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Abundance, movement and individual identification of leafy seadragons, *Phycodurus eques* (Pisces : Syngnathidae)

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Abstract. The aim of this study was to estimate, for the first time, abundance and degree of movement of leafy seadragons, *Phycodurus eques*, at one location in southern Australia. The pattern of wear and damage to the leafy appendages was found to vary among individuals but was not a reliable method of identification of individual fish over long periods. Photographic evidence of individual facial markings was more reliable and full-grown individuals could be recognised by their facial markings for at least 11 months. We made 45 sightings in 47 dives over 14 months. Sightings were made in depths of 3–11 m over brown algae, seagrass, and sand covered with drift macroalgae. Nine individual fish were sighted and all except one were sighted at least twice (mean of five sightings, s.e. 1.2, range 1–12). Capture and recapture calculations (moment estimator algorithm) estimated 9.2 (±0.3) seadragons in the study area (density 57 fish ha^{-1}). Resightings were made months apart, suggesting that the fish are remaining within a home range (range of 35–82 m, maximum distance between sightings for fish sighted >5 times). Information about patterns of movement of seadragons is directly relevant to management plans for this species and for marine protected areas designed to aid in their protection.

Extra keywords: Australia, conservation, dispersal, fish, marine protected areas, pipefish, seahorse.

Introduction

Leafy seadragons (*Phycodurus eques* Günther) are members of the family Syngnathidae, which also includes seahorses and pipefishes. Leafy seadragons are endemic to Australia, occurring among macroalgae-covered reefs and seagrass meadows along Australia's southern coast from Perth to just east of Melbourne (Gomon *et al.*1994; Kuiter 2000). Although some aspects of their reproductive biology are known from specimens held in aquaria (Kuiter 1988), the World Conservation Union has included the leafy seadragon in the 'data deficient' category of its Threatened Species Red List (IUCN 2000) because information on the basic ecology of the species, such as population sizes and movement, has never been gathered and there are no estimates of abundance at any location.

The specialized reproductive strategy of the leafy seadragon involves the hatching of eggs held externally on the male's tail, which precludes egg dispersal. Adults are weak swimmers (Kuiter 2000), but the extent to which juvenile and adult leafy seadragons travel has not been measured. Movement has not been measured in the closely related weedy seadragon, *Phyllopteryx taeniolatus* Lacépède.

Leafy seadragons are not involved in the Traditional Chinese Medicine trade (Vincent 1996). However, the assumptions of limited dispersal and low abundances imply that they are vulnerable to degradation of habitat and to incidental catch by humans. We have collected anecdotal evidence directly from trawl fishers that leafy seadragons are killed accidentally as bycatch during trawl fishing. Public interest in leafy seadragons in southern Australia has led to a community database of sightings. The extent of movement by marine animals is a major consideration in the selection and design of marine protected areas (Kenchington 1990) and the lack of information about movement patterns of leafy seadragons makes management of this species and its habitat difficult.

Home ranges and movement patterns have been measured in other syngnathid species, either by determining the position of individual fish identified using natural head markings (Gronell 1984) or tags (Vincent and Sadler 1995; Vincent *et al.* 1995) or by estimating population abundances over time at different locations (Bayer 1980; Lazzari and

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Able 1990). Home ranges of 1–100 m^2 have been recorded during the breeding season for a seahorse (Vincent and Sadler 1995) and a pipefish species (Gronell 1984). Movement patterns were dependent on sex (Gronell 1984; Vincent and Sadler 1995) and whether males were pregnant (Vincent *et al.* 1995).

Some species of pipefish have been shown to migrate seasonally. *Syngnathus fuscus* migrates up to hundreds of kilometres into deeper offshore waters in winter (Lazzari and Able 1990), *Syngnathus leptorhynchus* migrates away from lower estuarine sites in summer, probably up the estuary (Bayer 1980) and the seahorse *Hippocampus whitei* may also move into deeper water in winter (Vincent and Sadler 1995). Other pipefish species have been found to stay in the same shallow seagrass beds throughout the year (Howard and Koehn 1985).

The aim of this study was to assess the abundance of seadragons at a single location and to determine how far seadragons move and whether they have a home range. This is fundamental to any understanding of the ecology of leafy seadragons and for any management plan for the species.

