

Ontogenetic and sex-based differences in habitat preferences and site fidelity of White's seahorse *Hippocampus whitei*

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The aim of this study was to determine and compare habitat preferences for male and female adult and juvenile White's seahorse *Hippocampus whitei* and assess their movements and site fidelity over 4 years. Data were collected from three sites along 1.5 km of estuarine shoreline in Port Stephens, New South Wales, Australia, from 2006 to 2009 using *H. whitei* that had been tagged with visible implant fluorescent elastomer. Relative availability of 12 habitats and habitat preferences of *H. whitei* was determined, based on the habitat that *H. whitei* used as a holdfast. *Hippocampus whitei* occurred in nine different habitats; adults preferred sponge and soft coral *Dendronephthya australis* habitats with no difference between male and female habitat preferences whilst juveniles preferred gorgonian *Euplexaura* sp. habitat. There was a significant preference by adults for *D. australis* colonies with height >40 cm and avoidance of colonies <20 cm. Neither adults nor juveniles used sand or the seagrasses *Zostera muelleri* subsp. *capricorni* and *Halophila ovalis*. *Hippocampus whitei* showed cryptic behaviour with c. 50% of adult sightings cryptic and c. 75% for juveniles with crypsis occurring predominantly in *Sargassum* sp. for adults and *Euplexaura* sp. habitat for juveniles. Within sites, females moved significantly longer distances (maximum of 70 m) than males (maximum of 38 m) over 20 months. Strong site fidelity was displayed by *H. whitei* with males persisting at the same site for up to 56 months and females for 49 months and no *H. whitei* moved between sites. The longest period that an *H. whitei* was recorded on the same holdfast was 17 months for a male and 10 months for a female. As this species displays strong site fidelity, specific habitat preferences and has a limited distribution, future management needs to minimize the risk of habitat disturbance as loss of key habitats could have a negative effect on species abundance and distribution.

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Key words: *Dendronephthya australis*; elastomer; Port Stephens; soft coral; Syngnathidae.

INTRODUCTION

Conservation of species threatened with extinction requires understanding of the key processes that influence their distribution and abundance (Brown, 1984). Habitat loss has detrimental effects on biodiversity, leading to many species being threatened with extinction (Mace & Lande, 1991; Stuart *et al.*, 2004). Habitat loss and alteration can be natural or anthropogenic and the conservation of habitats and

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the ecological processes maintaining habitats are important for maintaining biodiversity, ecological processes and ecosystem function (Groombridge, 1992; Mora *et al.*, 2011). The conservation of threatened species is intrinsically linked to the protection of habitats that are essential for feeding, reproduction and shelter. To assist with species' conservation, it is important to distinguish between the habitat use and habitat preference. Habitat use refers to those habitats where a species occurs whilst habitat preference is a species' disproportionate use of a habitat in relation to its relative availability and is a consequence of habitat selection (Manly *et al.*, 1992).

Loss and alteration of important marine habitats can lead to population declines (Paddack *et al.*, 2009; Pratchett *et al.*, 2009; Bonin *et al.*, 2011). Numerous studies have detailed habitat relations of marine fishes, such as habitat use by a threatened serranid species (Harasti & Malcolm, 2013), habitat specificity of juvenile tropical fishes (Wilson *et al.*, 2010) and effects of habitat degradation on coral reef fish settlement (Feary *et al.*, 2007). Seahorses *Hippocampus* spp. of the family Syngnathidae include 48 recognized species worldwide (Vincent *et al.*, 2011). They are deemed to be under threat globally with several species listed as threatened in the IUCN Red List; 10 species are listed as vulnerable, one species is listed as endangered, one species as least concern and the remaining species are listed as data deficient (IUCN, 2013). Seahorses are considered to be threatened from incidental capture in trawl fisheries, over-exploitation from commercial fishing and through the loss of essential habitats (Vincent *et al.*, 2011).

Seahorses are known to utilize a wide range of habitats including seagrasses (Bell *et al.*, 2003; Vincent *et al.*, 2004), mangroves (Rosa *et al.*, 2007), coral reefs (Perante *et al.*, 2002) and artificial structures (Harasti *et al.*, 2010), as well as faunal substrata such as sponges and soft corals (Kuiter, 2009) and macroalgae (Moreau & Vincent, 2004). Some *Hippocampus* species are very habitat specific, such as the pygmy seahorses *Hippocampus bargibanti* Whitley 1970 and *Hippocampus denise* Lourie & Randall 2003, that are associated only with gorgonian fans (Baine *et al.*, 2008; Smith *et al.*, 2012) whilst other species such as the pot-belly seahorse *Hippocampus abdominalis* Lesson 1927 use a variety of habitats (Martin-Smith & Vincent, 2005). At a small spatial scale, the habitat of a seahorse is its holdfast, *i.e.* the substratum to which it attaches with its prehensile tail. The alteration or destruction of habitats has negative effects on populations of seahorses. Populations of the long-snouted seahorse *Hippocampus guttulatus* Cuvier 1829 were reduced in seagrass meadows that were damaged by seining (Curtis *et al.*, 2007) and populations of the tiger tail seahorse *Hippocampus comes* Cantor 1850 were reduced on coral reefs that had been subjected to blast and poison fishing (Marcus *et al.*, 2007). Populations of the dwarf seahorse *Hippocampus zosterae* Jordan & Gilbert 1882 declined following degradation of seagrasses caused by the construction of two adjacent marinas (Masonjones *et al.*, 2010) and abundance of White's seahorse *Hippocampus whitei* Bleeker 1855 declined when artificial habitats had been deliberately modified (Harasti *et al.*, 2010).

