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Reproduction, age and growth of *Sillago maculata* in south-eastern Australia

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Summary

Sillago maculata is endemic to the east coast of Australia where it is harvested by recreational and commercial fishers; however, little is known of the important aspects of its biology and ecology to assist with fisheries management planning. This situation is redressed here by investigating aspects of the reproduction, age and growth of estuarine populations of *S. maculata* in south-eastern Australia. Gonadosomatic index (GSI) values indicated peak spawning occurred between September and February and that the estimated mean fork length at maturity (L_{50}) was 14.6 cm for males and 15.2 cm for females. Females displayed an asynchronous pattern of oocyte development, with individuals probably spawning multiple times in a spawning season. A validated aging protocol using thin sectioned otoliths was used to estimate the age of fish. The maximum ages for males and females were 9.5 and 12.0 years, respectively. Growth differed between sexes, with males ($L\infty = 24.04$, $K = 0.70$, $t_0 = -0.09$) attaining a smaller maximum length than females ($L\infty = 25.01$, $K = 0.72$, $t_0 = -0.04$). The age composition of gill-net and beach-seine samples mainly consisted of individuals aged 2–4 years, and there was evidence of variable recruitment. Management implications are also discussed.

Introduction

The family Sillaginidae (whiting) consists of 31 species that occur in coastal and estuarine waters throughout the Indo-west Pacific (McKay, 1992). Thirteen species occur in Australian waters, and aspects of the biology and ecology of several species have been investigated. This is particularly true for coastal species in western and southern Australia (Hyndes and Potter, 1996, 1997; Hyndes et al., 1998; Fowler et al., 2000; Coulson et al., 2005). In contrast, little biological information exists for estuarine and coastal species in south-eastern Australia (but see Burchmore et al., 1988), even though several species are important in commercial and recreational fisheries (McKay, 1992; Kailola et al., 1993).

Sillago maculata Quoy and Gaimard, 1824 (trumpeter whiting) is endemic to the east coast of Australia, between Cape York and the Gippsland Lakes, where it is commonly found in estuaries and coastal embayments (McKay, 1992). Small juveniles generally inhabit shallow littoral waters, and move to deeper waters as they grow (Weng, 1986; Miskiewicz, 1987; Burchmore et al., 1988). Both juveniles and adults are benthic carnivores and consume mainly crustaceans and polychaetes (Burchmore et al., 1988).

Sillago maculata are harvested by commercial and recreational fishers throughout their distribution. In New South Wales (NSW) waters, they are primarily caught by commercial fishers using beach-seines (68%) and otter trawls (32%) with reported commercial landings in recent years averaging about 50 tonnes per annum. Although no comparative estimates of total harvests for the recreational sector are available, it was estimated that between 6 and 14 tonnes per year were retained by recreational fishers in one estuary (Lake Macquarie) alone (Steffe et al., 2005).

At present, no specific management arrangements exist for *S. maculata* in NSW, no assessment of the status of *S. maculata* populations has been made and little is known of its biology. In particular, no known studies have investigated the growth and age compositions of populations of *S. maculata* and only one study has investigated aspects of their reproductive biology, but this was restricted to one estuary (Botany Bay; Burchmore et al., 1988). The general aims of this study were to investigate in greater detail aspects of the life history characteristics of *S. maculata*, to assist in the development of sustainable management options. We specifically sampled populations in two estuaries to determine the spawning period and mode, length and age at maturity, patterns of growth, and length and age compositions of harvested populations.

Materials and methods

Study area and sampling procedures

Samples of *S. maculata* were obtained from a study investigating spatial and temporal differences in fish assemblages in Lake Macquarie (LM) (151°36′E, 33°06′S) and St Georges Basin (SGB) (150°36′E, 35°08′S), both shallow, micro-tidal, barrier estuaries (Roy et al., 2001) (Fig. 1).

Fish were sampled using multi-mesh gillnets, with each net (i.e. sampling unit) comprised of seven individual panels of netting of different stretched mesh sizes (36, 44, 54, 63, 76, 89 and 102 mm). Each panel was 50 m in length except for the 36 and 44 mm meshes, which were 20 m in length. A total of 12 nets were set across shallow seagrass (< 2 m), and shallow and deep bare substrata (< 2 m and > 4 m, respectively), at two locations within 2 km of the entrance channel in each estuary on a monthly basis between August 2004 and July 2005. Further samples were collected bi-monthly until November 2005 in SGB. All sampling was done between the first and last quarter of the moon and it took four nights to sample each estuary. All nets were bottom-set upon dusk (17.00–21.00 h, depending on time of year) and retrieved 1 h later.