Materials and methods

Study site and sampling protocol

This survey was done along a 100 m stretch of coast on the more protected north-western side of West Island (Fig. 1), South Australia (35°36′S 138°5′E). This shore consists of a reef of granite boulders covered by brown macroalgae (mainly *Cystophora* spp), separated from seagrass meadows (mixed stands of *Heterozostera tasmanica*, *Posidonia sinuosa* and *Amphibolis antarctica*) by a strip of bare sand ~2 m wide and 5–7 m deep. The island, a marine protected area, is subjected to strong swell from the Southern Ocean. Diving is difficult even on the sheltered side of the island and visibility is reduced to ~5 m for much of the year. The biology of this site is described more fully by Shepherd and Womersley (1970).

Two to four SCUBA divers searched the whole study area in a fixed pattern, from east to west (with additional searching in the western end) and then returned to the starting point. All dives included at least one or more of the authors, providing consistency in swimming speed, transect width and diver behaviour between dives. In total, 47 dives (95.1 diver hours) were made on 30 days between January 1996 and February 1997 (14 months), with 28 dives in the summer months (December–February) and 21 spread over other months.

When an individual seadragon was encountered for the first time on a field trip, it was photographed nine times: eight photos along the entire length of both sides of the body and face; and one photo from on top of the tail. Individual fish were identified by the damage patterns on appendages or by facial markings. Position, depth and habitat were noted at each location. Seadragon positions were recorded underwater by measuring diver body lengths (~ 2 m) to the two nearest markers in a set of markers mapped prior to the study. Markers were separated by approximately 10 m and were spaced along the study area. Fish were measured from the tip of the snout to the tip of the tail using a ruler. These measurements had an estimated error of <10%, derived by requesting divers to measure the same fish on consecutive dives.

Identification of individuals, estimation of abundance and movement

A labelling scheme for the 20 main appendages of seadragons was developed (Fig. 2). Information from photographs was catalogued so

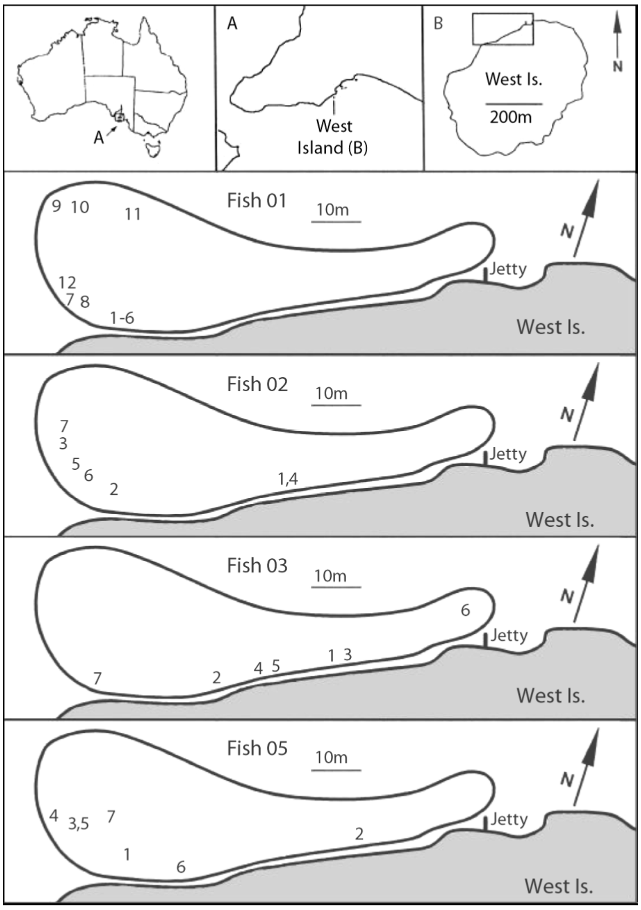

Fig. 1. Location map of study site and seadragon positions. Main maps include a line surrounding the dive area. Positions of sightings are shown for the four individuals sighted seven or more times, positions for each fish are numbered consecutively.

that patterns of damage to any appendage from any fish could be examined from different dates.