To protect seahorses in the wild from loss of essential habitats, the habitats that are used and preferred must be first determined. There have been very few studies that have assessed the habitat usage or preferences of seahorses: Kynsna seahorse *Hippocampus capensis* Boulenger 1900 preferentially used aquatic vegetation in estuaries (Teske *et al.*, 2007), *H. comes* used a variety of habitat types on a coral reef with no

holdfast preference and habitat usage differed with ontogeny (Morgan & Vincent, 2007), whilst two different studies have compared habitat utilization of *H. guttulatus* and short-snouted *Hippocampus hippocampus* (L. 1758) (Curtis & Vincent, 2005; Gristina *et al.*, 2014). The focus of this study was *H. whitei*, a medium-sized seahorse that is considered endemic to eight coastal estuaries of central New South Wales (NSW), Australia (Harasti *et al.*, 2012). *Hippocampus whitei* grows to a maximum total length (L_T) of 162 mm, exhibits rapid initial growth and maturity, lives for up to 5 years in the wild (Harasti *et al.*, 2012) and has a small home range (c. 9–14 m²) over short time scales of days to weeks (Vincent *et al.*, 2005). This species occurs in seagrasses, artificial structures and sponge garden habitats (Vincent *et al.*, 2005; Harasti & Gladstone, 2013) to depths of 20 m (Kuiter, 2009). Whilst these studies have reported habitats that *H. whitei* occupy; however, it is not known if they prefer these habitat types or whether they are using these habitats because their preferred habitats are not available. It is also not known if *H. whitei* show any preferences to more complex habitats as seahorses are considered to rely on crypsis to hide from predators (Kleiber *et al.*, 2011).

All seahorses are protected in NSW and are not at risk from fishing pressures, with the greatest potential threat being loss of essential habitats. Given the limited distribution of *H. whitei* and its distribution being located around the most highly developed region in Australia (NSW EPA, 2012), there is a need to determine the habitats that are of importance to this species to assist with its long-term conservation. In addition, as Morgan & Vincent (2007) found differences in habitat use between juvenile and adult *H. comes*, it is important to assess if *H. whitei* also displays ontogenetic differences in habitat preference. It is unknown if *H. whitei* prefers specific habitat types or whether it is a habitat generalist showing no significant preference or avoidance of habitats. If *H. whitei* prefers specific habitats, any loss of essential habitats could have a negative effect on population abundance and its distribution. Therefore, the aims of this study were to (1) determine and compare the habitat preferences of adult male and female and juvenile *H. whitei*, (2) assess if they displayed cryptic behaviour within particular habitats and (3) assess the long-term movements and site fidelity of *H. whitei*.

MATERIALS AND METHODS

STUDY SITES

This study was undertaken at Nelson Bay in the Port Stephens–Great Lakes Marine Park in Port Stephens on the New South Wales (NSW) mid-north coast, Australia (32° 43' 04" S; 152° 08' 29" E) (Fig. 1). The area was selected because *H. whitei* is known to be abundant (Harasti *et al.*, 2012) and its distribution within Port Stephens includes a large number of distinct habitats that are defined in Table I. The study was undertaken at three sites extending over 1.5 km of coastline, each site was c. 6000 m² in extent, and contained a variety of habitat types (Table I). The sites were similar in structure and configuration in that they were dominated by sponge garden reef habitat interspersed with sand and the soft coral *Dendronephthya australis* with seagrass meadows present in the shallow (2–5 m) sections. The depth range for each site was limited from 2 to 13 m as no *H. whitei* have been observed >12 m depth, even though numerous dives (100+) were conducted in the 13–25 m depth range at each of the sites from 2006 to 2009. It was observed at depths of 13–25 m that there was still continuous habitat available, particularly with extensive sponge garden and *D. australis* habitats but no *H. whitei* were ever recorded deeper than 12 m.

