Reproductive biology of longtail tuna (*Thunnus tonggol*) from coastal waters off Taiwan

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Abstract

A total of 588 longtail tuna ranging in size from 30.0 to 74.5 cm fork length (FL) and 0.43 to 5.9 kg rounded weight (RW) were collected from Taiwan waters between December 2005 and May 2011. Gonads were collected from 231 female fish, which comprised 40% of the sample. Gonads were classified into four stages of maturity, based on histological structures. Histological analysis indicated that the length-at-first maturity was 37 cm for females. Monthly variation in gonadosomatic indices peaked at December, but no gonads contained hydrated oocytes to indicate spawning was imminent. We rarely found longtail tuna larger than 80 cm, which may be due to a mis-match of spatial and/or temporal sampling effort for longtail tuna as they apparently migrate through the Taiwan region, or possibly selectivity of sampling gears. These artifacts may have contributed to an underrepresentation of the largest and smallest fish present in our sample.

Introduction

Longtail tuna *(Thunnus tonggol*) are widely distributed in Indo-Pacific between 47°N and 33°S (Froese and Pauly, 2009). The species' distribution is unique compared with those of other species in the genus *Thunnus* that generally range across open oceans, in that longtail tuna nearly exclusively occupy neritic areas close to landmasses, and are rarely found offshore (Yesaki, 1994). The maximum recorded size is 142 cm total length and 35.9 kg, the longevity has been estimated to be at least18 years (Griffiths et al. 2009)

This species is commercially-important throughout the Indo-Pacific and heavily exploited in rapidly expanding multi-species purse seine, gillnet and troll fisheries in many countries (Griffiths 2010). Surprisingly, very little is known of the species' basic biology, stock structure and catch by recreational and commercial fisheries. The size and age at sexual maturity and the sex ratio are fundamental biological parameters used in stock assessments. Estimates of body size or age at sexual maturity are necessary parameters for age- and size-structured models, such as the spawner biomass-per-recruit model (Gabriel et al. 1989) and other size- or age-structured models (Deriso et al. 1985, Quinn II et al. 1990). Spawning locations are thought to exist in the waters of Australia (Griffiths et al. 2010) and Southeast Asia, but there is no record of spawning around Japan (Itoh et al. 1999).

There has been no histological examination of the reproductive biology of longtail tuna in northwestern Pacific. Therefore, the objective of this study was to estimate sex ratios and the sexual maturity for longtail tuna in the waters off Taiwan. The results of this study can be used as biological input parameters for used in stock assessment of the longtail tuna population in the northwestern Pacific Ocean.

MATERIALS AND METHODS

Periods and investigated

Data used in the paper were derived from collections at three commercial set net locations around Taiwan and the troll fishery landings at Shinkang fish market (south eastern Taiwan) (Fig. 1). Fork length (FL), round weight (RW) and a sample of male and female longtail tuna gonads were collected from December 2005 to May 2011.

Collection of samples and general biological data

The sex of each sample was determined visually. Specimens were measured to the nearest millimeter for FL, to the nearest 0.1 kilogram for weight (RW) and to the nearest 0.1 g for ovarian weight (OW). The gonadosomatic index (GSI) was calculated as (Uchiyama and Shomura 1974):

$$\mathrm{GSI} = \frac{\mathrm{OW}}{\mathrm{RW}} \times 100$$

The sex ratios by length class (5-cm length and 0.5-kg weight intervals) and month intervals were expressed as the proportion of females to total numbers of females and males:

$$\text{sex ratio} = \frac{\text{number of females}}{\text{number of females} + \text{number of males}}$$

Preparation for histological examination

Gonads were preserved in 10% buffered formalin for histological examination. Subsamples taken from fixed gonads were washed, dehydrated in alcohol and xylene, and infiltrated with paraffin. Histological sections of 5-7 μ were cut with a Leica 2055 rotary microtome and stained with Meyer's Hematoxylin followed by eosin counterstain. The developmental stages of oocyte were categorized following several authors. Microscopic slides were examined with a Leica DM LS compound microscope at a magnification of 40-1000x. Histological classification of gonadal developmental stages were categorized based on the criteria of Chiang et al. (2006), and classified into the (1) immature stage, (2) developing stage, (3) maturing stage, (4) ripening stage, (5) spawning stage, (6) recently spawned stage, and (7) spent or

resting stag.

