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

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ABSTRACT

This study analyzed 508 gonad samples of southern bluefin tuna collected during April to September in year of 2010-2016. The fork length of samples concentrated between 90 and 150 cm. The GSIs of females increased from April to July and then revealed a decreasing trend, the GSIs of males reached the maximum value and then decreased gradually. The sexual maturity stages were determined based on developmental stages of histological sections of gonad samples. Most samples were designated as immature stage, and about 23% samples designated as mature but they were reproductively inactive. More mature female samples were regressed or regenerating stages during April to June, while most of male samples were regenerating stages during June to August.

1. INTRODUCTION

Several studies have been conducted for the reproductive biology of southern bluefin tuna (SBT), *Thunnus maccoyii*. Thorogood (1986) investigated the development of SBT gonads collected from waters off the south eastern and southern coasts of Australia. The results provided information on age-at-first-maturity, gonad Index, ova size-frequency and fecundity of SBT. 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 southern Ocean. Chen et al. (2013) investigated the sexual maturity of SBT based on the morphological and histological observations of the gonad samples collected by observers deployed on Taiwanese vessels in the southwestern Indian Ocean.

To collect scientific information on SBT, the scientific observers started being

deployed on board and conducting the observation program of SBT in 2002. The biological samples, including otoliths, muscle tissues, stomach and gonads of SBT, were carried out by observers on board. In this paper, we presented the updated analysis for gonad samples of SBT collected by Taiwanese scientific observer program.

2. MATERIALS AND METHODS

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

Because the measurements of body weight 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. Since the criteria of gonadal developmental stages were not available for SBT, the criteria of Farley et al. (2014), which were used for albacore in the southern Pacific Ocean, were 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 508 effective gonad samples of SBT were collected during April to September (i.e. the first fishing season of Taiwanese SBT longline fishery) in the year of 2010-2016. Female and male samples were 226 and 282 respectively.

Samples were collected in the waters of the southeast Indian Ocean (65°E-105°E, 29°S-40°S) (Fig. 1). The fork length of samples ranged from 80 to 178 cm and 60 to 185 cm for females and males respectively, with both concentrated between 90 and

150 cm (Fig. 2).

The gonad weights obviously increased with the growth of fork lengths for both sexes (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 for some samples (Fig. 4).

Fig. 5 shows the monthly trends of GSI for females and males. The GSIs of females increased from April to July and then revealed decreasing trends, the GSIs of males reached the maximum value and then decreased gradually. Since the samples were collected only from April to September, monthly trend of GSI cannot be explored for the entire year.

Preparations of histological sections were failed for some samples due to frozen preservation process. Histological sections of 289 female and male gonad samples collected from 2010 to 2015 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 about 23% of samples (27% for females and 17% for males) were designated as mature but most of these samples were reproductively inactive (regressed or regenerating stages) (Figs. 6-8).

The smallest mature samples were the fishes with fork length of 97 and 93cm for females and males 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 implies that mature fishes might migrate to the fishing ground of Taiwanese SBT fishery after reproductive activity.

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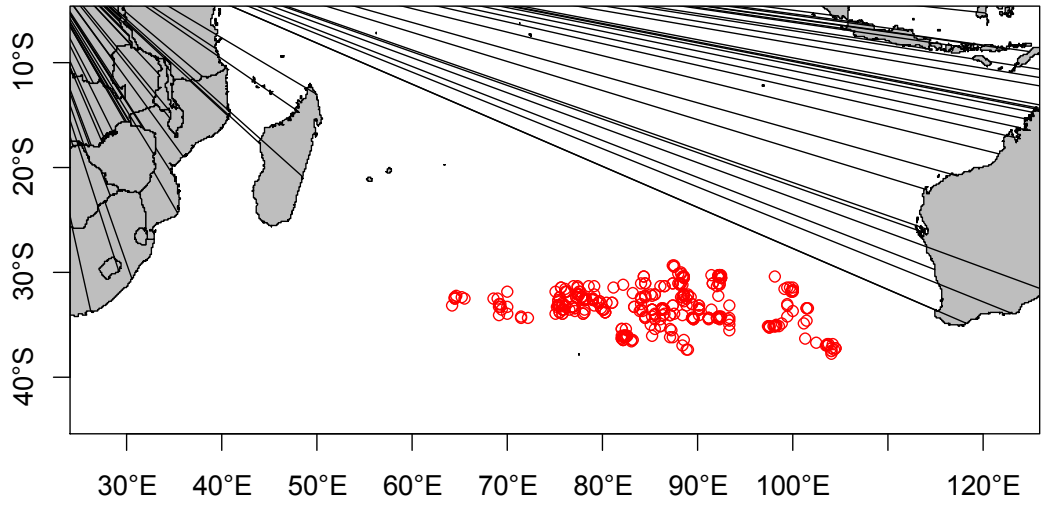


Fig. 1. Locations for gonad samples of SBT collected Taiwanese scientific observer program during 2010-2016.

