT had been investigated in the waters off the south eastern and southern Australia (Thorogood, 1986). Farley and Davis (1998) investigated the spawning dynamics of SBT using ovaries obtained from fish caught on the spawning ground in the northeast Indian Ocean and the main feeding ground in the south Indian Ocean. 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).

In order to collect scientific information of SBT, the scientific observers have been deployed on board and conducted the observation program of SBT since 2002. The biological samples such as otoliths, muscle tissues, stomach and gonads of SBT were collected by scientific observers 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 measurement of 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 examined and determined based on histological sections of gonad samples. Because the criteria of gonadal developmental stages were not available for SBT at this point time, we followed the criteria of Farley et al. (2014), which were used for albacore in the southern Pacific Ocean, and adopted to categorize the gonadal developmental stages for SBT. 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).

3. RESULTS AND DISCUSSION

A total of 590 effective gonad samples of SBT including 264 female and 326 male samples were collected during April to September (i.e. the first fishing season of Taiwanese SBT longline fishery) from 2010 to 2018.

The samples were collected in the waters of the southeast Indian Ocean (65°E-105°E, 29°S-40°S) (Fig. 1). The range of fork length of female and male samples were from 80 to 178 cm and 60 to 185 cm, respectively, and were concentrated between 90

and 150 cm in both female and male (Fig. 2).

In both sexes, the values of gonad weights increased with the growth pattern of fork lengths obviously, and revealed the variation with body growth (Fig. 3). Generally, the relationship between GSI and fork length revealed similar trend for 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 trends of GSI for females and males were shown in Fig.5. The GSIs of females increased from April to July and then revealed decreasing trends; the GSIs of males reached the maximum value in May and then decreased gradually with updated data of 2017. The monthly trends of GSI for females and males remained the same trends as the past. Because the samples were collected only from April to September, monthly trend of GSI would not be explored for the entire year.

Due to frozen preservation process, there were some samples failed for preparations of histological sections. Histological sections of 502 female and male gonad samples collected from 2010 to 2017 were successfully examined, and the sexual maturity stages were determined based on developmental stages.

Based on the observations, the gonadal developmental stages of most samples were designated as immature stage and some samples were developing stage. Most samples were designated as immature. And there were about 16% of samples (21% for females and 12% for males) designated as mature but most of these samples were reproductively inactive (regressed or regenerating stages) (Figs. 6-8).

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, except for the samples with fork length less than about 100cm (Figs. 10 and 11).

Based on monthly proportion of gonadal developmental stages, more mature female samples were regressed or regenerating stages during April to August, while most of mature male samples were regenerating stages during June to August (Fig. 12). The analyses of this study imply that mature fishes might migrate to the fishing ground of Taiwanese SBT fishery after reproductive activity.

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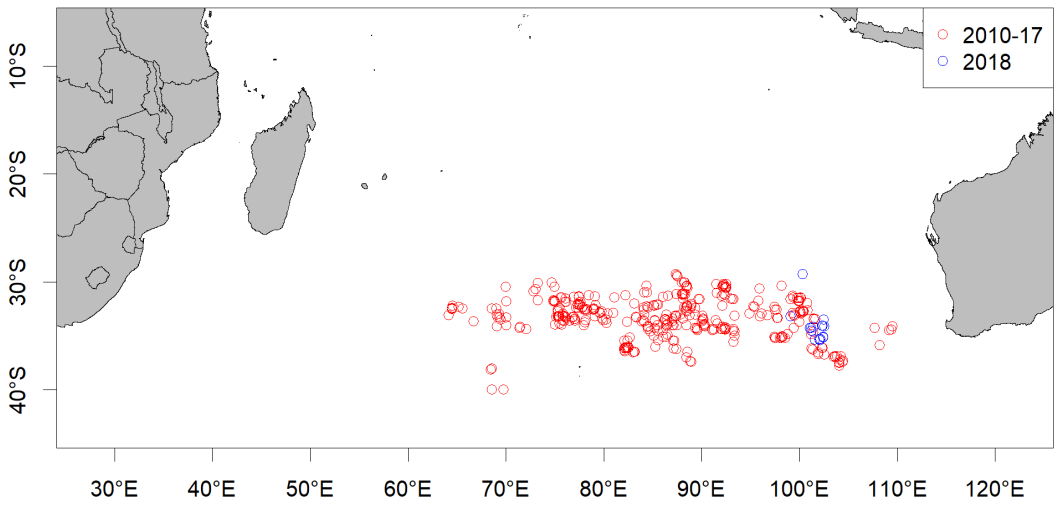


Fig. 1. Locations for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2018.

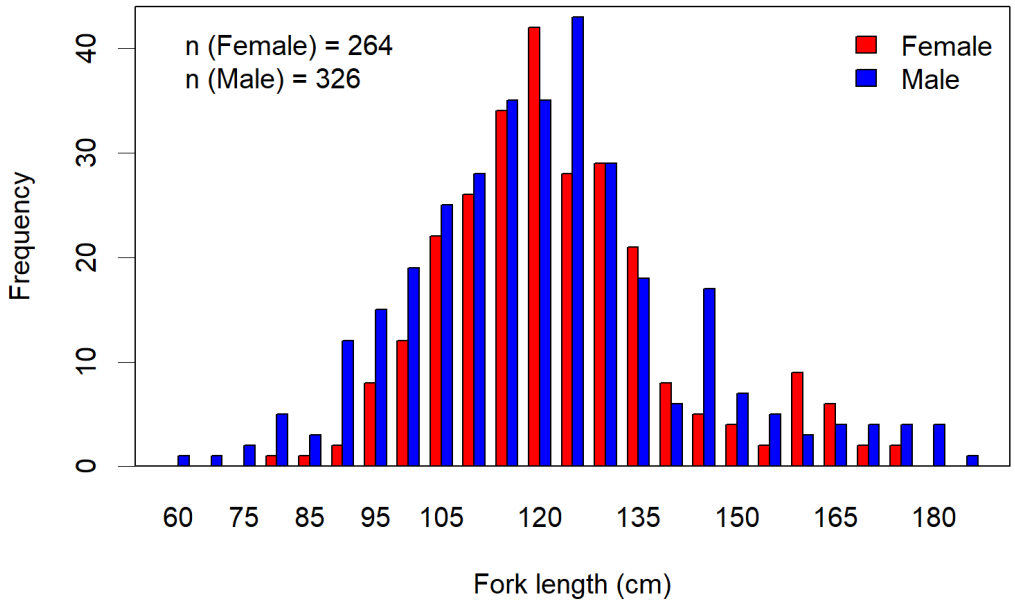


Fig. 2. Length frequency distributions (5 cm intervals) for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2018.

