

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

Sheng-Ping Wang¹, Hung-Hung Hsu², Wei-Chuan Chiang²,
Ching-Ping Lu¹, An-Chiang Huang³

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, Taiwan

ABSTRACT

A total of 569 gonad samples of southern Bluefin tuna were collected and analyzed during the period from April to September in the year of 2010-2017 in this study. 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 peak value in May and then decreased gradually. The sexual maturity stages were determined based on the developmental stages of histological sections of 442 gonad samples collected in 2010-2016. Most samples were designated as immature stage, and about 18% 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 the waters off the south eastern and southern Australia. The results provided information of 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 south Indian 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 southwest Indian Ocean.

In order to collect scientific information on SBT, the scientific observers started being deployed on board and conducting the observation program of SBT since 2002. The biological samples, including 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

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. 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 \geq stage 3. Stages 3 and 4 are reproductively active stages, and stages 1-2 and 5-7 are reproductively inactive stages (Table 1).

3. RESULTS AND DISCUSSION

A total of 569 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 2010-2017. There were 256 female and 313 male samples, respectively.

Samples were collected in the waters of the southeast Indian Ocean (65°E-105°E, 29°S-40°S) (Fig. 1). The values of fork length of female and male samples ranged

from 80 to 178 cm and 60 to 185 cm, respectively, and both concentrated between 90 and 150 cm (Fig. 2).

The values of gonad weights obviously increased with the growth pattern of fork lengths in both sexes, 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 peak value in May 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 442 female and male gonad samples collected from 2010 to 2016 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 18% of samples (23% for females and 14% 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 imply that mature fishes might migrate to the fishing ground of Taiwanese SBT fishery after reproductive activity.

REFERENCE

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., 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.

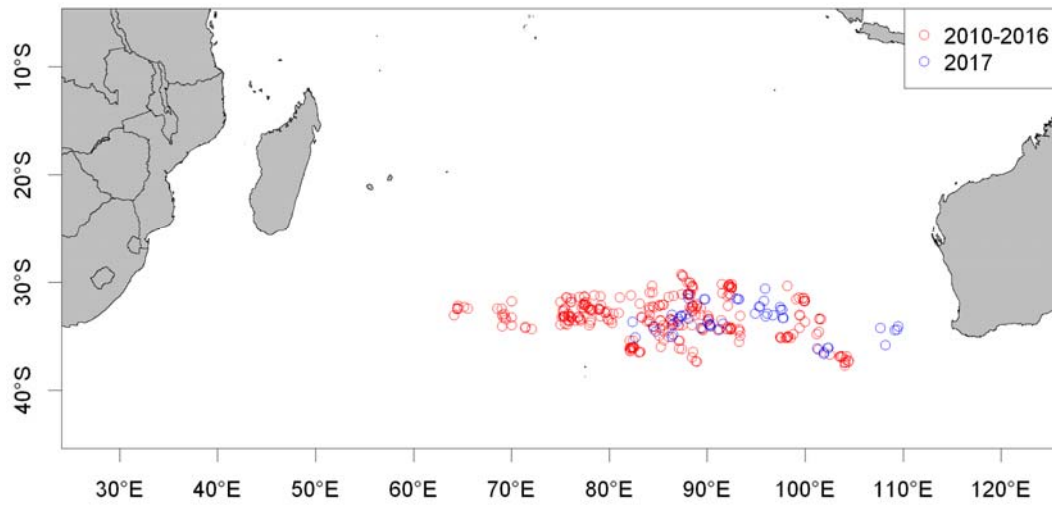


Fig. 1. Locations for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2017.

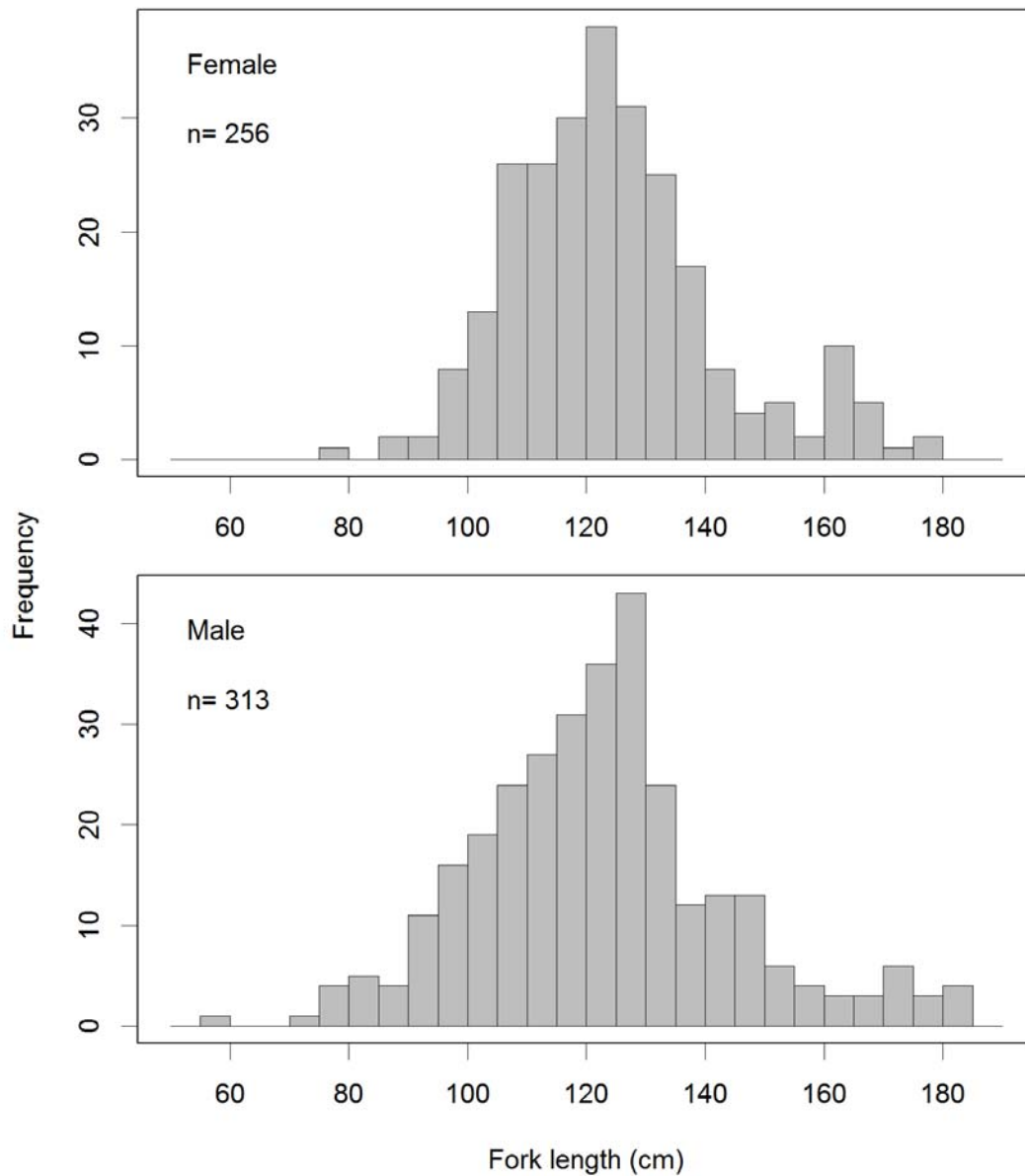


Fig. 2. Length frequency distributions (5 cm intervals) for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2017.

