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An artificial water body provides habitat for an endangered estuarine seahorse species

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ABSTRACT

Anthropogenic development, especially the transformation of natural habitats to artificial, is a growing concern within estuaries and coastal areas worldwide. Thesen Islands marina, an artificial water body, added 25 ha of new estuarine habitat to the Knysna Estuary in South Africa, home to the Knysna seahorse. This study aimed to answer: (I) Can an artificial water body provide suitable habitat for an endangered seahorse species? And if so (II) what characteristics of this new habitat are important in terms of seahorse utilization? Four major habitat types were identified within the marina canals: (I) artificial reno mattress (wire baskets filled with rocks); (II) *Codium tenue* beds; (III) mixed vegetation on sediment; and (IV) barren canal floor. Seahorses were found throughout the marina system with significantly higher densities within the reno mattress habitat. The artificial water body, therefore, has provided suitable habitat for *Hippocampus capensis*, a noteworthy finding in the current environment of coastal development and the increasing shift from natural to artificial.

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1. Introduction

The world's coastal areas are under pressure from population growth and it is this anthropogenic onslaught in the form of exploitation, habitat degradation, pollution and uncontrolled development that creates the biggest threat (Franco et al., 2011; Waltham and Connolly, 2011; Wetzel et al., 2014 and Wilson et al., 2015). One of the most pertinent threats to these systems is the inevitable change from a natural system to one wrought with artificial structures brought on by harbour, marina, and flood control development (Clynick, 2008a; Chapman and Underwood, 2011; Wetzel et al., 2014; Dafforn et al., 2015; Wilson et al., 2015).

The growing trend in the development of marina residential estates, which covered a global area of 270 km^2 in 2011 (Waltham and Connolly, 2011), is of particular concern. Waltham and Connolly (2011) define a marina estate as: "a development with 50% if its edges appearing straight or unnaturally smooth and greater than 50% of its perimeter utilized for residential living". According to Harvey and Stocker (2015) marina estates share three common elements: (I) used for residential purposes; (II) located on artificial waterways made up of interconnected canals to maximise

waterside area; and (III) a connection with a natural water resource to enable flushing of the system. Marina estates can be developed by the alteration and reclamation of natural wetland, saltmarsh or mangrove areas (Heavily Modified Water Body) or by the development of canals and the related aquatic habitat in a terrestrial environment located beyond natural tidal levels (Artificial Water Body) (European Commission, 2003; Waltham and Connolly, 2011). The habitat created by the latter development type is new additional aquatic habitat previously unavailable to aquatic biota. The global extent of marina estates and the changes to the natural environment brought on by such developments make them deserving of attention from ecologists to understand the ecological role they may play (Waltham and Connolly, 2011).

Impacts on coastal and estuarine systems leave many species vulnerable and exploited, particularly *Hippocampus* spp. (Syngnathidae) as they are generally known to occur in these shallow, coastal systems and have a number of characteristics (sparse distribution, low mobility, small home-ranges, and low fecundity) which leave them vulnerable to habitat destruction and over-exploitation (Foster and Vincent, 2004). The endangered Knysna seahorse (*Hippocampus capensis* Boulenger, 1900) is especially sensitive to habitat alteration owing to its limited range (endemic to only three estuaries on the southern coast of South Africa), small

population size, and habitat vulnerability (Whitfield, 1995; Bell et al., 2003; Lockyear et al., 2006; Teske et al., 2007). Changes to natural estuarine systems owing to development and the replacement of seagrass meadows with hard structures have the potential to seriously affect this species (Whitfield, 1995; Teske et al., 2007). How seahorses adapt to habitat alterations and additions, if at all, is an important aspect which must be understood to ensure successful future conservation (Vincent et al., 2011).