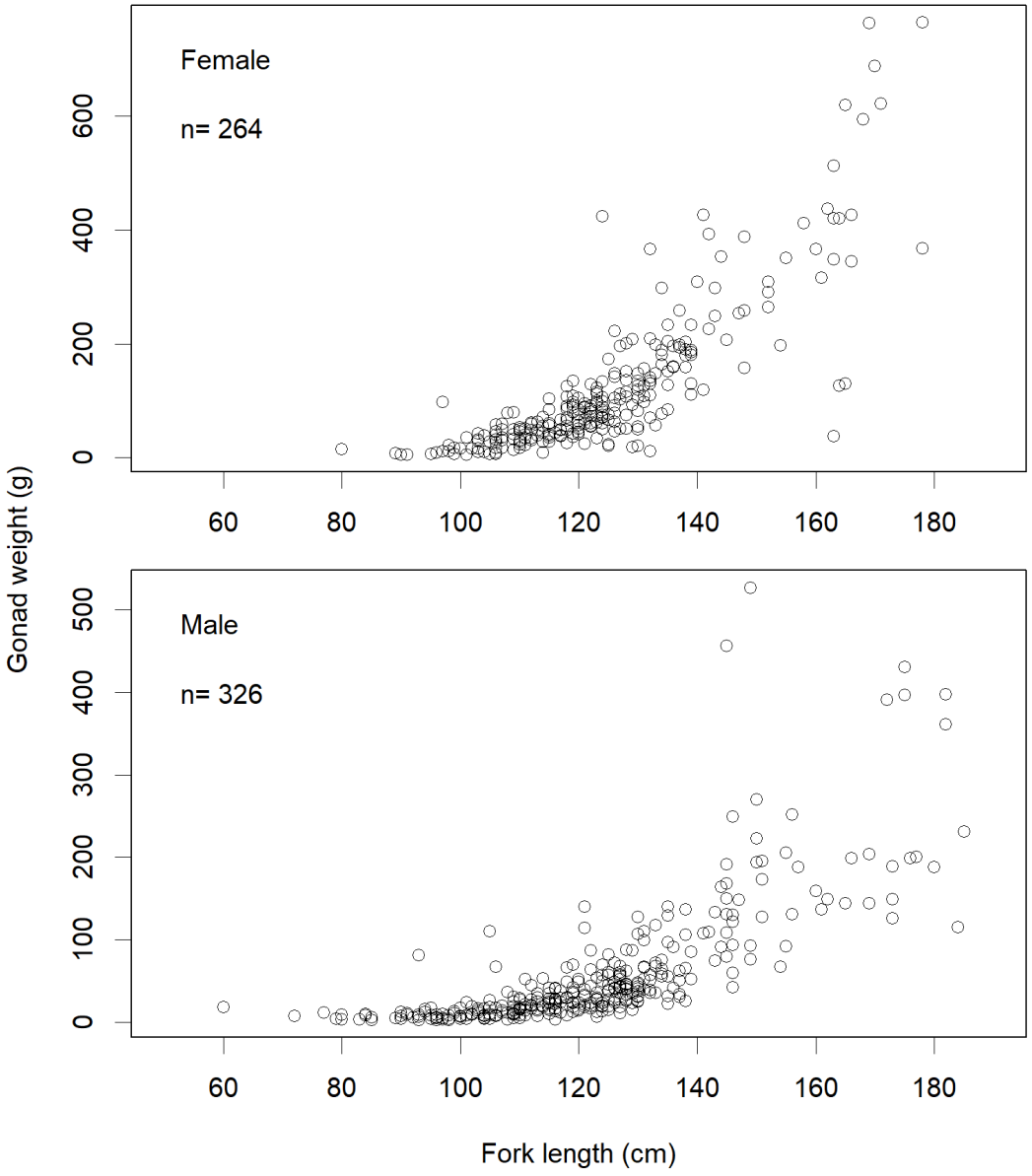


Fig. 3. Relationship between fork length and gonad weight for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2018.