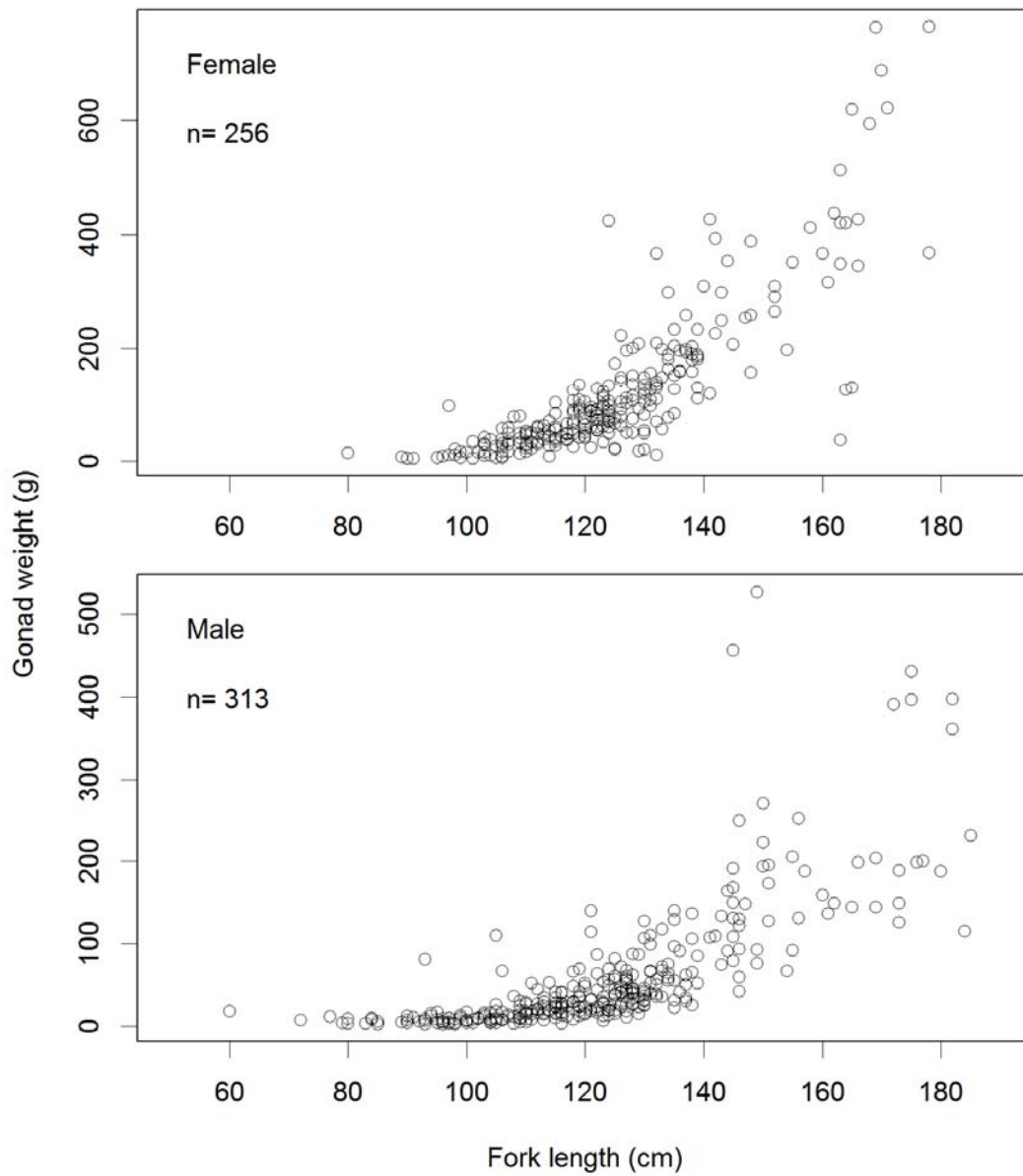


Fig. 3. Relationship between fork length and gonad weight for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2017.

