Movement, home range and site fidelity of the weedy seadragon *Phyllopteryx taeniolatus* (Teleostei: Syngnathidae)

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Synopsis

We measured for the first time movement, home range and site fidelity of the protected and endemic Australian fish weedy seadragon *Phyllopteryx taeniolatus*. Ninety-two individuals were identified using visual implant fluorescent elastomer and studied over a one-year period. Identified animals remained at the same site over the year within limited home ranges. These home ranges and the movement patterns recorded were independent of sex although movement to shallow sheltered waters to hatch the young was observed at the end of the breeding season for some pregnant males. The site fidelity and restricted home range of the weedy seadragon, as well as the reproduction-related movement have implications for effective management of this protected species.

Introduction

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

Although knowledge of the ecology of syngnathids is necessary for conservation management, few studies have quantified factors such as movement, home range and site fidelity of these species. Most recent studies have focused on syngnathid sexual behaviour (e.g. Berglund & Rosenqvist 1993, Masonjones & Lewis 1996, Jones & Avise 2001) and taxonomy (e.g. Lourie et al. 1999, Kuiter 2001) as well as improving survival of captive seahorses (e.g. Payne & Rippingale 2000, Woods 2000).

One of the limitations of studying syngnathids in the field is that their unusual morphology of body plates makes the use of long-term reliable tagging techniques difficult (Woods & Martin-Smith in press). Natural markings (Gronell 1984, Connolly et al. 2002a) and various tagging methods (e.g. Vincent & Sadler 1995, Kvarnemo et al. 2000) have been used to identify other species of syngnathids usually for seasonal studies. These studies recorded small home ranges during the breeding season for the seahorses *Hippocampus whitei* (Vincent & Sadler 1995) and *Hippocampus subelongatus* (Kvarnemo et al. 2000) and the tropical pipefish *Corythoichthys intestinalis* (Gronell 1984). Movement patterns for those species differed with sex (Gronell 1984, Vincent & Sadler 1995, Kvarnemo et al. 2000) and whether males were pregnant (Vincent et al. 1995). Some pipefishes have been shown to migrate seasonally (Lazzari & Able 1990, Bayer 1980) while others have

been resident in the same seagrass beds throughout the year (Howard & Koehn 1985).

Although the weedy seadragon is fully protected in New South Wales, Australia, under the Fisheries Management Act 1994, studies of seadragons in the field are virtually non-existent and little is known about their ecology. The World Conservation Union (IUCN) lists weedy seadragons as data deficient[1] meaning that insufficient information is available to make an assessment of the species' risk of extinction.

The aim of this study was to provide information on the ecology of the weedy seadragon in their natural environment. First, we recorded evidence of their site fidelity. Second, we determined their movement patterns and home ranges. The knowledge of these attributes is necessary for conservation management.

Material and methods

Study species

The weedy seadragon is a syngnathid endemic to Australian southern waters. It is distributed from Port Stephens, NSW, on Australia's Eastern coast to Geraldton, WA, on Australia's western coast, including the waters around Tasmania (Hutchins 1986). *P. taeniolatus* have elongate, non-prehensile tails and can grow up to 45 cm in length. They have a remarkable colour pattern, consisting principally of an orange–red background colour, iridescent blue stripes on the chest and numerous white spots and yellow markings (Edgar 2000). Males are responsible for the offspring that they fertilise and incubate on the outside of the tail with each egg partly embedded in the skin (Kuiter 2000). Weedy seadragons live among the larger algae on exposed reefs and feed mainly on mysid crustaceans (Edgar 2000).

Study sites

Site descriptions

Tagging and observation took place at three sites around Sydney, NSW, Australia in 2001–2002. The three sites of study were rocky reef formations parallel to shore with presence of kelp *Ecklonia radiata*. These reefs ended on a gently sloping sand flat. The main two sites of study, Sites 1 and 2, were in the

[1] Vincent, A. *Phyllopteryx taenilatus. In*: IUCN 2002. 2002 IUCN Red List of Threatened Species. http://www.redlist.org Downloaded on 21 January 2003.
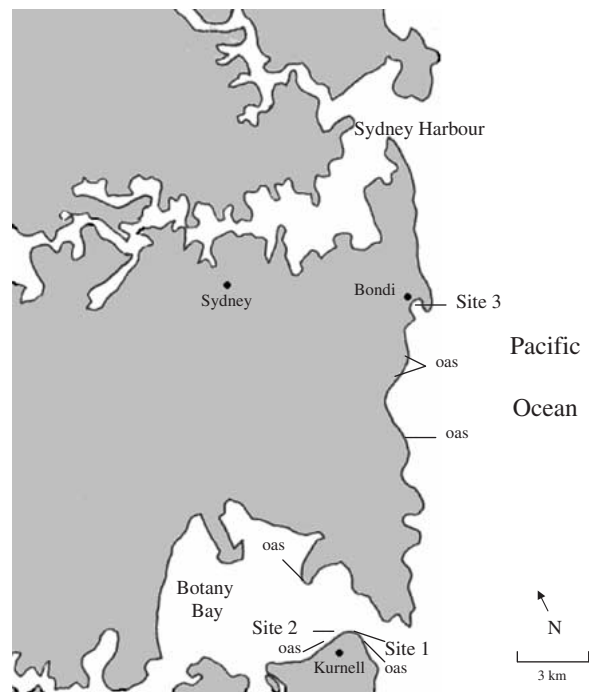

Figure 1. Sites in Botany Bay and Bondi, NSW, Australia, where seadragons were tagged. oas = other areas surveyed for tagged seadragons.