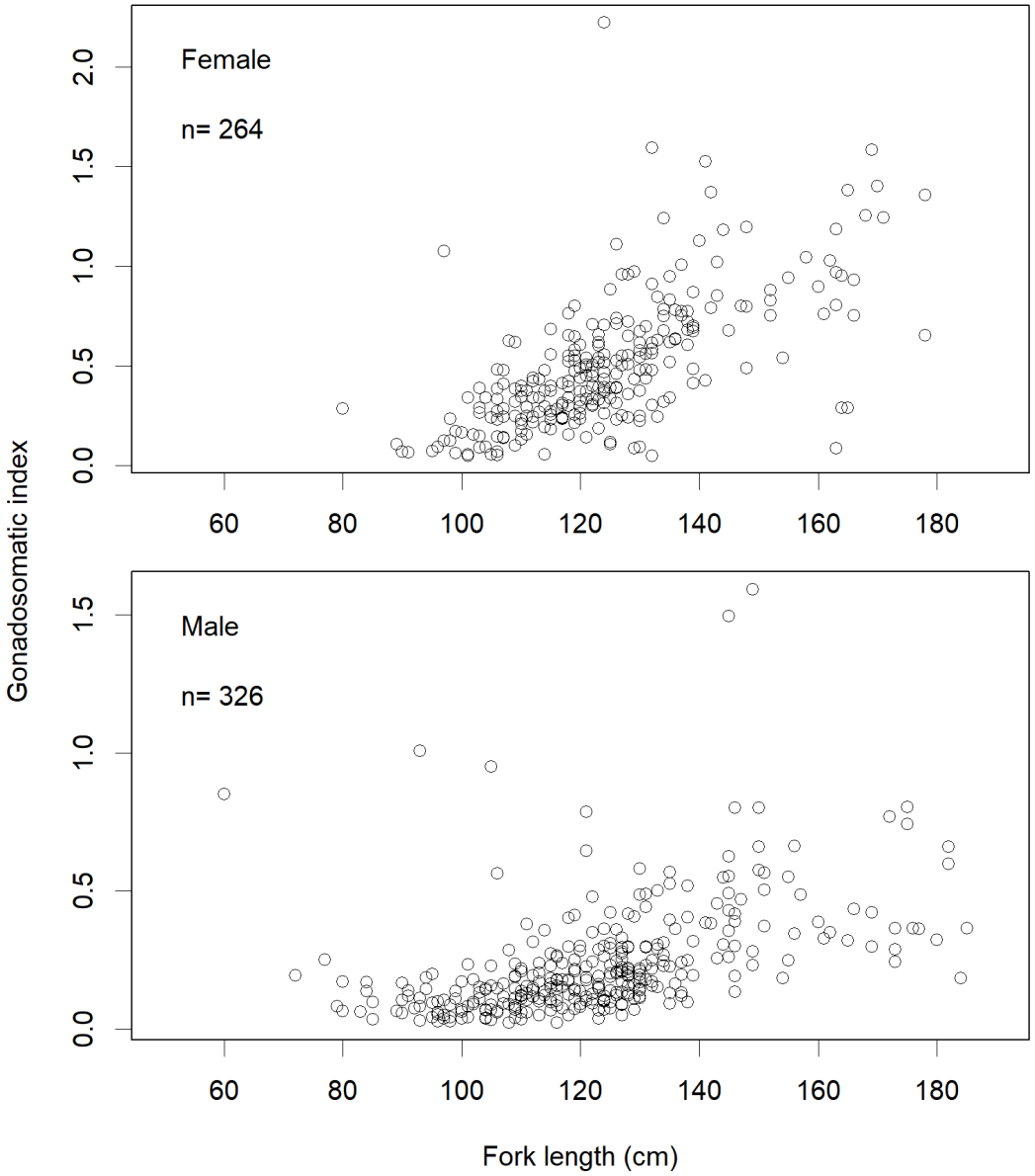


Fig. 4. Relationship between fork length and gonado-somatic index (GSI) for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2018.

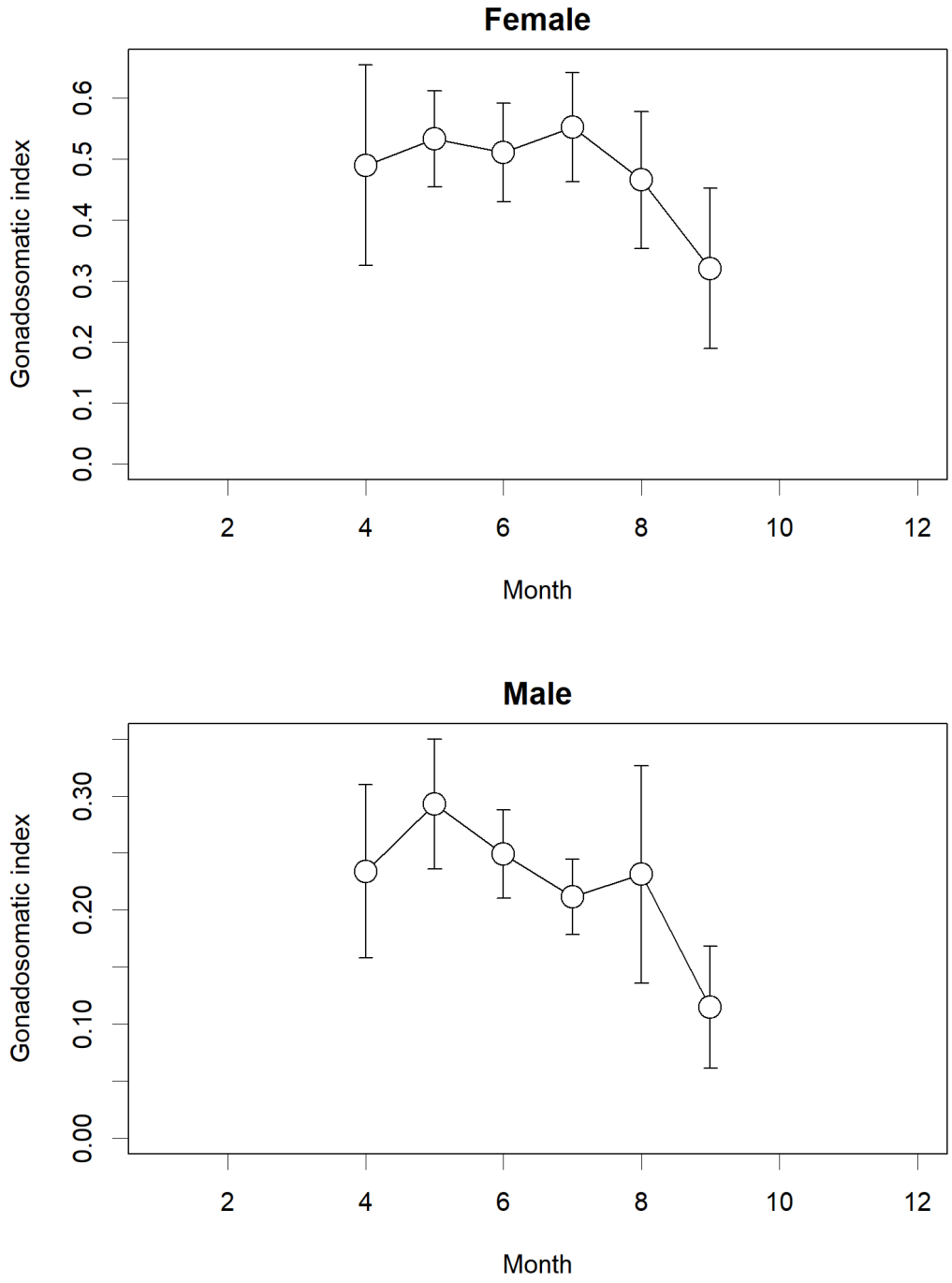


Fig. 5. Monthly trends of gonado-somatic index (GSI) for gonad samples of SBT collected by Taiwanese scientific observer program. Vertical bars represent the 95% confidence interval for means during 2010-2018.