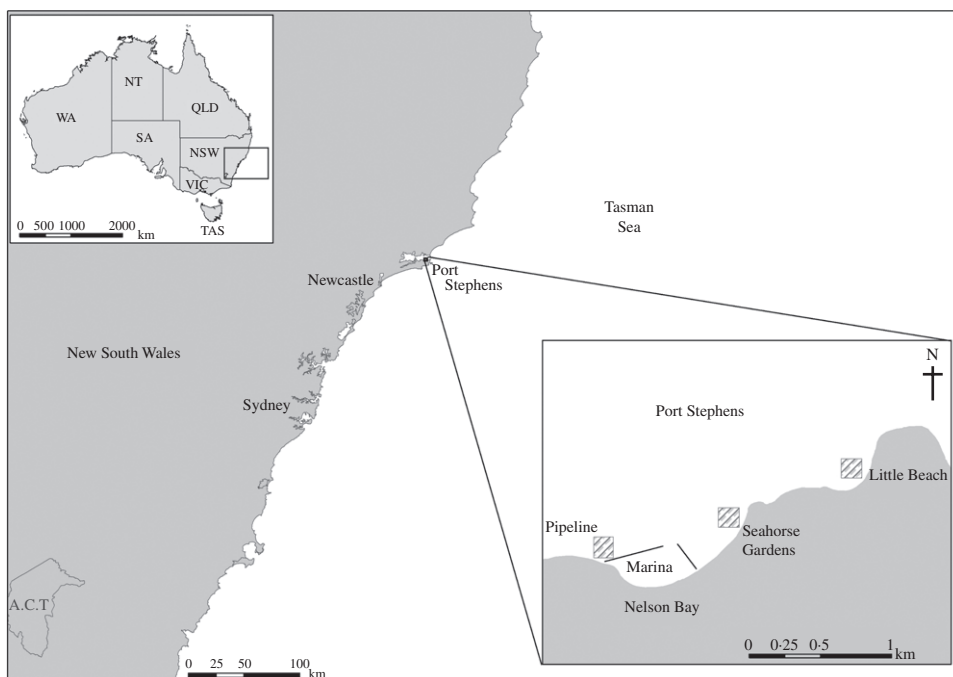


FIG. 1. Location of *Hippocampus whitei* study sites, Port Stephens, New South Wales, Australia

HABITAT PREFERENCE

The null hypothesis that *H. whitei* would not display a significant preference for a specific habitat was tested by comparing habitat availability with habitat use and determining habitat preference scores (Manly *et al.*, 1992; Light & Jones, 1997; Gladstone, 2007; DeMartini *et al.*, 2010). A point-transect method was used to provide an estimate of the relative availability of each habitat type (Choat & Bellwood, 1985) where 20 transects measuring 30 m in length were haphazardly placed at each site. To avoid overlapping of transects, the initial transect was placed at one end of the site with all subsequent transects laid one after the other towards the other end of the study site. The habitat occurring directly below the transect at 1 m intervals was recorded (Table I), providing a total of 600 habitat points for each site. These surveys were undertaken in January 2009. In addition, the height of *D. australis* was also recorded in three size classes (<20, 20–40 and >40 cm) with the size class estimated visually by the diver. The area to 50 cm on both sides of the transect was thoroughly searched for seahorses. When an *H. whitei* was found, the following information was recorded: habitat (being the habitat used as a holdfast by the *H. whitei* using its prehensile tail to anchor itself), sex and depth. The number of *H. whitei* encountered using the transect point-count method, however, was very low ($n = 21$ *H. whitei* across all three sites from 60 transects) and insufficient for any meaningful statistical analysis on habitat association.

In addition to *H. whitei* being recorded on the habitat transects, data on *H. whitei* habitat use were also collected monthly at each site from January 2008 to December 2009 using a random 60 min roaming diver survey technique (Kingsford & Battershill, 1998) which included the diver actively searching through habitats with hands to find any hiding *H. whitei*. When an *H. whitei* was observed, its depth, holdfast habitat, sex and state of maturity were recorded. Adult males were determined by presence of a brood pouch whilst females were determined as those without a brood pouch and were >75 mm L_T . Juveniles were those animals considered to be not mature and <75 mm L_T as *c.* 75 mm is considered to be the average size for sexual maturity for *H. whitei* in Port Stephens (Harasti *et al.*, 2012). When *H. whitei* were observed on *D. australis*, the height

TABLE I. Descriptions of habitat types from habitat preference study and observed habitat depth range for *Hippocampus whitei*

Habitat type	Description	Depth range (m)
Algae	Algal habitats included small turfing and clumping brown and red algae such as <i>Hormophysa</i> sp., <i>Euptilota</i> sp. <i>Zonaria</i> sp. and <i>Codium</i> sp.	1–25
Ascidian	Constituted several different species of Ascidiacea such as <i>Clavelina meridionalis</i> and <i>Sycozoa</i> sp.	3–25
<i>Carijoa</i> sp.	Family: Clavulariidae. Undescribed species of <i>Carijoa</i> sp. The colony is coated by an orange sponge and has large white polyps. Colony length to 25 cm	5–25
<i>Dendronephthya australis</i>	Family: Nephtheidae. Highly branched and bushy soft coral colony that has pink stalk and branches with white sclerites. Colony grows to a maximum height of c. 70 cm and was found to vary greatly in size	4–23
<i>Euplexaura</i> sp.	Family: Plexauridae. Yellow gorgonian fan found to grow to a maximum height of 40 cm and width of 70 cm	5–25
<i>Halophila ovalis</i>	Family: Hydrocharitaceae. Has ovate leaves with stalk-like petioles. Commonly referred to as paddle weed with a maximum leaf length of 4 cm	2–10
<i>Ecklonia radiata</i>	Family: Alariaceae. Large brown-green coloured seaweed that has several fronds arising from a central supporting stipe stem. Grows to a maximum height to 2 m. Commonly referred to as kelp	1–25
<i>Posidonia australis</i>	Family: Posidoniaceae. Commonly referred to as strapweed with tough leaves with a leaf length of 45 cm and width of 2 cm	1–5
Sand	Patches of bare sand that contained no other habitat type	0–25
<i>Sargassum</i> sp.	Family: Sargassaceae. Constitutes brown alga in genus <i>Sargassum</i> , such as <i>Sargassum vestitum</i> , and is brown-yellow in colour. Maximum observed length is 1.5 m	4–18
Sponge	Sponge habitats constituted a variety of species from phylum Porifera. Some of the more common and identifiable species included <i>Echinoclathria</i> sp., <i>Holopsamma laminaefavosa</i> , <i>Plumohalichondria australis</i> and <i>Mycale australis</i>	5–25
<i>Zostera muelleri</i> subsp. <i>capricorni</i>	Family: Zosteraceae. Commonly referred to as ribbon weed with a narrow blade that grows to maximum length of 50 cm	1–6