All *S. maculata* caught were measured (nearest 0.5 cm fork length; FL) and approximately 30 specimens were retained from both LM and SGB each month for reproduction and age analyses. To enhance the size ranges of samples for analyses of length at maturity and growth, additional specimens were also collected using beam trawls and seine nets from Port Hacking,

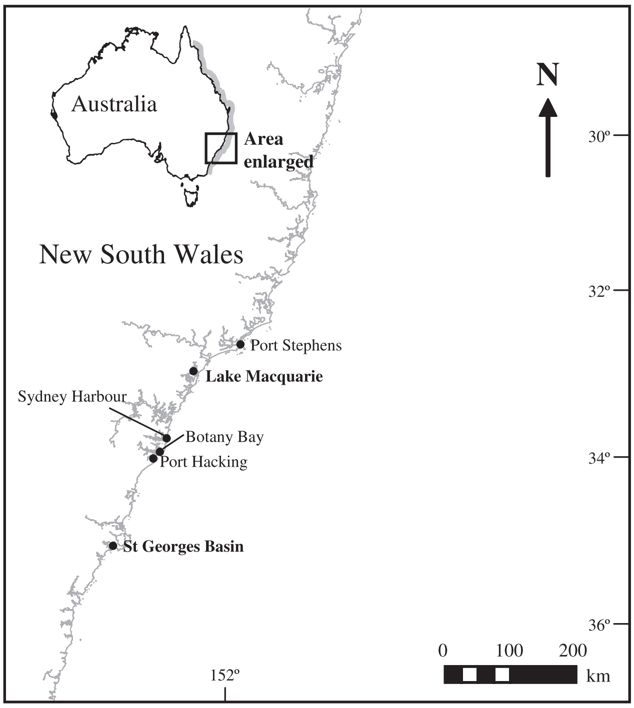


Fig. 1. Map of Australia showing approximate distribution of *S. maculata* along eastern Australia (in grey) and locations of estuaries in south-eastern Australia mentioned in the text

(n = 25), Port Stephens (n = 52), Sydney Harbour (n = 16), and Tuggerah Lakes (n = 47).

Reproductive biology

For each retained fish, information on the date and location of capture, weight (nearest 0.1 g), length (FL, nearest 0.1 cm), sex (macroscopic determination based on presence of ovaries or testes) and stage of gonad development was recorded. Stage of gonad development was based on the criteria outlined in Haddy and Pankhurst (1998); for males: I = immature; II = spermatogenic; III = partially spermiated; IV = fully spermiated; V = spent; for females: I = immature; II = regressed; III = vitellogenic; IV = hydrated; V = ovulated; VI = spent. Gonads were removed and weighed (0.1 g) and the Gonadosomatic index (GSI) was calculated using the following equation:

$$\text{GSI} = (\text{gonad mass}/\text{fish mass}) \times 100$$

The GSI values and macroscopic staging patterns (of individuals larger than the estimated length at maturity – L_{100}) were used to estimate the spawning season in LM and SGB. Elevated GSI values and high proportions of stage III and IV (and V for females) individuals were interpreted as probable spawning.

The length at sexual maturity was estimated for males and females from gonad stage assignments. Gonads staged III–VI were defined as mature and gonads staged I collected during the estimated spawning season were defined as immature; they were considered incapable of spawning during that particular spawning season. The proportion of fish assigned as being mature in each 1 cm length-class was calculated and logistic curves were then fitted to the data using a non-linear least squares procedure (Solver sub-routine in Microsoft Excel 2003). The length at which 50 and 100% (L_{50} and L_{100}) of individuals were mature was determined from the equation of the fitted logistic curve. This was determined separately for each sex from samples combined across all locations, as insufficient data was available to do meaningful analyses for each estuary.

Patterns of oocyte development were examined from the ovaries of five stage III individuals. Individual oocytes were removed from each gonad and placed in a Petri-dish. The diameters of 200 oocytes chosen at random were then measured (mm) using a scanner and IMAGE J (version 1.0) image analysis software.

Age and growth

Two sagittal otoliths were extracted from each retained fish, cleaned, dried, and stored in envelopes (minimum 3 days) prior to processing. One otolith from each pair was embedded in a block of clear resin and a transverse section 300 μm thick was taken through the core perpendicular to the long axis using a Gemmasta Saw. Sections were mounted with resin on a glass slide for viewing.

Age estimates were made by examining the sectioned otoliths under a compound microscope with reflected light against a black background. The opaque zones visible in the internal structure of the otolith were counted along a radius from the primordium to the outer edge of the ventral lobe. All sections were read without knowledge of the sample details (i.e. length, location, date of capture). About 2 months after the initial reading, 200 otoliths were drawn at random and read a second time to assess reader variability in assigning age. The coefficient of variation (CV) for the two readings for each otolith was calculated and an average across all otoliths was obtained using the method described in Kimura and Lyons (1991) and Campana (2001).

Marginal increment analyses (MIA) were used to examine the periodicity of opaque zone formation in otoliths. Measurements were made from the core of the sectioned otolith to each successive opaque zone and to the otolith edge along the ventral edge of the sulcus. These were made using a microscope mounted video camera interfaced with a computer running 'IMAGE PRO PLUS' image analysis software. The Marginal increment (MI) was defined as: for fish with one opaque zone, the distance from the first opaque zone to the otolith edge as a proportion of the distance from the core to the first opaque zone; for fish with ≥2 opaque zones, the distance from the most recently completed opaque zone to the otolith edge as a proportion of the last completed increment.

Counts of opaque zones were converted into age estimates (years and months) using the ageing protocol developed during this study (see Results). These age estimates were then used to model the growth of each sex in LM, SGB, and all locations combined, using the von Bertalanffy Growth Function (Von Bertalanffy, 1938). Differences in growth curves for *S. maculata* were assessed using the technique of Kimura (1980), where 95% confidence ellipses were generated around the parameter estimates of K and $L\infty$. Confidence ellipses that did not overlap indicated significant differences in growth. The parameter t_0 was constrained to 0 for these analyses.

