

Reproductive cycle and growth of *Phyllopteryx taeniolatus*

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In this study, 36 males, 33 females and 15 juveniles of the common or weedy seadragon *Phyllopteryx taeniolatus*, a syngnathid fish endemic to the waters of southern Australia, were identified using visual implant fluorescent elastomer tags and pattern of appendages and their reproductive cycle and growth was studied from May 2001 to June 2002. Brooding males were present for a period of >6 months, from June–July to early-January. The percentage of males that were pregnant in the studied areas peaked in November–December, near the end of the breeding season. Two pregnancies were reported for some males. Ten recruits were identified from November to June. Growth rates for young-of-the-year, young of the previous year, males and females were measured. The von Bertalanffy growth constant K was estimated at 0.098 month^{-1} .

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Key words: breeding season; common or weedy seadragon; elastomer tagging; recruitment period; syngnathid.

INTRODUCTION

The common or weedy seadragon *Phyllopteryx taeniolatus* (Lacépède) is the only member of the genus *Phyllopteryx* (Family Syngnathidae) and, along with the leafy seadragon *Phycodurus eques* (Günther), are the only representatives of what are commonly known as seadragons. The Syngnathidae, which also includes seahorses, pipefishes and pipehorses, is unique among fishes with males incubating the eggs deposited by the female in a specialized incubation area or brood pouch on either the tail or the trunk of the male (Herald, 1959).

Studies on Syngnathidae reproduction have focused on sexual behaviour (Berglund, 1993; Kvarnemo *et al.*, 2000; Masonjones & Lewis, 2000) and the description of the mating systems (Jones & Avise, 2001; Wilson *et al.*, 2001; Poortenaar *et al.*, 2004). Syngnathidae growth studies have addressed survival rates and growth of captive specimens under different diets (Payne *et al.*, 1998; Payne & Rippingale, 2000; Woods, 2000; Wong & Benzie, 2003). Studies on wild

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specimens were based on captured individuals (Bayer, 1980; Howard & Koehn, 1985; Lazzari & Able, 1990; Takahashi *et al.*, 2003). Very few studies have been based on observations *in situ* (Gronell, 1984; Vincent & Sadler, 1995). Amongst the syngnathids, seahorses are the best-studied taxon, but there are few data for seahorses on growth rates in captivity and even fewer in the wild (Foster & Vincent, 2004). One of the limitations has been that the unusual syngnathid morphology of body plates makes the use of reliable long-term tagging techniques difficult (Woods & Martin-Smith, 2004). There are also no validated ageing methods (Foster & Vincent, 2004).

The common seadragon is listed by the World Conservation Union (IUCN) as data deficient (Vincent, 1996) meaning that insufficient information is available to make an assessment of the species' risk of extinction. Habitat degradation (Kuitert, 1988; Sanchez-Camara & Booth, 2004) and over-collecting for the marine aquarium fish trade (Pogonoski *et al.*, 2002) have been identified as the main threats for seadragon populations. Kuitert (1988) briefly describes the reproductive ecology and growth of common seadragon of Victoria but without explaining the material and methods used. A database analysis based on forms sent by divers reported brooding males from July to January in New South Wales (NSW) (Baker, 2000a) and from August to February in South Australia (Baker, 2000b). Recently, Sanchez-Camara & Booth (2004) described movement, home range and site fidelity of this fish suggesting well-defined home ranges occasionally altered due to reproductive behaviour necessities. The reproduction and growth of *P. taeniolatus* has not yet been specifically addressed.

The aim of this study was to provide specific information on the reproductive cycle and growth of the common seadragon in their natural environment using a non-destructive method of *in situ* monitoring. Firstly, the duration of the breeding cycle, the peak breeding times and the recruitment period were determined. Secondly, other important observations related to reproduction such as pregnancies per season, duration of pregnancies and intervals, size and age of first maturity were noted. Thirdly, average and maximum adult sizes and a growth equation for common seadragons were estimated.

MATERIAL AND METHODS

STUDY SPECIES

The common seadragon is distributed from Port Stephens, NSW, on Australia's eastern coast to Geraldton, Western Australia, on Australia's western coast, including the waters around Tasmania (Hutchins & Swainston, 1986). The fish have elongated non-prehensile tails and can grow up to 45 cm in standard length (L_S). Males care for the eggs which they fertilize and incubate on the outside of the tail with each egg partially embedded in the skin (Kuitert, 2000). Common seadragon live among the larger algae and feed mainly on mysid crustaceans (Edgar, 2000).

STUDY SITES

Tagging and observation took place at three sites around Sydney, NSW, Australia. Site 1 was at Kurnell, in the Botany Bay National Park, near the south head of the

bay [Fig. 1(a)]. It consisted of a rocky reef formation that extended from near the coastline to *c.* 10–14 m in depth [Fig. 1(b)]. It covered an area parallel to the coastline 350 m in length and 20–50 m in width with a total area of *c.* 10 000 m². The substratum in shallow waters consisted predominantly of large encrusted boulders (barren habitat) and sponge gardens interspersed with some areas of sand and *Sargassum* sp., with a diverse population of temperate reef fishes. Kelp (*Ecklonia radiata*) was abundant from *c.* 8–13 m deep. The kelp zone ended in a gently sloping sand flat.