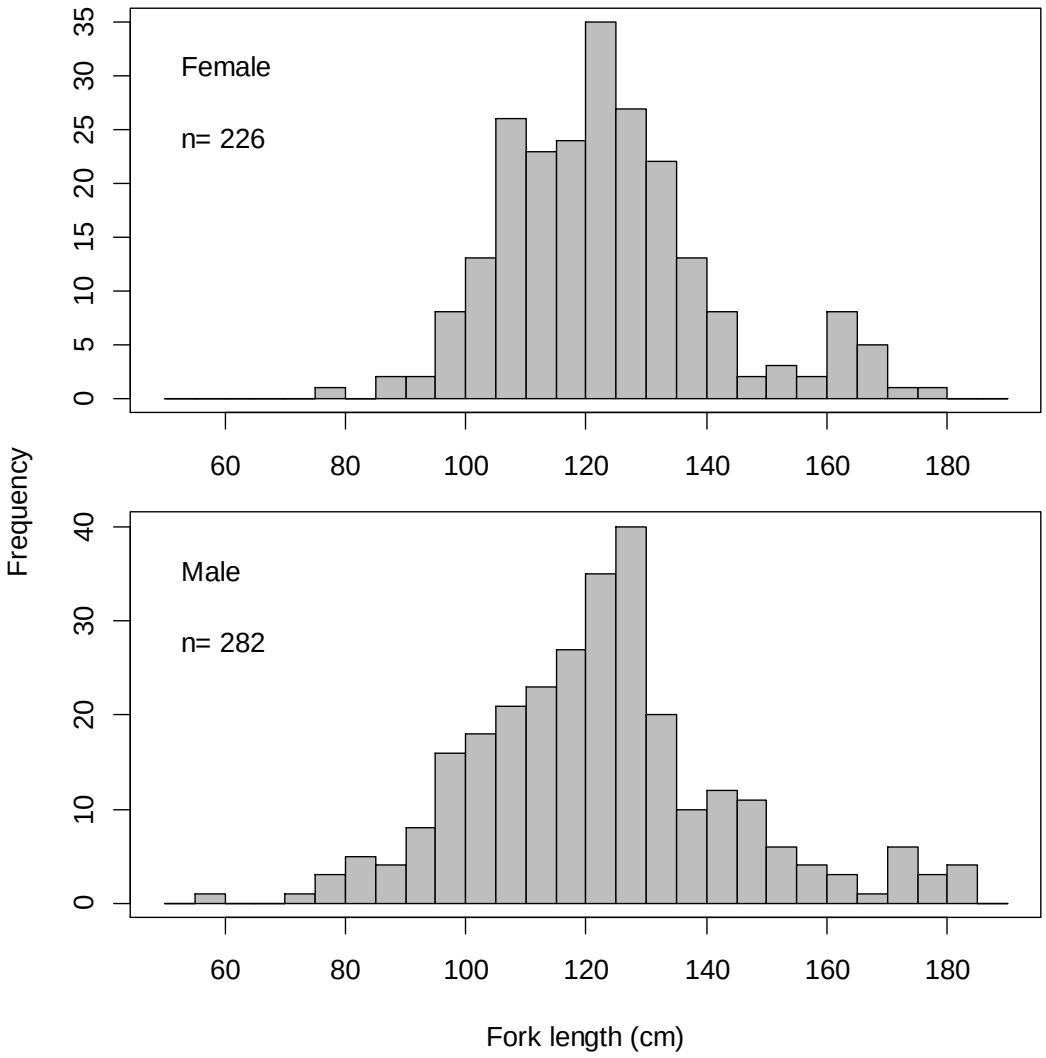


Fig. 2. Length frequency distributions (5 cm intervals) for gonad samples of SBT collected Taiwanese scientific observer program during 2010-2016.

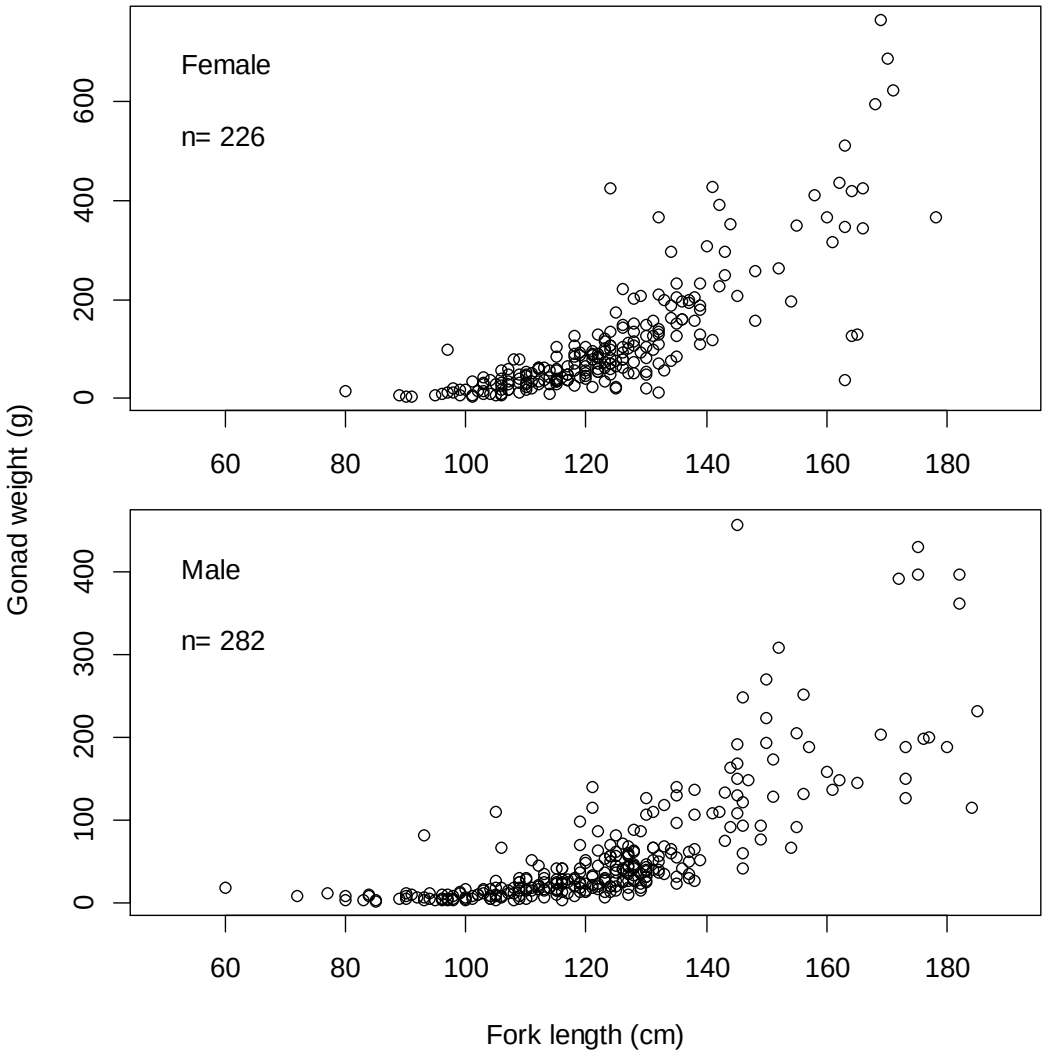


Fig. 3. Relationship between fork length and gonad weight for gonad samples of SBT collected Taiwanese scientific observer program during 2010-2016.