of the colony was estimated using the height classes described above. For sightings in all habitat types, it was also recorded if the *H. whitei* sighting was cryptic. For the purpose of this study, cryptic refers to 'was the seahorse hidden within its habitat and could not be visually seen by the diver?' It was considered to be cryptic when the *H. whitei* was obscured from initial view until the habitat was actively searched thoroughly by the diver using hands and *H. whitei* was detected within or underneath the habitat. All encountered habitats that were considered complex were actively searched for hidden *H. whitei*. Whilst the classification of cryptic was subject to interpretation by the diver, the cryptic recording was kept consistent throughout the surveys as data were only collected by the first author. The results from each monthly survey ($n = 24$) were combined for each site for habitat preference analysis. Additionally, water temperature was recorded monthly at each site from two Mares dive computers (www.mares.com).

LONG-TERM MOVEMENT

As part of a larger research project on the biology and ecology of *H. whitei* by Harasti *et al.* (2012), *H. whitei* at each of the three study sites had been previously tagged using small visible implant fluorescent elastomer tags (VIFE, Northwest Marine Technologies; www.nmt.us) using the techniques described in the study of Woods & Martin-Smith (2004). Fish were individually tagged with three 1–2 mm elastomer tags and inserted into unique locations on the body to allow for individual identification on subsequent resighting. The use of elastomer tags in seahorses has not been shown to alter their behaviour or growth (Woods & Martin-Smith, 2004) and even though these tags are considered permanent, they are unlikely to affect cryptic as animals have been observed alive 4 years after initial tagging (Harasti *et al.*, 2012). Specific elastomer colours were used for each site (Pipeline = red, Seahorse Gardens = yellow and Little Beach = orange). A total of 948 *H. whitei* were tagged across the three sites between 2006 and 2009 (Pipeline: $n = 548$, Seahorse Gardens: $n = 387$ and Little Beach $n = 13$).

An initial survey was undertaken from January to February 2008 to mark the location of each *H. whitei* in each site. The location of tagged *H. whitei* was recorded by a diver towing a tethered Garmin Map 60 GPS (www.garmin.com) on a surface float that was time-synchronized to a MARES dive computer. The time during when the *H. whitei* was recorded was matched to the correct GPS co-ordinates when the GPS track was downloaded into Google Earth software (www.google.com/earth). The location of each *H. whitei* that was recorded during the initial survey was monitored bi-monthly using the roaming diver survey technique until August 2009. Distance moved between surveys was measured by plotting points in Google Earth and measuring the distance between each point. For each individual, a small washer with numbered flagging tape was pushed into the substratum marking the *H. whitei* location to assist estimating movements on subsequent resighting and if a *H. whitei* was found within close proximity to its marker (<5 m), the distance moved was estimated by the diver underwater. If the *H. whitei* was found on the same holdfast as the previous survey, the distance moved was recorded as 0 m.

SITE FIDELITY

To gain an understanding of site fidelity, monthly surveys were undertaken from January 2006 to December 2009 at the Seahorse Gardens and Pipeline, as these were the two sites where large populations of tagged *H. whitei* occurred (Harasti *et al.*, 2012). On each occasion, a tagged *H. whitei* was resighted, its locality details were recorded through the use of the diver-towed GPS or by its proximity to a marked position.

DATA ANALYSIS

Habitat preferences

One-factor permutational multivariate analysis of variance (PERMANOVA) was used to determine if the habitat composition of the three sites differed, using PERMANOVA+Version 1.0.5 within PRIMER-E 6 (Plymouth Routines in Multivariate Ecological Research; www.primers-e.com) (Anderson, 2001). The number of occurrences of each habitat on

each transect was summed, and data were square-root transformed. The analysis was done on the Bray–Curtis similarity matrix, with site analysed as a fixed factor, and significance was determined from $n = 9999$ permutations. Habitat composition of the three sites did not differ ($F_{2,59} = 1.84$, $P > 0.05$) and hence the habitat preferences for *H. whitei* are reported with all three sites combined.

To determine the habitat availability and preferences of *H. whitei* in Port Stephens, the resource selection probability function (RSPF) was used (Manly *et al.*, 1992). RSPF is a function that computes the probability that a particular resource, as characterized by a combination of environmental variables, will be used by an individual animal (Manly *et al.*, 1992). The use of the RSPF has been widely applied in terrestrial and marine studies for assessing habitat preferences (Gladstone, 2007; Aarts *et al.*, 2013; Hooten *et al.*, 2013). The RSPF is generally estimated from observations of (1) presence or absence (used *v.* unused) or (2) presence or available (used *v.* available) resource units (Boyce *et al.*, 2002). The RSPF was used to determine the preferred habitats of *H. whitei* using the formula $\hat{W}_i = O_i/\pi_i^{-1}$, where O_i is the proportional use of habitat type i , π_i is proportional availability of habitat type i and \hat{W}_i is the preference score for habitat type. To determine the statistical significance of preference scores, 95% c.i. were used for \hat{W}_i , where the upper confidence interval was <1 , the habitat was significantly avoided. If the confidence interval was between <1 and >1 , the habitat was used in proportion to its availability (*i.e.* *H. whitei* showed no preference or avoidance to habitat) and if the lower confidence interval was >1 , the habitat was significantly preferred. Those habitat types where no *H. whitei* were recorded were excluded from the habitat preference analysis (Manly *et al.*, 1992).