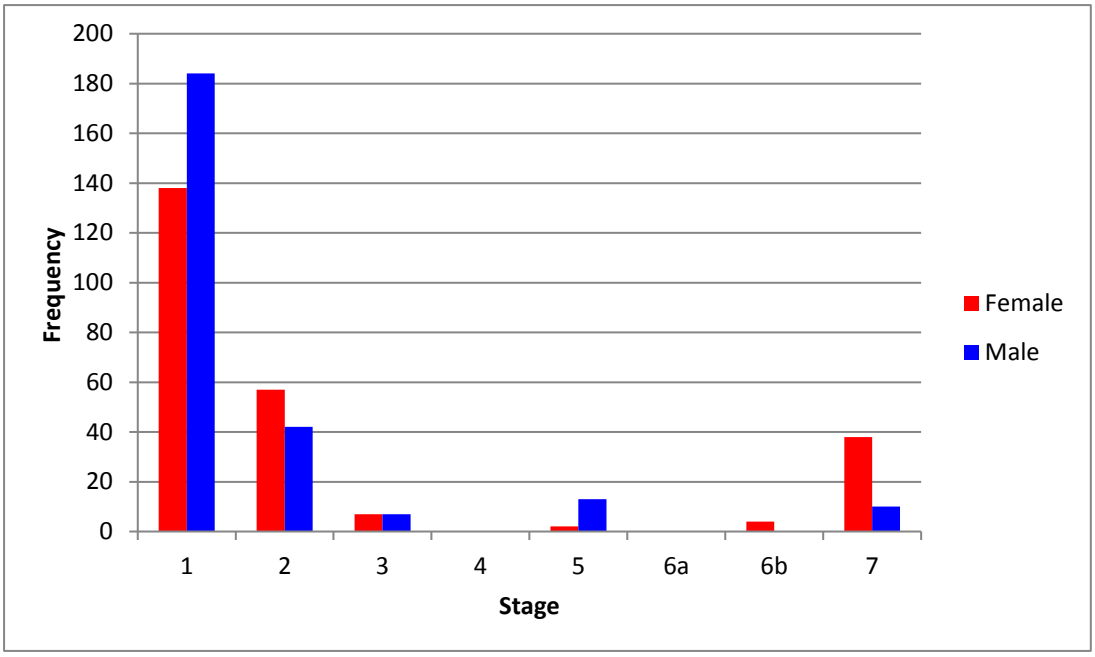
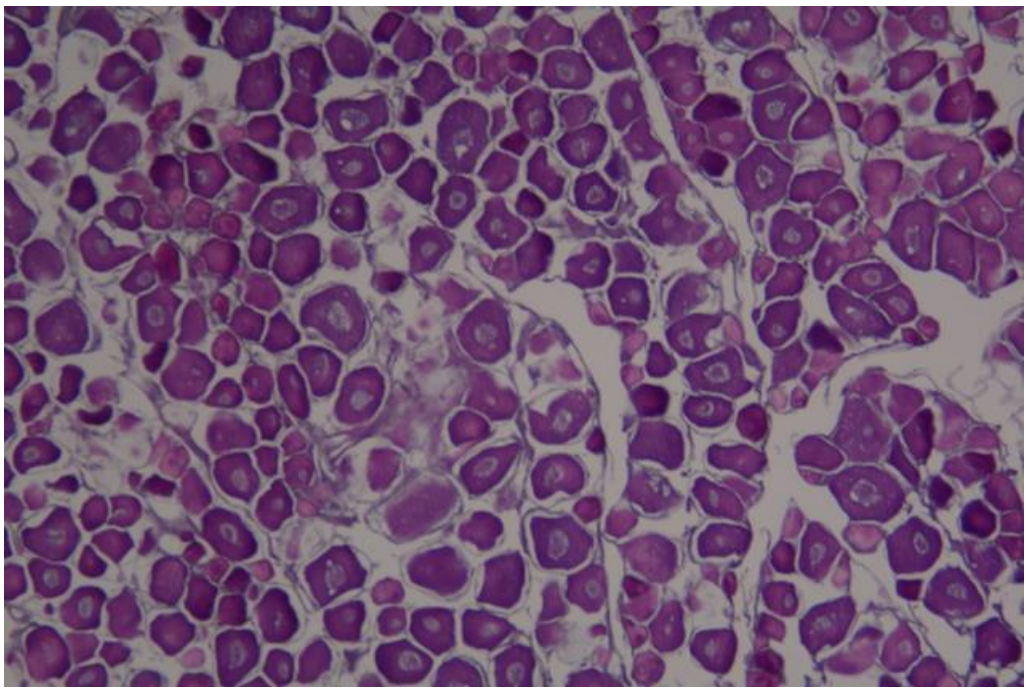
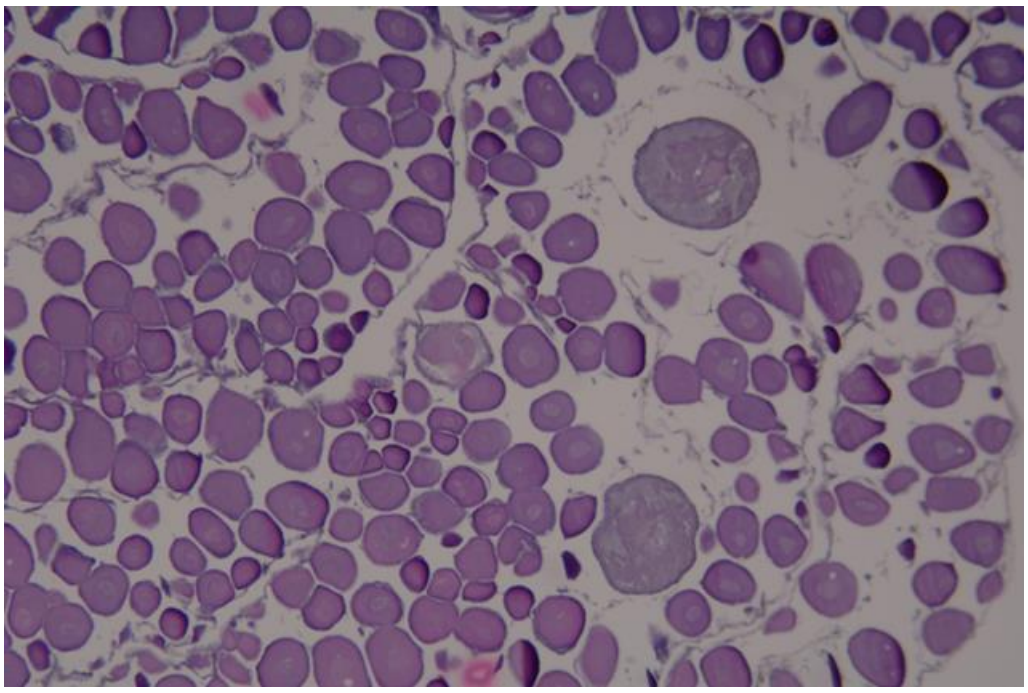


Fig. 6. Number of samples by maturity classes for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2017.