RESULTS & DISCUSSION

Size distribution

In total, 588 specimens were collected (231 females, 266 males and 91 unsexed), from which gonad samples were collected from 380. Size ranged from 30.0 to 74.5 cm FL for females and 32.2 to 75.3 cm FL for males, with both and unsexed samples clustered between 30.0 and 79.6 cm FL. Round weight ranged between 0.43 to 5.9 kg for females and 0.51 to 9.9 kg for males, with both and unsexed samples clustered between 0.43 and 10.2 kg (Figs. 2 & 3).

Sizes of longtail tuna caught in set nets, purse seine, pole & line, stick-held dip net and trolling in Japan ranged from 17.9 to 72.0 cm/ 1.8 to 10 kg (Itoh et al. 1996). In the gillnet and sport fishery at Australia, the catch size of 461 longtail tuna ranged from 23.8 to 125.0 cm and 0.26 to 27.8 kg. Therefore, longtail tuna in Taiwan appear to be of smaller size than in Australia and Japan, possibly indicating that the northwestern Pacific Ocean may be an important nursery ground.

Sex ratio

The total number of male samples was greater than that of females. The estimated sex ratio for all samples was 0.46 which did not significantly differ (χ^2 = 2.4647; $p > 0.01$) from the expected 0.5 (Table 1). The monthly sex ratio fluctuated without a significant pattern at the FL and RW (Figs. 3 & 4), although there were no samples collected from July to October. This also indicates that longtail tuna may only be temporary residents in Taiwanese waters as they migrate north to waters of southern Japan or travel south to the Philippines where catches of longtail tuna occur during these months.

Longtail tuna is a gonochoristic species and there is no evidence of sexual dimorphism (Griffiths et al., 2010), and the sex ratio for longtail tuna has not been found to significantly differ from the expected 1:1 in other regions of the world (Wilson, 1981; Griffiths et al., 2010). The sex ratio of several tuna species is often skewed towards males at larger size classes (Schaefer, 1998; Gunn et al., 2008). Griffiths et al. (2010) indicated a (2:1) bias towards males for large fish (>100 cm) along the east coast of Australia, but unfortunately we have not collected any sample in this size class for a comparison to be made.

Sexual maturity

The peak gonadosomatic index of male and female longtail tuna occurred during December and November to December, respectively (Fig. 5). The sea surface isotherm during these periods is 20°C to 21°C in this area. Of the total 231 female ovarian samples, 43 (18.6%) were designated as mature (developmental stage ≥ stage 4). The ovaries were divided into four stages of maturity based on the development and their histological characteristics (Fig. 6):

1. Immature stage: only primitive oogonia are present and no vitellogenesis basophilic cytoplasm, darkly stained with Hematoxylin.
2. Developing stage: chromatin nucleolar and early perinucleolar stage oocytes are present.
3. Maturing stage: late perinucleolar, previtellogenic oocytes of different sizes and small vitellogenic oocytes are present, red staining yolk granules and globules noticeable.
4. Ripening stage: active stage of vitellogenic oocytes and perinucleolar and small vitellogenic oocytes are present.

The length-at-first maturity from the histology analysis was 37 cm FL. From the macroscopic method, we determined the size at first maturity as 40 to 60 cm (Yesaki, 1982; Wilson, 1981; Cheunpan, 1984). In this study, we found mature females at "Ripening stage" but we did not find any fish in the "Spawning" stage. A possible mis-match of spatial and/or temporal sampling effort for longtail tuna or selectivity of sampling gears around Taiwan may have contributed to an underrepresentation of the largest and smallest fish present in the population.

Future work

Additional research involving high intensity sampling across a wider spatial scale using a wide variety of gears, genetic and tagging experiments is necessary to further our understanding of longtail tuna in the northwestern Pacific Ocean. This will help determine to what extent, if any, the population of longtail tuna from this area is connected to population elsewhere in the world. This will most certainly involve international cooperative research and cross-jurisdictional management to maintain sustainable harvest levels. Continued sampling of longtail tuna in Taiwanese waters for population characteristics determination and a collaborative study between on longtail tuna stock structure will begin to fill some of the large knowledge gaps that currently exist for this little-studied tuna species.

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Figure 1. The sampling area for longtail tuna at waters off Taiwan showing the three set net fisheries (white square) and the Shinkang fish market in southeastern Taiwan (anchor).