Site 2 was adjacent to site 1 but was considered separately because it was further inside the bay coinciding with a change in the coastline orientation [Fig. 1(b)] and common seadragon populations of sites 1 and 2 were different (Sanchez-Camara & Booth, 2004). Less exposed than site 1, it was more affected by tide currents, with dead kelp and poor visibility in the area. The transition between the kelp zone and the sand flat varied from 13 to only 5–6 m in depth. The shallower areas were further inside the bay, sheltered from the strong tide currents that affected the rest of the site and the swell that sometimes affected site 2. This shallow zone was fully covered with *E. radiata* and *Sargassum* sp. and, in the sandy areas, *Halophila ovalis* was abundant. Site 2 covered an area 350 m in length and 20–50 m in width with a total area of *c.* 10 000 m².

The third site was at Bondi Beach, only a few kilometres from the Sydney city centre. This site consisted of an exposed reef located between Port Jackson and Botany Bay [Fig. 1(a)]. Shallow areas were mainly covered with boulders. Kelp was less abundant than in sites 1 and 2 and it was patchily distributed near the rock-sand limit. The site extended from *c.* 5 m deep and followed the transition between the sand and the kelp to *c.* 19 m deep. It covered an area similar in size to sites 1 and 2 of *c.* 10 000 m². Several additional surveys were also conducted in areas adjacent or close to the study sites (Fig. 1).

TAGGING AND IDENTIFICATION OF INDIVIDUALS

In total, 92 common seadragon were identified from June 2001 to January 2002, of which 81 were resighted at least once. Seventy of these 92 individuals were tagged using subcutaneous injections of visual implant fluorescent elastomer (VIFE, NorthWest Technologies, Pty. Ltd., U.S.A.) following Beukers *et al.* (1995) and the other 22 common seadragon were identified by natural marks and pattern of appendages. The tagging was done *in situ* by gently restraining the animal with one hand and injecting the tagging material with the other (Sanchez-Camara & Booth, 2004). Required permits were obtained from NSW Fisheries and previous ethics approval was obtained from the University of Technology Sydney/Royal North Shore Hospital Animal Care. No signs of handling stress were observed. Ten recruits (young-of-the-year, YOY) were identified from November 2001 to June 2002 by natural marks and pattern of appendages. Photographs were taken using a Sea & Sea MX10 photo camera to aid in identifying animals. Each identified individual was coded as M (male), F (female), J (juvenile) or Y (YOY) followed by a number.

SAMPLING PROTOCOL

All observations were conducted using SCUBA, from May 2001 to June 2002. Two divers conducted a total of 128 dives over this time completing 290 diver hours. At site 1, 59 dives were conducted from May 2001 to June 2002. At site 2, 39 dives were conducted from August 2001 to June 2002. Eleven dives were conducted at site 3 from December 2001 to June 2002. Nineteen dives were done in areas adjacent to sites 1, 2 and 3. Standardized common seadragon outlines on acetate sheets were taken underwater for making annotations. Temperature was measured on each dive. For each common seadragon observed the