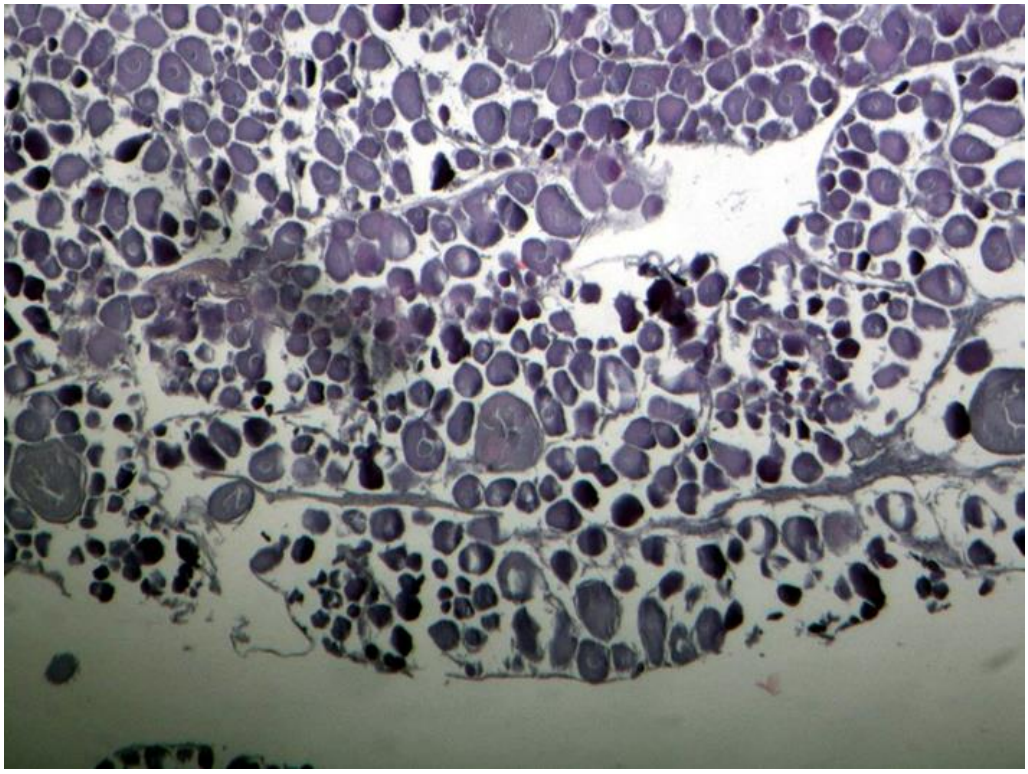


FL: 133cm, GW: 133.67g (Class 1, immature stage)

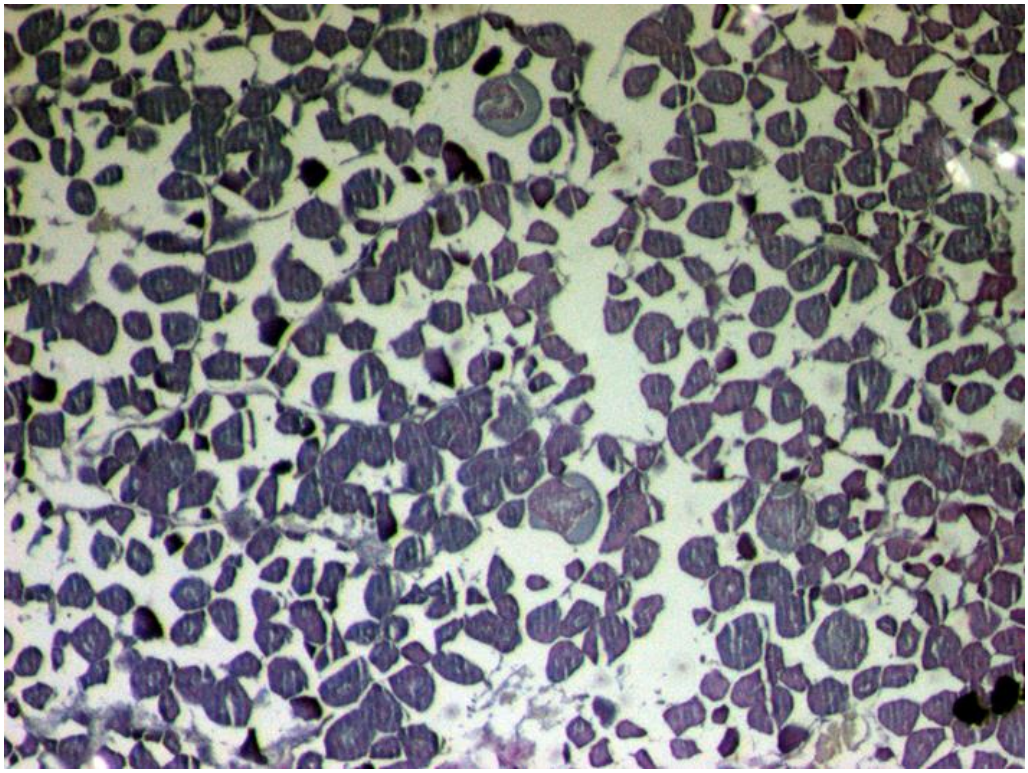


FL: 130cm, GW: 82.1g (Class2, developing stage)

Fig. 7. Histological sections and measurements of oocytes for gonad samples of female SBT collected by Taiwanese scientific observer program during 2010-2017.