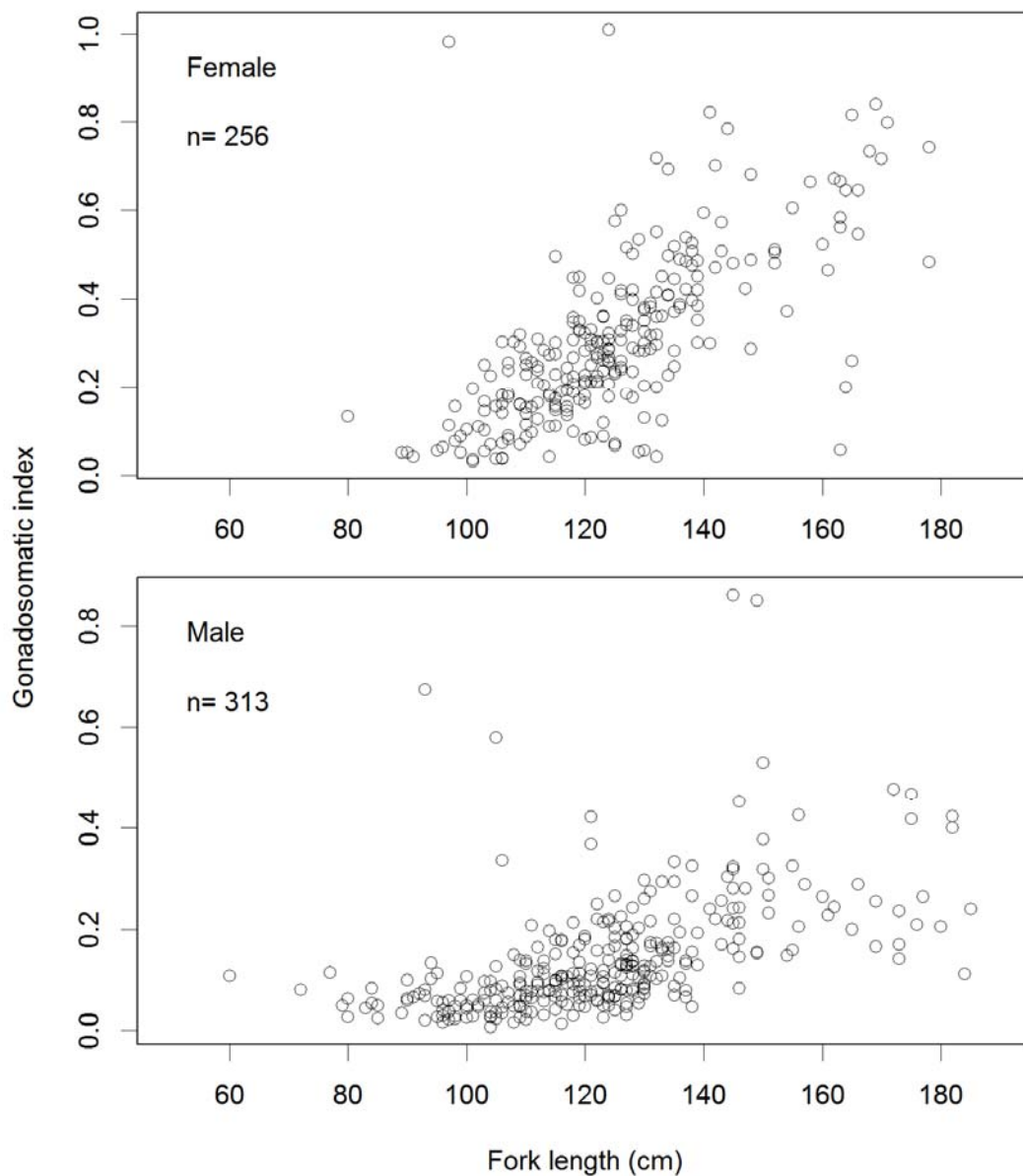


Fig. 4. Relationship between fork length and gonado-somatic index (GSI) for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2017.

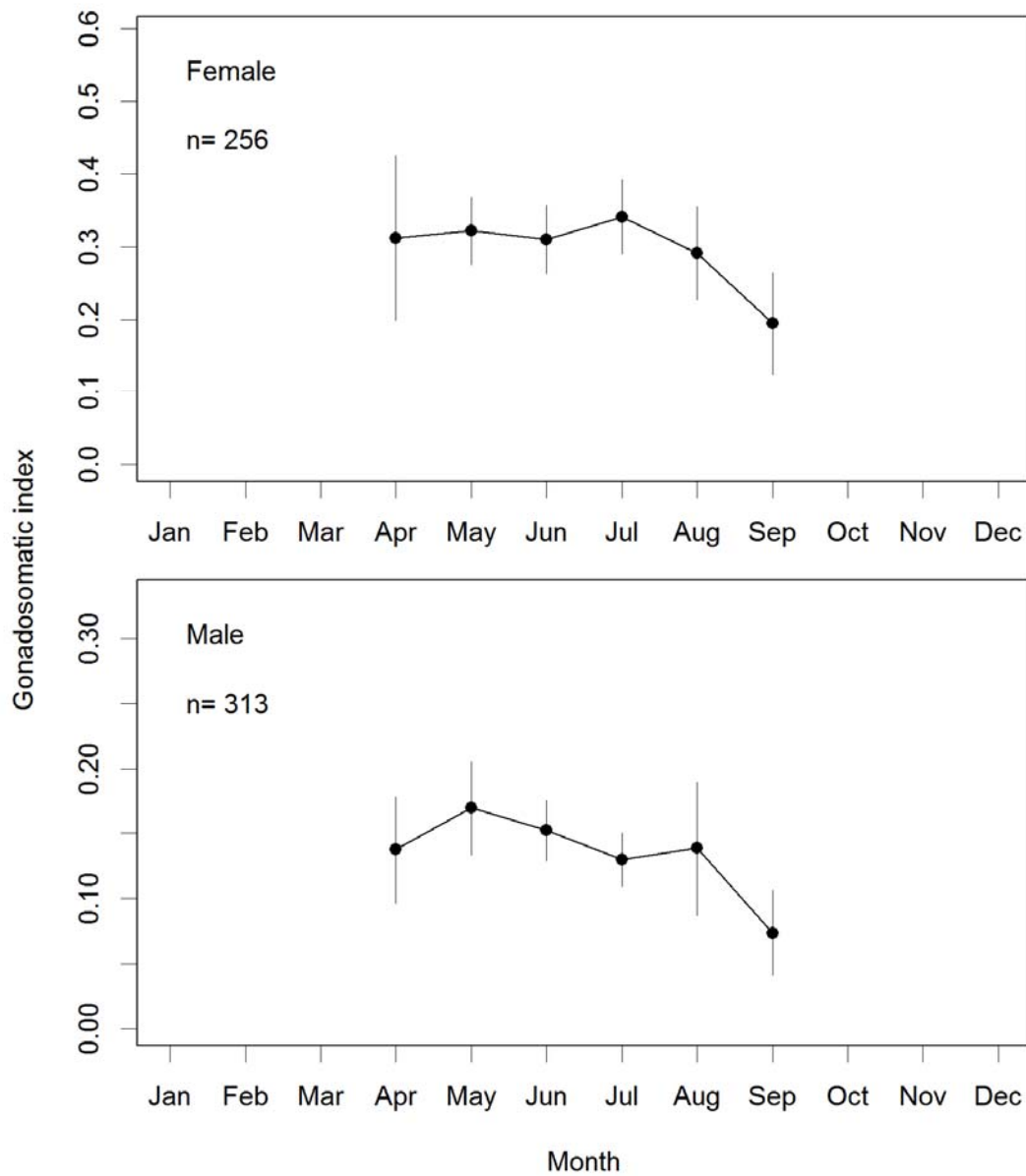


Fig. 5. Monthly trends of gonado-somatic index (GSI) for gonad samples of SBT collected by Taiwanese scientific observer program. Vertical bars represent the 95% confidence interval for means during 2010-2017.