The Knysna Estuary (Fig. 1), an estuarine embayment (Whitfield, 1992), is located on the southern coast of South Africa (34° 4′56.19″S, 23° 3′34.85″E) and is considered to be the country's most important estuary in terms of biodiversity (Turpie et al., 2002). Three residential marina estates have been developed in the estuary in the past ten years of which Thesen Islands Marina (Figs. 1 and 2) is the largest (≈25 ha of canals). Thesen Islands Marina can be classified as an Artificial Water Body (European Commission, 2003) as it was developed on an existing island within the Knysna Estuary.

Early anecdotal observations of seahorses within the marina system allowed an opportunity to investigate the adaptability of *Hippocampus capensis* to anthropogenic impacts on and additions to its natural environment. Two questions were considered: (I) Can artificial water bodies provide suitable habitat for an endangered seahorse species? And if so (II) what characteristics of this new habitat are important in terms of seahorse utilization? The physico-chemical and habitat features of the marina are described, together with a population assessment of *H. capensis*. This is the first study of *H. capensis* in the Knysna Estuary since the last population survey of 2001 (Lockyear et al., 2006) which was undertaken prior to the development of Thesen Islands Marina.

2. Materials and methods

2.1. Study species

Hippocampus capensis is an estuarine seahorse species found exclusively in the Knysna, Swartvlei and Keurbooms Estuaries, all in close proximity to each other on the south coast of the Western Cape of South Africa. It was the first seahorse species to be listed as Endangered on the IUCN Red Data List in 2000 (Hilton-Taylor, 2000). The Knysna seahorse has a maximum recorded standard length of 12 cm (Whitfield, 1995) with an adult range of 5.3−11.2 cm (Lourie et al., 2004) and is found in depths of 0.5 m−20 m (Whitfield, 1995). It breeds from late September to early April when water temperatures rise above 20 °C (Lourie et al., 2004). Sexual maturity is reached within a year at a standard length of 6.5 cm and a gestation period of two to four weeks (dependant on water temperature) has been recorded (Grange and Cretchley, 1995; Whitfield, 1995; Lockyear et al., 1997; Lourie et al., 2004).

2.2. Study site

Thesen Islands Marina (34° 2′47.16″S, 23° 3′18.84″E) is a 90.6 ha residential marina estate located on Thesen Island (Figs. 1 and 2) in the lower bay regime of the Knysna Estuary (Largier et al., 2000; Rademeyer, 2008). The marina development commenced in 2000 and was completed in 2005. Six hundred housing units were built on the island with 25 ha of newly created canals. The marina is connected to the estuary by two wide access entrances — one at the
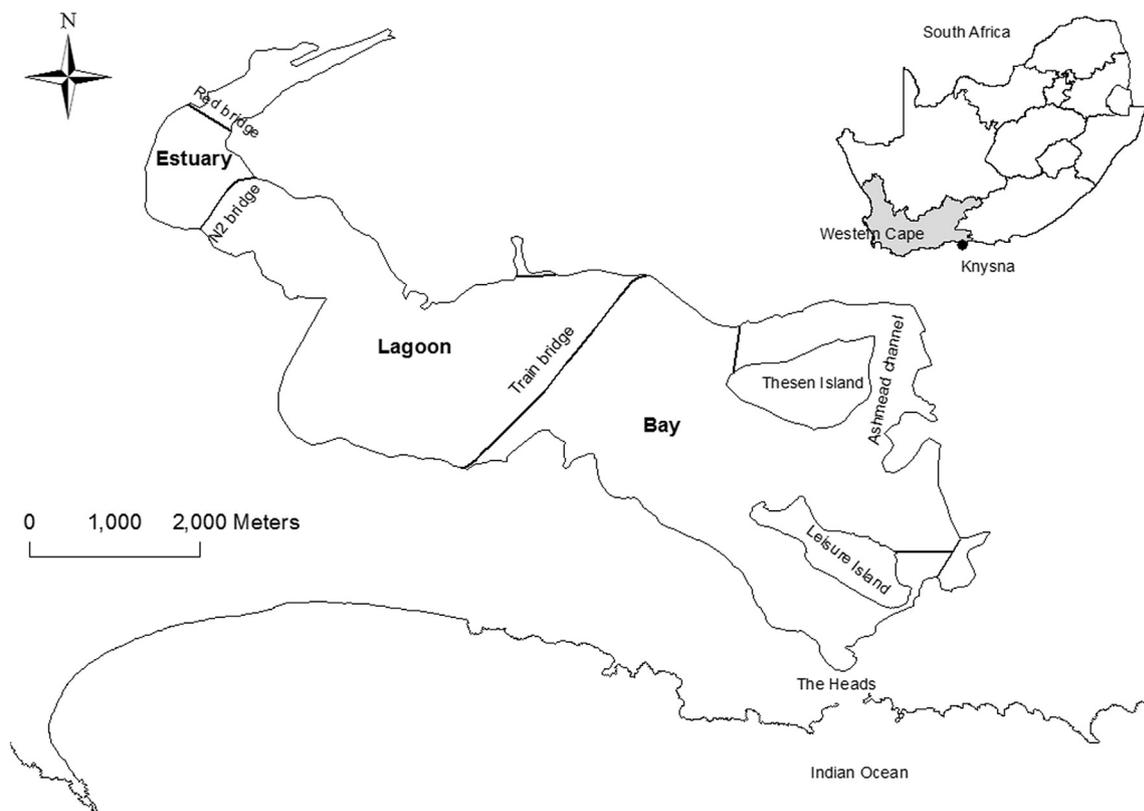