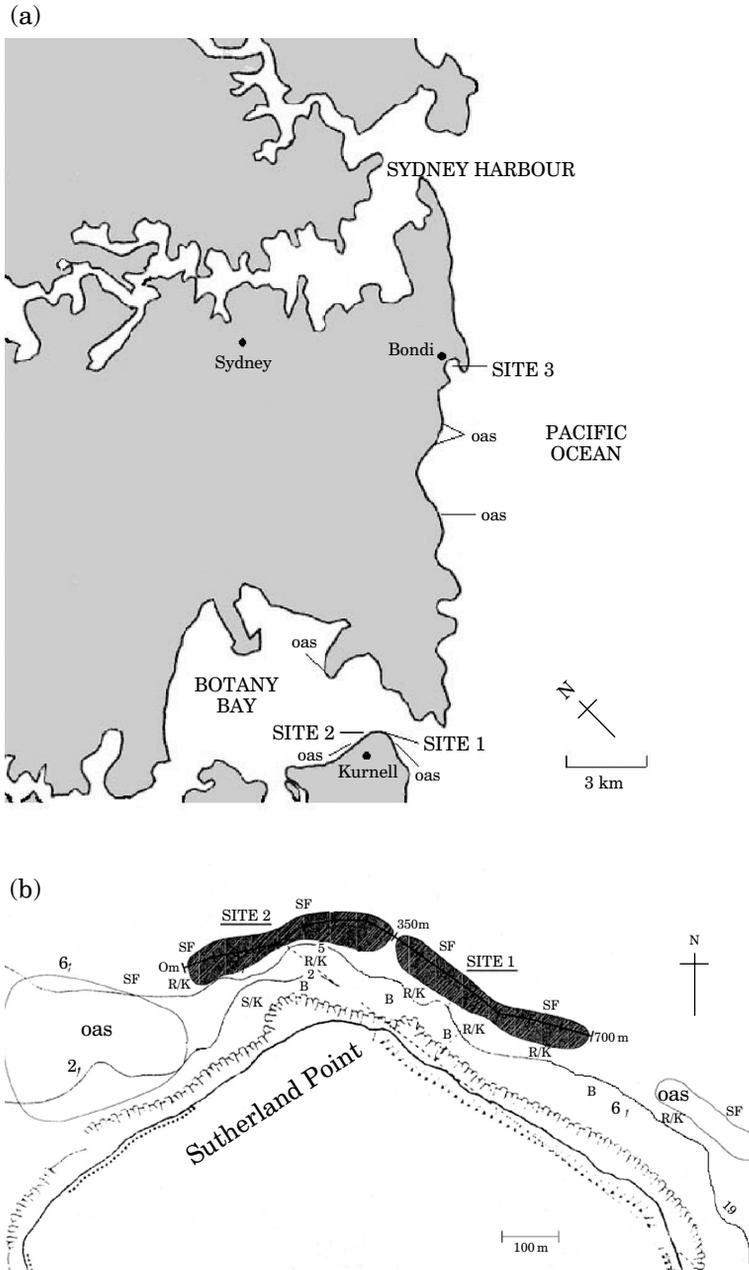


FIG. 1. (a) Sites around Sydney, New South Wales, Australia, where common seadragons were tagged. oas, Other areas surveyed for tagged fish. (b) Detail of sites 1 and 2. (B, boulders; R, rock; S, sand; K, kelp; SF, sand flat.)

sex and the reproductive status were recorded. Tags were checked using an underwater UV torch. Some of the tagged males, females, juveniles and YOY were periodically measured. Natural marks and appendages were noted for tagged and untagged fish.

REPRODUCTIVE CYCLE

It was not possible to externally determine the reproductive status of the females. For each male common seadragon sighted, his reproductive status was noted as: (1) with eggs (with visible incubating eggs); (2) had eggs recently (for a few weeks after having eggs, skin depressions corresponding to the places where the eggs were incubated remained clearly visible on the male's tail); (3) ready to receive eggs (a few days before the transfer of eggs took place the male's tails got wider and thicker and acquired a spongy appearance); (4) no signs of reproductive activity.

GROWTH

Individuals were measured (L_S) by gently placing a 50 cm ruler behind the fish and waiting for the fish to be fully extended. An error of ± 1 cm was estimated from different measurement at the same sampling time. Only one or two measurements were done for most animals to avoid possible stress. Measurements of selected animals taken over time were used to study individual growth. Juveniles were, for this study, those individuals first identified before 4 January 2002 whose sex could not be determined and were the YOY in 2000–2001 (corresponding to the breeding season June 2000 to January 2001). They were individuals of 25–30 cm L_S when first seen. Adults were, for this study, all the common seadragon whose sex could be determined. Males have thinner bodies and thicker tails while females have deeper bodies and thinner tail (P. Quong, pers. com.). Both males and females were >30 cm L_S . The definition of juveniles and adults was an operational one, as many common seadragon probably became adults before their sex could be visually identified.

RECRUITMENT

Recruitment was defined as the presence of YOY in the study sites from November 2001 to June 2002. The YOY were easily distinguished from the other common seadragon because of their size and shape. Juveniles from the previous year were already 30 cm L_S and were starting to be sexually discernible when the new YOY appeared. The YOY had thin bodies and were approximately half the size of the juveniles from the previous year. The YOY also had a pair of appendages on the snout. These snout appendages were generally lost in the adults (only one case of an adult bearing snout appendages was seen in the whole study).

GROWTH ESTIMATION

After trying different models, a von Bertalanffy growth curve (Bertalanffy, 1938) was fitted using measurements of identified recruits and juveniles. Because the length of the study was 1 year and common seadragon reproduction follows a 1 year cycle (Baker, 2000a), the incremental measurement of recruits were used to estimate growth during the first year and measurement of juveniles to estimate growth during the second year. Obviously, juveniles and recruits in the study belonged to different cohorts and the explicit assumption was made that the growth parameters of the two cohorts were roughly equivalent and could be combined. The von Bertalanffy equation has the form (von Bertalanffy, 1938): $L_t = L_\infty(L_\infty - L_0)e^{-Kt}$, where L_t is L_S (cm) of an individual of age t (months), L_∞ is the maximum size attainable and L_0 is the size at hatch. The L_∞ was set to 42 cm as it corresponded with the largest fish measured in this study, L_0 was set to 2.5 cm following Kuiter (1988) and the parameter K was then fitted to the data using a non-linear iterative procedure (NONLIN module of the Systat programme with least squares estimation and the Gauss–Newton algorithm). The exact date of birth of the young was unknown, so age was determined as $t - t_0$ (t_0 , or time of birth, being one of the parameters estimated by the programme). Thus, a common birth date, the one that optimized the overall fit of the model, was assigned to the fish (for juveniles, the same

date, but a year before, was used). Although clearly a simplification, this step was necessary to be able to estimate K . To validate the accuracy of the coefficient K obtained, the equation was applied to the first recruit found, Y1, from which more measurements were taken. Obviously, readings from this individual were not used in the initial parameter estimation.

RESULTS

REPRODUCTIVE CYCLE

At site 1, the first male reported as pregnant in 2001 was from early July. The last pregnant males were seen at this site in mid-December. The number of pregnant males seen per hour of search peaked in July and November. The most were seen in November with an average of 1.1 pregnant males seen per hour [Fig. 2(a)]. The percentage of pregnant to total males peaked also in July and November when *c.* 50% of the males seen were pregnant [Fig. 2(a)]. The time courses of the two variables analysed, pregnant males per hour of search and pregnant to total males seen were similar, indicating that the results were not influenced by differences in sampling effort (number of dives) across dates. Few pregnant males (using both variables) were found at site 1 in October 2001. From January to May 2002, no pregnant males or other indications of sexual activity were observed. In mid-June 2002 one pregnant male was found again at the site.