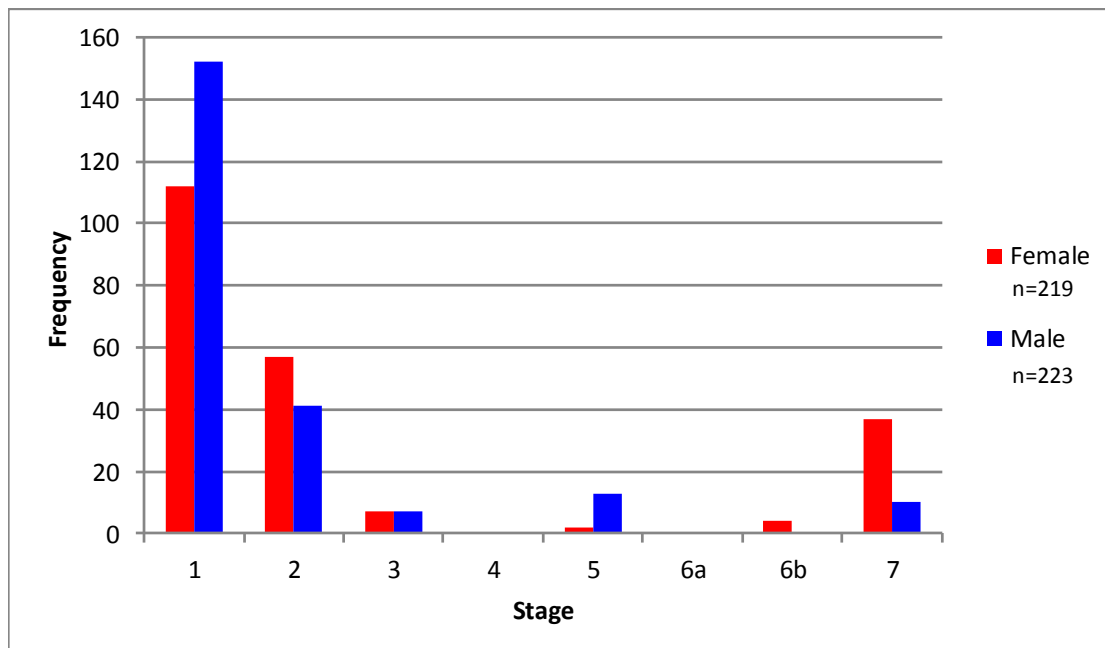
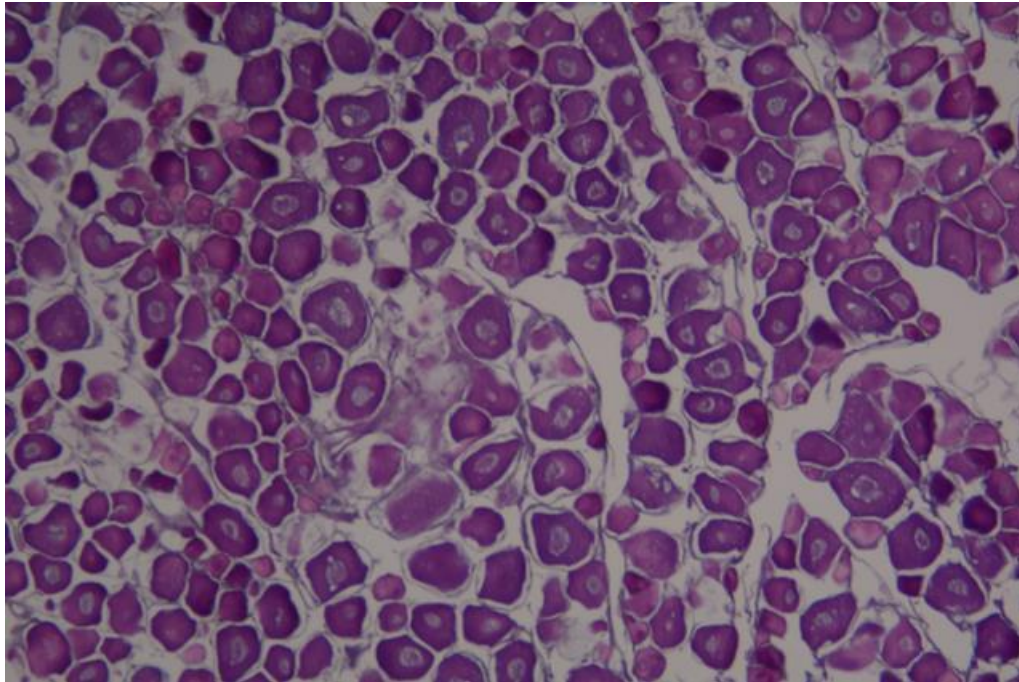
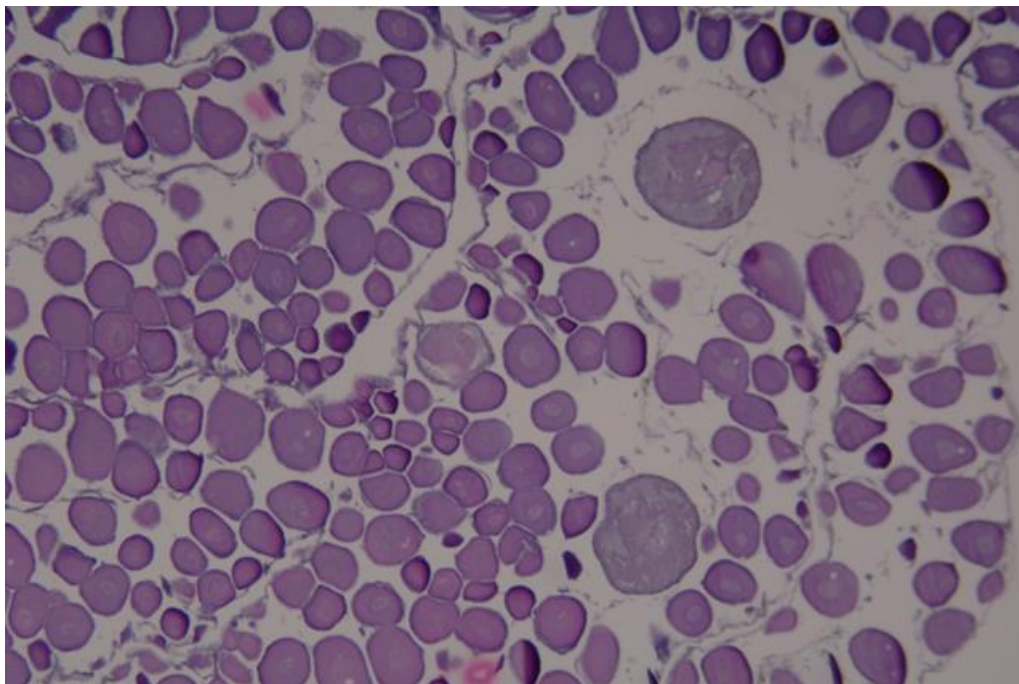


Fig. 6. Number of samples by maturity classes for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2016.