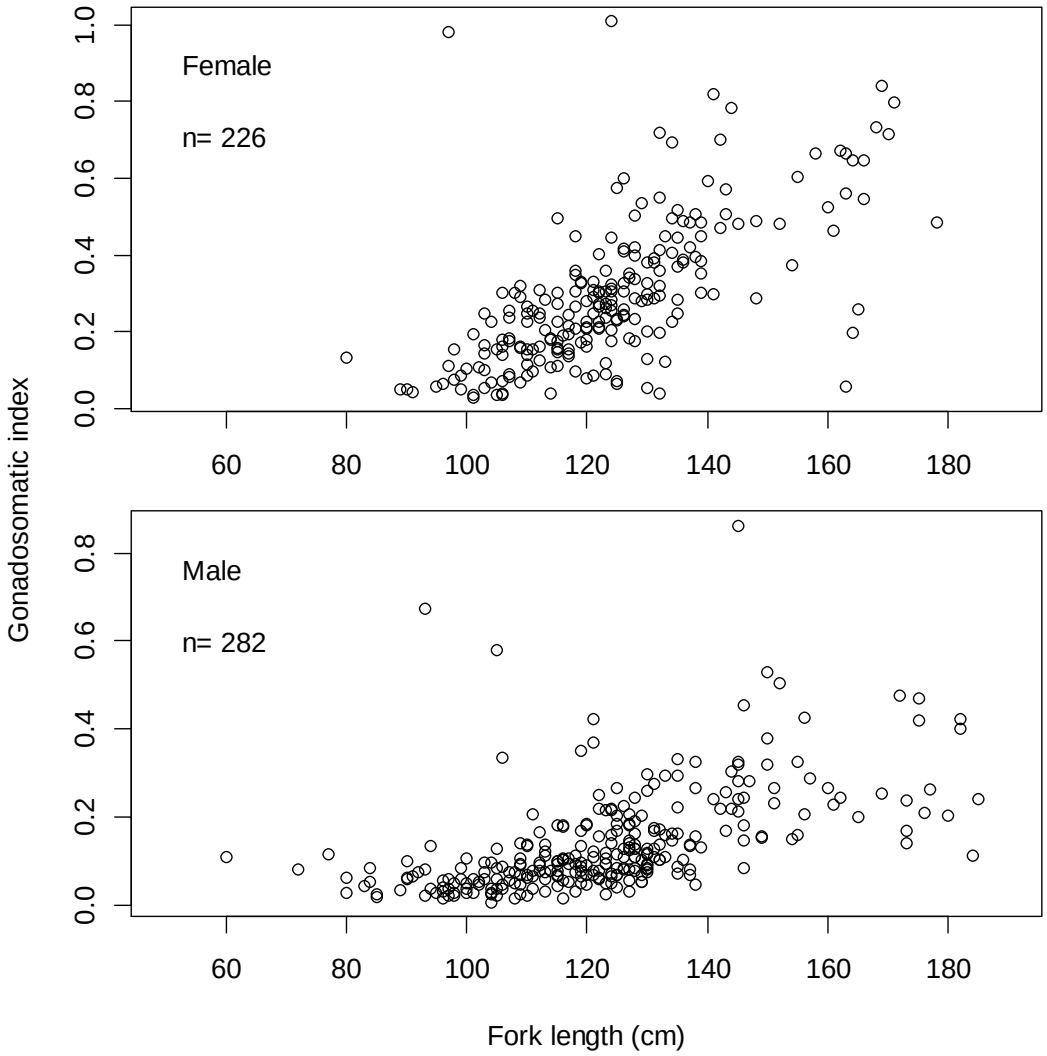


Fig. 4. Relationship between fork length and gonado-somatic index (GSI) for gonad samples of SBT collected Taiwanese scientific observer program during 2010-2016.

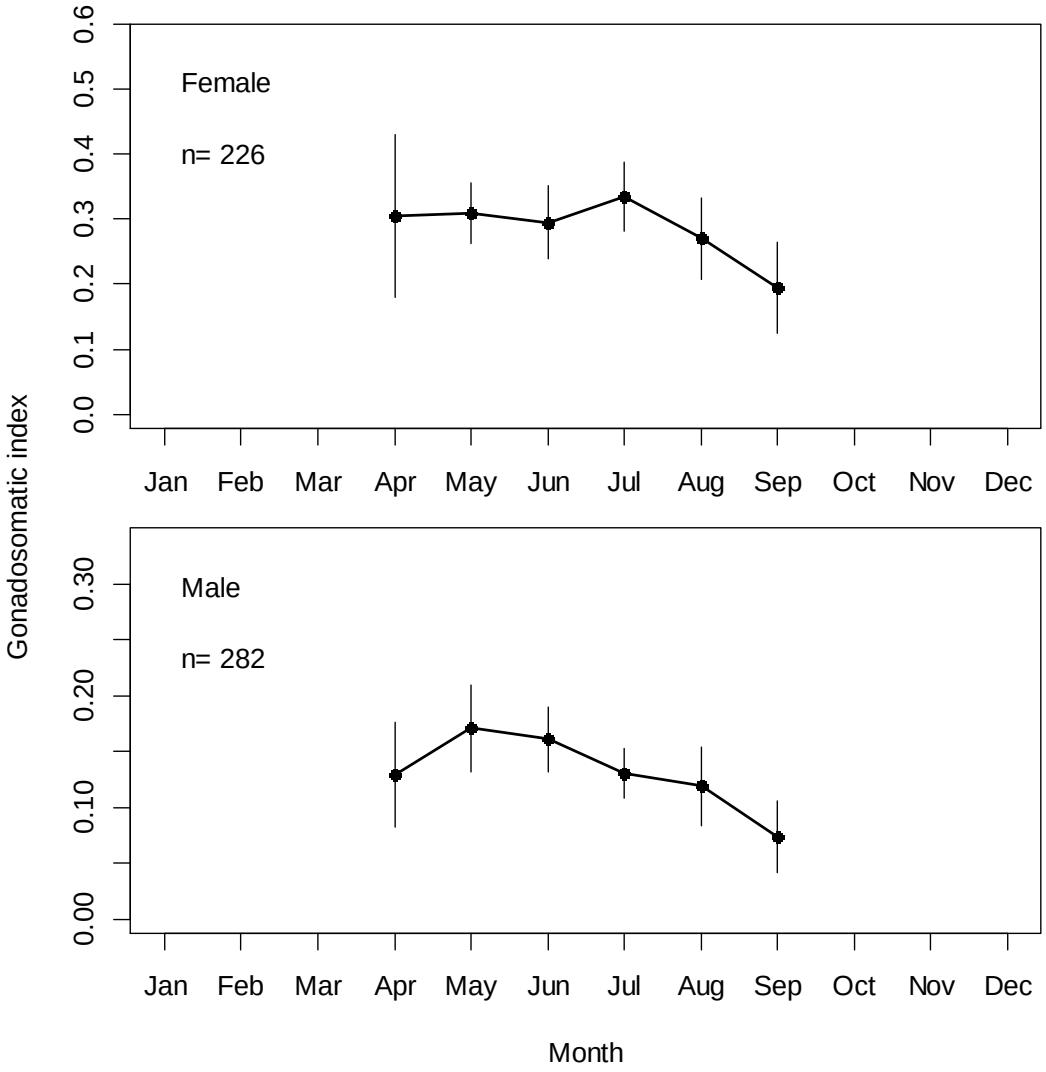


Fig. 5. Monthly trends of gonado-somatic index (GSI) for gonad samples of SBT collected Taiwanese scientific observer program. Vertical bars represent the 95% confidence interval for means during 2010-2016.