Long-term movements and depth

To test the null hypothesis that the depth *H. whitei* occurred did not differ among sites or between sexes and juveniles, a two-factor analysis of variance (ANOVA) was conducted. The factors site and sex were treated as fixed orthogonal factors. The null hypothesis that the distance moved by *H. whitei* over 17 months did not differ between sexes and among sites was tested by a two-factor ANOVA. The factors sex and site were treated as fixed orthogonal factors. The data analysed were the total distances moved by 36 *H. whitei* across all nine bi-monthly surveys from the Seahorse Gardens (seven males: mean \pm s.e. $L_T = 124.4 \pm 2.6$ cm, eight females: mean \pm s.e. $L_T = 125.9 \pm 3.2$ cm) and Pipeline (11 males: mean \pm s.e. $L_T = 126.2 \pm 2.1$ cm, 10 females: mean \pm s.e. $L_T = 125.1 \pm 3.6$ cm) sites. To meet the assumptions for repeated measures ANOVA, only *H. whitei* that were recorded on each of the nine surveys were included in the analysis. Data did not assume normality (Shapiro–Wilk; d.f. = 36, $P < 0.05$) and were square root transformed. All statistical analysis for movements was undertaken in the software package SPSS 20 (www.ibm.com/spss).

RESULTS

HABITAT AVAILABILITY AND PREFERENCES

Sand was the most dominant habitat present across all sites combined (33% of habitat present) followed by sponge habitat (16%), algal habitat (15%) and soft coral *D. australis* habitat (13%) (Fig. 2). The monthly 60 min surveys recorded a total of 1146 *H. whitei* observations. *Hippocampus whitei* occurred in nine of the available habitats; no *H. whitei* were recorded in sand, or the seagrass habitats *Zostera muelleri* subsp. *capricorni* and *Halophila ovalis*. Juveniles were also not observed in ascidian and *Carijoa* sp. habitats. There was no significant difference in habitat preference scores between male and female *H. whitei* as the c.i. for males and females were similar [Fig. 3(a)]. Adult males and females exhibited a significant preference for sponge and *D. australis* habitats, showed no preference for ascidian, *Carijoa* sp., and gorgonian *Euplexaura* sp. habitats and showed a significant avoidance of algal, *Posidonia australis*, *Ecklonia*

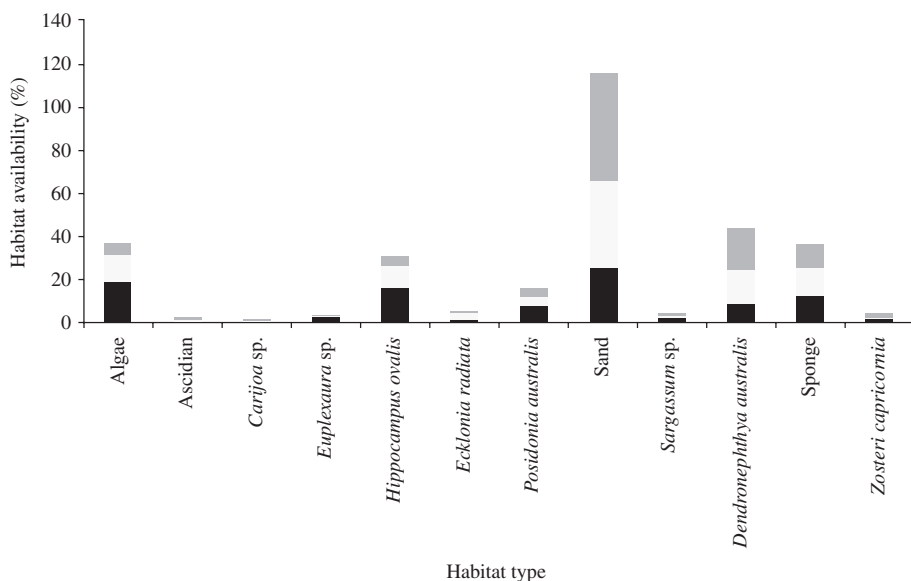


FIG. 2. Habitat availability (expressed as % occurrence in all transects in each site) at the three *H. whitei* study sites in January 2009: Seahorse Gardens (■), Pipeline (□) and Little Beach (▒).

radiata and *Sargassum* sp. habitats [Fig. 3(a)]. Juveniles displayed different habitat preference to adults with a significant preference for *Euplexaura* sp. gorgonian habitats, no preference for *E. radiata*, *Sargassum* sp., sponge and *D. australis* habitats and a significant avoidance of algal and *P. australis* seagrass habitat [Fig. 3(b)].

A total of 262 occurrences of *D. australis* were recorded across all three sites, and the occurrence of the three size classes was similar (Fig. 4). The standardized habitat preference scores combined for all sites found that both adult and juvenile *H. whitei* had a strong preference for the larger *D. australis* soft corals (>40 cm height), no preference for soft corals of 20–40 cm and a significant avoidance of soft corals <20 cm (Fig. 5).