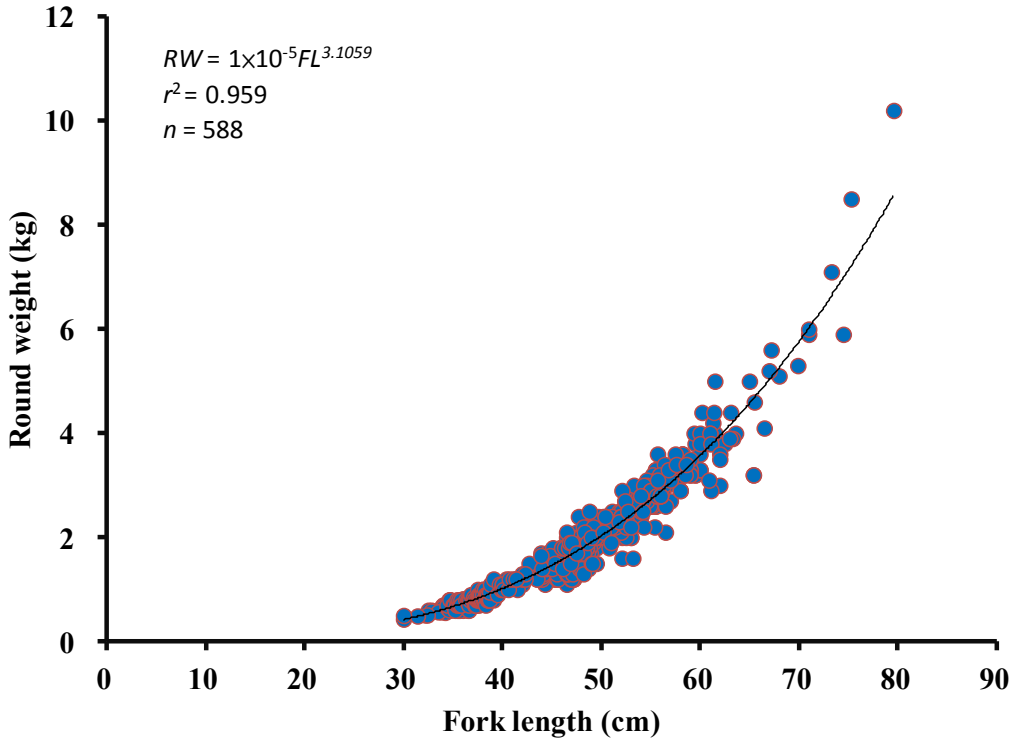

Figure 2. Relationship between round weight (*RW*) and fork length (*FL*) for longtail tuna in the waters off Taiwan