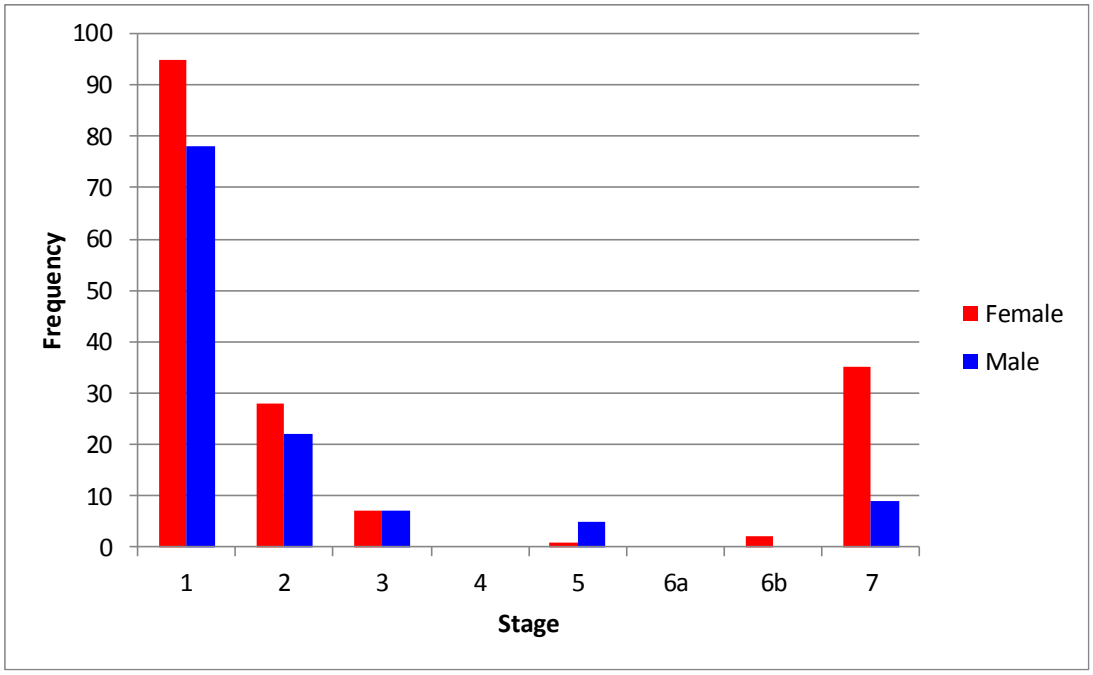
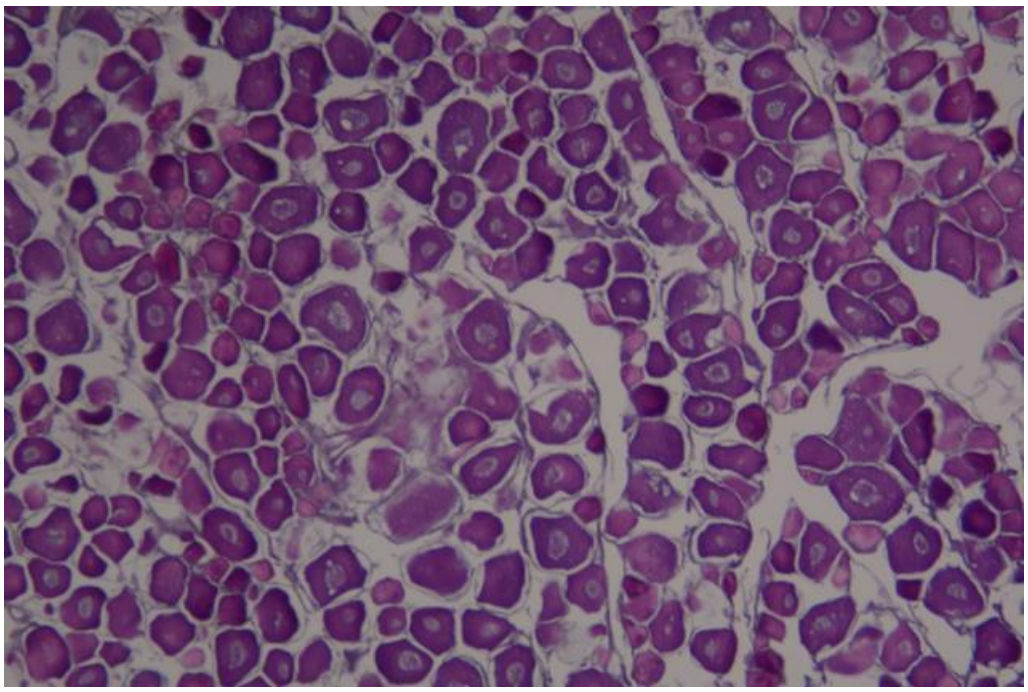
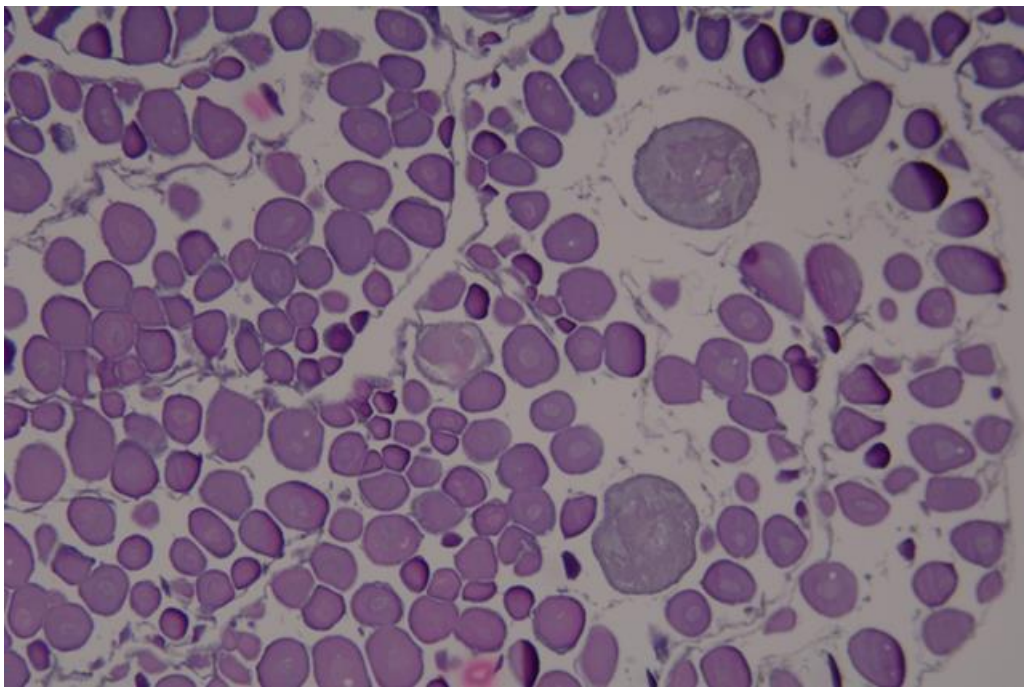


Fig. 6. Number of samples by maturity classes for gonad samples of SBT collected Taiwanese scientific observer program during 2010-2015.