Mean \pm S.E. water temperature from 2008 to 2009 was $19.5 \pm 0.1^\circ \text{C}$ with the maximum monthly mean recorded in March ($21.6 \pm 0.5^\circ \text{C}$) and the minimum monthly mean \pm S.E. recorded in August ($16.9 \pm 0.2^\circ \text{C}$).

CRYPTIC SIGHTINGS

Across the three sites, 50.3% of adult *H. whitei* sightings were of cryptic individuals. Adults were found to be most cryptic in *Sargassum* sp. (91.7% of sightings cryptic) and *D. australis* (73.9%) whilst they were most easily detected in sponge habitats (26.1%). Juveniles were more cryptic (75.3% of all sightings cryptic) and were most cryptic in gorgonian *Euplexaura* sp. (85.4%) and *D. australis* (75.0%) habitats compared to sponge habitats (42.3%).

DEPTH

There was no significant difference in the depths recorded between adult males and females and juveniles (two factor ANOVA, $F_{2,1213} = 1.5$, $P > 0.05$) and there was no

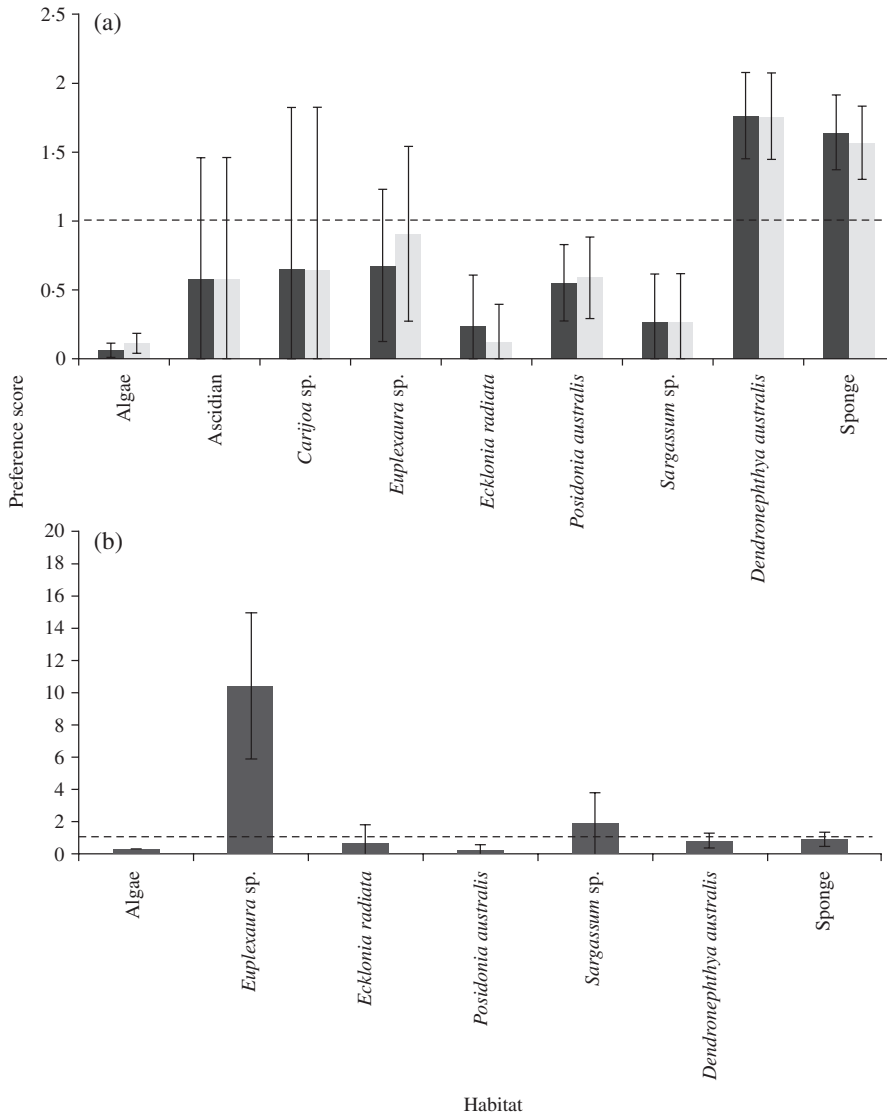


FIG. 3. Habitat preferences scores ($\pm 95\%$ C.I.) of (a) adults (■, males; □, females) based on 1146 *Hippocampus whitei* observations and (b) juveniles based on 100 individual *H. whitei* observations across three sites in Port Stephens, New South Wales, Australia, from January 2008 to December 2009. Preference scores with a lower $\pm 95\%$ C.I. of > 1 (—) indicate a significant habitat preference.

significant difference in the depth *H. whitei* occurred across sites (two factor ANOVA, $F_{2,1213} = 0.02$, $P > 0.05$); however, there was a significant site \times sex interaction (two factor ANOVA, $F_{4,1146} = 12.3$, $P < 0.00$). This interaction occurred at the Seahorse Gardens site where the mean \pm S.E. depth for juveniles was 6.5 ± 0.4 m compared to a depth of 8.5 ± 0.1 m for males and 8.4 ± 0.1 m for females. The mean \pm S.E. depth of *H. whitei* observed at the Pipeline was 7.8 ± 0.1 m, which was similar to the mean