Botany Bay National Park, near the South Head of the Bay (Figure 1). Sites 1 and 2 were adjacent but were monitored independently because:

— After a few surveys at Site 2, none of the tagged seadragons from Site 1 were seen.
— Site 2 is further inside the bay coinciding with a change in the coastline orientation (Figure 1). The border between Sites 1 and 2 is an area of strong tide currents and less kelp (*E. radiata*) with lower abundance of seadragons.
— This change in the coastal orientation implies different physical conditions with Site 1 mainly affected by ocean swell and Site 2 by tidal currents (pers. observ.). This implies also differences in substrate distribution, flora and fauna (unpublished data).
— Each site could be covered on a single dive.

The third site was at Bondi Beach, only a few kilometres from the Sydney CBD (Figure 1). Surveys of this site started later than at Sites 1 and 2 and only a few surveys were accomplished. Therefore, results from Site 3 have been excluded for some analysis such as site fidelity. Several surveys were also conducted in areas adjacent or close to the study sites (Figure 1).

Site marking

At Sites 1 and 2, two permanent transects parallel to shore of 350 m length following the limit between the reef and the sand were used (Figure 1). Permanent marks were placed every 50 m. This marking method was used because most of the seadragons in previous surveys were found close to the kelp-sand limit. At Site 3, the depth of the site increases gradually along the transect (limit between the rocks and the sand) so depth and distance to the transect were used to record position.

Tagging and identification of individuals

We identified 92 seadragons at the three sites of study from 28 June 2001 to 4 January 2002 (Table 1). Seventy

Table 1. Number of seadragons identified at the three sites of study from 28 June 2001 to 4 January 2002.

	Males	Females	Juveniles	Total identified
Site 1	18	19	10	47
Site 2	17	15	4	36
Site 3	4	2	3	9
Total	39	36	17	92

individuals were tagged using subcutaneous injections of fluorescent elastomer paint following Beukers et al. (1995) and 22 seadragons were identified by natural marks and pattern of appendages.

Tagging
The tagging was done *in situ* by gently restraining the animal with one hand and injecting the tagging material with the other. No signs of adverse reaction to the tagging were observed with some fishes showing feeding behaviour immediately after tagging. Four fluorescent colours easily seen using UV flashlight were used. Tagging was done in 24 different parts of the body (Figure 2) allowing for a distinctive marking for each individual.

Identification by natural marks
Twenty two seadragons were identified by natural marks and pattern of appendages. Damaged appendages as well as the position, right or left, of the last tail appendages (T3, T4, T5 and T6 when present) were noted (Figure 2). At Site 3, due to the small population, identification without tagging was possible for all individuals. At Sites 1 and 2, males that were pregnant at the time of tagging were identified by this method to avoid the possible handling
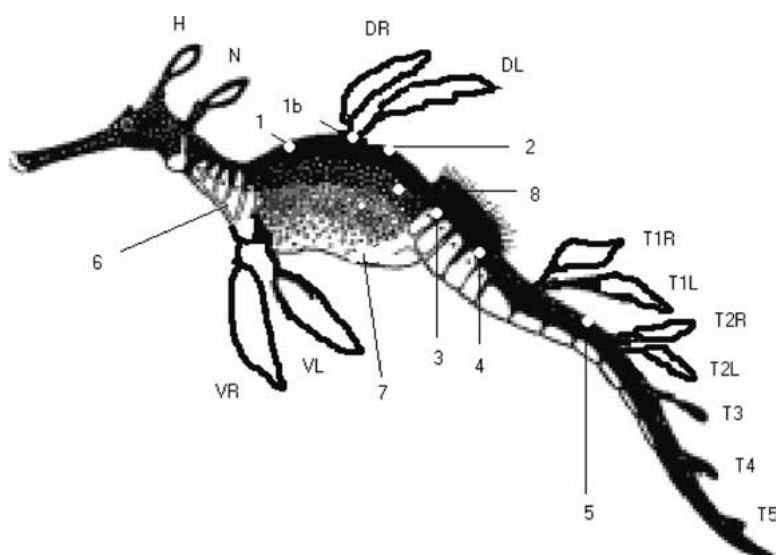

Figure 2. Nomenclature of appendages used for identification; H = head appendage, N = nape appendage, D = dorsal appendage, V = ventral appendage, T = tail appendage, and parts of the body were weedy seadragons were tagged; 1, 1R, 1L, 1b, 2, 2R, 2L, 3R, 3L, 4R, 4L, 5, 6R(2t), 6R(3t), 6R(4t), 6R(5t), 6R(6t), 6R(7t), 6L(2t), 6L(3t), 6L(4t), 6L(5t), 6L(6t), 6L(7t), 7 and 8. R = right side, L = left side, t = trunk ring number.

stress. Females with clearly distinguishable patterns of damaged appendages were also identified without tagging.

Photos were taken using a Sea & Sea MX10 photo camera and video recorded with a Sony VX-700 digital video in a Stingray Housing to aid in identifying untagged animals.

Sampling protocol

All observations were conducted using SCUBA, from May 2001 to June 2002. A total of 128 dives were conducted over this time. Two divers conducted most dives and, occasionally, one or two additional divers were present. The total underwater time was 290 diver hours. Waterproof data sheets with a standardised seadragon outline were taken underwater. On each dive at the marked sites, the transect was followed from one end to the other with constant short incursions into the rocky reef and the sand flat. For each seadragon found, sex (as specified below), location, depth and substrate were recorded. The seadragons sighted were always checked for tags using an UV torch. For untagged fish, natural marks and appendages were noted to allow a possible later identification. When VIE injectors were taken underwater, unidentified individuals seen were tagged.

Site fidelity

Site fidelity was examined by studying the persistence at Sites 1 and 2 of the originally-tagged individuals. Observation times were divided into 3-month blocks to increase the chances of sighting the tagged seadragons present in the area, since tagged individuals were not seen on every occasion.