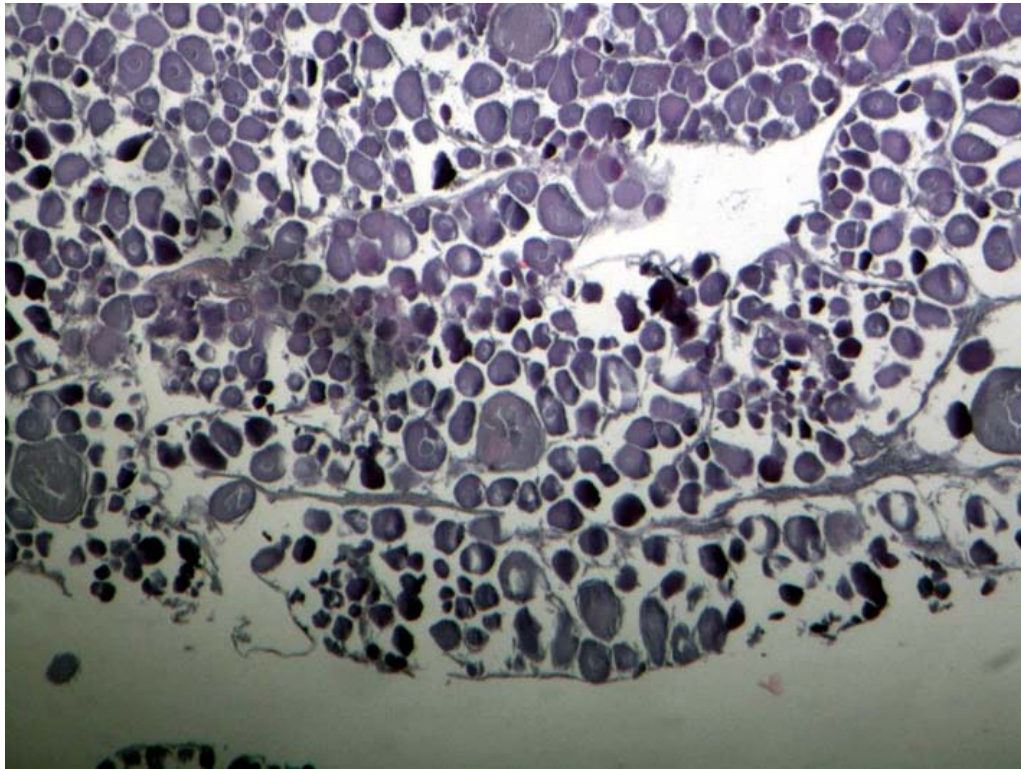


FL: 133cm, GW: 133.67g (Class 1, immature stage)

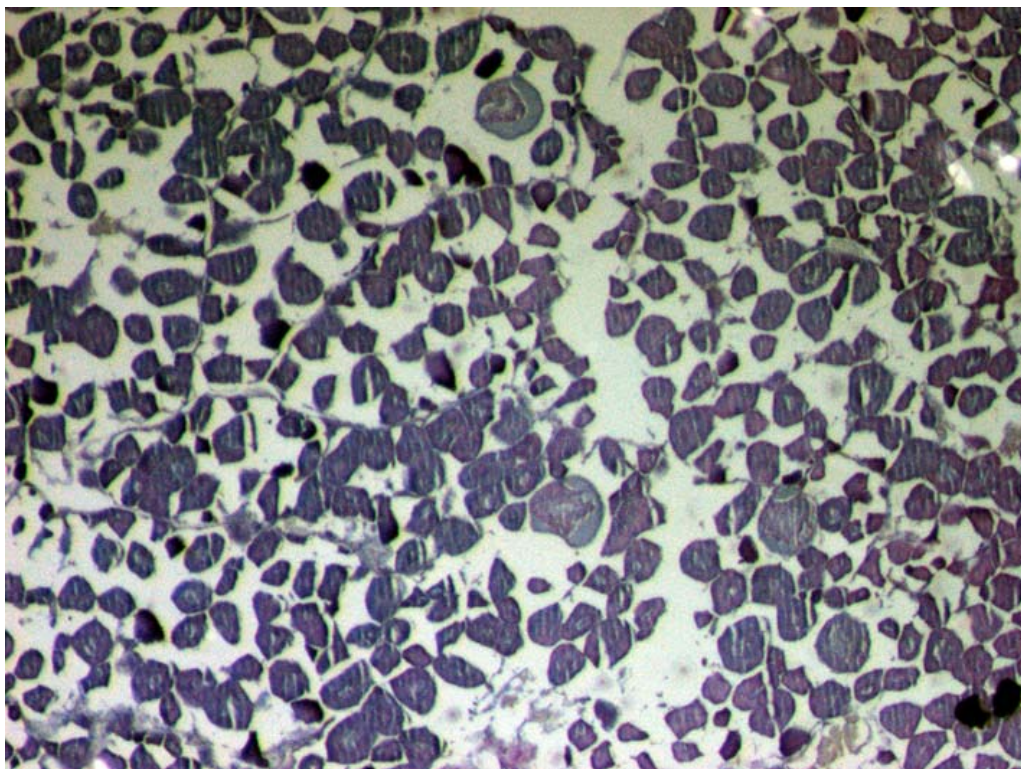


FL: 130cm, GW: 82.1g (Class2, developing stage)

Fig. 7. Histological sections and measurements of oocytes for gonad samples of female SBT collected by Taiwanese scientific observer program during 2010-2016.