Fig. 1. Locality of Knysna (insert) and the layout of the Knysna Estuary. The bay regime stretches from the Heads to the train bridge; the lagoon regime from the train bridge to the N2 bridge and the estuary regime from the N2 bridge up to the Knysna River (Largier et al., 2000). The Ashmead channel lies on the eastern side of Thesen Island (Switzer, 2003). Both Thesen and Leisure Islands are situated within the bay regime.
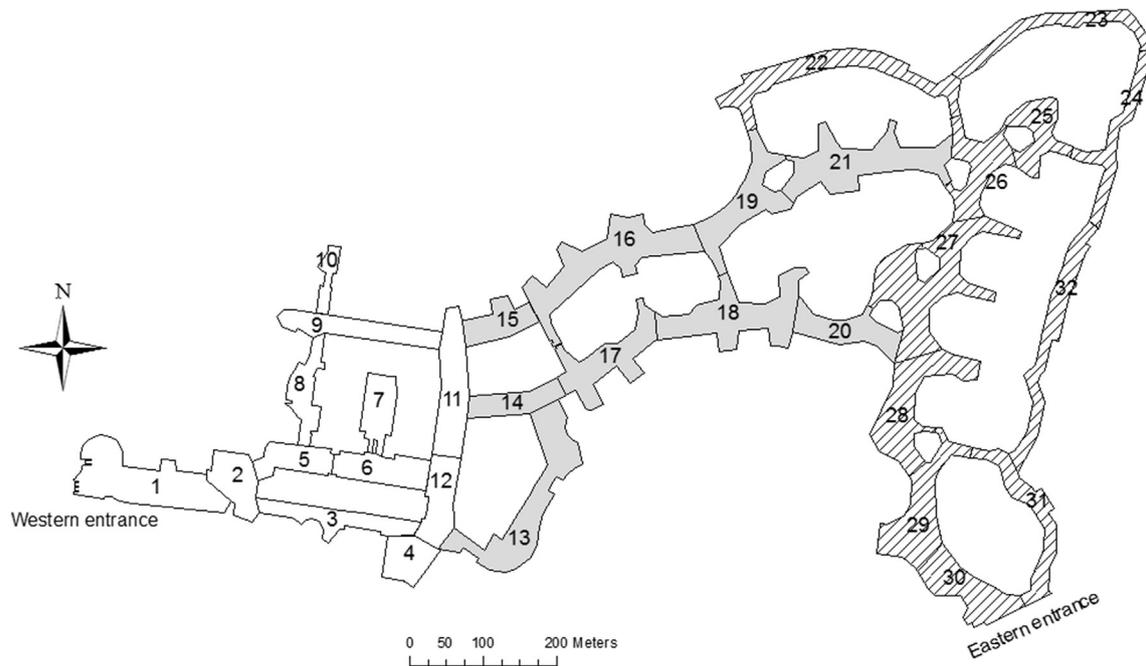
Fig. 2. The canals of Thesen Islands Marina can be divided into three zones along the west-east gradient of the marina: (I) western high velocity zone (white); (II) the middle crossover zone (grey); and (III) eastern low velocity zone (hatched). The canals were also divided into 32 smaller sample sites. Numbering starts on the western section of the marina.