Movement and home range

The locations of seadragons in Sites 1 and 2 were estimated by recording the positions of each seadragon in the transect described above. Depth and the approximate distance to this transect were recorded. For Site 3, depth was used to record position of seadragons as well as distance to the kelp-sand interface.

Movement was determined by recording the different locations where each identified seadragon was found at all sample times during the length of this study. Home ranges were measured as the length of the transect covering all this positions. Seadragons were always found in or near the marked transect. Large

boulders dominated shallower areas while in deeper water sand was the only substrate. Home range lengths of males, females and juveniles at each site were compared using one-factor ANOVA except whenever the normality test failed, in which case the Kruskal–Wallis test was used instead. T-tests or Mann–Whitney tests whenever normality test failed were used to compare home range sizes of males, females and juveniles measured at Site 1 to those measured at Site 2.

Results

Site fidelity

Persistence of seadragons tagged from July to September 2001 is shown in Figure 3. Seadragons never seen again after tagging have not been included. Seadragons tagged after September 2001 have not been included since the study period was considered too short to study site fidelity. Therefore, only data from Sites 1 and 2 were used since identification of seadragons at Site 3 started on December 2001.
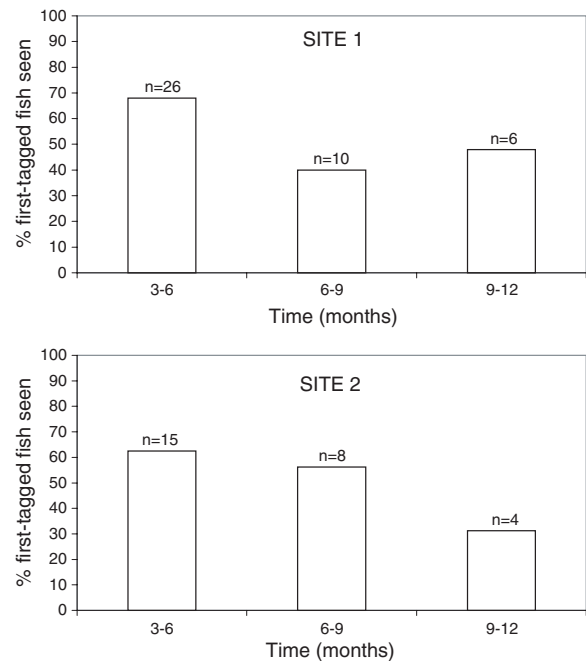

Figure 3. Percentage of first-tagged seadragons seen on Sites 1 and 2. Time was divided in 3-month blocks to assure most identified seadragons present in the area were found. Initial numbers of tagged fish were 25 for Site 1 and 16 for Site 2. n = number of dives during that period.

At Site 1, 48% of the seadragons tagged from July to September 2001 were seen in the site from April to June 2002. Curiously, this number is higher than for the previous period when only 40% of these first-tagged fish were seen. At Site 2, 31% of the seadragons tagged during the first 3 months were found during the last 3 months of the study. Seadragons identified at Sites 1 and 2 were never seen in other areas surveyed a hundred metres from Sites 1 and 2 (Figure 1). At Site 3, identification started after September 2001 so we have no available data to compare with Sites 1 and 2. However, 80% (8 of 10) of the seadragons identified at Site 3 were seen during the full length of the study at that site (6 months).

Movement and home range

Horizontal movement and home range
In general, seadragons moved during the year within limited home ranges (115 ± 10.0 m, mean $\pm$ se, n = 68). Home ranges of males, females and juveniles frequently overlapped (Figures 4 and 5) with more than 25 seadragons overlapping home ranges in areas of Site 1 (Figure 4).

At Site 1 most seadragons had well-defined home ranges (110 ± 12.6 m, mean $\pm$ se, n = 43) with patterns of movement similar to those of three individuals M1, F17 and J1 shown in Figures 6a–c. There were no significant differences in home range length between males, females and juveniles (Kruskal–Wallis, $H = 2.08$, d.f. = 2, $p = 0.35$). Only one seadragon (M16) moved at least 550 m (Figures 4 and 6f). This large-scale movement was noted just after the breeding season and could indicate movement back to his normal home range out of the study area so these data was excluded from the analysis. At Site 2, most seadragons also had well-defined home ranges (124 ± 16.6 m, mean $\pm$ se, n = 25) although movement out of this home ranges was observed for 6 individuals at the end of the breeding season following similar pattern as M28 (Figure 6e). There were also no significant differences between home range length of males, females and juveniles (ANOVA, $F = 0.87$, d.f. = 24, $p = 0.43$).

Home range lengths were also not significantly different between Sites 1 and 2 for males (Mann–Whitney, $U = 230$, $p = 0.60$), females (Mann–Whitney, $U = 135$, $p = 0.14$) and juveniles (t-test, $t = 0.48$, d.f. = 10, $p = 0.64$). Data from F27, F28, F29 and M32 are excluded from both analysis because they were seen only for a few days at the end of the breeding season in a very localised area and probably their home ranges were out of the study area.

Seadragons from Sites 1 and 2 were never recorded more than 25 m away from their respective transects. Large boulders dominated shallower areas while in deeper water sand was the only substrate. Therefore, the mean home range area for seadragons at the study site was less than 6 hectares.

At Site 3, the transect was not marked but well-defined home ranges from 50 to 200 m in length (estimated from the records of depth and mapping of the area) were observed. Seven of the eight identified seadragons resighted were found in shallower waters from late December to early January than for the rest of the year and one male that had just hatched the juveniles was found in shallow waters on 4 January 2002 and not seen again. Seadragons were always found near the kelp-sand interface. No seadragons from Site 3 were observed away from the site. Efforts to locate identified seadragons from Site 1 or 2 in other surveyed areas (Figure 1) were also fruitless.