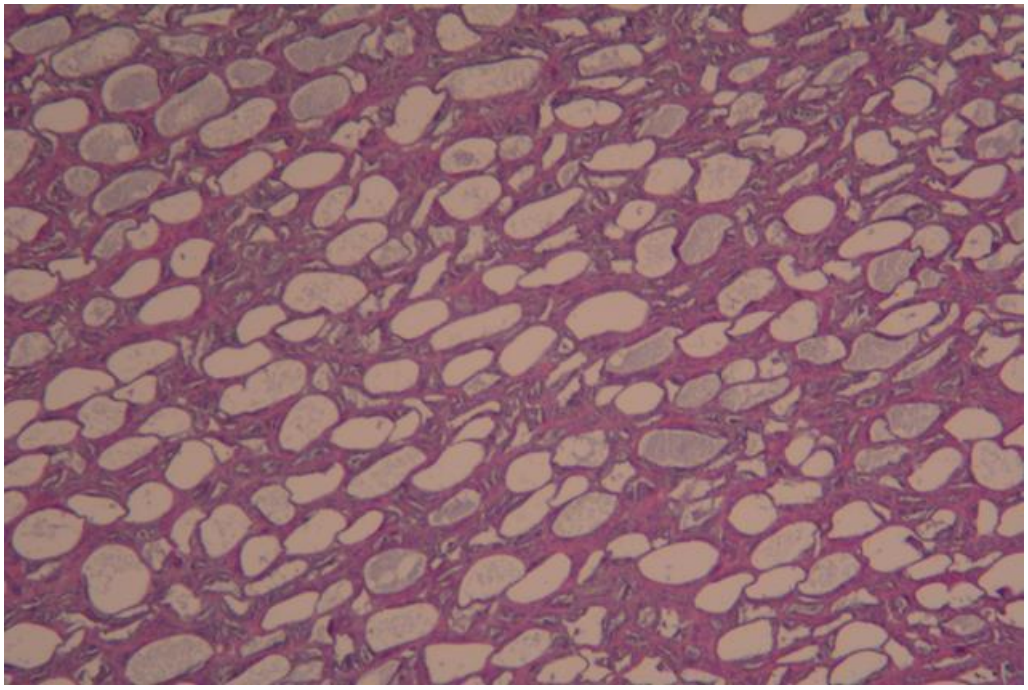


FL: 130cm, GW: 54.51g (Class 6b, regressed2 stage)

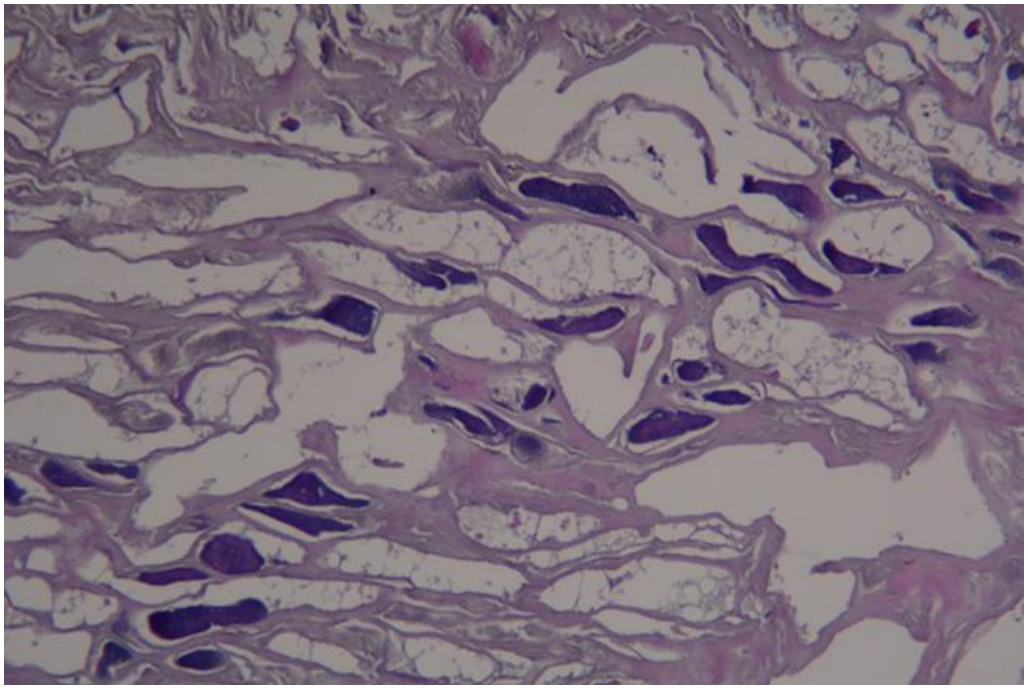


FL: 169cm, GW: 764.15g (Class 7, regenerating stage)

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 2010-2017.