Facial markings at the end of the tubular snout were traced from projected slides. These markings were unique to individual fish at West Island (Fig. 3), and also differed from those of fish photographed elsewhere. The total number of seadragons in the study area was estimated by using the capture and recapture method. The most appropriate algorithm for our data set, where several animals were sighted no more than twice, is the moment estimator (Chao 1988). We used the moment estimator on the complete data set and, in an attempt to increase independence of sightings, also on a data set limited only to dives five or more days apart. The moment estimator algorithms for population estimation and associated error are, respectively:

$$N_1 = S + f_1^2 / (2f_2)$$

$$\text{Var } N_1 = f_2 \{0.25 (f_1 / f_2)^4 + (f_1 / f_2)^3 + 0.5 (f_1 / f_2)^2\}$$

where N_1 is the estimate of population size,
S is the number of distinct animals captured in the t trapping sessions,
and f_k is the number of animals captured exactly k times in the t trapping sessions.

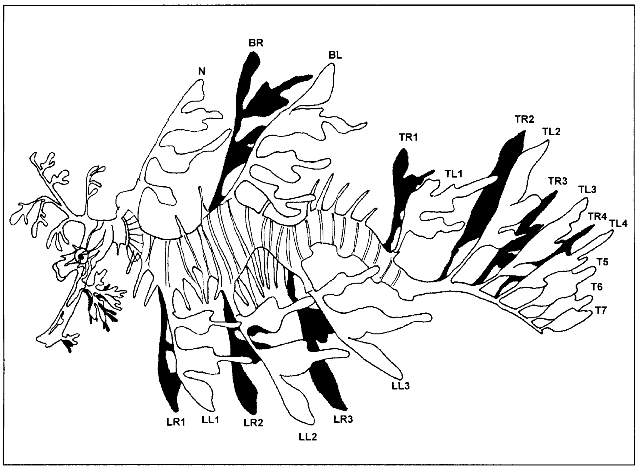

Fig. 2. Outline and marking patterns of a leafy seadragon, showing labelling of appendages: N, nape; B, back; T, tail; L (as first letter), lower; R, right; L (as second letter), left.

Results

Estimation of abundance

Nine individuals were sighted during the 14-month study. All were 27–32 cm long except Fish 01, which was 20 cm when first recorded and 27 cm one year later at the end of the study, and Fish 09, which was 13 cm when sighted once only near the end of the study (Table 1). Eight of the nine fish were sighted at least twice (Table 1). Photography and measurement did not appear to influence fish position or fish behaviour

Capture and recapture calculations using the moment estimator algorithm on the complete data set gave an estimate of 9.2 (±0.3) fish. This equates to a density of 57 fish ha^{-1}. Analysis of the limited data set using the moment algorithm, including only the 16 dives that were five or more days apart, gave an estimate of 8.0 (±3.5) fish.

The number of sightings in each calendar month varied, but was strongly correlated with the number of dives and amount of underwater time (regression results, respectively: $r^2 = 0.78$, $r^2 = 0.75$, $n = 12$, $P < 0.001$ in both cases; 2 months excluded because no diving occurred). The probability of sighting a seadragon is mostly explained by searching effort.

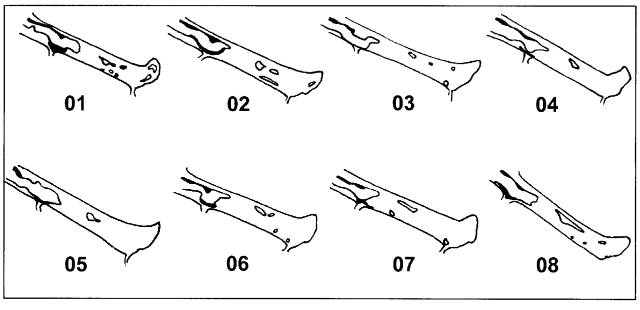

Fig. 3. Differences in snout markings among individual seadragons (numbers are fish numbers). Snouts of eight fish are shown. Fish 09 was too small for markings to show clearly in photographs.