Vertical movement
Vertical movement of identified seadragons is shown in Figure 7. In general, all individuals remained in depth ranges of less than 4 m. However, many sightings of identified seadragons in shallower waters occurred during December and early January at sites 2 and 3. These sightings were mostly of pregnant and post-pregnant males. This migration in depth was coincident in time with the horizontal migration.

At Site 1, all identified seadragons remained from 9 to 14.2 m depth (Figure 7) except for one post-pregnant male (M16), originally identified at 5.5 m and later seen several times at depths ranging from 9 to 11.5 m. At Site 2, the depth of most sightings ranged from 8 to 15 m, with seadragons exhibiting similar behaviour to those at Site 1, although vertical movement accompanied by horizontal movement was observed in December for five pregnant males (M19, M26, M27, M28, M30) and one female (F24). They all migrated to shallow waters during this period following a similar movement pattern to M28 (Figure 6e). The exception was one male (M24) found giving birth at 3.3 m on 1 September and seen again at 7.7 m 9 months later.

Records from Site 3 started on 31 December 2001, when the breeding season was close to its end. Despite this fact, as in Site 2, more sightings occurred in shallow waters at the end of the breeding season. Three males
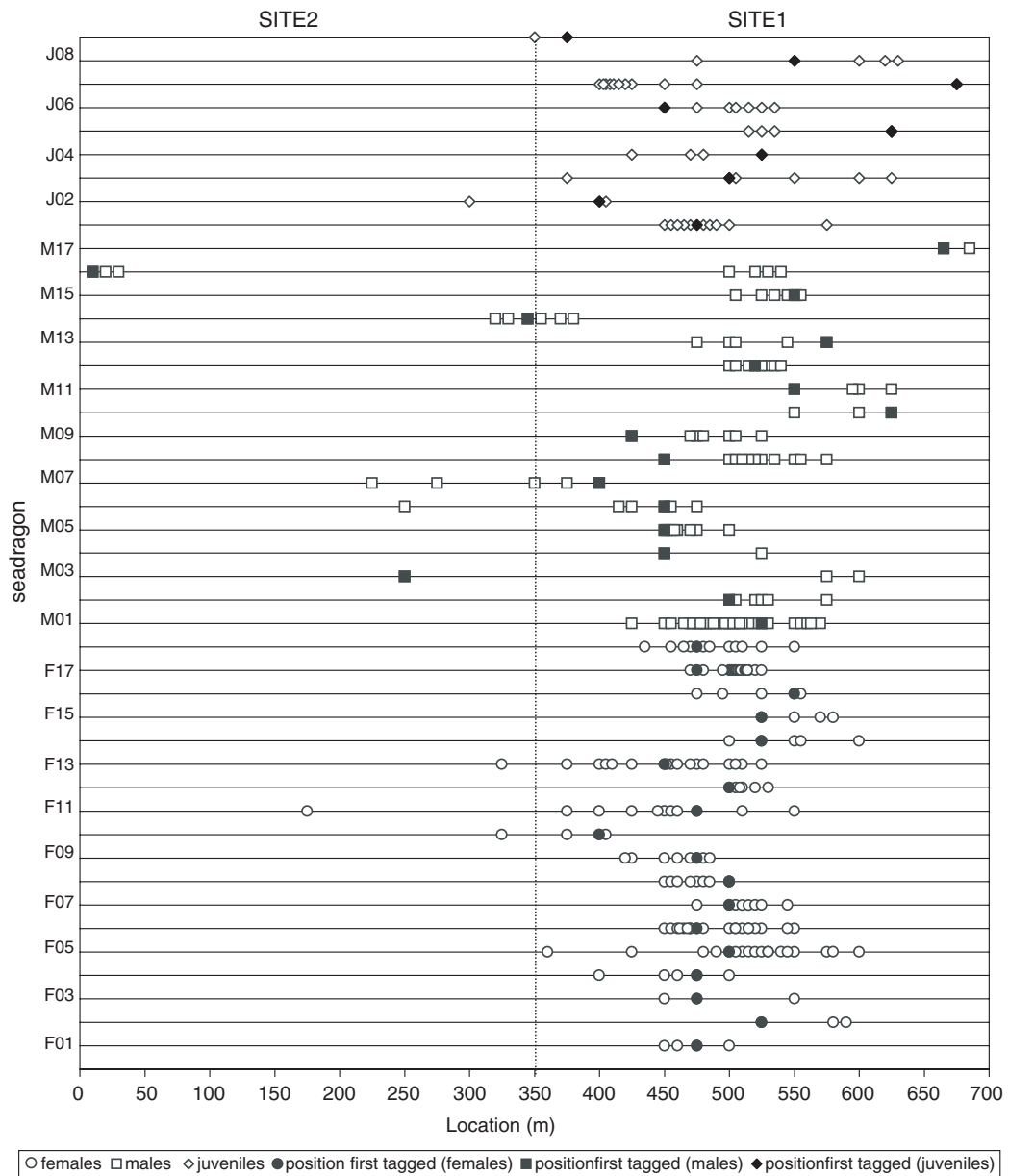
Figure 4. Locations along the marked transect where each identified female (F01–F18), male (M01–M17), and juvenile (J01–J09) seadragon was found from June 2001 to June 2002 at Site 1.

in their last stages of pregnancy were seen in shallow waters from 31 December 2001 to 4 January 2002.