western end connected to the main channel of the Knysna Estuary and one at the eastern end located off the Ashmead Channel (Fig. 2). The marina canals, excavated to −1.75 mean sea level, were built from vertical gabion walls which rest upon a 2 m wide horizontal reno mattress. Gabions are wire cages filled with rocks (Maccaferri, 1915) used in hydrological and environmental engineering applications such as stormwater control, erosion prevention and canal linings. Additional geotextile material is used as an extra lining to promote sediment retention and erosion control. A reno mattress refers to a horizontal gabion structure used in the lining of canal beds. Few estuarine developments use gabion structures as material of choice and no ecological research studies on the suitability of these structures as novel habitats for estuarine fauna were found.

An earlier hydrographical study of the marina (Schumann, 2004) showed no signs of tidal asymmetry with a free exchange of water in the system. There was no significant difference in tidal amplitude between the western and eastern section of the marina, but a lag time of 10 min between the two sections was noted. Temperatures were found to be similar to that of the adjacent estuary (Schumann, 2004).

2.3. Physico-chemical features

Thesen Islands Marina can be divided into three distinct current velocity zones: (I) western high velocity zone; (II) the middle crossover zone; and (III) eastern low velocity zone (Schumann, 2004) (Fig. 2). Ten sampling stations, increasing in distance from the western marina entrance (Fig. 2), were selected to assess the physico-chemical features of the marina. Samples were collected throughout the year. Dissolved oxygen concentrations and temperature were measured along a vertical gradient of 0.5 m with a YSI 550A dissolved oxygen meter (Yellow Springs Incorporated, Yellow Springs, Ohio). Surface turbidity samples were taken at each station and measured with a Eutech TN-100 turbidity meter (Thermo Scientific, Singapore). Vertical conductivity, temperature and depth profiles were taken at each station during high tide using

a Sea-Bird Standard Electronic 19-03 CTD (Sea-Bird Electronics, Seattle).

2.4. Habitat description

An aquatic vegetation survey took place in the summer and winter of 2014 to obtain an overview of the likely habitats found in the marina canals. Haphazardly located transects (N = 72) with a mean length and search width of 35 m and 1 m respectively were surveyed by snorkelling across the width of the canals. The dominant vegetation type and percentage cover were estimated by the diver across each transect.

Major habitat types were assigned to one of the following four categories (Fig. 3):