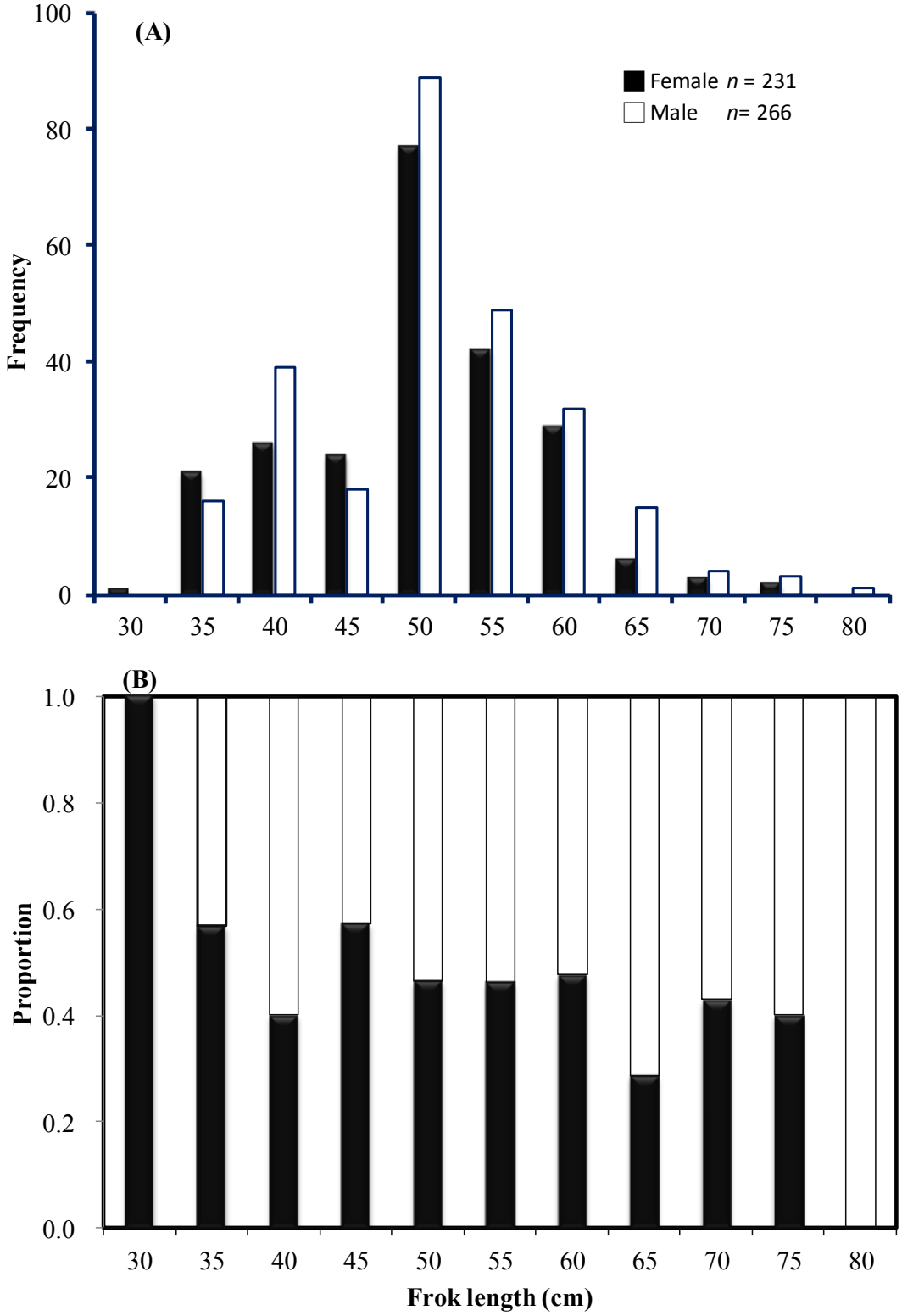

Figure 3. Size-frequency (A) and size-proportion (B) by 5-cm interval for longtail tuna collected from the waters off Taiwan.