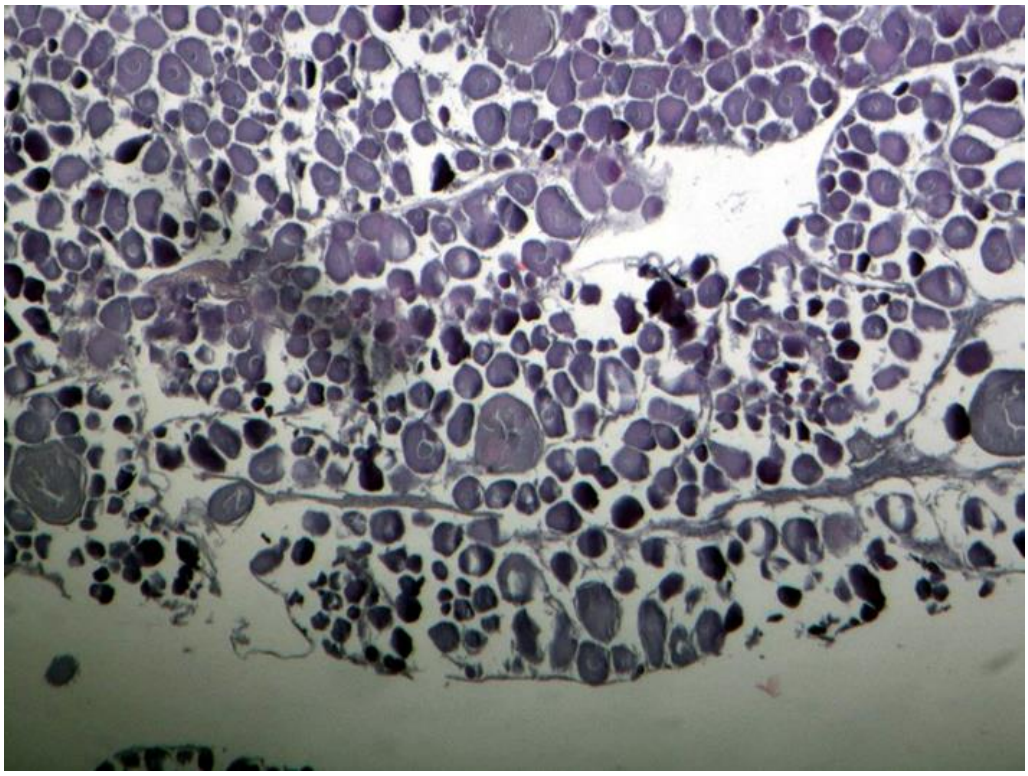


FL: 133cm, GW: 133.67g (Class 1, immature stage)

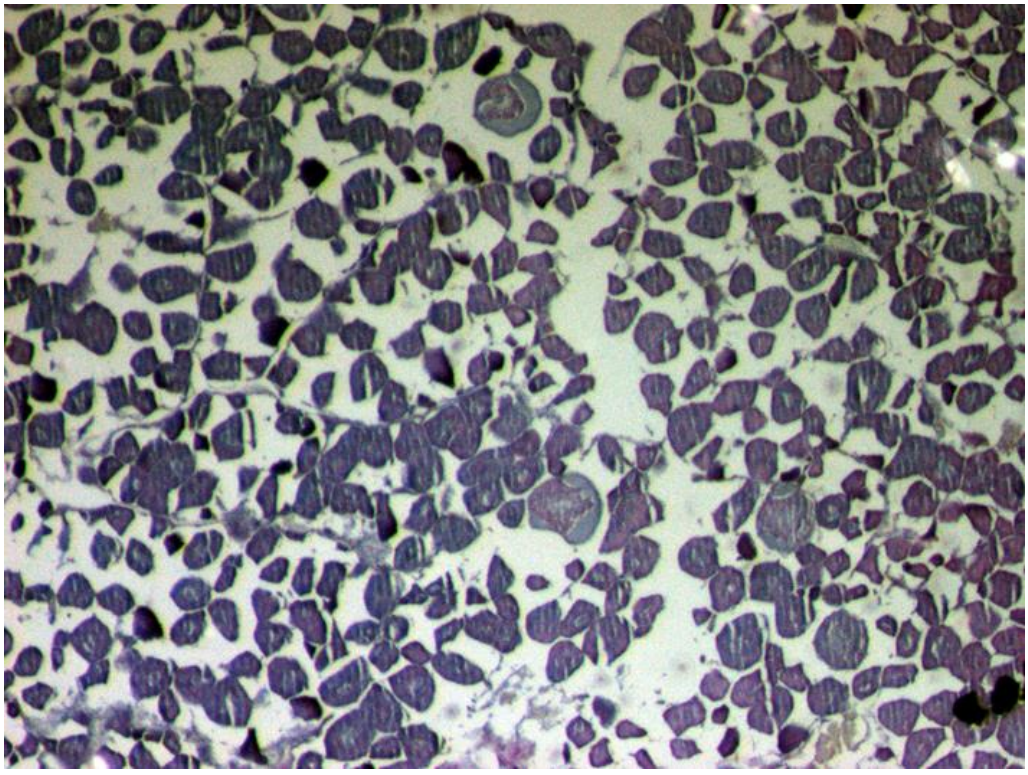


FL: 130cm, GW: 82.1g (Class2, developing stage)

Fig. 7. Histological sections and measurements of oocytes for gonad samples of female SBT collected Taiwanese scientific observer program during 2010-2015.

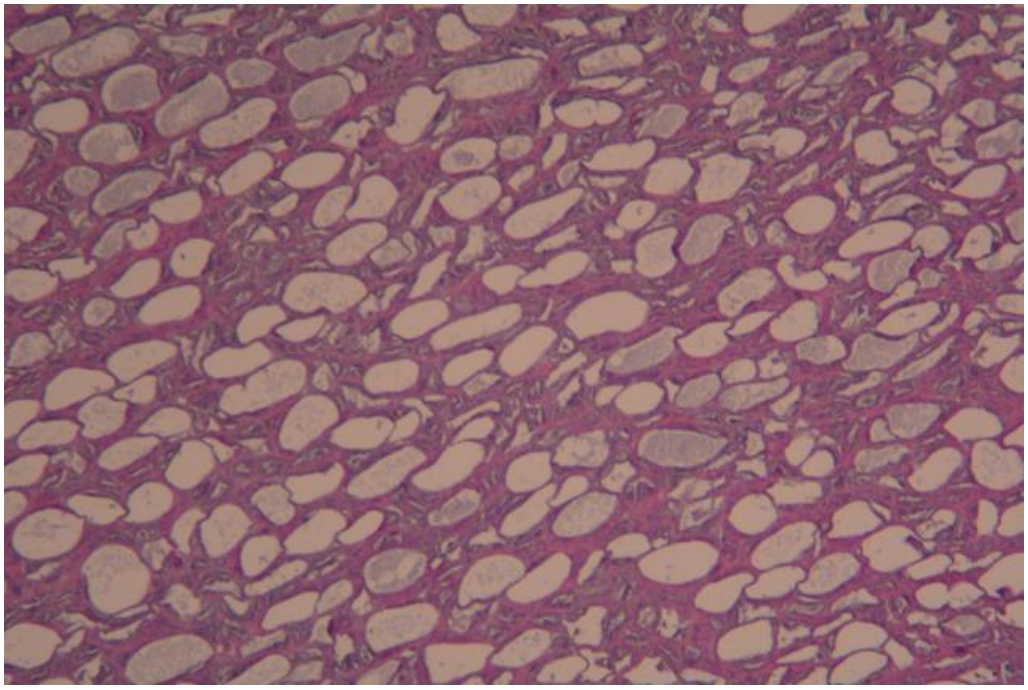


FL: 130cm, GW: 54.51g (Class 6b, regressed2 stage)