Table 1. Description and number of sightings of leafy seadragons found during study

Fish number	Number of sightings	First sighted	Last sighted	Time between first and last sighting (days)	Size range (cm)
01	12	15 Jan. 96	23 Dec. 96	343	20–27
02	7	15 Jan. 96	10 Oct. 96	269	28–30
03	7	16 Jan. 96	15 Jun. 96	151	27–32
04	2	16 Jan. 96	18 Jan. 96	2	30–32
05	7	19 Jan. 96	23 Dec. 96	339	28–31
06	5	27 Apr. 96	29 Aug. 96	124	27–28
07	2	27Apr. 96	20 May. 96	23	n/a
08	2	12 Dec. 96	3 Jan. 97	22	n/a
09	1	18 Feb. 97	18 Feb. 97	0	13

Movement

Several individuals were re-sighted in the study area many times over long periods (Table 1). Sightings were made at depths of 3–11 m over brown algae, seagrass and the in-between strip of sand, which was often covered by mats of drift macroalgae. The mean number of sightings per fish was 5.0 (s.e. 1.2, range 1– 12). Position recordings for the four fish sighted seven times or more (Table 1, Fig. 1) were scattered across the study area. The maximum distance between sightings for these individuals was 35–82 m. At times, the same individual was found in the same location (to the nearest metre or alongside a particular rock), either on multiple dives on a single day or on separate surveys made up to three weeks apart. Despite the overlap in position recordings of the four most commonly re-sighted fish, no observations were made of any interactions between seadragons.

Discussion

In this study, individual fish were identifiable by patterns of damage to appendages in the short term and by facial markings for at least 11 months. Although the pattern of damage or wear to appendages remained constant for at least several months in some individuals, it was not constant in others, so appendage damage patterns are not considered a reliable method of identifying individuals over long periods. We did not record healing of damaged appendages, but this might prove useful in future studies.

The snout markings of most of the fish remained the same from the first to the last sighting; for Fish 05, this was a period of 11 months. Only Fish 01, which grew 7 cm during the study period, showed changes in facial markings over time (Fig. 4). It may be that facial markings change as an individual grows, so facial markings should not be considered reliable in identifying adults from photographs of juveniles. More fish need to be examined before it can be established how markings change as fish grow.

The simplest explanation for the frequent resightings and the paucity of new sightings is that leafy seadragons have a

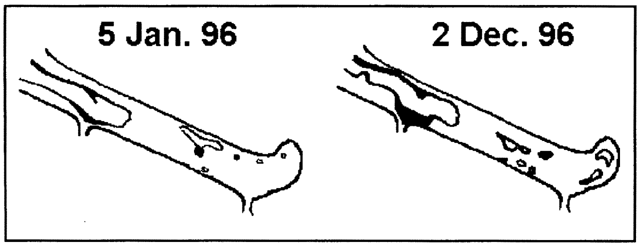

Fig. 4. Snout markings over time in Fish 01. The sightings are 11 months apart, sub-adult at first sighting (5 Jan. 1996) and adult at last sighting (2 Dec. 1996).

home range. Of the eight seadragons sighted more than once, all except one were in the study area on occasions at least 20 days apart. However, the long periods during which these same individuals could not be found suggests that part of their home ranges lay outside the study area.

Increased reproductive success, juvenile survival and intrinsic fitness have been used to explain large-scale seasonal movements of fish (Godin 1997). Of the few syngnathid species in which movements have been described, some make a marked seasonal migration (Bayer 1980; Lazzari and Able 1990), and even species known to have a small home range during the summer breeding season may move to deeper water during the winter (*Hippocampus whitei*, Vincent and Sadler 1995). There was no evidence for seasonal migration among the leafy seadragons in this study.

Although leafy seadragons at West Island appeared to have a home range, even the most frequently sighted fish was seen on only 25% of dives. Habitat selection, foraging tactics, predator avoidance, reproductive behaviour and territoriality have generally been used to explain small-scale movements of fish (Godin 1997). The lack of observations of interactions among seadragons in this study suggests that they are not territorial.

Although a more complete determination of home ranges, including any diel changes in movement patterns, is required, our results show that marine protected areas of the size of West Island are likely to contain a significant portion of the area needed to protect populations of seadragons. However, this conclusion would be affected should it be shown that juvenile seadragons disperse more widely than adults. A management plan for leafy seadragons is being contemplated, and the present study provides some preliminary scientific information on which such a plan can be based.

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