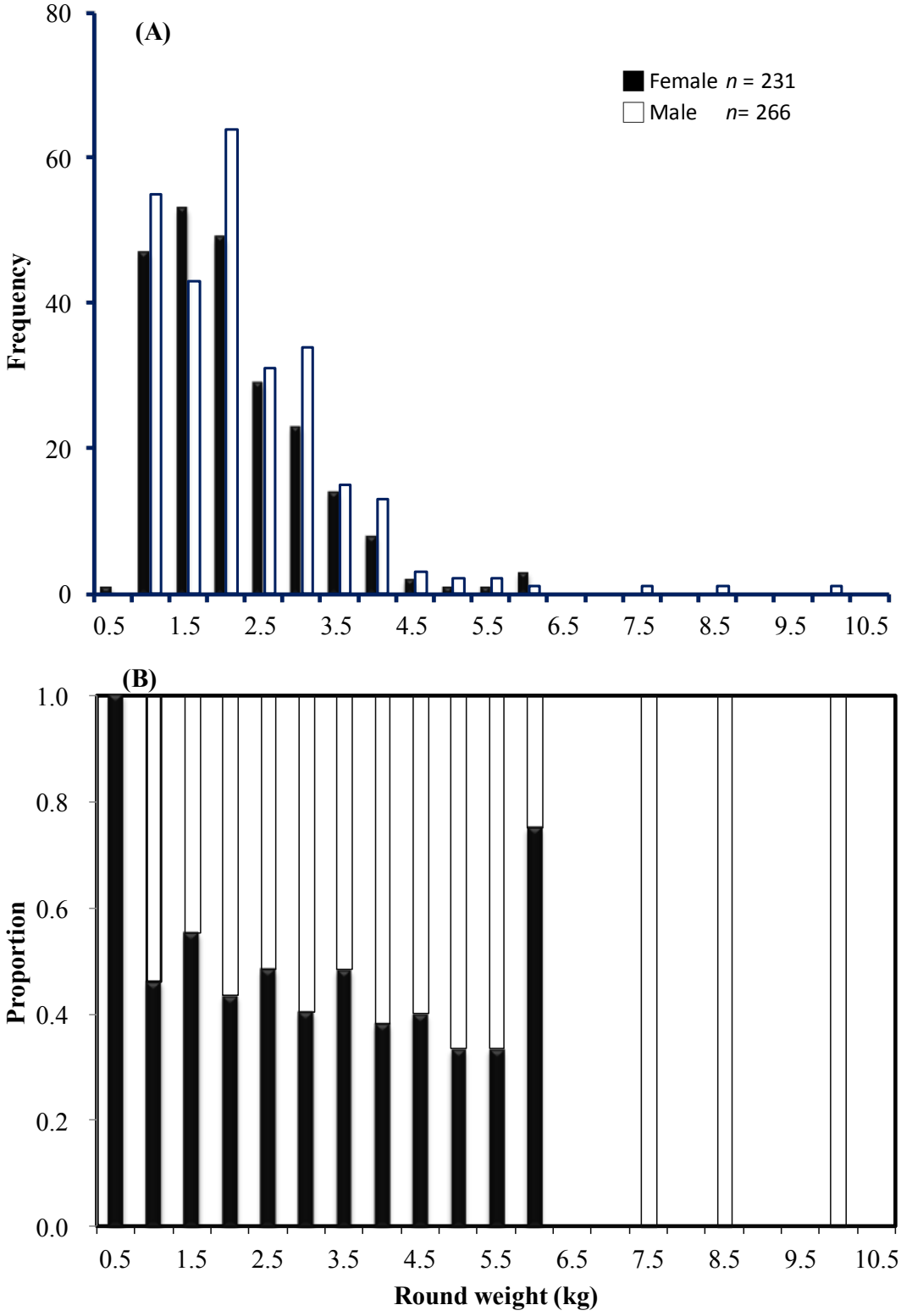

Figure 4. Size-frequency (A) and size-proportion (B) by 0.5-kg interval for longtail tuna collected from the waters off Taiwan.