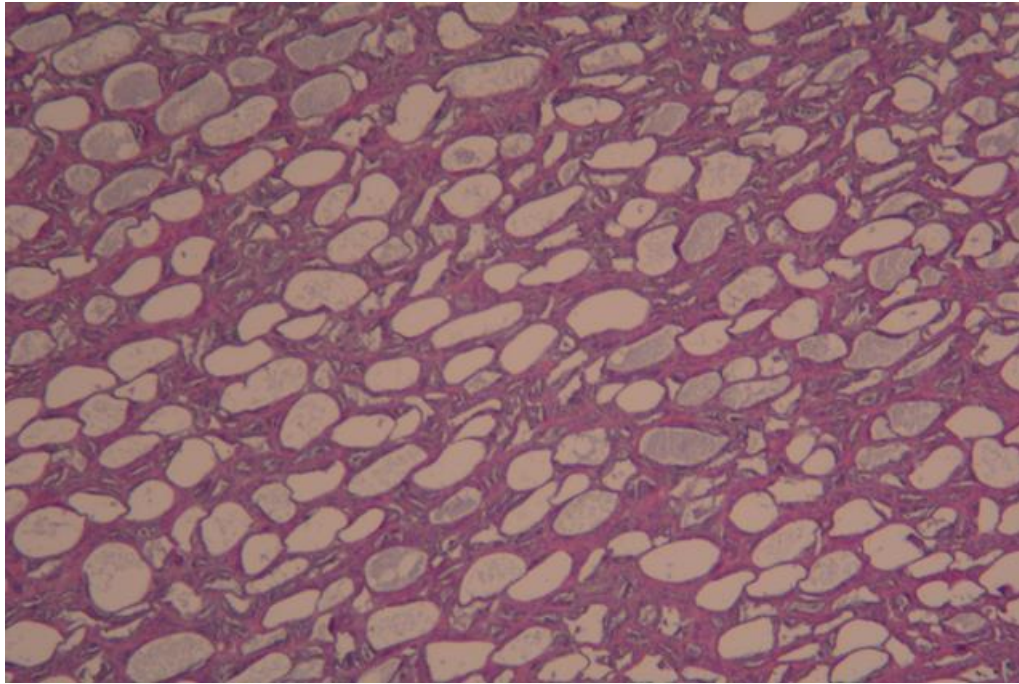


FL: 130cm, GW: 54.51g (Class 6b, regressed2 stage)

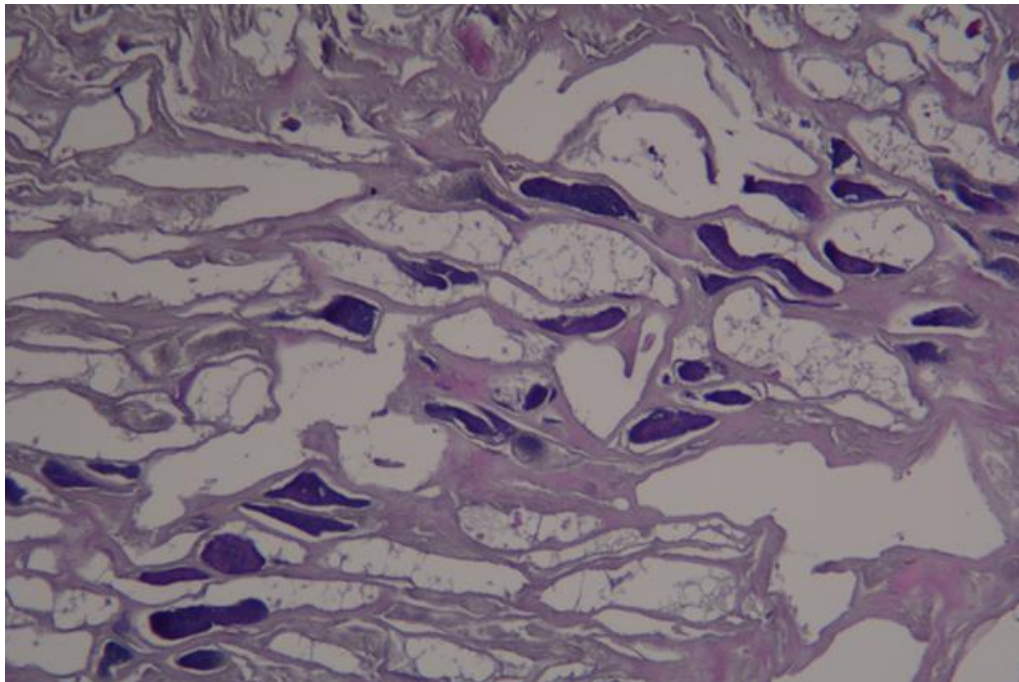


FL: 169cm, GW: 764.15g (Class 7, regenerating stage)

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 2010-2016.

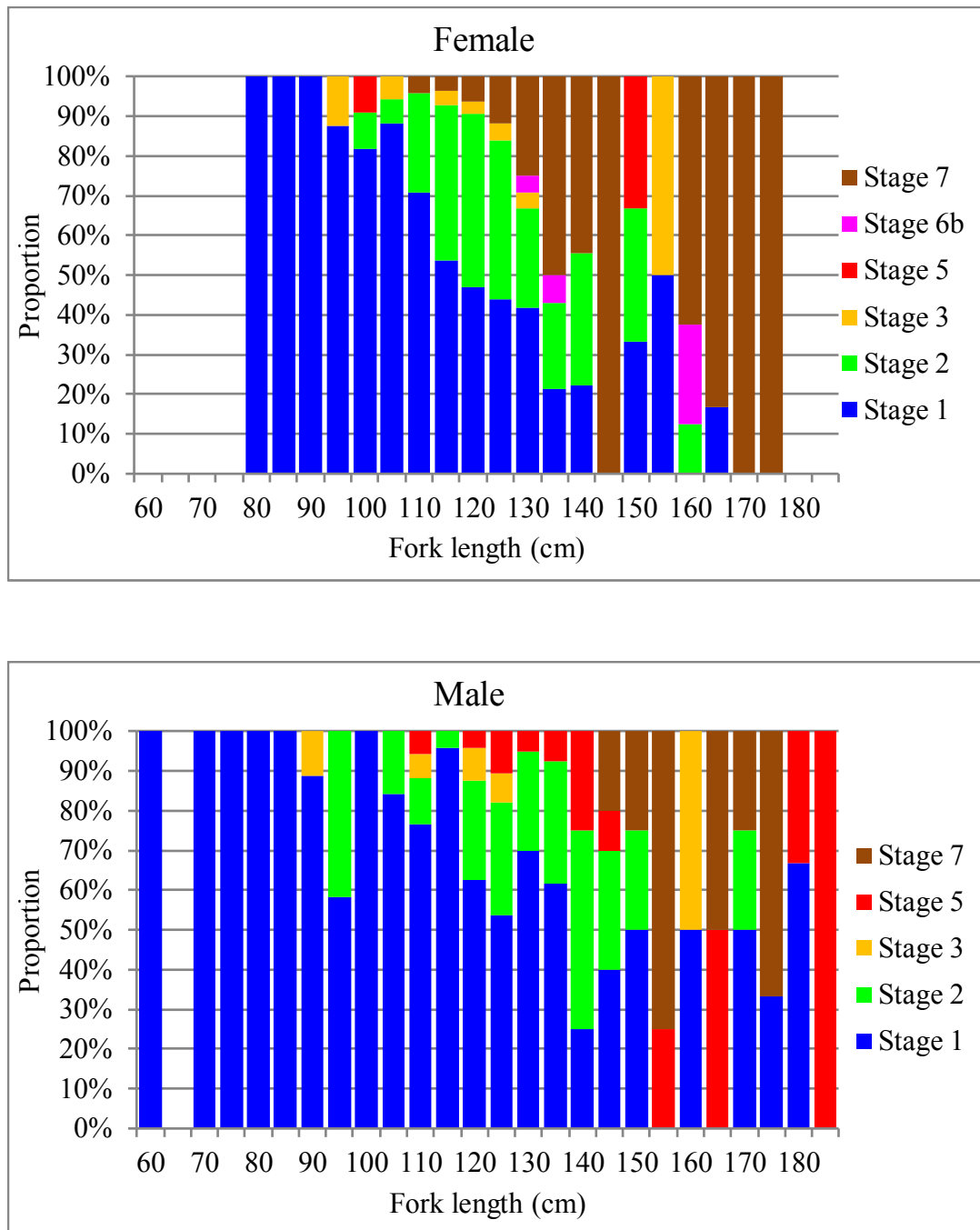


Fig. 91. Proportion of samples by maturity classes for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2016.