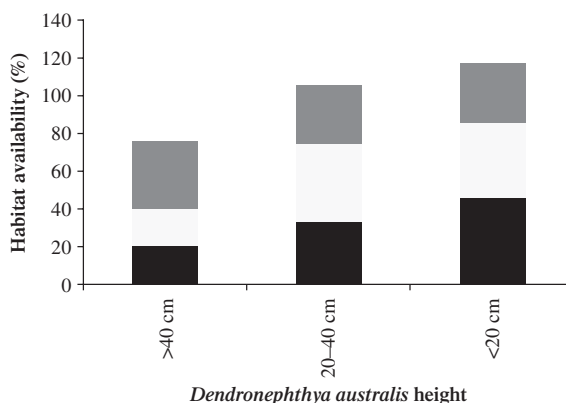


FIG. 4. *Hippocampus whitei* habitat availability (%) for the various size classes of the soft coral *Dendronephthya australis* across all three sites in Port Stephens: Seahorse Gardens (■), Pipeline (□) and Little Beach (▒).

depth at Little Beach of 7.8 ± 0.2 m. The minimum observed depth for *H. whitei* was 1.7 m and a maximum was 11.8 m.

LONG-TERM MOVEMENT

The mean \pm s.e. total distance moved over 17 months by *H. whitei* at the Seahorse Gardens was 21.8 ± 3.9 m for males and 39.4 ± 4.6 m for females compared to 16.4 ± 3.1 m for males and 24.1 ± 2.4 m for females at the Pipeline. The total distance moved differed significantly between the two sites ($F_{1,36} = 6.93$, $P < 0.05$) and between sexes ($F_{1,36} = 11.55$, $P < 0.05$) but the sex \times site interaction was not significant ($F_{1,36} = 0.48$, $P > 0.05$). The greatest distance an individual was found to move across all surveys combined ($n = 9$) was for a female at the Seahorse Gardens that moved a combined distance of 70 m compared to only 38 m for a male at the

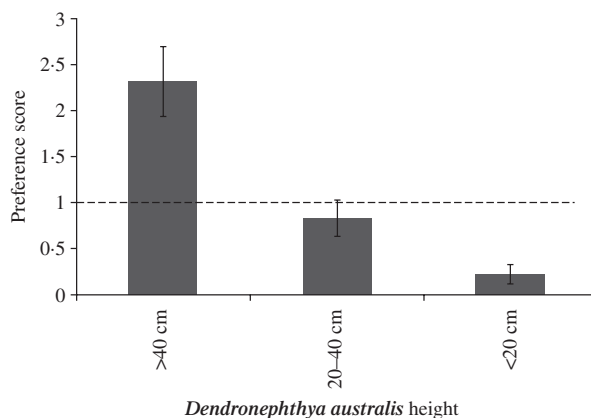


FIG. 5. Standardized habitat preference scores (mean \pm 95% c.i.) for adult and juvenile *Hippocampus whitei* combined across all three sites in relation to height classes for *Dendronephthya australis*. Preference scores with a lower \pm 95% c.i. of > 1 (—) indicate a significant habitat preference.

Seahorse Gardens. The largest distanced moved by a *H. whitei* between two survey periods (c. 50 days) was 43 m for a female compared to only 15 m for a male, both from Seahorse Gardens.

SITE FIDELITY

No *H. whitei* moved between any of the three sites, with tagged fish being resighted only at the site at which they were initially tagged. From 2006 to 2009, the longest time during which individuals were recorded at the Seahorse Gardens site was 56 months for a male and 49 months for a female, and the longest time during which tagged individuals were recorded at the Pipeline site was 52 months for a male and 42 months for a female. The longest period that a *H. whitei* was recorded on the same holdfast, and not observed on any other holdfasts, was 17 months for a male and 10 months for a female, both observed at the Pipeline. A juvenile that was originally tagged at 33 cm resided on the same gorgonian holdfast for 5 months at the Pipeline site.

DISCUSSION

Various studies have found that individual fish species are associated with particular habitat types and many species show ontogenetic changes in habitat use between adult and juvenile stages (Light & Jones, 1997; DeMartini *et al.*, 2010; Boaden & Kingsford, 2013). It is important to understand how habitat use can vary between different life stages of species as ontogenetic differences may require protection or individual management of various habitat types if the species is considered threatened. Determining the habitat preferences for *H. whitei* is a useful measure that can assist with the species long-term conservation through the protection of habitats that it uses. It is evident from this study that *H. whitei* utilizes a variety of habitat types, and that habitat preference by juveniles was found to differ from adults.

As seahorses are slow moving, sedentary species (Kuitert, 2009), they rely on crypsis for survival as they have little ability to swim quickly away from predators (Kleiber *et al.*, 2011). The *D. australis* habitat offers a complex structure that provides excellent camouflage for seahorses to hide from predators, hence the high level of crypsis (74%) displayed by seahorses using this habitat. The larger the soft coral colony, the greater the structural complexity because of the increased number of branches, and hence this is probably why *H. whitei* had a significant preference for large *D. australis* (>40 cm height) whilst showing significant avoidance of smaller ones that lacked complexity. Similar to *D. australis*, the gorgonian *Euplexaura* sp. habitat that was significantly preferred by juvenile *H. whitei* is also a very complex habitat with juveniles displaying strong crypsis (85%) by hiding amongst the gorgonian branches. The reliance and preference for habitat complexity by seahorses are unknown; however, it is thought that seahorses prefer more complex habitats as they provide better camouflage to avoid predators but also allows for successful ambush predation (Flynn & Ritz, 1999). Complex habitats potentially provide a good source of prey for seahorses as amphipods and copepods, considered a main prey of seahorses (Kendrick & Hyndes, 2005; Kuitert, 2009), were significantly more abundant in habitats that provided more structural complexity (Hellyer *et al.*, 2011). With both the

sponge and *D. australis* habitats being structurally complex, there is greater potential for hippocampid prey to occur within these habitats providing a food resource for *H. whitei*.