Age composition

During March and June 1996 in SGB, and February 1997 in LM, *S. maculata* from commercial beach-seine catches were measured for FL (0.5 cm). Of these, a random sample of 150 fish from SGB, and 192 fish from LM, had their otoliths removed allowing their age to be estimated. These fish were used to estimate the age composition of these populations, allowing a comparison with the 2004 ⁄ 5 samples.

Estimates of the age composition of populations were made using the length composition (Fig. 9) and age-length-keys constructed for each sample (i.e. LM – 1997 and 2004 ⁄ 5 and SGB – 1996 and 2004 ⁄ 5) using the estimates of length at age determined.

Results

A total of 267 *S. maculata* were caught in the monthly gill-net samples of LM (193) and SGB (74) between August 2004 and July 2005. Of these, most fish were caught from the deep (> 4 m) substrata (LM = 74.1%, SGB = 73.0%), in mesh sizes 36 mm (41.9%), 44 mm (34.4%) and 54 mm (15.7%).

Reproduction

A total of 539 *S. maculata*, collected from all locations were examined for reproductive analyses. Of these, 32 were juveniles, 251 were males and 256 were females.

Changes in GSI values were similar for males and females in both estuaries, with peak values occurring from September to January in LM and October to February in SGB (Fig. 2). The maximum individual GSI was 6.6% for males and 10.0% for females. Macroscopic staging patterns were also similar in both estuaries with stage III males present from November to May, and stage III and IV females present from November to May with highest proportions from November to March (Fig. 3).

The estimated length at maturity (L_{50} and L_{100}) for males was slightly smaller than for females: 14.6 and 15.2 cm FL, respectively (Fig. 4). The smallest mature male was 13.3 cm and the female 14.0 cm FL. Both males and females began maturing at approximately 1 year (56 and 38%, respectively), with most individuals mature by 2 years (96 and 80%, respectively), and all individuals mature by 3 years.

Vitellogenic (stage III) ovaries contained a broad batch of oocytes ranging in diameter from 0.025 to 0.550 mm. In all samples, a peak at approximately 0.050–0.100 mm was present, and in b, c, and e a second peak at about 0.350 mm was also present (Fig. 5). All individuals showed evidence of asynchronous oocyte development.

Age and growth

A total of 526 individuals were examined for age estimation and analyses of growth. Otoliths had clear patterns of alternating translucent and opaque zones and counts of

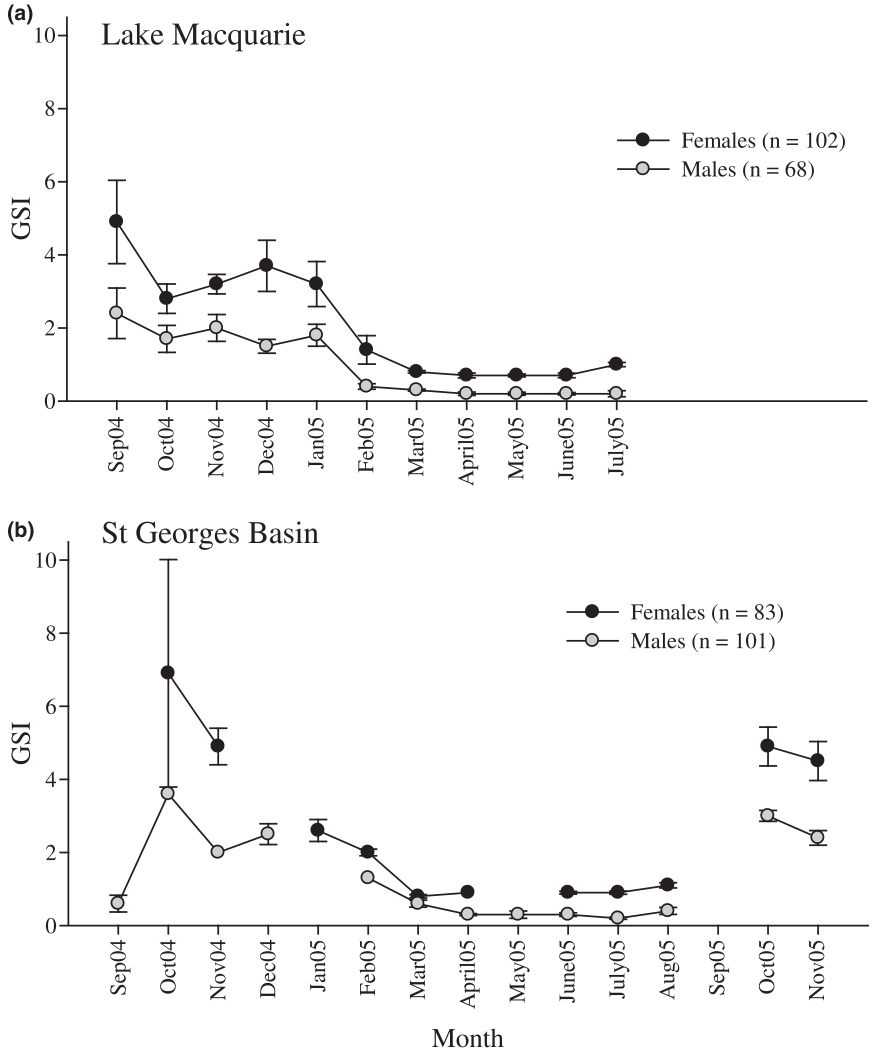


Fig. 2. Sample gonadosomatic indices (mean GSI ± SE) from male and female *S. maculata* collected from (a) Lake Macquarie (monthly sample sizes ranged from n = 1 to n = 22) and (b) St Georges Basin (monthly sample sizes ranged from n = 3 to n = 17)