At site 2, surveys started later than at site 1 (August 2001). The first pregnant male was not found until 1 September, but two males with the tail showing signs of recent pregnancies were found in the area in mid-August, suggesting that some males were pregnant in July. The last pregnant male of the season was seen on 27 December. The number of pregnant males seen per hour of search peaked from October to December [Fig. 2(b)] with a maximum in December when an average of two pregnant males were seen per hour of search. The percentage of pregnant per total males peaked also from October to December with >55% of the males pregnant on each month [Fig. 2(b)]. Both, numbers and percentages peaked during a few days in early December due to the high number of pregnant males (nine tagged males and two further untagged males) seen in the deepest area of the transect. Six of these males and nine more were found in late December in the shallower area of the transect (0–50 m) [Fig. 1(b)]. They were all pregnant or with signs of very recent pregnancies. In fact, from middle December to early January six dives were done and were concentrated in the shallow area of site 2. No other males were seen in this area apart from the 15 pregnant and post pregnant males mentioned.

The total number of pregnant males sightings was higher at site 2 ($n = 37$) than at site 1 ($n = 24$) despite diving effort being similar (134 diver hours at site 1 and 132 diver hours at site 2). The percentage of pregnant per total males and pregnant males seen per hour of search was higher for site 2 than for site 1 from September to December 2001. More tagged males were reported pregnant at site 2 (93%) than at site 1 (50%). Six of the 18 identified males resighted at site 1 were reported to have one pregnancy and three were reported to have two pregnancies in the same season. From the 15 identified males resighted at site 2, 12 were reported to have one pregnancy and two were reported to have two

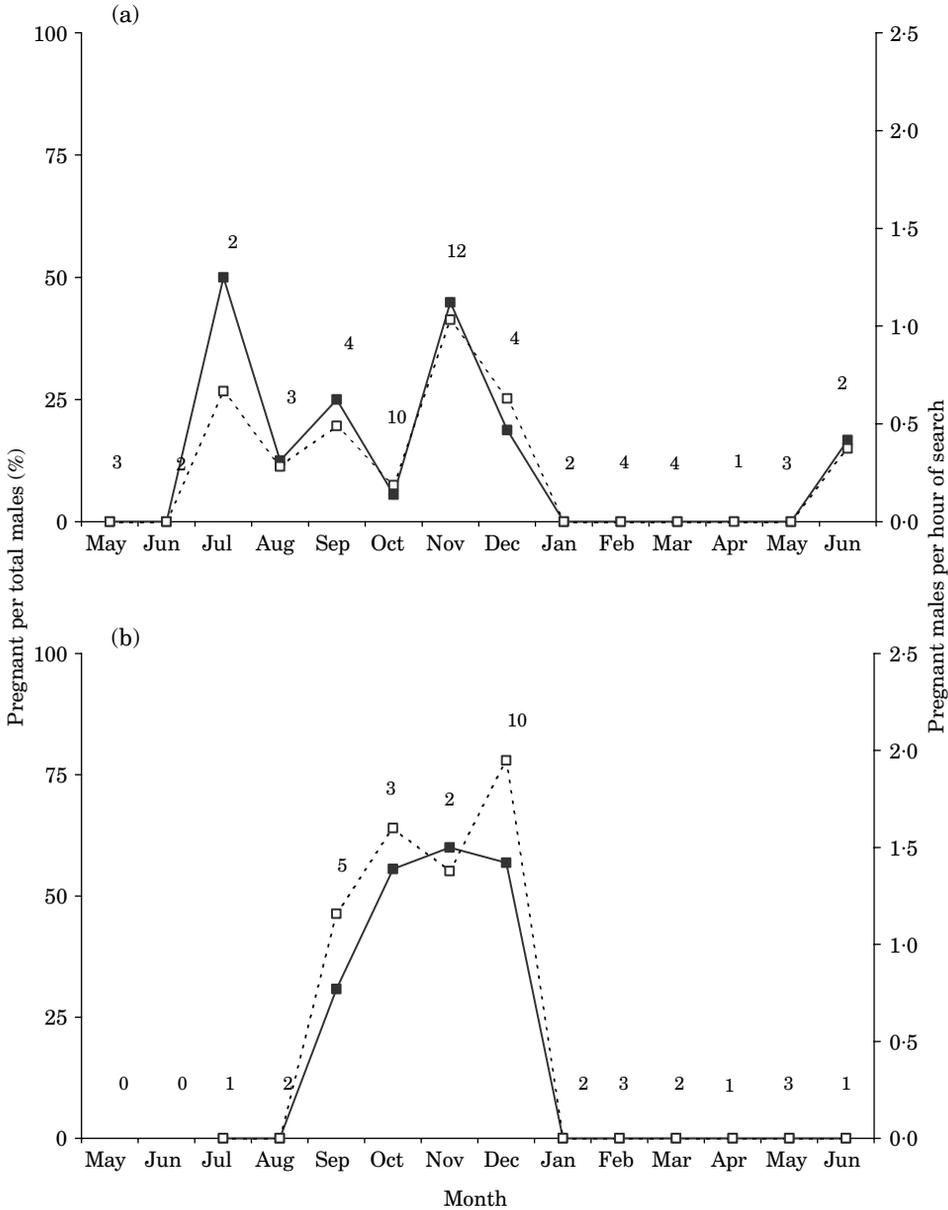


FIG. 2. Percentage of pregnant per total males seen on each dive (■) and monthly average of pregnant males sighted per hour of search (□) at sites (a) 1 and (b) 2. Number of dives each month are indicated

pregnancies in the season despite tagging and surveying started at this site later than at site 1. A χ^2 contingency analysis of the data on the frequency of pregnancies showed that the differences between sites were significant (χ^2 , d.f. = 2, $P = 0.015$). The shortest period observed between two pregnancies of the same male was 57 days at site 1 and 60 days at site 2. This period was

presumably shorter because probably it was not measured from the last day of the first pregnancy to the first day of the second. The pregnancies were observed to last between 30 and 38 days although data were insufficient to compare the duration of the pregnancies at the beginning and at the end of the season or to compare duration of first and second pregnancies.