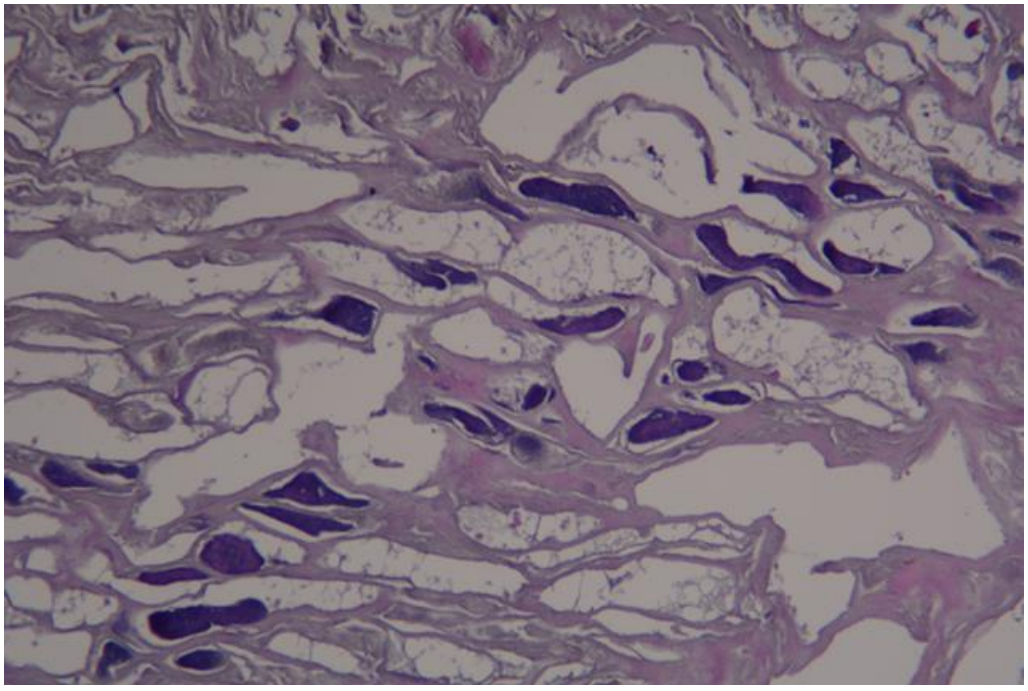


FL: 169cm, GW: 764.15g (Class 7, regenerating stage)

Fig. 7. (continued).

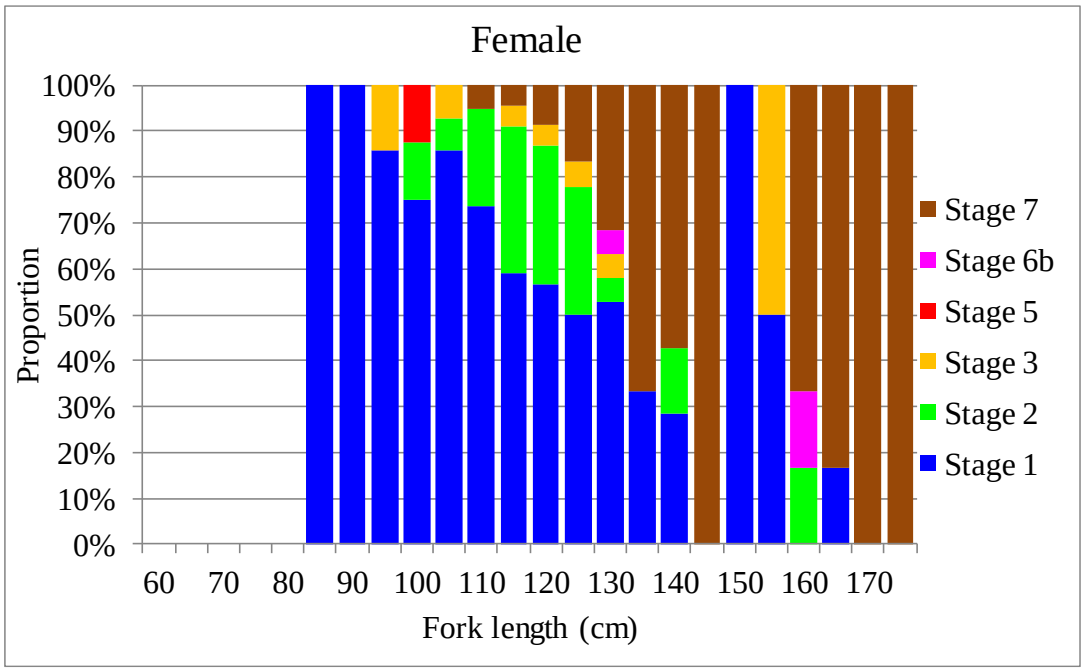


FL: 125cm, GW: 18.94g (immature stage)



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

Fig. 8. Histological sections and measurements of oocytes for gonad samples of male SBT collected Taiwanese scientific observer program during 2010-2015.