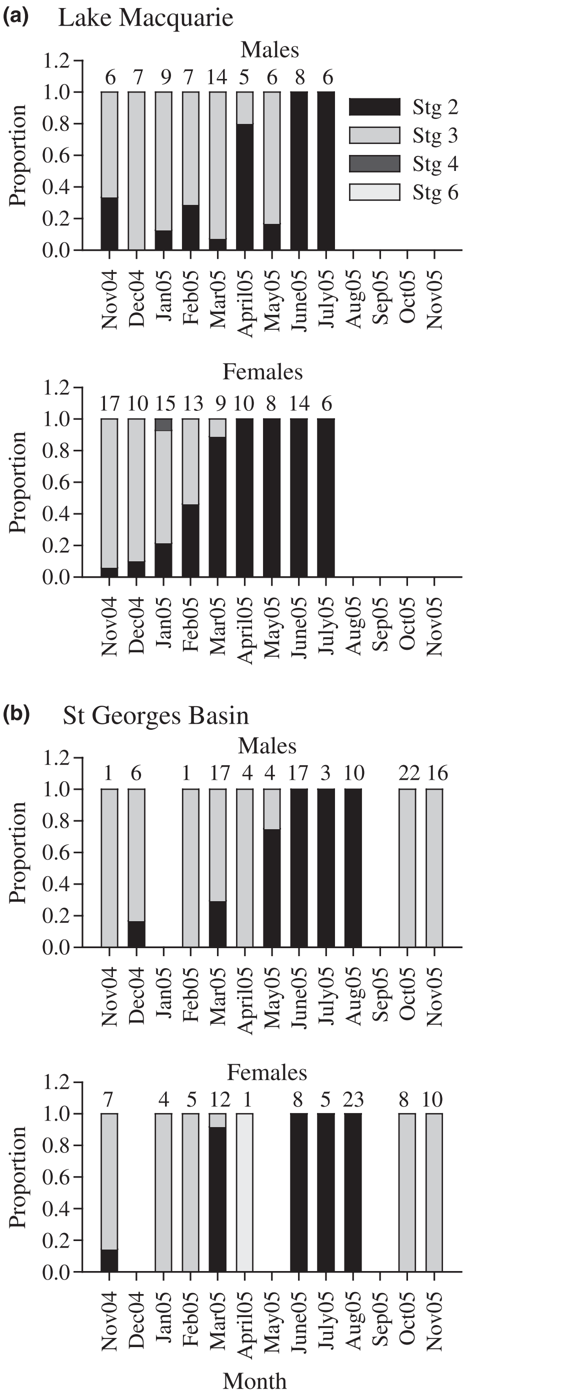


Fig. 3. Monthly gonad stages for male and female *S. maculata* collected from (a) Lake Macquarie and (b) St Georges Basin. Sample sizes given above the bar for each month

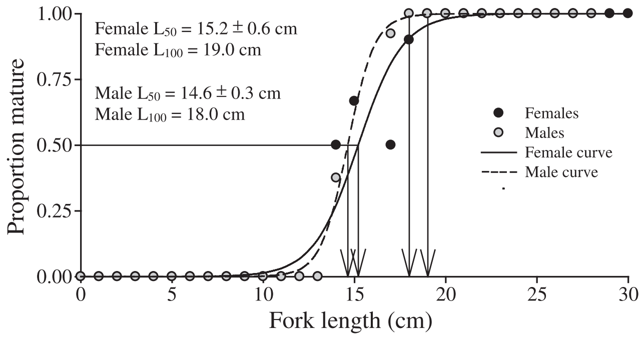


Fig. 4. Logistic curves showing 50% (L_{50}) and 100% (L_{100}) length at maturity for male (n = 184) and female (n = 135) *S. maculata*

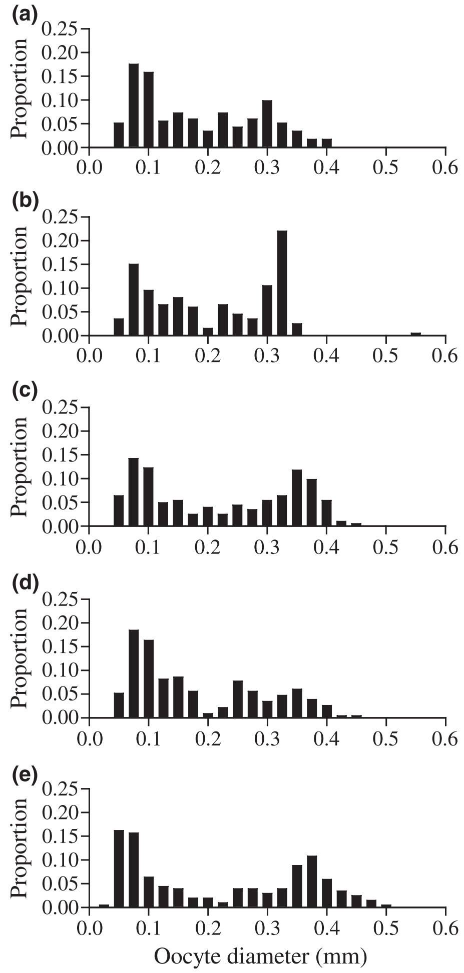


Fig. 5. Oocyte diameter frequency distribution taken from five *S. maculata* ovaries (a–e) (stage III – vitellogenic). Sample sizes range from n = 200 to n = 234

opaque zones were assigned to all individuals examined, ranging from 0 to 12. Agreement between comparative counts of opaque zones was 94.5%. The small level of inconsistency was due to misinterpretation of: (i) a newly formed ring (edge) 54.5% and (ii) the first ring (45.5%). The CV averaged across all ages was 0.01.