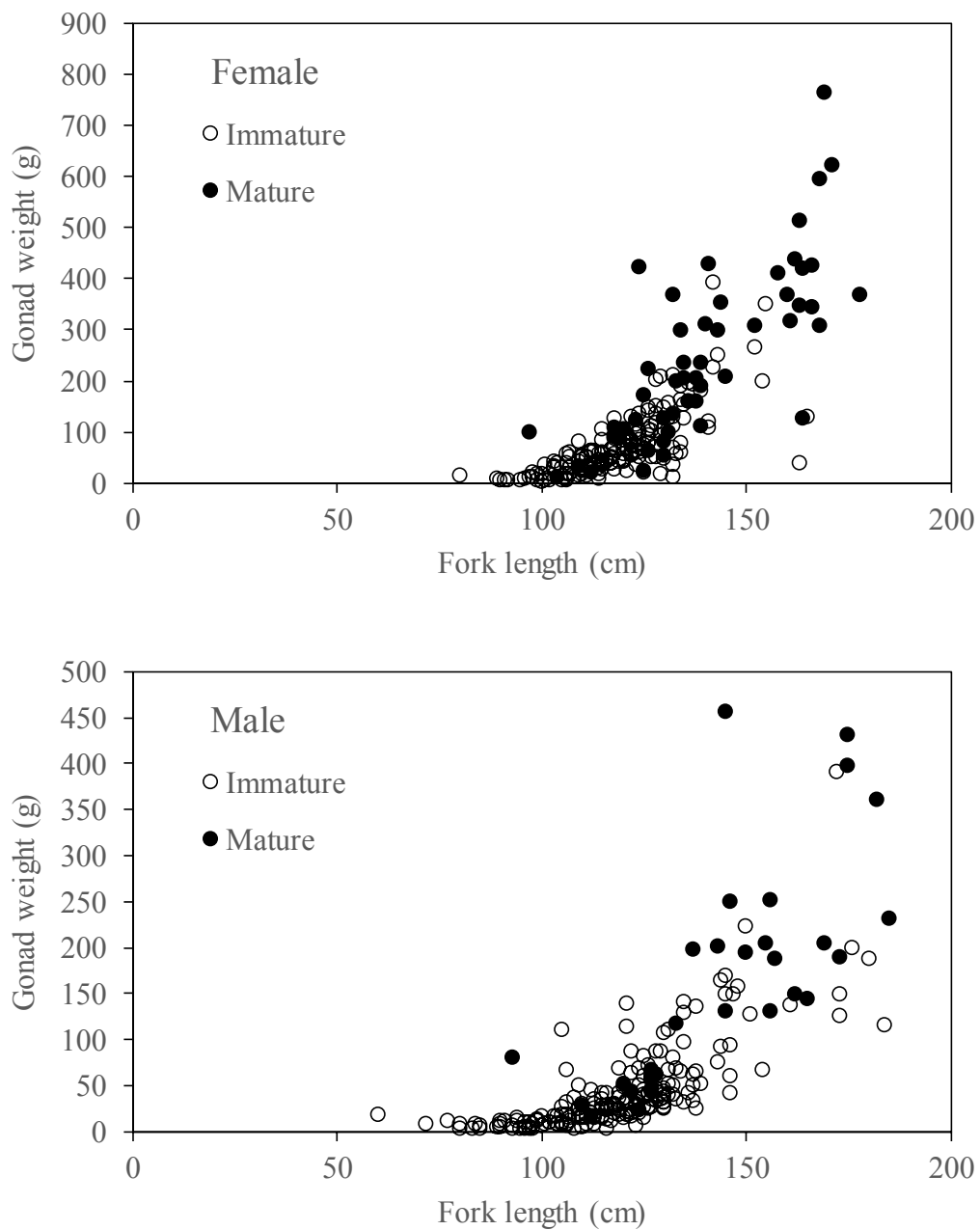


Fig. 10. Relationship between fork length and gonad weight by mature status for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2016.