This ontogenetic change in habitat preference between juveniles and adults is similar to *H. comes*, which preferred macroalgal habitats as juveniles and corals as adults (Morgan & Vincent, 2007). The reason for ontogenetic variation in habitat use is unknown; however, the small size of the *Euplexaura* sp. gorgonians made it difficult for larger adults ($L_T > 100$ mm) to hide so they possibly move to larger more complex habitats as they mature for greater crypsis. As juveniles and adults were found in close proximity to each other on their preferred habitats, there was no evidence of any size segregation as reported in other studies (Morgan & Vincent, 2007). It has been suggested that ontogenetic habitat changes may be attributed to reproductive opportunity (Whiteman & Côté, 2004; Morgan & Vincent, 2007); however, this is unlikely for *H. whitei* as pregnant males were found occurring across nine different habitat types and were found using the same habitat types as juveniles.

Adult *H. whitei* were found to display a strong preference for the soft coral habitat *D. australis*, which is considered a rare habitat in NSW and has a very limited distribution within Port Stephens with it being the most prevalent in the same area as this study (NSW DPI, unpubl. data). The *D. australis* habitat has been found to contain high biodiversity when compared with other adjacent habitats and is considered to be an important nursery habitat for many fish species (Poulos *et al.*, 2013). In addition to its limited distribution in Port Stephens, *D. australis* has only been confirmed to occur from Port Hacking (Sydney) to Port Stephens (NSW DPI, unpubl. data) which coincides with most of the known range of *H. whitei* (Harasti *et al.*, 2012).

Female *H. whitei* moved significantly greater distances than males over the 17 month observation period and males were more likely to remain on the same holdfast for longer duration than females. In a previous study, *H. whitei* displayed small home ranges in seagrass habitat over 2–3 months, with females having a larger (*c.* 14.4 m²) home range than males (*c.* 9 m²) (Vincent *et al.*, 2005). It is speculated that males potentially move less to conserve energy for brooding embryos in their pouch with the large pouch also hindering their movements through increased mass and drag (Vincent *et al.*, 2005). It has been hypothesized that *H. whitei* maintain small ranges because the costs of movement are greater than the benefits in terms of survival, growth and reproduction (Vincent *et al.*, 2005) and it is probably a combination of these factors that have led to *H. whitei* displaying site fidelity within Port Stephens.

There was no evidence to suggest that any of the *H. whitei* moved between sites in Port Stephens and they displayed site persistence which is similar to a study of *H. whitei* in seagrass (Vincent *et al.*, 2005) and for other seahorse species (Perante *et al.*, 2002; Curtis & Vincent, 2006; Rosa *et al.*, 2007). Whilst this study indicates *H. whitei* is very site-associated, individual fish can still move large distances as showed by a female that was found to move 43 m within 50 days. In a displacement experiment using *H. guttulatus*, it was found that tagged individuals were able to travel large distances in a short time period (150 m over 8 days) with a single animal moving 60 m in 1 day (Caldwell & Vincent, 2013). Unlike this study, however, Caldwell & Vincent (2013) found no significant difference in movements between males and females. Additionally, in a pilot study, 70% of displaced *H. guttulatus* were able to move 20 m or less to return to their original home location indicating the ability of *H. guttulatus* to navigate back to their preferred habitat when displaced (Caldwell & Vincent, 2013).

Even though some individual *H. whitei* were observed moving around their site, they displayed strong site fidelity as evident through repeated observations of the same individuals existing at the same sites and even on the same holdfasts for long durations in this study. *Hippocampus whitei* from the Seahorse Gardens moved significantly greater distances than individuals from the Pipeline and this could be attributed to the available habitat being sparser at the Seahorse Gardens which was the site with the most sand habitat (38% sand v. 30% at Pipeline), a habitat which *H. whitei* did not use. *Hippocampus whitei* may therefore have had less available habitat to choose from and were therefore forced to move larger distances over sand when changing holdfasts.

Additionally, it was observed during the surveys that the Seahorse Gardens site was subjected to frequent anchoring as it provides a safe anchorage for vessels in the majority of weather conditions and is closer to Nelson Bay town than the other sites. This frequent anchoring caused damage to the habitats, particularly *D. australis* soft corals that were easily dislodged from the benthos by moving anchor chains. This anchor damage may have forced individual *H. whitei* to involuntarily move to alternate holdfasts through changes and loss of their existing habitat. Since 2010, both *D. australis* and sponge habitats within Port Stephens have been adversely affected as a result of sand inundation (NSW DPI, unpubl. data); however, no apparent decline in available habitats was observed during this study. The degradation of habitats important for *H. whitei* could have a detrimental effect on this species given its very limited distribution (Harasti *et al.*, 2012) and its range occurring along some of the most heavily populated estuaries in Australia (NSW EPA, 2012). Even though this species is protected within NSW from fishing pressures, the loss of essential habitats through anthropogenic effects could have ramifications for the future conservation of this species.

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