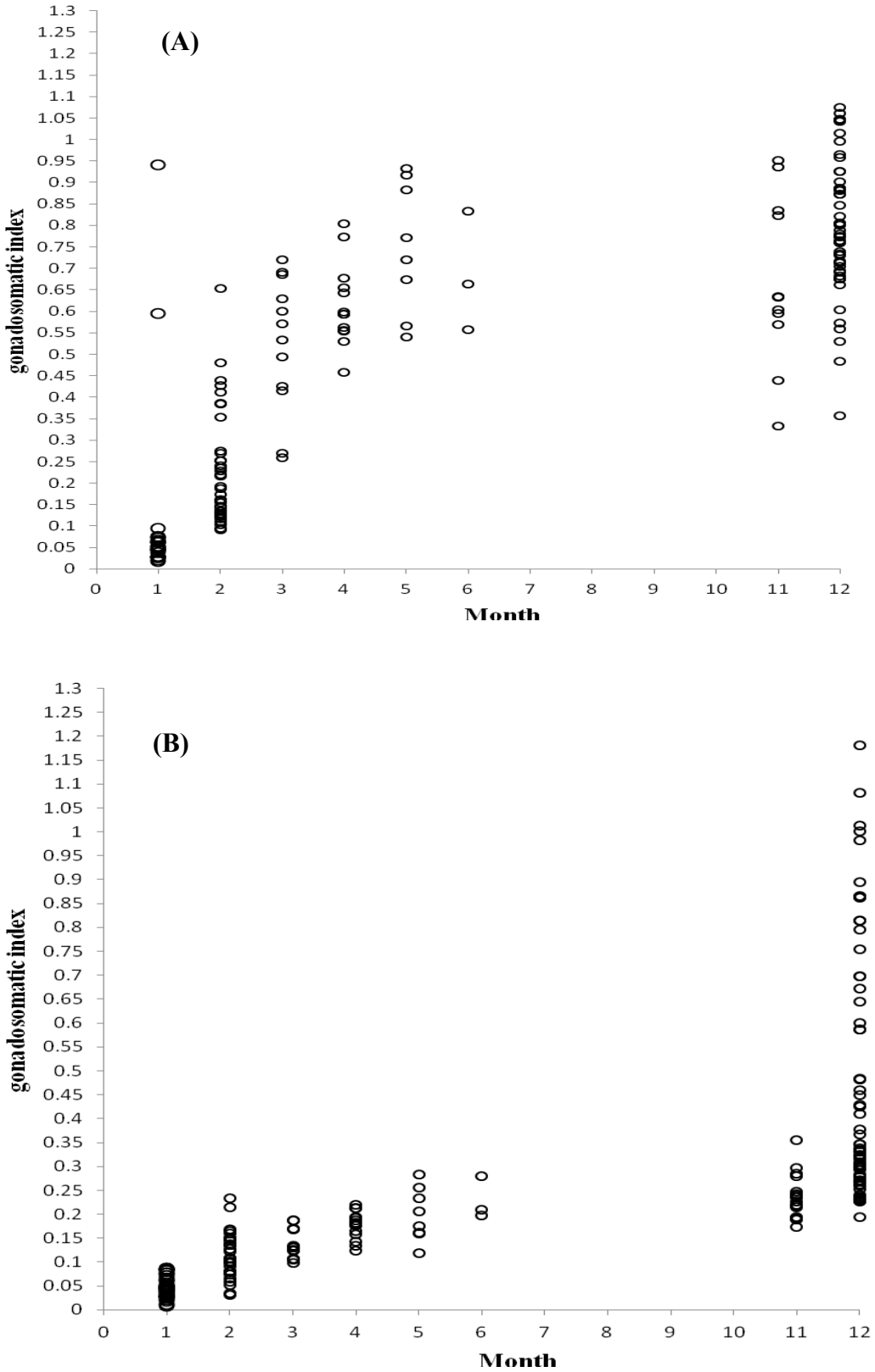

Figure 5. Monthly variation in gonadosomatic index of female (A) and male (B) longtail tuna collected from the waters off Taiwan.

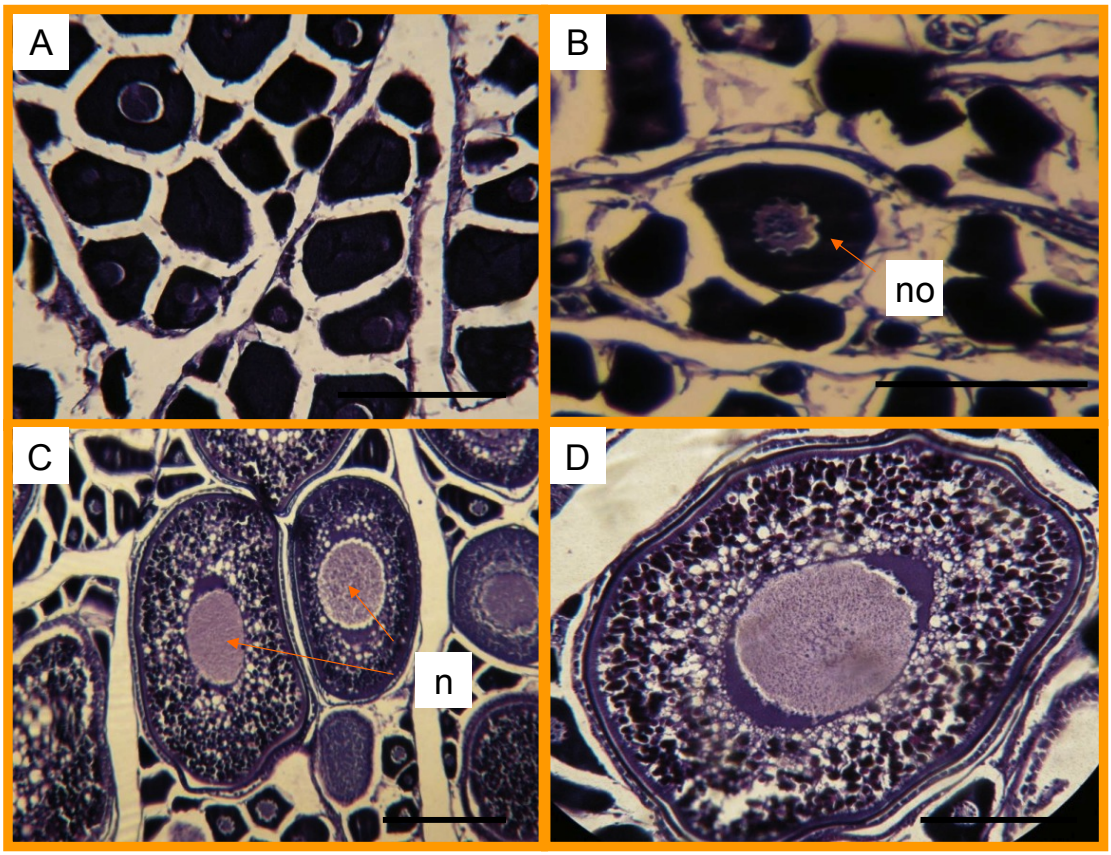

Figure 6. Histological sections of the female longtail tuna illustrating (A) chromatin nucleolar oocytes, (B) perinucleolar oocytes, (C) previtellogenic oocytes, (D) vitellogenic oocytes, n: nucleus; no: nucleoli. Scale bar = 0.1 mm.