MI values were lowest from November to January (Fig. 6), indicating that newly deposited opaque zones are first visible during this period (spring / early summer). This pattern was visible in fish of all age-classes (Fig. 6). The mean distance from the core to the middle of the first opaque zone for all *S. maculata* with one or more opaque zones was 0.60 mm (± 0.06 SD).

Using the date of capture, an assigned birth date of 1 November (based on GSI values – see Results), and MI values, counts of opaque zones were converted to estimates of age in years and months. Because not all individuals deposited opaque zones (annual increments) at exactly the same time, a protocol was developed to assign an individual into its most likely year class for the period from September to December, the period when individuals generally have relatively large or relatively small MI values (Fig. 6). Otoliths were assigned an edge status of wide, medium or narrow (Table 1). For individuals collected in September and October and assigned

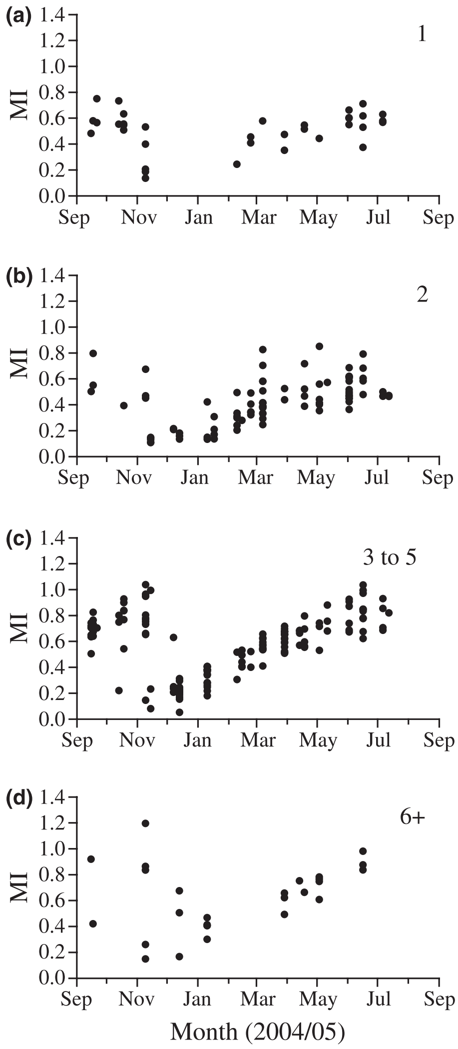


Fig. 6. Marginal increment plots for *S. maculata* with (a) one opaque zone (n = 39); (b) two opaque zones (n = 116); (c) three to five opaque zones (n = 180); and (d) six or more opaque zones (n = 27)

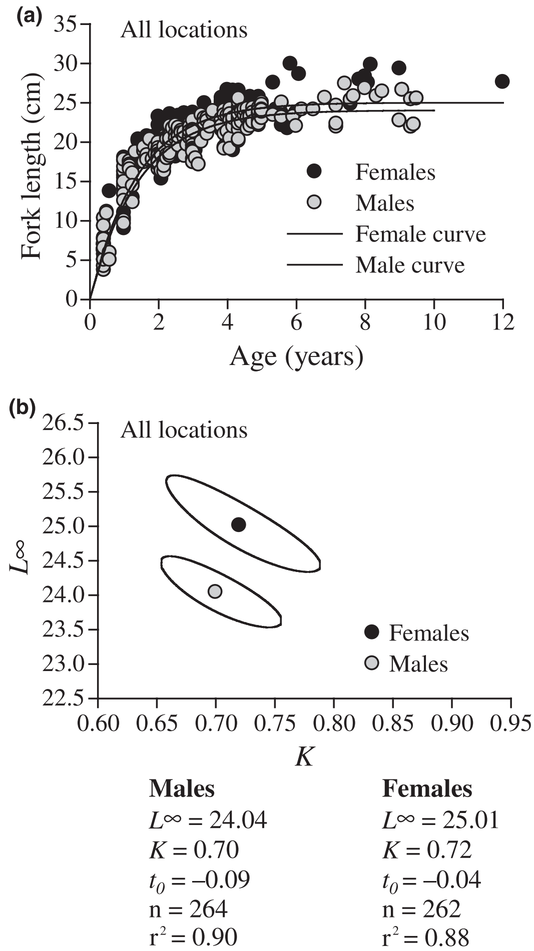


Fig. 7. (a) Size-at-age data for male and female *S. maculata* collected from all locations combined. (b) 95% confidence ellipses are given for parameters *K* (growth coefficient) and $L\infty$ (mean asymptotic length)

a narrow edge status, a 1 was deducted from the number of opaque zones counted for age assignment. Similarly, for individuals collected in November and December and assigned a wide edge status, a 1 was added to the number of opaque zones counted for age assignment.