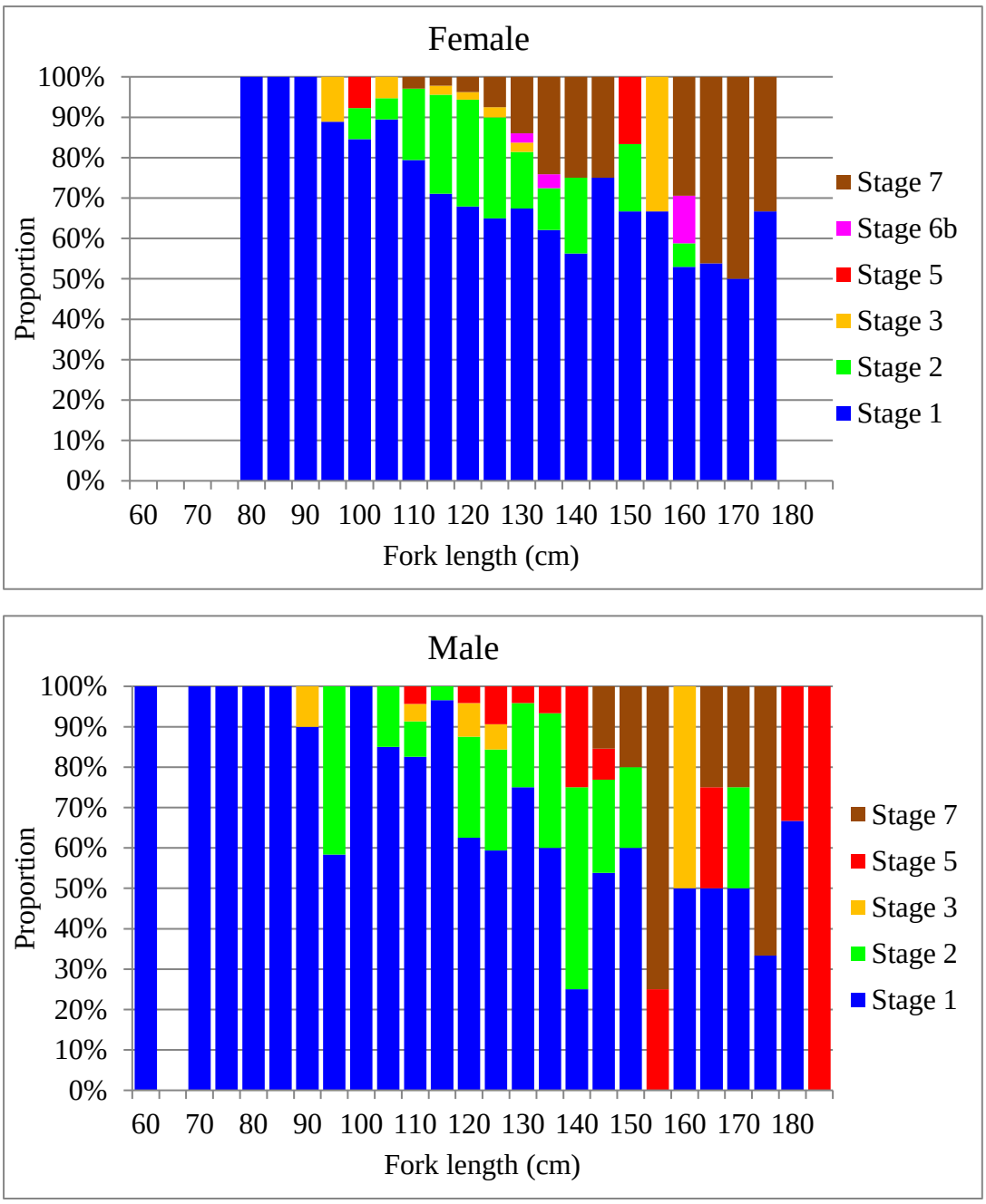


Fig. 91. Proportion of samples by maturity classes for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2017.

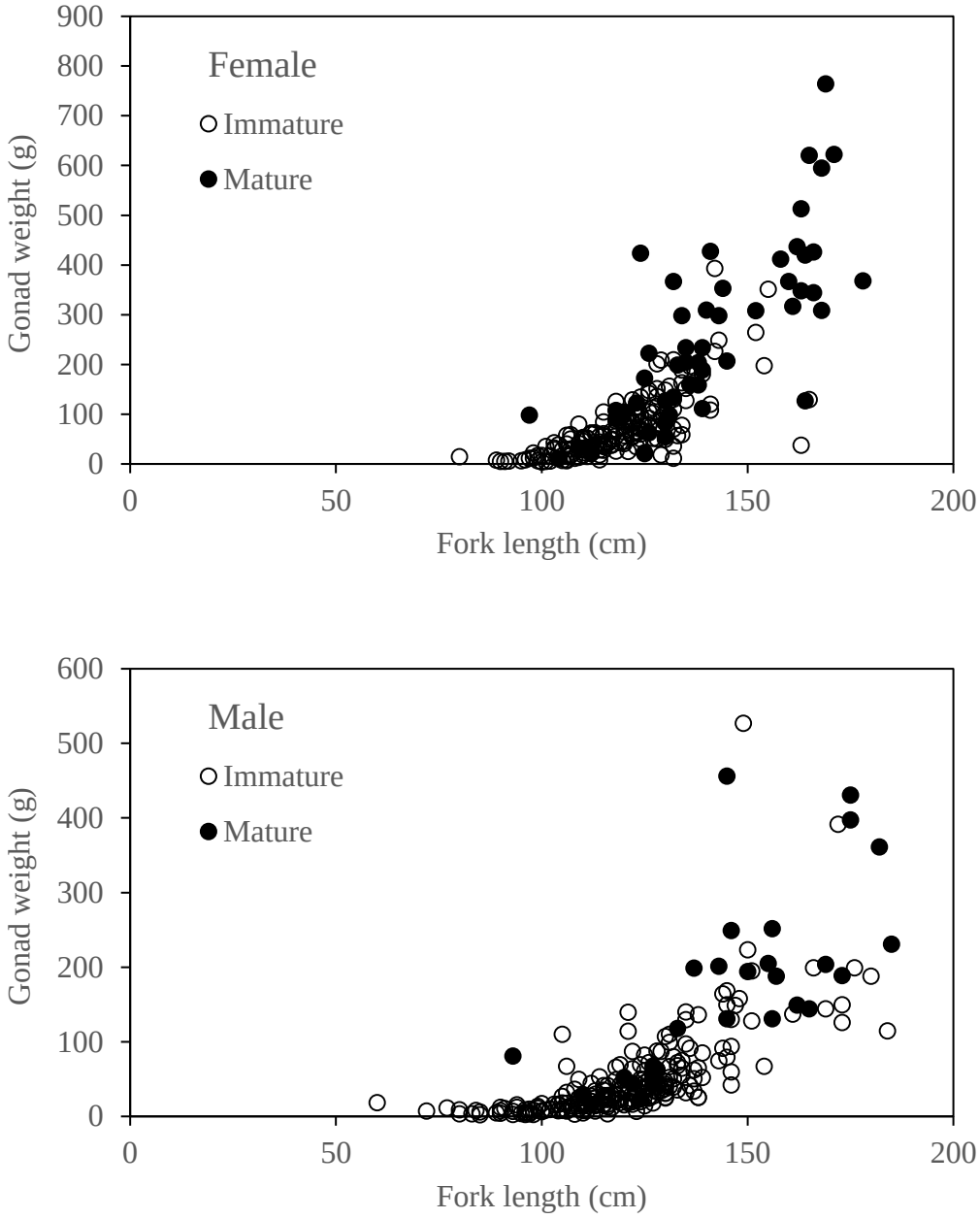


Fig. 10. Relationship between fork length and gonad weight by mature status for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2017.