  I Reno mattress habitat. This habitat type is located along the canal edges. The wire and rocks used to fill the mattress are visible. The 2 m wide habitat is exposed to the atmosphere every spring low tide for a period of up to two hours. The dominant vegetation types found include *Asparagopsis taxiformis* (an invasive red alga species from Indo-Pacific origin (Bolton et al., 2011)) and *Polysiphonia* sp.
 II *Codium tenue* beds. These macro-algal stands collect within low current velocity areas such as inlets and dead-end canals within marinas and harbours. The dense vegetation layer lies unattached on the canal bottom and varies in density and thickness. Large diurnal fluctuations in dissolved oxygen concentrations take place with super saturation (120% saturation) during the day and hypoxic (<20% saturation) conditions at night.
III Mixed vegetation (*Zostera capensis*, *A. taxiformis*, *Polysiphonia* sp, *Caulerpa filiformis*, and *Halophila ovalis*) on sediment. This habitat type is generally found in the middle of the marina canals and shares similar characteristics to the natural seagrass beds found in the larger estuary (Bell et al., 2003; Lockyear et al., 2006; Teske et al., 2007).
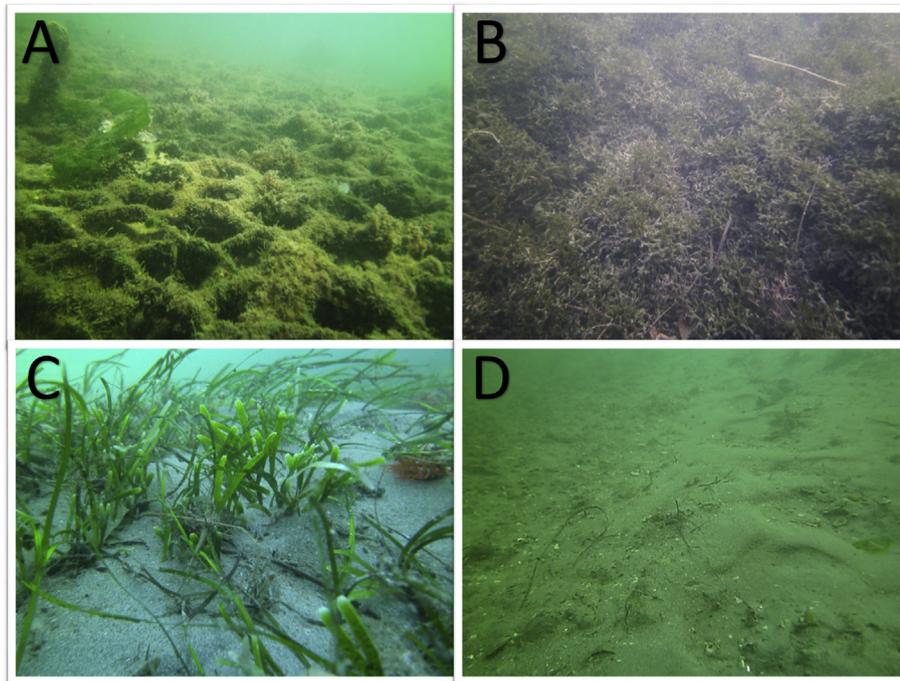
Fig. 3. Four major Habitat types identified within Thesen Islands Marina: A: (I) Reno mattress habitat (wire baskets filled with rocks); B: (II) Dense *C. tenue* beds; C: (III) Mixed vegetation on sediment and D: (V) Barren canal floor.

IV Barren canal floor with sparse vegetation or broken shell beds. The western zone of the marina is characterised by marine sediment and large areas of broken shell beds. The character of the sediment changes to mud and fine silt along the west-east gradient.

2.5. Hippocampus capensis population assessment

2.5.1. Habitat types I (reno mattress) and III (mixed vegetation)

A preliminary seahorse population assessment took place from August (late austral winter) to October (early austral spring) 2014. The marina was subdivided into 32 smaller sample sites (Fig. 2) to ensure a systematic sample approach. Structural features of the marina were used for this demarcation. Underwater visual survey transects as per Curtis et al. (2004) using SCUBA were used. The preliminary assessment focused on Habitat type I situated along the canal edges, and type III in the middle of the canals, using a stratified sampling design. Twelve sites (Fig. 4) were sampled during high tide in depths which ranged from 1.5 to 3 m. Ten transect samples, 10 m long with a 1 m search width (100 m^2), were surveyed per habitat type at each sample site by a single diver and a total area of 2230 m^2 was surveyed. The co-ordinates of each transect, taken with a handheld Garmin GPSmap 62, and the direction, chosen arbitrarily, were logged. Surface water temperature and turbidity were measured at each site.