Discussion

Seadragons lived in resident groups throughout the year with males, females and juveniles occupying broadly overlapping home ranges. The size of these home ranges was independent of sex, and movement outside home ranges was rare. However, movement related to reproduction was observed, with some pregnant males and a few females moving from their home ranges to shallow sheltered areas at the end of the breeding season. This behaviour observed at Site 2 suggests the
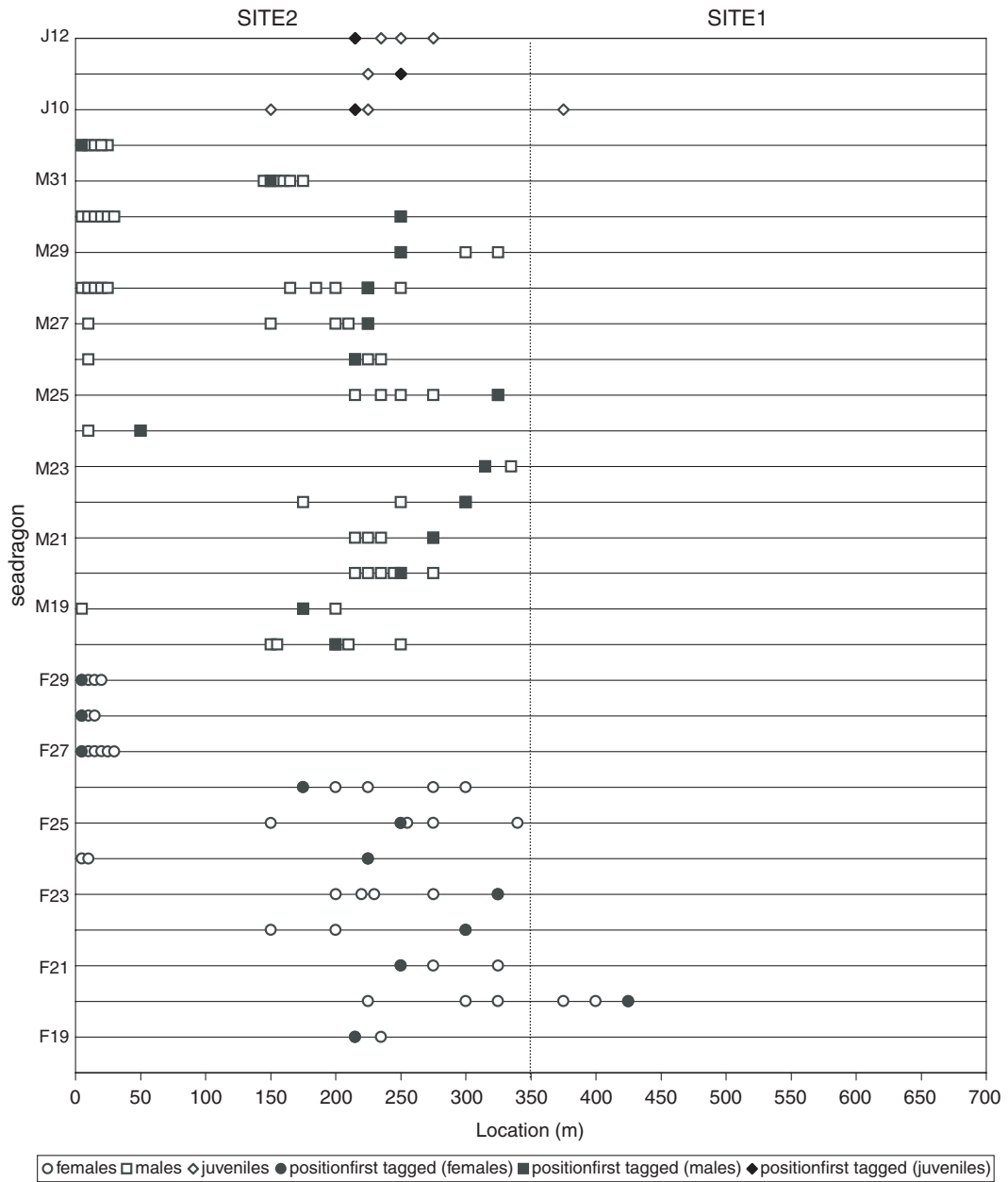
Figure 5. Locations along the marked transect where each identified female (F19–F29), male (M18–M32), and juvenile (J10–J12) seadragon was found from August 2001 to June 2002 at Site 2.

existence of hatching grounds (nursery areas). Results from Site 3 (a more exposed, less densely populated site) suggest similar behaviour.