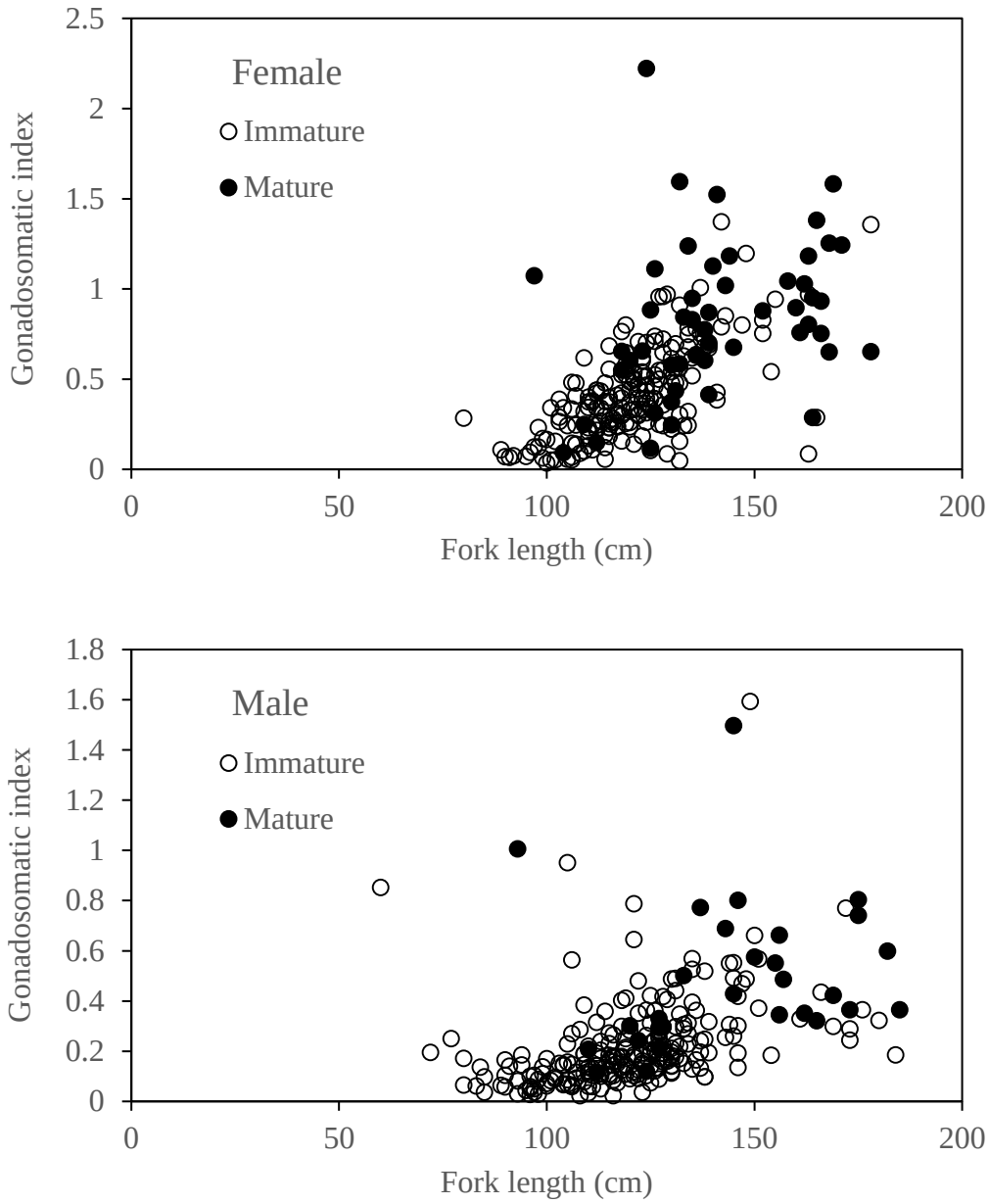


Fig. 11. Relationship between fork length and gonado-somatic index (GSI) by mature status for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2017.

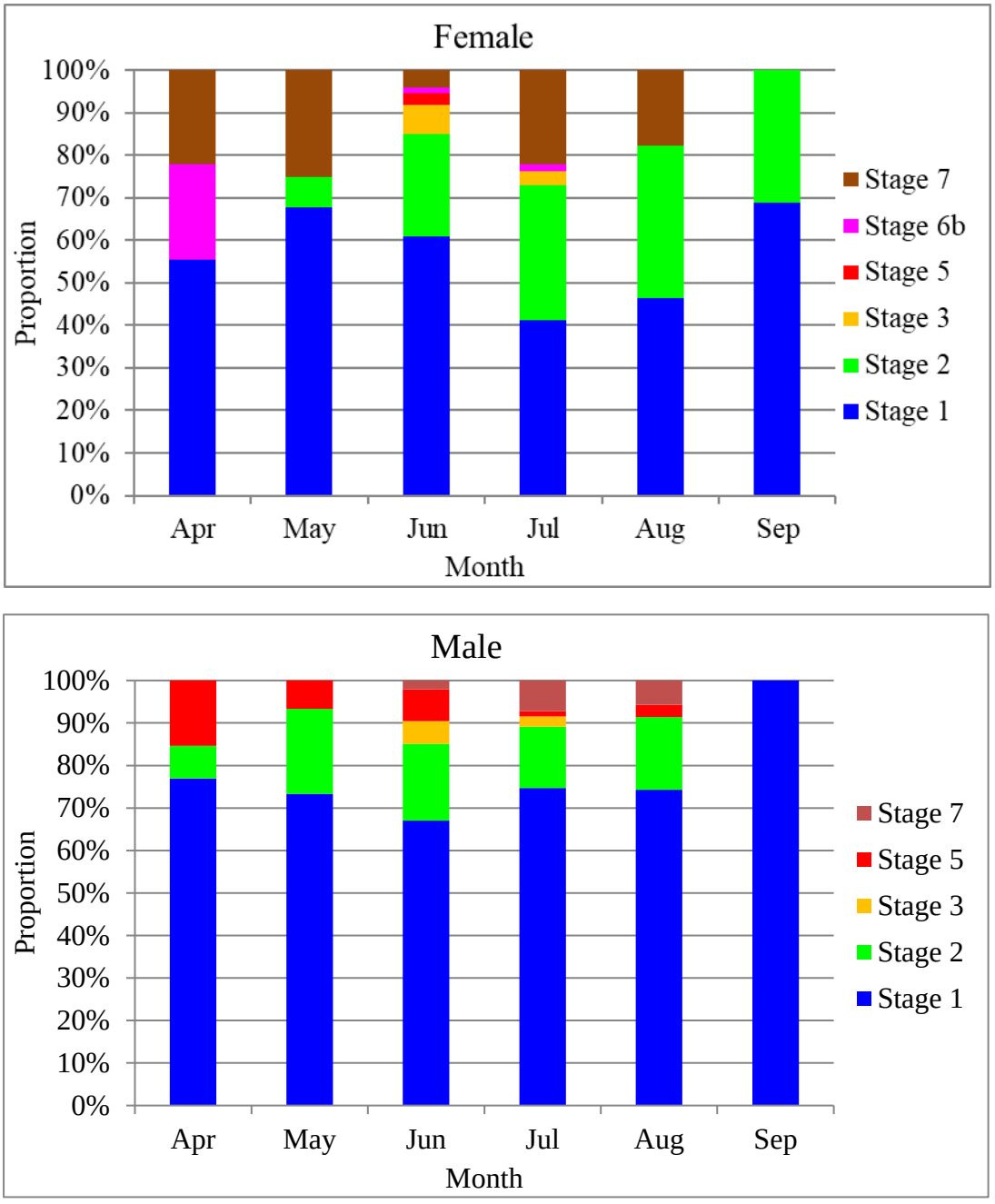


Fig. 12. Proportion of samples by maturity classes for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2017.

Table 1. The criteria of gonadal developmental stages for albacore in the south Pacific Ocean (Farley et al., 2014).

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