At site 3, observations started in December 2001 and, therefore, they are not included in Fig. 2. Despite this, one male was found with eggs and finished hatching in early January 2002. Two more had just hatched the juveniles when the study started. Another male was seen in January 2002 that had just hatched the juveniles but was never seen again. No other males were seen at site 3 during the observations.

Some males lost eggs during the first days of pregnancy but some males with the tail still fully covered with eggs were observed hatching developed juveniles. Sometimes embryo eyes were visible inside the eggs and sometimes they were not, even though the males were in the latest stages of pregnancy. The eggs usually had clean surfaces, although some, especially during the last days of incubation, were partially or fully covered with algae (Sanchez-Camara, 2002).

Water temperatures at sites 1 and 2 are given in Fig. 3. The low average temperature in January at site 1 corresponded with 2 days of unusual cold currents. Water temperatures recorded at the three studied sites ranged from 14–23° C. Common seadragon were seen pregnant at all temperatures within the range but no pregnant males were seen during the months when hatching would imply young growing during the period of decreasing temperatures (Figs 2 and 3). The period of highest reproductive activity (October to December) was just previous to that of highest temperatures (December to March) so the first months of life of the young were coincident with the warmer waters.

The first and only common seadragon tagged as juvenile (YOY August to December 00) to be found pregnant in 2001 was at the end of November with an expected age of 11 to 16 months.

GROWTH AND RECRUITMENT

Data on sizes of identified juveniles are presented in [Fig. 4(b)]. By September 2001, when measuring juveniles was started (presumably 9–14 months old), they were all >25 cm L_S . These measurements are in accordance with size data of YOY that were between 22 and 27 cm by June 2002 [Fig. 4(a)]. Sex of identified juveniles at the three sites began to be visually discernible by the end of the year 2001 with a size slightly >30 cm and an expected age of 12–17 months.

Standard length of identified males are represented in Fig. 4(c) and of identified females in Fig. 4(d). These measurements were not used to estimate the growth curve because the age of each adult could not be estimated. Visually discernible males and females were individuals >30 cm L_S with no discernible temporal trend. In May to July 2002 all the common seadragon initially identified as adults (individuals >28 months old) were >33 cm. By this time, the largest common seadragon initially tagged as juveniles (individuals from 16–21 months old) were about the size of the smallest adults. Males had a mean \pm s.e. L_S of 36.3 \pm 0.4 cm ($n = 45$) and females 35.3 \pm 0.4 cm ($n = 48$). There were

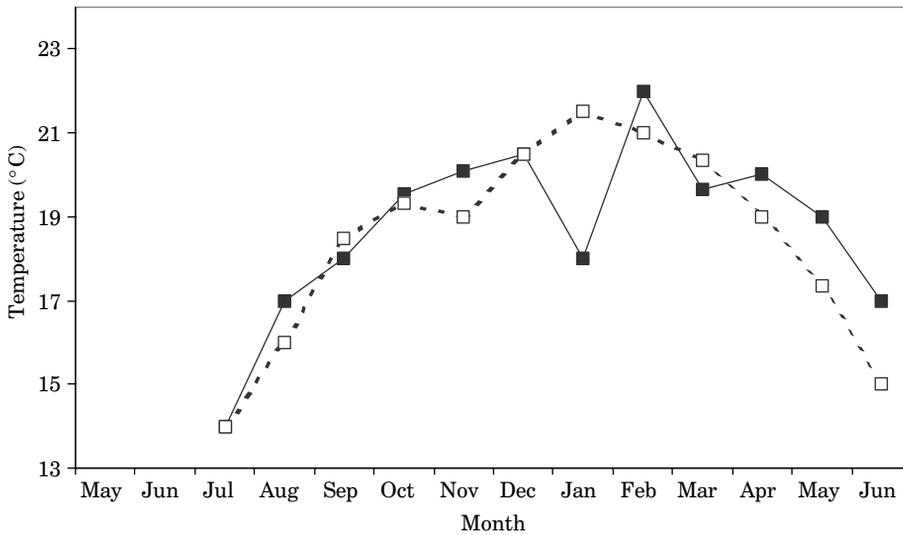


FIG. 3. Average temperatures recorded at sites 1 (■) and 2 (□).

no significant differences in size between males and females (t -test). The largest male seen was 41.5 cm and the largest female was 40.0 cm.

Only one sighting occurred of YOY of <14 cm and it was a neonate of $c.$ 3 cm found in December 2002 near six pregnant males with partially covered tails and another male that had just hatched eggs. The neonate was found swimming at 8.2 m deep. It was over sand covered with the seagrass *H. ovalis* but with *E. radiata* and *Sargassum* sp. in the area. Water conditions were calm with no current and there were plenty of very tiny mysid shrimp in the area. Efforts to find more neonates that day and other days were fruitless.