Males and females grew quickly until approximately 2 years of age, after which the rate of growth slowed (Figs 7a and 8a,b). Males on average attained a smaller maximum length than females, and the observed maximum lengths 27.4 and 29.9 cm FL, respectively (Fig. 7a). The oldest male was estimated to be 9.5 years and the female 12.0 years (Fig. 7a). The confidence ellipses around the growth parameters indicated that growth of *S. maculata* differed between sexes (Fig. 7b), but not between populations in LM and SGB (Fig. 8c).

Table 1
Classification of *Sillago maculata* otolith edges

S. maculata	Edge status		
No. of opaque zones	Wide	Medium	Narrow
0	N/A	N/A	N/A
1	MI > 0.4	0.3 < MI < 0.4	MI < 0.3
2	MI > 0.4	0.3 < MI < 0.4	MI < 0.3
3–5	MI > 0.6	0.3 < MI < 0.6	MI < 0.3
6+	MI > 0.6	0.3 < MI < 0.6	MI < 0.3

MI is marginal increment as defined in the text.

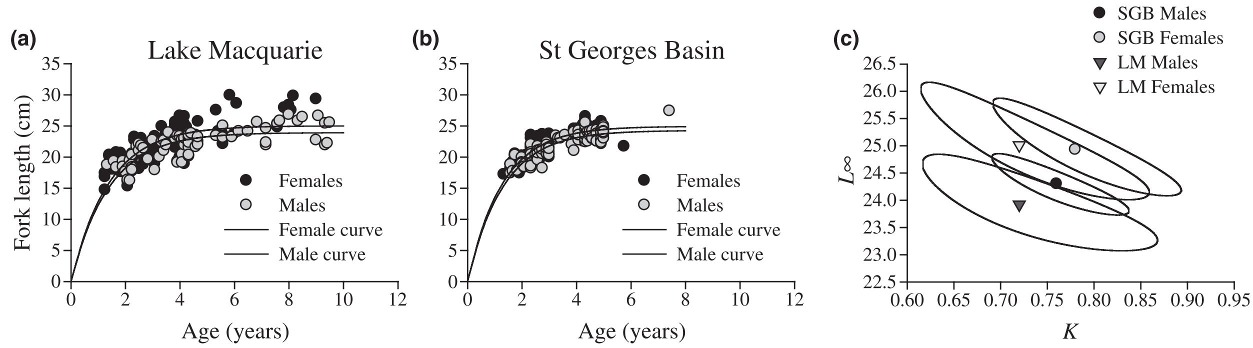
Length and age compositions

The length composition of all samples was dominated by fish approximately 17–25 cm FL (Fig. 9). The estimated age compositions of samples displayed differences between years (1996/7 and 2004/5) and estuaries. In LM, in 1997 retained fish ranged from 1 to 7 years with the catch dominated by 2-year-olds, whereas in 2004/05 sampled fish ranged from 1 to 9 years, with most fish 2–4 years of age (Fig. 9a). In SGB, in both years there were strong and weak age classes. In 1996, retained fish ranged from 1 to 6 years, dominated by 2-year-old fish. In 2004/05, sampled fish ranged from 1 to 7 years with 2- and 4-year-olds the most abundant year-classes (Fig. 9b).

Discussion

Reproduction

The peak spawning period of *S. maculata* was similar in LM (September–January) and SGB (October–February) and concurs with that previously observed for *S. maculata* in Botany Bay (October–April; Burchmore et al., 1988). This timing (spring/summer) is also consistent with spawning periods observed in other silliginids in south-eastern and south-western Australia, and Japan (Table 2). This coincides



Males	Females	Males	Females
$L\infty = 23.92$	$L\infty = 25.01$	$L\infty = 24.27$	$L\infty = 24.93$
$K = 0.72$	$K = 0.72$	$K = 0.76$	$K = 0.78$
$T_0 = 0$*	$T_0 = 0$*	$T_0 = 0$*	$T_0 = 0$*
n = 76	n = 117	n = 101	n = 78
$r^2 = 0.57$	$r^2 = 0.57$	$r^2 = 0.75$	$r^2 = 0.72$

Fig. 8. Size-at-age data for male and female *S. maculata* collected from (a) Lake Macquarie and (b) St Georges Basin. (c) 95% confidence ellipses are given for S parameters *K* (growth coefficient) and $L\infty$ (mean asymptotic length)