Regarding site fidelity, weedy seadragons in a bay (Kurnell) and on a more exposed reef (Bondi) were site-attached. No seadragons were observed to change site during the study. At Kurnell, seadragons with their home ranges within Site 2 were not observed to move into Site 1. Seadragons with their natural home ranges within Site 1 were not observed to move into Site 2. A few seadragons were reported to have their home ranges in the boundaries of Sites 1 and 2 and were the
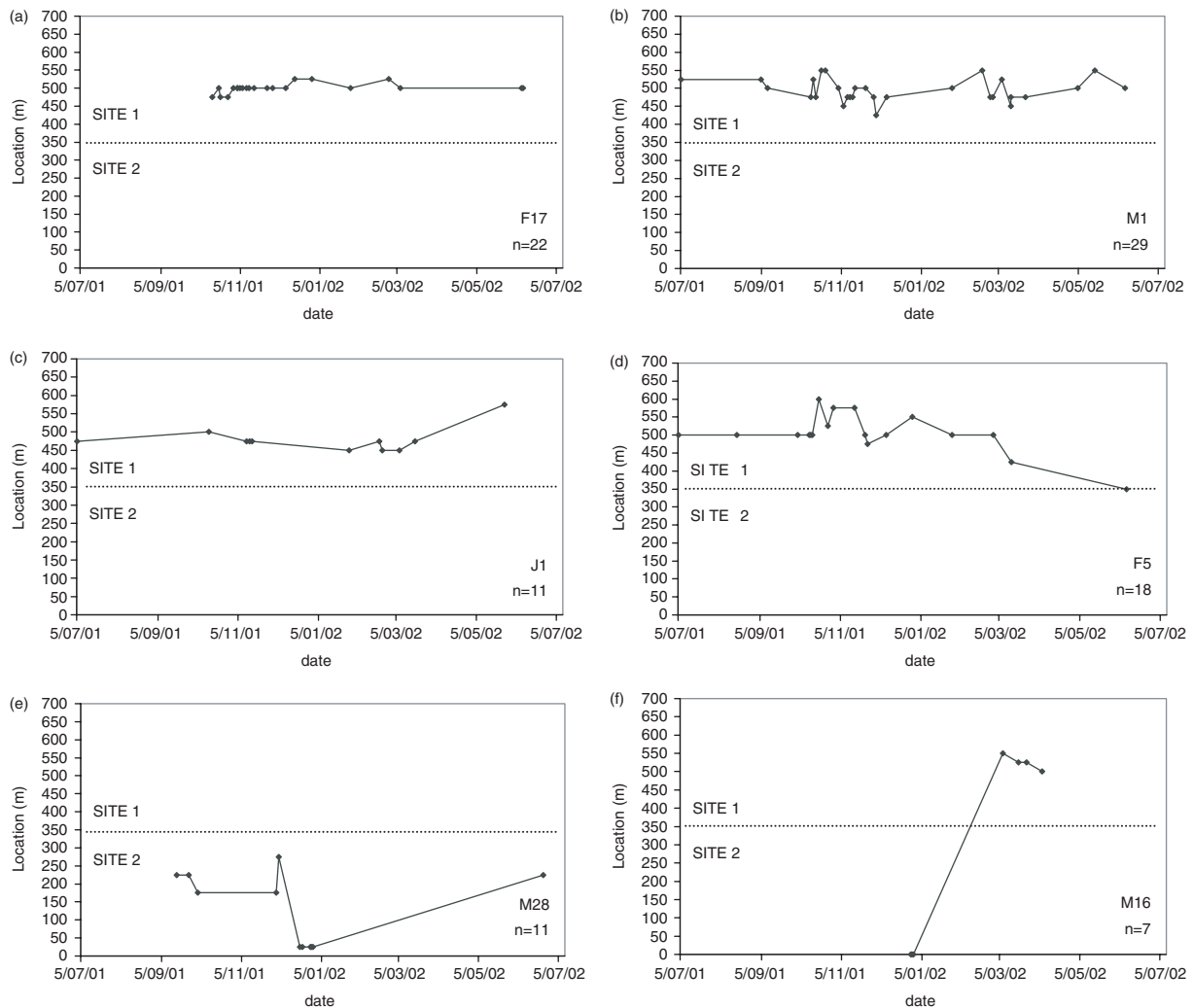
Figure 6. Examples of movement patterns observed at Sites 1 and 2. (a) = F17; (b) = M1; (c) = J1; (d) = F5; (e) = M28; (f) = M16. n = number of times seen.

ones seen in both sites. The fact that identified seadragons of Sites 1 and 2 were never seen in another searched areas near Sites 1 and 2, or in other sites on the other side of the bay suggests that seadragons have a marked site fidelity.

The disappearance of tagged seadragons due to mortality and the lack of completeness of the censuses have, most likely, underestimated our result of site fidelity. However, the percentage of seadragons that were not found 9–12 months after tagging could also be a result of tags missed during observation due to deterioration in tag quality (Morgan and Peveley 1996) or growth of pigmented tissue over the tag (Olsen and Vollestad

2001). This would be contrary to recent studies on captive pot-bellied seahorses that reported a decrease in tag visibility for the human eye but not under UV light with tags remaining clearly discernible for up to 14 months (Martin-Smith in press)