Nine YOY measuring >14 cm were found at site 1 from November 2001 to June 2002 [Fig. 4(a)]. The first one (Y1) was found on 29 November 2001, with a L_S of 14 cm. The other eight were identified from February to June 2002. Only one YOY was identified at site 2 during this period. No YOY was seen at site 3. Sizes of identified YOY are represented in Fig. 4(a). By May 2002 the sizes of all the young seen were between 21 (Y2) and 26 cm (Y1). Data from the first YOY identified showed individual growth rates of 3 cm month⁻¹ for individuals of $c.$ 15 cm L_S . These growth rates decreased rapidly to slightly >1 cm month⁻¹. Data for sizes of YOY and juveniles were used in the estimation of the growth equation. The von Bertalanffy growth curve parameters were $L_{00} = 42$ cm, $L_0 = 2.5$ cm and $K = 0.098$.

The exact moment of birth of each young is unknown. The estimation that maximizes the fit of the growth curve is that, on average, recruits were born on 30 October 2001 (linear regression, $r^2 = 0.947$). Juveniles were assigned the same date but 1 year before. Fig. 4(a), (b) depict the estimated growth curves superimposed over the actual data for recruits and juveniles, respectively. Juveniles measured at site 3 tended to be below the size of juveniles at sites 1 and 2 [Fig. 4(b)].

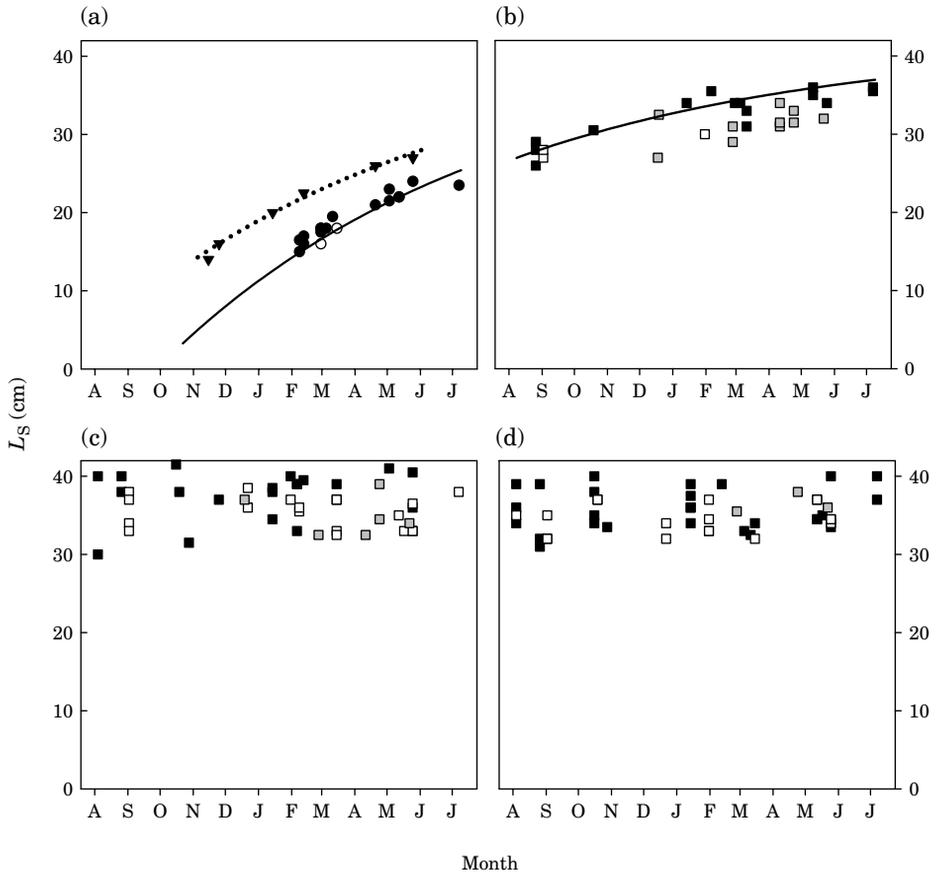


FIG. 4. (a) Standard lengths taken from identified young-of-the-year at sites 1 (●) and 2 (○) (no YOY was found at site 3) from August 2001 to July 2002. The estimated growth curve (—) and this growth curve fitted to the first recruit found (Y1; ..., ▼) are given. (b) Standard length taken from identified juveniles at sites 1 (■), 2 (□) and 3 (■) from August 2001 to July 2002. Estimated growth curve (—) is given. (c) Standard length taken from identified males at sites 1 (■), 2 (□) and 3 (■) from August 2001 to July 2002. (d) Standard length taken from identified females at sites 1 (■), 2 (□) and 3 (■) from August 2001 to July 2002. In (a) and (b) the von Bertalanffy coefficients for fitting the curve were: $L_{\infty} = 42$ cm, $L_0 = 2.5$ cm, $K = 0.098$ and birth date = 30 October.