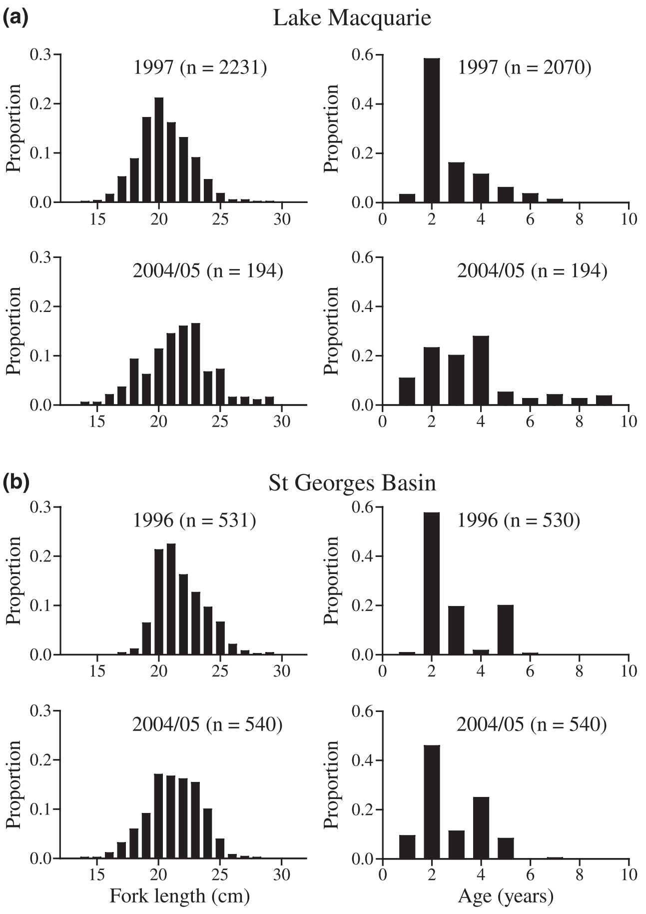


Fig. 9. Length and age compositions of *S. maculata* populations in (a) Lake Macquarie (1997 and 2004/5) and (b) St Georges Basin (1996 and 2004/5). Age compositions estimated using separate age-length-keys for each estuary in each year

with periods of increasing/maximum water temperatures and photoperiods (Bell, 1980; Hyndes and Potter, 1996), indicating that these environmental factors may trigger reproductive development.

The estimated length at maturity (L_{50} and L_{100}) of *S. maculata* was slightly greater for females than males, which is consistent with some other silliginids (Table 2). This is likely related to differences in their growth rates. The estimates of length and age at maturity of *S. maculata* were also within the range documented for other sillaginids (Table 2). Our estimated mean lengths at maturity (L_{50}) were less than those reported for *S. maculata* in Botany Bay (Burchmore et al., 1988) even though both studies used very similar methodology (macroscopic stages and analyses). We could not ascertain why these estimates varied so much, but it may be related to spatio-temporal variations among populations; our samples were pooled from a number of locations.

The oocytes of *S. maculata* developed in an asynchronous pattern, indicating that individuals have indeterminate fecundity and are likely to spawn multiple times in a spawning period (De Vlaming, 1983; Hunter and Macewicz, 1985; West, 1990). This concurs with the findings of previous studies on a number of silliginids (Hyndes and Potter, 1996; Hyndes et al., 1996) and supports the hypothesis by Hyndes and Potter (1997) that silliginids are typically multiple spawners. This spawning strategy allows fish to increase the number of eggs produced in a spawning period (Burt et al., 1988), and can also aid in buffering adverse biotic and abiotic fluctuations, such as water temperature, food availability and predation (Lambert and Ware, 1984). We could not determine the frequency and number of spawnings by an individual throughout the spawning season. Thus the total number of eggs that each individual produces in a spawning season (total fecundity) could not be estimated (Hunter and Macewicz, 1985).

Age and growth

Counts of opaque zones on thin sectioned otoliths were an effective, and validated, method for estimating the age of *S. maculata*. The alternating opaque and translucent zones were clearly visible and allowed for high levels of repeatability of age estimation.

Table 2
Summary of aspects of reproductive biology of a number of Silliginidae

Species	Location	Spawning season	Length at maturity (cm) Male; Female	Age at maturity (years)	Mode of spawning	Author
S. aeolus	Japan	Feb–May	11.3; 12.0 SL (smallest mature)	1–2	Multiple	Rahman and Tachihara (2005a)
S. analis	West Australia	Jan–Mar	18.4; 21.6 TL (L_{50})	1–3		Coulson et al. (2005)
S. bassensis	West Australia	Sep–April	20.0; 20.0 TL (L_{50})	3		Hyndes and Potter (1996)
S. burrus	West Australia	Dec–Jan	12.0; 13.0 TL (L_{100})	1	Multiple	Hyndes et al. (1996)
S. ciliata	East Australia	Dec–April	24.0; 24.0 FL (L_{50})			Burchmore et al. (1988)
S. flindersi	East Australia	Not defined	14.0; 14.0 FL (L_{50})			Burchmore et al. (1988)
S. maculata	East Australia	Sep–Mar	14.6; 15.2 FL (L_{50})	1–3	Multiple	This Study
S. maculata	East Australia	Oct–April	19.0; 19.0 FL (L_{50})			Burchmore et al. (1988)
S. punctata	South Australia	Not defined	32.0 TL (smallest mature)	≥3		Fowler et al. (2000)
S. punctata	West Australia	Jun–Sep	41.0 TL (L_{50}) – F only	3–4	Multiple	Hyndes et al. (1998)
S. robusta	East Australia	Not defined	17.0; 18 FL (L_{50})			Burchmore et al. (1988)
S. robusta	West Australia	Dec–Mar	12.0; 12.3 TL (L_{50})	1–2		Hyndes and Potter (1996)
S. schomburgkii	West Australia	Aug–Dec	19.5; 22.3 TL (L_{50})	2		Coulson et al. (2005)
S. schomburgkii	West Australia	Dec–Feb	20.0; 20.0 TL (L_{50})	2–3	Multiple	Hyndes and Potter (1997)
S. vittata	West Australia	Nov–Feb	13.0; 16.0 TL (L_{100})	1–2	Multiple	Hyndes et al. (1996)

L_{50}, length at 50% maturity; L_{100}, length at 100% maturity.