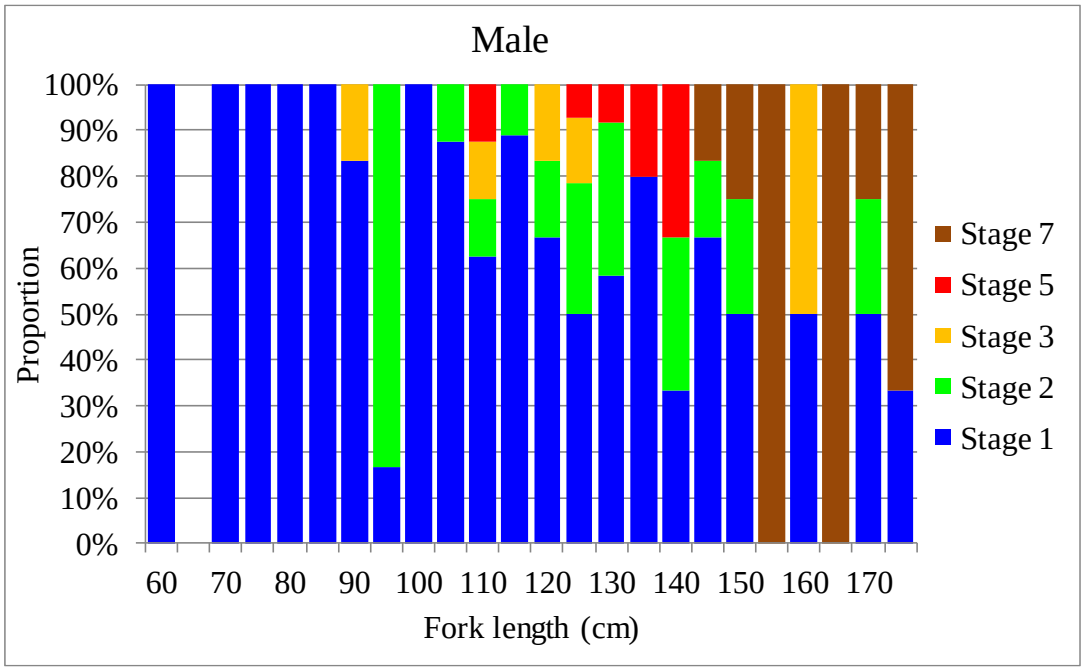


Fig. 91. Proportion of samples by maturity classes for gonad samples of SBT collected Taiwanese scientific observer program during 2010-2015.

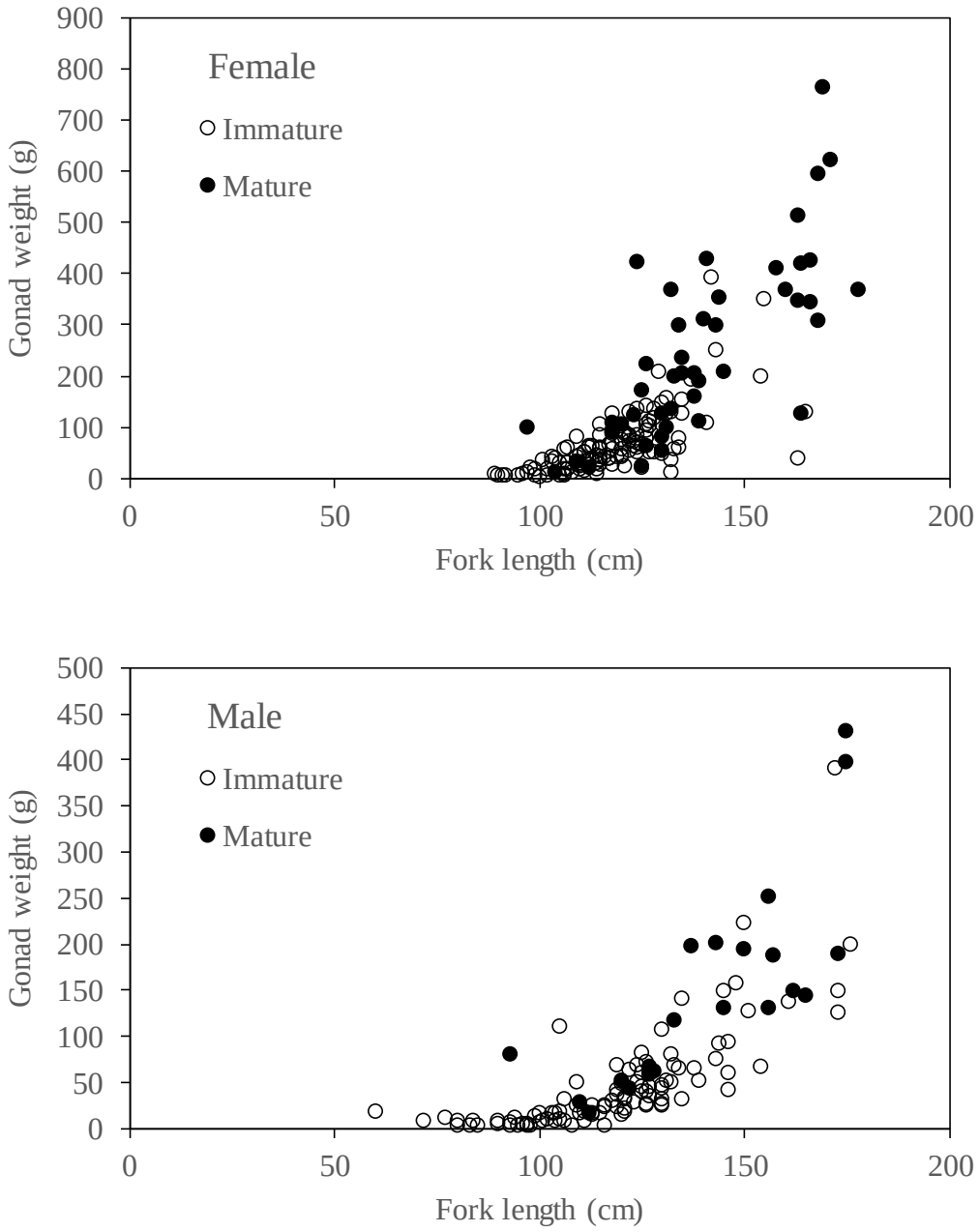


Fig. 10. Relationship between fork length and gonad weight by mature status for gonad samples of SBT collected Taiwanese scientific observer program during 2010-2015.