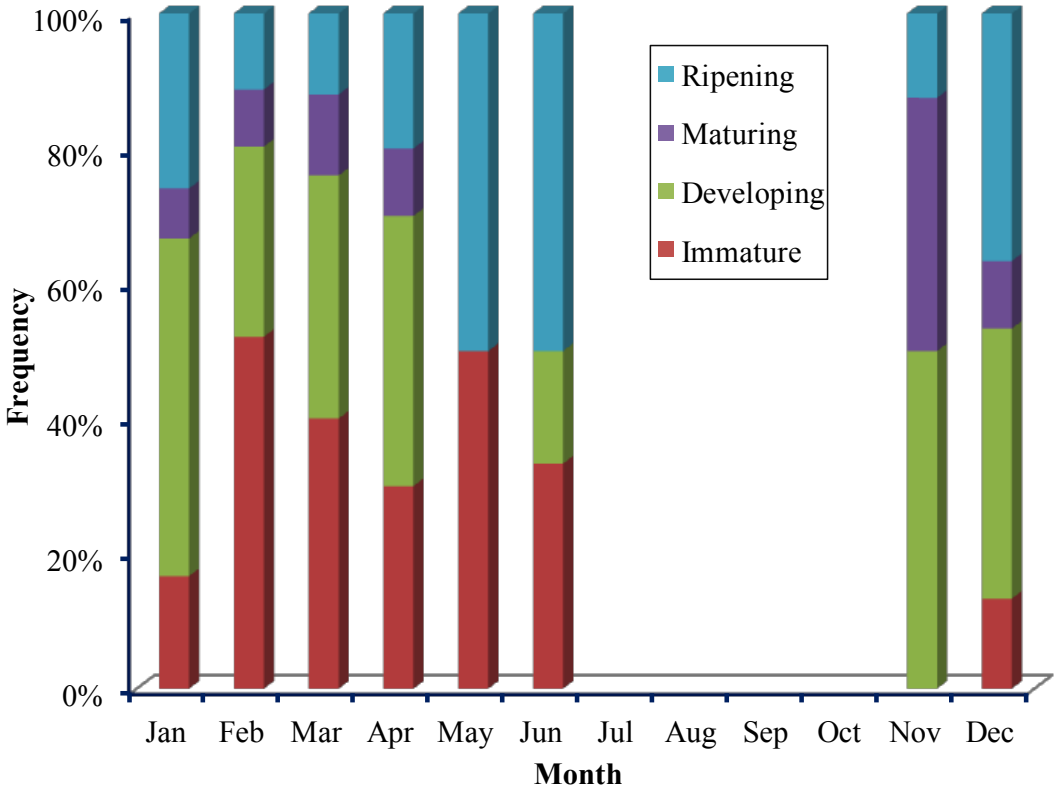

Figure 7. Monthly proportions of four maturity stages for female longtail tuna collected from the waters off Taiwan.

Table 1. Numbers of female and male longtail tuna sampled during each month, monthly sex ratios, and chi-square values assuming a 1:1 sex ratio in each monthly interval

Month	Female	Male	Sex ratio	Chi-square Value	*P* value		DF
Jan	44	48	0.48	0.173913043	0.67666		1
Feb	41	35	0.54	0.473684211	0.4913		1
Mar	21	25	0.46	0.347826087	0.55535		1
Apr	21	23	0.48	0.090909091	0.76302		1
May	13	12	0.52	0.04	0.84148		1
Jun	5	5	0.50	1.5708E-18	1		1
Jul	--	--					
Aug	--	--					
Sep	--	--					
Oct	--	--					
Nov	18	35	0.34	5.452830189	0.01954	**	1
Dec	68	83	0.45	1.490066225	0.22221		1
Total	231	266	0.46	2.464788732	0.11642		8
**Significant at 5% level							
-- No sample							