Assuming all fish were born between September and February (based on GSI values), the MIA indicated the first opaque zone was generally first visible the following November or December when fish were approximately 9–14 months old. The MIA also indicated that newly formed opaque zones were visible annually between October and December throughout the entirety of an individuals' life. This spring/early summer timing is very similar to that observed for silliginids both in Australia (Hyndes et al., 1996; Hyndes and Potter, 1997; Fowler and Short, 1998) and Japan (Sulistiono et al., 1999; Rahman and Tachihara, 2005b).

Growth of *S. maculata* was relatively rapid for the first 2 years, and slowed thereafter. This reduction in growth rate coincided with the age at first maturity, indicating that once maturity is reached, much of the available energy is used for reproduction rather than for somatic growth. Compared with the growth of other sillaginids, *S. maculata* are a small- to medium-sized species with a pattern of growth most similar to *S. analis* (Table 3).

Female *S. maculata* grew faster and attained a larger maximum length than males, a common pattern observed among other sillaginids, including *S. aeolus* (Rahman and Tachihara, 2005b), *S. analis* (Coulson et al., 2005), *S. punctata* (Hyndes et al., 1998) and *S. schomburgkii* (Coulson et al., 2005).

The maximum age estimated for *S. maculata* was 12 years; this is in the upper range reported for related species in western and southern Australia (Table 3). As the largest fish examined in this study (29.9 cm FL or 31.7 cm TL) was similar to the maximum reported length of *S. maculata* (30 cm TL; McKay, 1992), we assume that 12 years is a reasonable estimate of longevity for this species.

Length and age composition

Catches of *S. maculata* in our multi-mesh gillnets (2004/5 samples) and in the retained component of commercial beach-seines (1996/7 samples) were dominated by fish 18–25 cm FL aged 2–4 years. This dominance of young individuals has also been observed in the age structures of other harvested sillaginids both in Australia and Japan: *S. vittata* and *S. burrus* (Hyndes et al., 1996), *S. robusta* (Hyndes and Potter, 1996; Butcher and Hagedoorn, 2003), *S. schomburgkii* (Hyndes and Potter, 1997), *S. japonica* (Sulistiono et al., 1999) and *S. aeolus* (Rahman and Tachihara, 2005b).

The strong and weak cohorts we observed in the age compositions of populations indicate that recruitment is variable in space and time, particularly in SGB. Such variation makes it difficult to accurately estimate the instantaneous total mortality (Z) using catch curve analyses, unless a long time-

Table 3
Summary of von Bertalanffy growth parameters for a number of Silliginidae

Species	Location	Maximum age	$L\infty$ (M,F)	K (M,F)	t_0 (M,F)	Author
S. aeolus	Japan	4	21.0, 29.8 SL	0.7, 0.42	0.58, 0.61	Rahman and Tachihara (2005b)
S. analis	West Australia	8	25.4, 28.0 TL	0.75, 0.72	0.12, 0.09	Coulson et al. (2005)
S. bassensis	West Australia	9	30.7, 32.9 TL	0.29, 0.26	−0.75, −0.80	Hyndes and Potter (1996)
S. burrus	West Australia	4	17.9, 18.8 TL	2.44, 2.37	0.00, 0.01	Hyndes et al. (1996)
S. japonica	Japan	4	34.2, 46.9 TL	0.25, 0.17	–	Sulistiono et al. (1999)
S. maculate	East Australia	12	24.0, 25.0 FL	0.70, 0.72	−0.09, −0.04	This Study
S. parvisquamis	Japan	–	33.3, 28.9 TL	0.58, 0.64	–	Imoto et al. (1997)
S. punctata	West Australia	14	50.0, 53.2 TL	0.53, 0.47	0.16, 0.13	Hyndes et al. (1998)
S. robusta	East Australia	5	22.2 FL	0.48	−1.27	Butcher and Hagedoorn (2003)
S. robusta	West Australia	6	17.2, 16.9 TL	0.98, 1.03	−0.04, −0.11	Hyndes and Potter (1996)
S. schomburgkii	West Australia	9	29.0, 34.6 TL	0.59, 0.48	0.01, −0.01	Coulson et al. (2005)
S. schomburgkii	West Australia	12	32.5, 33.3 TL	0.49, 0.53	−0.22, −0.16	Hyndes and Potter (1997)
S. vittate	West Australia	7	31.2, 33.1 TL	0.45, 0.43	−0.23, −0.21	Hyndes et al. (1996)

M, male; F, female.

series of data are available. Nevertheless, the length and age composition of samples collected 8–9 years apart, suggest that the population structure in LM and SGB remained stable throughout this period.

Management implications

Minimum legal lengths (MLLs) are often used in fisheries management regulations to protect a proportion of the population from exploitation. Often, the MLL is set at the L_{50} or L_{100} to allow some individuals to spawn prior to harvesting; this would correspond to 15 cm FL and 19 cm FL, respectively, for *S. maculata*. However, prior to any such implementation, other factors need to be considered, including the selectivity of fishing gear, and rates and release mortalities of discards.

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