When the equation was fitted to the data of individual Y1 for validation, the best fit was obtained by assuming that it was born on 2 August 2001 (linear regression, $r^2 = 0.987$). This estimate was in accordance with the data for timing of pregnancies [Fig. 2(a), (b)]. Therefore, Y1 would have been <4 months old when it was found on 29 November 2001 measuring 14 cm, and was near 10 months old when it was last seen with a size of 27 cm. All the other young found had similar growth to Y1 but they lagged *c.* 12 weeks behind [Fig. 4(a)]. A close fit of the sizes predicted from the growth equation and those actually observed in individual Y1 was obtained [Fig. 4(a)], thus indicating that the coefficients of the growth equation were reasonable.

From the growth curve it was estimated that common seadragon reach >6 cm L_S during the first month of life. They reach 9.5 cm at 2 months, 12.5 at 3 months, >15 cm at 4 months and 20 cm at 6 months. Common seadragon in the study area measure *c.* 30 cm at 12 months, almost the size at which they started to become sexually dimorphic.

DISCUSSION

REPRODUCTIVE CYCLE

A breeding season from June to January with a peak of brooding males at the end of the season is consistent with the findings of this study. Contrary to some literature (Pogonoski *et al.*, 2002), the long breeding season of >6 months allowed some of the males to become pregnant twice in the season and this is probably a common feature of males in the area. The length of the reproductive period is within the range observed for other syngnathid species (Lyons & Dunne, 2003; Takahashi *et al.*, 2003; Foster & Vincent, 2004). Two pregnancies per season for some males with an extensive period for recovery would result in some areas displaying smaller peaks at the beginning of the reproductive period. The number of pregnancies per season for one male, however, is lower than that reported for other seahorse species (Foster & Vincent, 2004). One or two pregnancies per season with *c.* 250 eggs per brood (Kuitert, 1988, 2000) would result in lower annual reproductive outputs (250–500 eggs per male per year) compared to seahorse (Foster & Vincent, 2004) and pipefish species (Gronell, 1984; Matsumoto & Yanagisawa, 2001) increasing the necessity of high survival rates of the young. The breeding season from winter to early summer is consistent with data provided by local divers (Baker, 2000*a*) and reflects an earlier start compared to common seadragon in more southern areas (Kuitert, 2000; Baker, 2000*b*). The peak of brooding males again corresponded with observations from local divers (Baker, 2000*a*; E. Howe, pers. comm.).

The breeding season from winter to early summer is earlier to that reported for other temperate syngnathids (Takahashi *et al.*, 2003). Similar reproductive patterns with the absence of brooding males during autumn and early winter, however, were reported for pipefish populations of *Urocampus carinirostris* Castelnau and *Vanacampus phillipi* (Lucas) in eelgrass beds of Victoria, Australia (Howard & Koehn, 1985). Hatching of the young seems in any case to correlate with increasing temperatures. Higher temperature within the normal range accelerates syngnathidae growth in both captive (James & Woods, 2001; Wong & Benzie, 2003) and wild environments (Strawn, 1958; Takahashi *et al.*, 2003). Mortality is growth-dependent, declining with respect to body size (Houde, 1997). The peak of brooding males before the warmer temperatures would result in faster growth of the young and therefore, in lower mortality. The breeding season seems also correlated with the breeding of mysids. Newly hatched common seadragon were reported mostly in areas with concentrations of small mysidaceans (Kuitert, 1988) and juveniles also have a diet composed of mysid crustaceans (Edgar, 2000). The correlation between the cycle of mysids and common seadragon as well as the factors triggering the fish's reproduction

which are probably related to light, temperature and the moon and tidal cycles (K. Forsgren pers. com.) should be incorporated in further studies.

Most available information on age and length at first maturity for syngnathids is from *ex situ* observations on only a few species. In seahorses the most commonly used determinant of sexual maturity has been the presence of a fully developed brood pouch in the males and, in some studies, the smallest recorded pregnant male (Foster & Vincent, 2004). Although this may not be accurate, maturity can be inferred without having to kill the animal. Using either the age or length at which sexual dimorphism was observed or the youngest pregnant male, common seadragon would mature within an age of 12–17 months and of 30–32 cm L_S . Although a few pregnant males were found of this L_S , only one of the 15 common seadragon initially tagged as juveniles was later found pregnant at this age. Therefore, most likely, the first pregnancy is more common during the second year as was suggested by Kuiter, (1993). Thus, age at first maturity is higher than for pipefishes (Howard & Koehn, 1985; Takahashi *et al.*, 2003) and seahorses (Foster & Vincent, 2004). Externally, males and females appeared to mature at the same time and size. The observed L_S at first maturity represents 71–80% of the maximum L_S . This is similar to what has been reported for some pipefish species such as *Syngnathoides biaculeatus* (Bloch) and *Doryrhamphus baldwini* (Herald & Randall) (Takahashi *et al.*, 2003). It is, however, considerably higher than that found for most seahorse species (Foster & Vincent, 2004) and *Syngnathus leptorhynchus* Girard (Bayer, 1980).

The observed gestation periods of 30 to 38 days would be within the top range of those reported for seahorse species (Foster & Vincent, 2004). It is shorter, however, than the 2 months previously reported for common seadragons (Kuiter, 2000). This difference in the length of the gestation period could be a result of the warm temperatures of the study sites, which are among the highest recorded for this species. The incubation period of captive males was 6 weeks at 16.7° C and 4 weeks at 17.8° C (K. Forsgren, pers. com.). Some pregnant males, especially at the end of the breeding season and in shallow waters, were observed carrying algae around and between the embryos (Sanchez-Camara, 2002). This probably decreases their conspicuousness (Svensson, 1988) since the eggs are attractive to other fishes such as tetraodontids and monacanthids (Kuiter, 1988).