The dominant vegetation type and percentage cover were estimated by the diver for each 10 m^2 transect. Height (Lourie, 2003), sex, brood pouch status and holdfast used by each specimen found were recorded. Males were identified by the presence of a brood pouch. Animals larger than 4 cm with no brood pouch were considered to be females. An individual which showed no sexual differentiation and was smaller than 4 cm was considered to be juvenile (Lockyear et al., 2006). The same methods were used in

subsequent seasonal seahorse surveys within Habitat type I (January and June 2015).

2.5.2. Habitat type II (C. tenue beds)

Underwater visual survey transects (Curtis et al., 2004) were not suitable for use in Habitat Type II because animals were found to hide within the algal mass. To overcome this constraint an alternative sampling method was established. A net (38 cm × 19 cm × 30 cm) was used to collect *C. tenue* (two scoops per sample with an average weight of 3.5 kg). The collected sample was placed on a floating platform and sorted. All seahorses found were measured (Lourie, 2003), sexed and the brood pouch status assessed. The *C. tenue* sample was weighed to the nearest 100 g to establish the drained wet weight. The vegetation sample and seahorses were returned to the sample location. Sampling was done from a boat to prevent disturbance of the *C. tenue* beds and underlying mud. Habitat type II sampling took place in the summer (February) and winter (June) of 2015. Ten samples were collected from each of the twelve sample sites selected (Fig. 4). An average seahorse density per drained wet weight of *C. tenue* was established.

2.6. Statistical analysis

The statistical programme R (R Development Core Team., 2014) was used in all analyses. A Kruskal Wallis test was used to test for any significant differences in physico-chemical features across marina zones and seasons and a Kruskal Nemenyi post-hoc test to assess those features found to be significantly different. The PMCMR package was used for Kruskal Wallis and post-hoc analyses (Pohlert, 2014).

The distribution of *H. capensis* was found to be over-dispersed (variance > mean) and followed a negative binomial distribution. A Negative Binomial Generalised Linear Model (GLM) was used to test the hypothesis that seahorse densities varied across Habitat
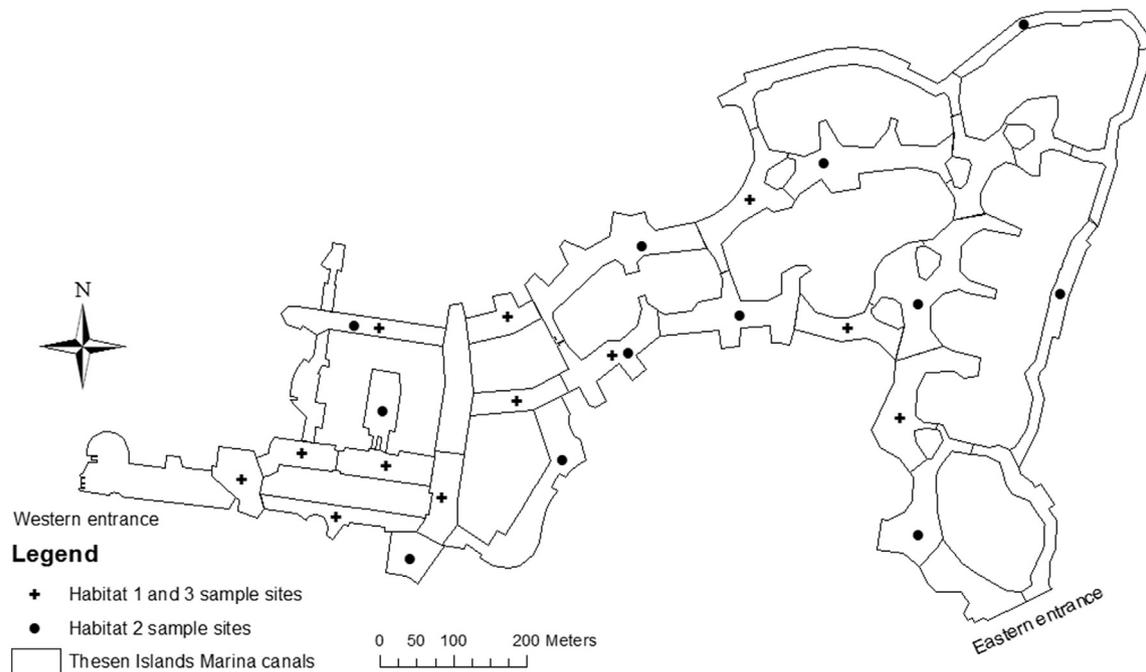
Fig. 4. The twelve sample sites within Thesen Islands Marina surveyed during the preliminary (2014) seahorse survey within Habitat type I and III (+) as well as the comparative summer and winter (2015) survey within Habitat type I (+) and during the summer and winter (2015) seahorse survey within Habitat type II (●). The numbers used refer to the 32 demarcated sample sites (Fig. 2).