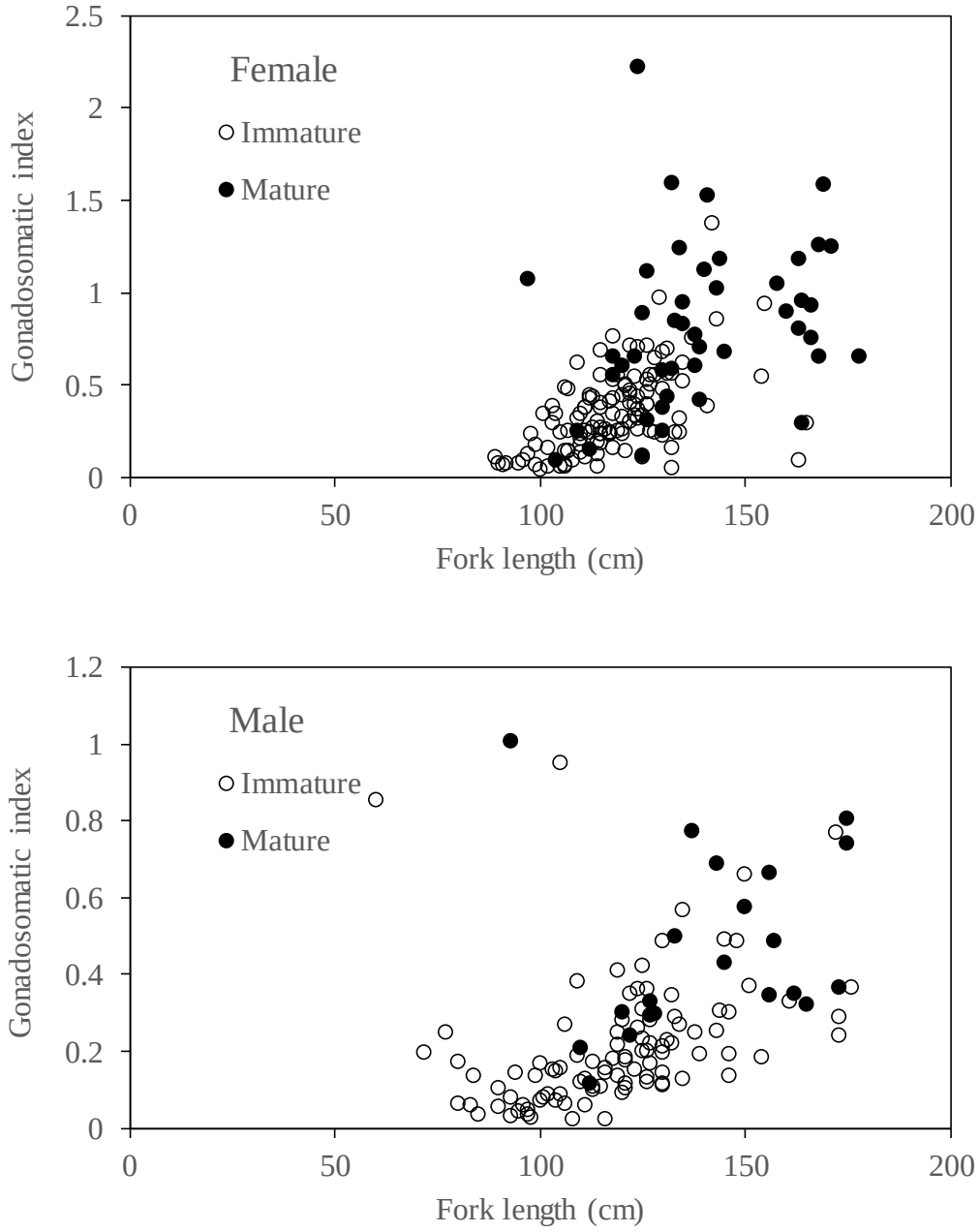


Fig. 11. Relationship between fork length and gonado-somatic index (GSI) by mature status for gonad samples of SBT collected Taiwanese scientific observer program during 2010-2015.

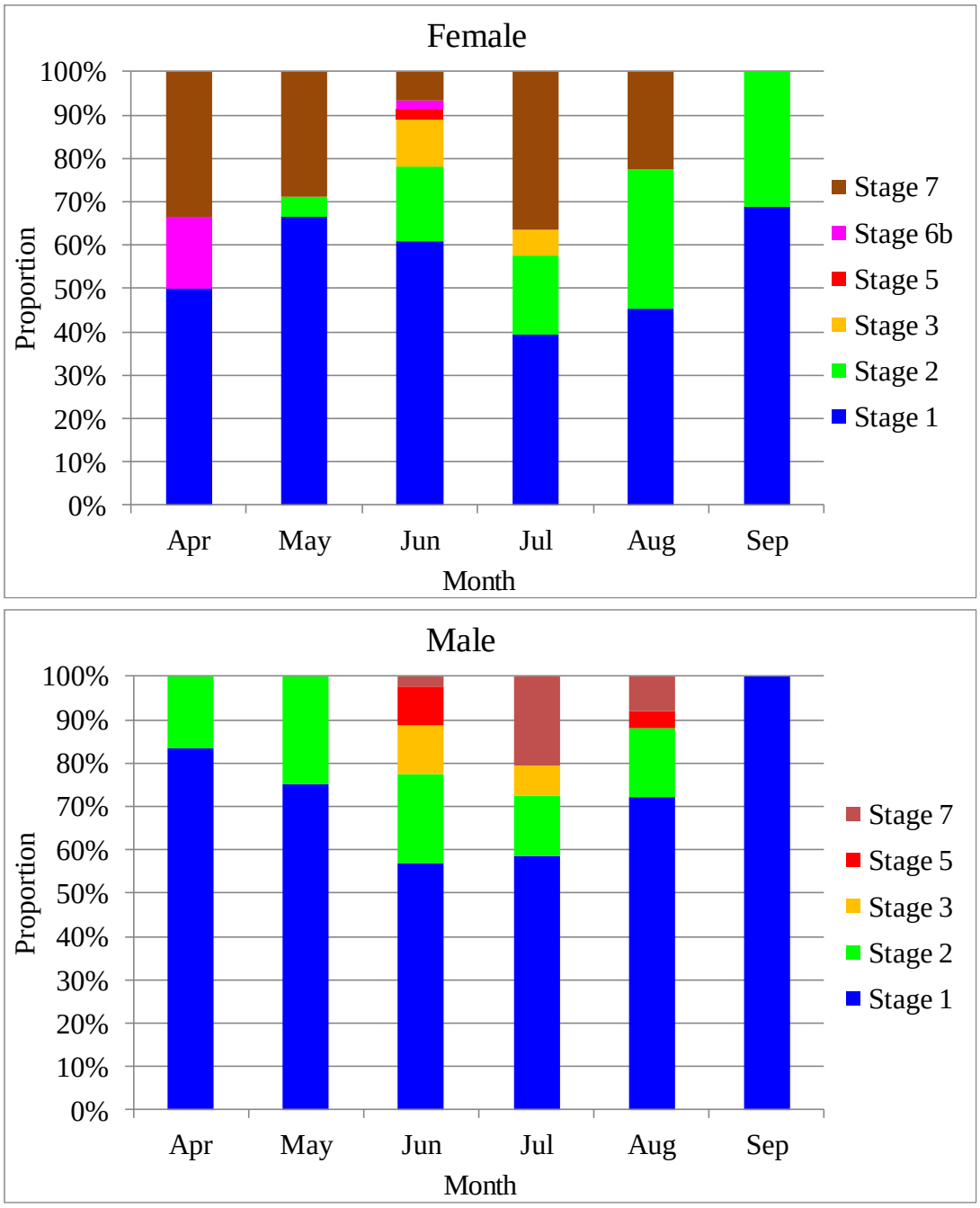


Fig. 12. Proportion of samples by maturity classes for gonad samples of SBT collected Taiwanese scientific observer program during 2010-2015.

Table 1. The criteria of gonadal developmental stages for albacore in the southern 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