In the Syngnathidae, monogamy has been documented for highly monomorphic species including most species of seahorses and some pipefishes (Foster & Vincent, 2004). In addition, sexual dimorphism has been found associated with polygamous species (Jones & Avise, 2001). Monogamous behaviour in syngnathids has been associated with conventional sex roles, with males competing most intensely for mates and females being more selective (Wilson *et al.*, 2003) except for one species, *Corythoichthys haematopterus* (Bleeker) (Matsumoto & Yanagisawa, 2001). Monogamous mating and conventional sex roles were suggested for the leafy seadragon *Phycodurus eques* Günther (Wilson *et al.*, 2003). In the present study, maximum and average size was similar for both males and females exhibiting weak sexual dimorphism. This would suggest monogamous behaviour and, therefore, conventional sex roles supported by sex ratios closed to 1 : 1 (Sanchez-Camara, 2002). In this study, however, pair bonding was not observed. Observation from aquaria suggests that one single female common seadragon can court two males at the same time and transfer

eggs to both in a term of only 2 weeks and that often one female produces more eggs than a male can accommodate (K. Forsgren, pers. com.). If that is the case, polygamous and sex-role reversal behaviour could be occurring.

GROWTH AND RECRUITMENT

Recruits started to appear in the residence areas from November to March measuring *c.* 15 cm. This recruitment period does not differ from those observed in two temperate pipefishes, *Urocampus carinirostris* Castelnau and *Vanacampus phillipi* Lucas, of more southern waters (Howard & Koehn, 1985). Before this period, recruits are likely to remain in sheltered waters with abundance of small mysid prey, which is consistent with observations of this study and with a previous study in a more southern area (Kuitert, 1988). Nevertheless, assessing whether most newborn grow up in specific nursery areas or whether they grow up in the same residence areas as adults needs further investigation. In residence areas that are favourable for hatching the young, males do not move out of their home ranges while probably males with their home ranges in deeper, more exposed waters or with less small-size mysid prey moved to more adequate areas to hatch their young. This is consistent with home range switches detected in the present study area by Sanchez-Camara & Booth (2004). It is likely that neonates can also reach favourable nursery areas drifting on local currents (P. Quong pers. com.). The observation that YOY started to be visible in the adult habitat at 15 cm L_S was reported for weedy seadragons from more southern areas at a size of *c.* 10 cm (Kuitert, 1988). This study also reported a size of 75 mm for 21 day old tank-raised common seadragons, which is larger than the 52 mm estimated by the present growth curve for individuals of that age. This suggests either a later average birth date of YOY than estimated by the growth curve or faster early growth of tank-raised common seadragons compared to wild ones.

The fast growth observed in this study for individuals >15 cm coincides with warm temperatures during summer and autumn months and is followed by a period of slower growth during cold months. This early growth is higher than that reported recently for *S. biaculeatus* in Queensland, Australia (Takahashi *et al.*, 2003), although K was higher for that species (0.0076 day^{-1}) than for common seadragon (0.0032 day^{-1}). The growth rates reported here, with individuals reaching 20 cm L_S at the age of 6 months and near 30 cm after 1 year, is higher than reported for common seadragon in Victoria (Kuitert, 1988), south of NSW, where this study was carried out. This previous study reported a size of 18 cm for 6 month-old individuals and 24 cm for 1 year-old common seadragons. Faster growth in more northern waters may be due to the higher temperature of the water as growth increased at warmer temperatures in other syngnathidae studies (James & Woods, 2001; Takahashi *et al.*, 2003; Wong & Benzie, 2003). The maximum L_S observed was 40.0 cm for females and 41.5 cm for males. These are less than the 46 cm reported for common seadragon of more southern areas (Kuitert, 1988). This could be due to common seadragon in Sydney having faster early growth but lower maximum size than those of colder southern waters, suggesting southern common seadragon living longer than those of warmer waters. Unfortunately, data on longevity to compare these populations are unavailable at present.

Pogonoski *et al.* (2002) proposed the designation of adequately sized and suitably located marine protected areas (MPA) to protect this species. The present study shows a yearly cycle of reproductive and demographic events taking place in a restricted area of coastline. The areas of coastline where common seadragons are abundant are often sheltered reefs and bays (Kuitert, 2000). Protection of these bays is expected to be more efficient because the reserve will have a high area : edge ratio and will therefore retain fishes more effectively (Kramer & Chapman, 1999). This combined with the site fidelity and restricted home ranges of common seadragon (Sanchez-Camara & Booth, 2004) suggests a high effectiveness of MPA on a local scale (hundreds of metres to 10 km linear dimension). Similar marine protected areas have been proposed for the leafy seadragon by Connolly *et al.* (2002). Protecting common seadragon from over-collecting, although important, may not guarantee the future of the species. An extensive reproductive season but a low annual reproductive output needs to be balanced with high early growth to increase survival rates. This growth will depend on the abundance of their main prey, mysids, which feed on fine particles produced by the decomposition of kelps and seagrasses (Edgar, 2000) and are highly sensitive to pollutants (Nimmo & Hamaker, 1982; Roast *et al.*, 1998). Therefore, the degradation of the habitat may be the main threat for these animals.

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