types I and III. Sex ratios were assessed with a Chi-square test. The Car (Fox and Weisberg, 2011) and Mass (Venables and Ripley, 2002) packages were used for Generalised Linear Model analyses.

3. Results

3.1. Physico-chemical features

The physico-chemical features of the marina ranged within historic limits recorded for the Knysna Estuary (Table 1). Both surface ($\chi^2 = 42.7$; d.f. = 3; P < 0.01) and bottom ($\chi^2 = 29.7$; d.f. = 3; P < 0.01) water temperature changed significantly across seasons and surface temperatures within zone 1 were significantly colder ($\chi^2 = 6.8$; d.f. = 2; P = 0.03) compared to Zone 2 and 3. Dissolved Oxygen concentrations were similar across seasons and marina zones. Significantly higher turbidity was found within Zone 3 ($\chi^2 = 8.5$; d.f. = 2; P = 0.01).

3.2. Habitat description

Codium tenue was dominant during the summer 2014 vegetation survey with 32.9% coverage. Barren sandy areas and *Asparagopsis taxiformis* had an overall coverage of 26.7% and 21.9% respectively. Other major vegetation types found included *Zostera*

Table 1
Summary of the physico-chemical features recorded in Thesen Islands Marina 2014–2015. The table includes the maximum, minimum, mean and standard deviation (Std. Dev.) recorded for each feature.

	Max	Min	Mean	Std. dev.
Depth (m)	3.1	0.6	2	0.7
Temperature (°C)	25	11.5	17.6	2.9
Dissolved Oxygen (% Sat)	121.8	54.4	91	12.4
Turbidity (ntu)	7.03	0.08	2.61	1.36
Salinity	37	28	33.2	2.4

capensis (1.8%); *Halophila ovalis* (0.3%) and *Caulerpa filiformis* (13.3%). Only 3.1% of reno mattress habitat was present. In winter *C. tenue* cover decreased to 23% with a corresponding increase in barren sandy areas (32.9%) and *A. taxiformis* (31.2%). *C. filiformis* coverage decreased to 6.4% while *Z. capensis* (1.6%) and *H. ovalis* (1.8%) showed a slight increase. The area of reno mattress habitat remained constant (3.2%) throughout the year.

Habitat types showed a similar seasonal pattern with a decrease in Habitat type II from summer to winter (32.9%–23%) and corresponding increases in Habitat type III (37.3%–41.1%) and IV (26.7%–32.9%). Habitat type I remained constant with 3.1% coverage.