Regarding home range most seadragons had well-defined home ranges varying from 50 to 150 m in length (with always less than 50 m in width) and 2–4 m in depth. Well-defined home ranges were also reported recently for the leafy seadragon *Phycodurus eques* (Connolly et al. 2002b). In this study, the length of the home range was independent of sex, being very similar for males, females and juveniles.
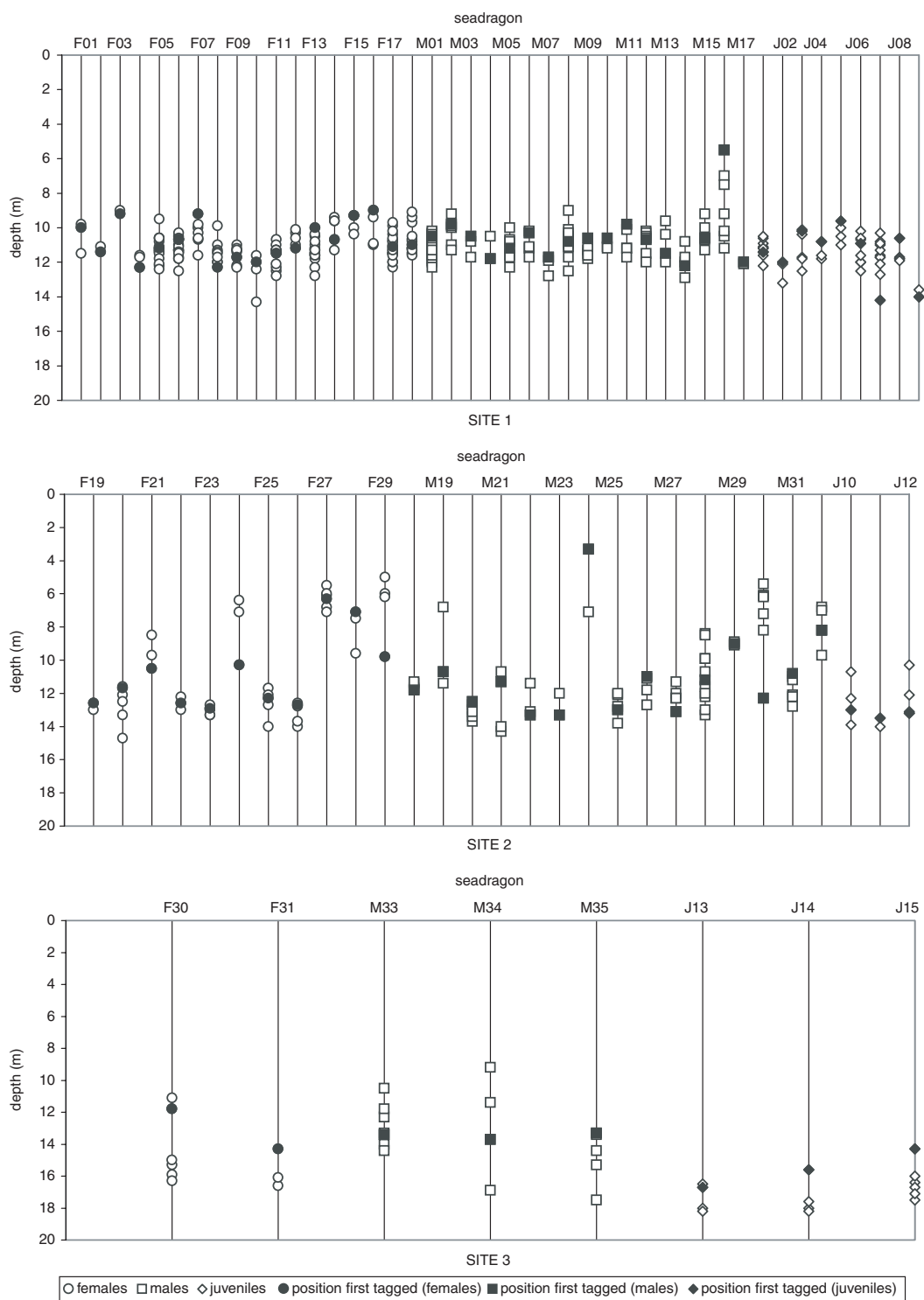
Figure 7. Depths where each identified male, female and juvenile seadragons were found from August 2001 to June 2002.

This is contrary to what has been reported for other syngnathids where females had broader home ranges and moved longer distances (Gronell 1984, Vincent & Sadler 1995, Kvarnemo et al. 2000). Home ranges of individuals of all sexes clearly overlap with no territorial behaviour observed as reported for some pipefish species (Gronell 1984) and leafy seadragon (Connolly et al. 2002a). The depths of these home ranges appeared to correlate with substrate type (the limit between the rocky reef with kelp and the sand) and the presence of mysid prey (unpublished data). Seadragons at Site 3, a more exposed site, were found deeper than at Sites 1 and 2. Large numbers of seadragons were frequently observed in depths ranging from 15 to 25 m in a surveyed area near Site 1 with abundant kelp beds and mysids crustaceans (unpublished data). Many seadragons are found in shallow waters from 3 to 6 m deep in more southern areas if these waters are not too exposed (Quong, Howe pers. comm., pers. observ.). At the sites studied, the swell, the tide currents, and the habitat dominated by boulders were probably limiting seadragon numbers in shallower waters.

As for movement patterns, despite seasonal migrations having been described for several pipefish species (e.g. Bayer 1980, Lazzari & Able 1990) most seadragons in this study were reported to move within a small area throughout the year. However, horizontal and vertical movement was observed in some individuals related to reproduction.

Movement to shallow sheltered waters related to reproduction occurred at the end of the breeding season, most likely related to the hatching of the young. The number of seadragons seen inside the bay, in shallow sheltered waters, peaked at the end of the breeding season to an average of 9 or 10 seadragons sighted per dive and declined dramatically after the breeding season to 1 or 0 sightings per dive (unpublished data). All the males reported in the shallow area on December were in their last stages of pregnancy or had just hatched the juveniles (the shape of the eggs remained clearly visible on the male's tails for a few days after the hatching). Some of these individuals had their home ranges near this shallow area but others (such as M16) came from areas out the studied sites and did a longer breeding-related movement. Male seahorses looking for a partner have been reported to move greater distances than those with a partner (Kvarnemo et al. 2000). Connolly et al. (2002b) recently reported a leafy seadragon moving without a well-defined home range. In this study, movement was related to hatching young incidence, because males observed to move to shallow water were those carrying eggs. Some tagged males were seen in their normal home ranges carrying new eggs and were seen days later in the mentioned shallow waters. It is unclear why a few females were found as well in this shallow area. Courtship displays of partners with the male already carrying eggs have been observed before for seahorses (Vincent et al. 1995) and pipefish species (Gronell 1984) although this was not observed in the present study. Kuiter (1987) cited this reproductive movement to shallower waters as a normal behaviour of weedy seadragons in Victoria but not in NSW, where this study was carried out.