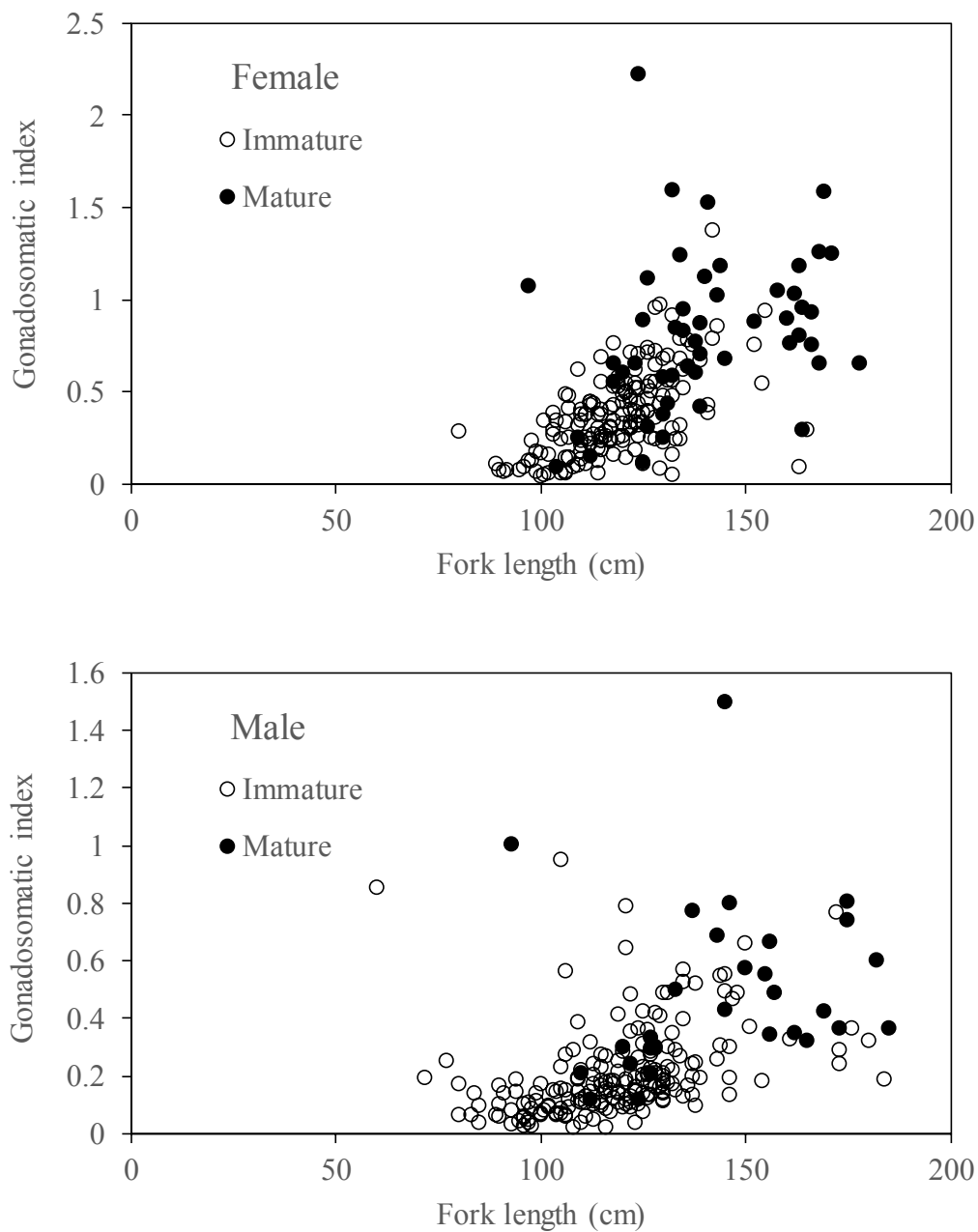


Fig. 11. Relationship between fork length and gonado-somatic index (GSI) by mature status for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2016.

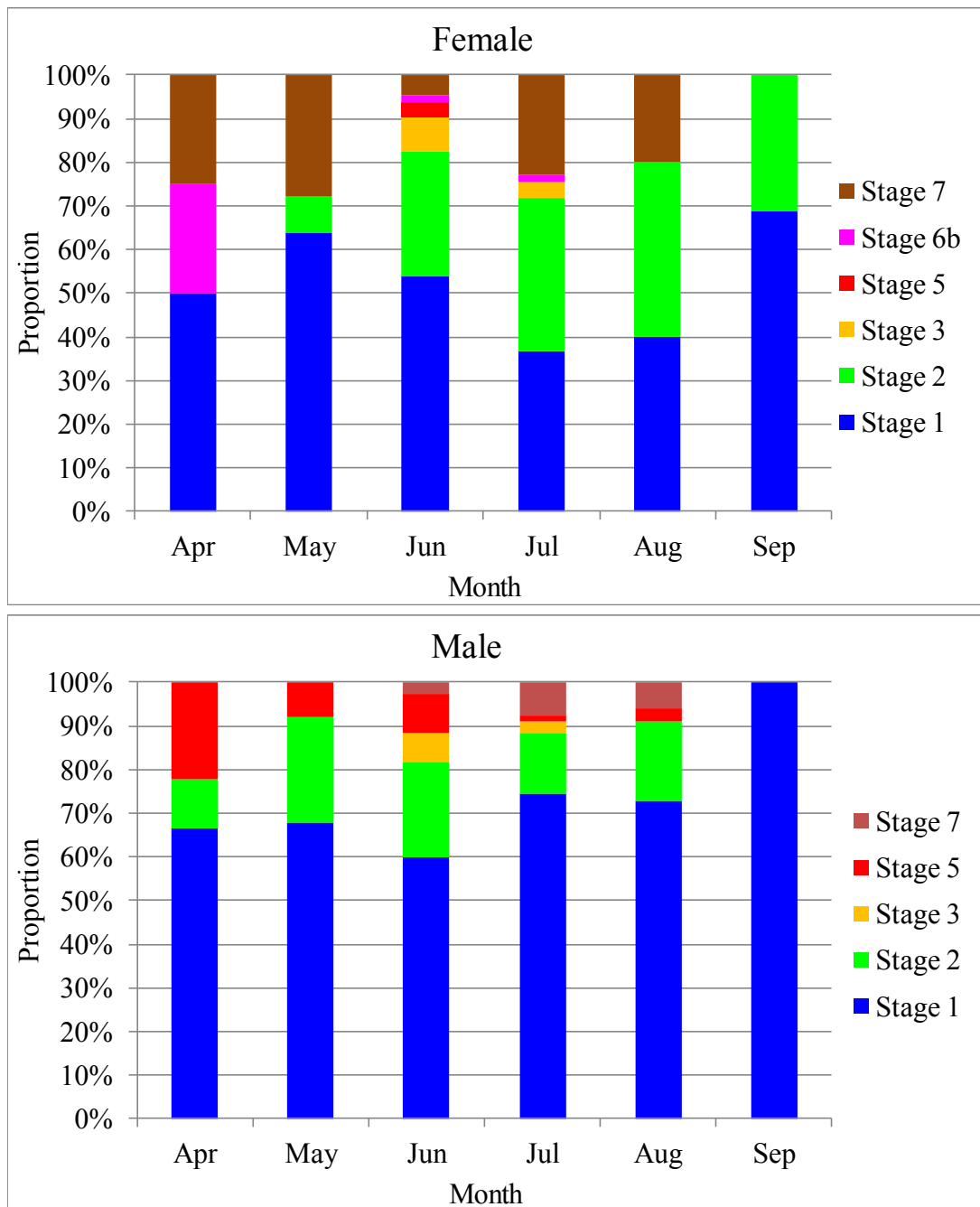


Fig. 12. Proportion of samples by maturity classes for gonad samples of SBT collected by Taiwanese scientific observer program during 2010-2016.

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 β atresia of yolked oocytes
1	Immature	Inactive	Immature	Unyolked,no POFs	Absent
2	Immature	Inactive	Developing	Early yolked,no POFs	Absent
3	Mature	Active	Spawning capable	Advanced yolked,no POFs	<50% α and β atresia may be present
4	Mature	Active	Spawning	Migratory nucieus or hydrated and/or POFs	<50% α and β atresia may be present
5	Mature	Inactive	Regressing-potentially reproductive	Advanced yolked,no POFs	\geq 50% α and β atresia present
6a	Mature	Inactive	Regressed 1	Unyolked or early yolked, no POFs	100% α and β atresia may be present
6b	Mature	Inactive	Regressed 2	Unyolked or early yolked, no POFs	No α and β atresia present
7	Mature	Inactive	Regenerating	Unyolked or early yolked, no POFs	Absent