At a more exposed, less populated reef, pregnant males also moved to shallower waters to hatch their young and so did some females. Males may do so to provide the young with a nursery area, less exposed to currents and with adequate shelter. Inside Botany Bay this shelter would likely be *Sargassum* spp. and kelp *E. radiata*, while at Site 3 it was probably the dead *Sargassum* and kelp moved into shallow water by local currents. Even more importantly, this movement would provide the young with the mysid prey they need, since the biggest schools of the smallest mysids were seen near the pregnant and post-pregnant males in December at depths of around 3 m (unpublished data). Similar observations in other areas (Kuiter, per. comm.) suggest a correlation between the breeding cycle of mysids and seadragons.

The spatial dynamics of these seadragon populations suggest resident groups of individuals with well-defined home ranges. These home ranges clearly overlapped and were similar in size for males, females and juveniles. These resident groups may persist among years with movement out of their home ranges and even within sites dictated by breeding needs such as providing the young with a nursery area. Preserving the habitat of resident and nursery areas may be the key to assure the future of this protected and unique Australian fish.

References

Bayer, R.D. 1980. Size, seasonality, and sex ratios of the bay pipefish (*Syngnathus leptorhynchus*) in Oregon. Northwest Sci. 54: 161–167.

Beukers, J.S., G.P. Jones & R.M. Buckley. 1995. Use of implant microtags for studies of populations of small reef fish. Mar. Ecol. Prog. Ser. 125: 61–66.

Berglund, A. & G. Rosenqvist. 1993. Selective males and ardent females in pipefishes. Behav. Ecol. Sociobiol. 32: 331–336.

Connolly, R.M., A.J. Melville & J.K. Keesing. 2002a. Abundance, movement and individual identification of leafy seadragons, *Phycodurus eques* (Pisces: Syngnathidae). Mar. Freshw. Res. 53: 777–780.

Connolly, R.M., A.J. Melville & K.M. Preston. 2002b. Patterns of movement and habitat use by leafy seadragons tracked ultrasonically. J. Fish. Biol. 61: 684–695.

Edgar, G.J. 2000. Australian Marine Life. The Plants and Animals of Temperate Waters. Reed New Holland. 425 pp.

Gronell, A.M. 1984. Courtship, spawning and social organization of the pipefish, *Corythoichthys intestinalis* (Pisces: Syngnathidae) with notes on two congeneric species. *Z. Tierpsychol.* 65: 1–24.

Herald, E.S. 1959. From pipefish to seahorse-a study of phylogenetic relationships. Proc. Calif. Acad. Sci. 29: 465–473.

Howard, R.K. & J.D. Koehn. 1985. Population dynamics and feeding ecology of pipefish (Syngnathidae) associated with eelgrass beds of Western Port, Victoria. Aust. J. Mar. Freshw. Res. 36: 361–70.

Hutchins, B.S. 1986. Sea Fishes of Southern Australia. Swainston Publishing, Perth. 95 pp.

Jones, A.G. & J.C. Avise. 2001. Mating systems and sexual selection in male-pregnant pipefish and seahorses: Insights from microsatellite-based studies of maternity. Amer. Genetic Assoc. 92: 150–158.

Kuiter, R.H. 1987. Note sur les soins parentaux, l'eclosion et l'elevage des Dragons de mer (Syngnathidae). Rev. Franc. Aquar. 14: 113–122.

Kuiter, R.H. 2000. Seahorses, Pipefish & Their Relatives. England: TMC publications. 79 pp.

Kuiter, R.H. 2001. Revision of the Australian seahorses of the genus *Hippocampus* (Syngnathiformes: Syngnathidae) with descriptions of nine new species. Rec. Aust. Mus. 53: 293–340.

Kvarnemo, C., G.I. Moore, A.G. Jones, W.S. Nelson & J.C. Avise. 2000. Monogamous pair bonds and mate switching in the Western Australian seahorse *Hippocampus subelongatus*. J. Evol. Biol. 13: 882–888.

Lazzari, M. A. & K.W. Able. 1990. Northern pipefish, *Syngnathus fuscus*, occurrences over the Mid-Atlantic Bight continental shelf: Evidence of seasonal migration. Environ. Biol. Fish. 27: 177–185.

Lourie, S.A., J.C. Pritchard, S.P. Casey, S.K. Truong, H.J. Hall, & A.C.J. Vincent. 1999. The taxonomy of Vietnam's exploited seahorses (family Syngnathidae). Biol. J. Linn. Soc. 66: 231–256

Masonjones, H.D. & S.M. Lewis. 1996. Courtship behaviour in the dwarf seahorse, *Hippocampus zosterae*. Copeia 3: 634–640.

Morgan, R.I.G. & D.S. Paveley. 1996. A simple batch mark for fish studies using injected elastomer. Aqua. Res. 27: 631–633.

Olsen, E.M. & L.A. Vollestad. 2001. An evaluation of Visible Implant Elastomer for marking age-0 brown trout. N. Amer. J. Fish. Manag. 21: 967–970.

Payne, M.F. & R.J. Rippingale. 2000. Rearing West Australian seahorse, *Hippocampus subelongatus*, juveniles on copepod nauplii and enriched Artemia. Aquaculture 188: 353–361.

Vincent, A.C.J. & L.M. Sadler. 1995. Faithful pair bonds in wild seahorses, *Hippocampus whitei*. Anim. Behav. 50: 1557–1569.

Vincent, A.C.J., A. Berglund & I. Ahnesjo. 1995. Reproductive ecology of five pipefish species in one eelgrass meadow. Environ. Biol. Fish. 44: 347–361.

Woods, C.M.C. 2000. Improving Initial survival in cultured seahorses, *Hippocampus abdominalis* Leeson, 1827 (Teleostei: Syngnathidae). Aquaculture 190: 377–388.

Woods, C.M.C. & K.M. Martin-Smith (in press). Visible implant fluorescent elastomer tagging of the big-bellied seahorse, *Hippocampus abdominalis*. Fisheries Research.