3.3. Hippocampus capensis population assessment

3.3.1. Habitat types I (reno mattress) and III (mixed vegetation on sediment)

Seahorse densities varied across habitat types and significantly (Z = −3.8; Std. Error = 0.54; P < 0.01) lower seahorse densities were found in Habitat type III compared to Habitat type I. An assessment of the pooled data showed an equal female: male sex ratio of 1.2:1 ($\chi^2 = 1.6$; d.f. = 1; P = 0.2). Average height was (mean ± s.d.) 6.4 ± 2.0 cm. Two juveniles were recorded. Only 27% of males had a fully inflated brood pouch. Habitat type I was exposed to the atmosphere during spring low tide for up to two hours. During these events seahorses were noted in very shallow (<30 cm) water and in some cases became stranded. In such instances, they kept their gills moist by placing their heads against the moist sediment until the tide returned. No seahorse mortalities were noted during these periods.

Eighty-one percent of seahorses were found within the western marina zone, with 16% and 3% in the transitional zone and eastern zone respectively.

Seahorse density within Habitat type I decreased in January 2015 (Table 2) and the sex ratio (1.8:1) was female biased ($\chi^2 = 8.1$; d.f. = 1; P < 0.01). Mean (±s.d.) height was 5.5 ± 3.2 cm. No juveniles

Table 2
Summary of the preliminary seahorse survey within Habitat III (2014); preliminary seahorse survey within Habitat I (2014); summer seahorse survey within Habitat I (January 2015) and winter seahorse survey within Habitat I (June 2015). The area surveyed and dive hours are included to indicate sampling effort for the respective surveys.

Date	Habitat type	Habitat description	Seahorse abundance	Females	Males	Juveniles	Average seahorse density (Indv/m^2)	Max seahorse density (Indv/m^2)	Area surveyed (m^2)	Dive hours
Sep-Oct 14	III	Mixed veg	23	13	9	0	0.02	0.11	1200	13.6
Aug -Oct 14	I	Reno mattress	182	95	81	2	0.18	0.64	1030	14.6
Jan 15	I	Reno mattress	100	62	34	0	0.12	0.32	820	14.5
June 15	I	Reno mattress	179	80	88	0	0.17	0.63	1060	17.4

were found. Nearly three quarters (73.5%) of males had a fully inflated brood pouch indicative of breeding. Sexually mature males (inflated brood pouch) were noted at a height of 5 cm. An increase in seahorse densities were found during the winter survey (Table 2) with an equal sex ratio ($\chi^2 = 0.4$; d.f. = 1; P = 0.5). Mean ($\pm$s.d.) height was 6.2 $\pm$ 2.4 cm. No juveniles or any indication of breeding were noted. The highest densities of seahorses were continually found within the western section (Zone 1) of the marina (Fig. 5).

3.3.2. Habitat type II (C. tenue beds)

Seasonal seahorse densities within Habitat type II were stable (Table 3). Inflated brood pouches were noted in 70% of males during the summer survey and none of the males during the winter survey. Mean ($\pm$s.d.) heights of 7.5 $\pm$ 0.9 cm and 7.1 $\pm$ 1.2 cm were recorded for summer and winter respectively. Seahorse height was significantly different ($\chi^2 = 13.8$; d.f. = 1; P < 0.01) between Habitat types I and II. An equal female: male sex ratio of 1: 1.2 ($\chi^2 = 0.4$; d.f. = 1; P = 0.5) and 1:1.1 ($\chi^2 = 0.2$; d.f. = 1; P = 0.6) was found during the summer and winter survey respectively. The distribution of seahorses within Habitat type II was similar across all sample sites and showed limited variation across seasons (Fig. 6).

3.4. Habitat use

During the preliminary survey (2014) 50% of seahorses used *Asparagopsis taxiformis* as a holdfast and 42% used the reno mattress wire mesh (Fig. 7).The use of *A. taxiformis* as a holdfast increased to 70% during the summer (2015) while the use of wire mesh decreased to 17%. During winter (2015) 69% of seahorses used the wire (Fig. 7) mesh as a holdfast and 9% *A. taxiformis*. *Codium tenue* was exclusively used as holdfast within habitat type II.

4. Discussion

Four habitat types were identified within the canals of a residential marina estate within the Knysna Estuary, South Africa, and
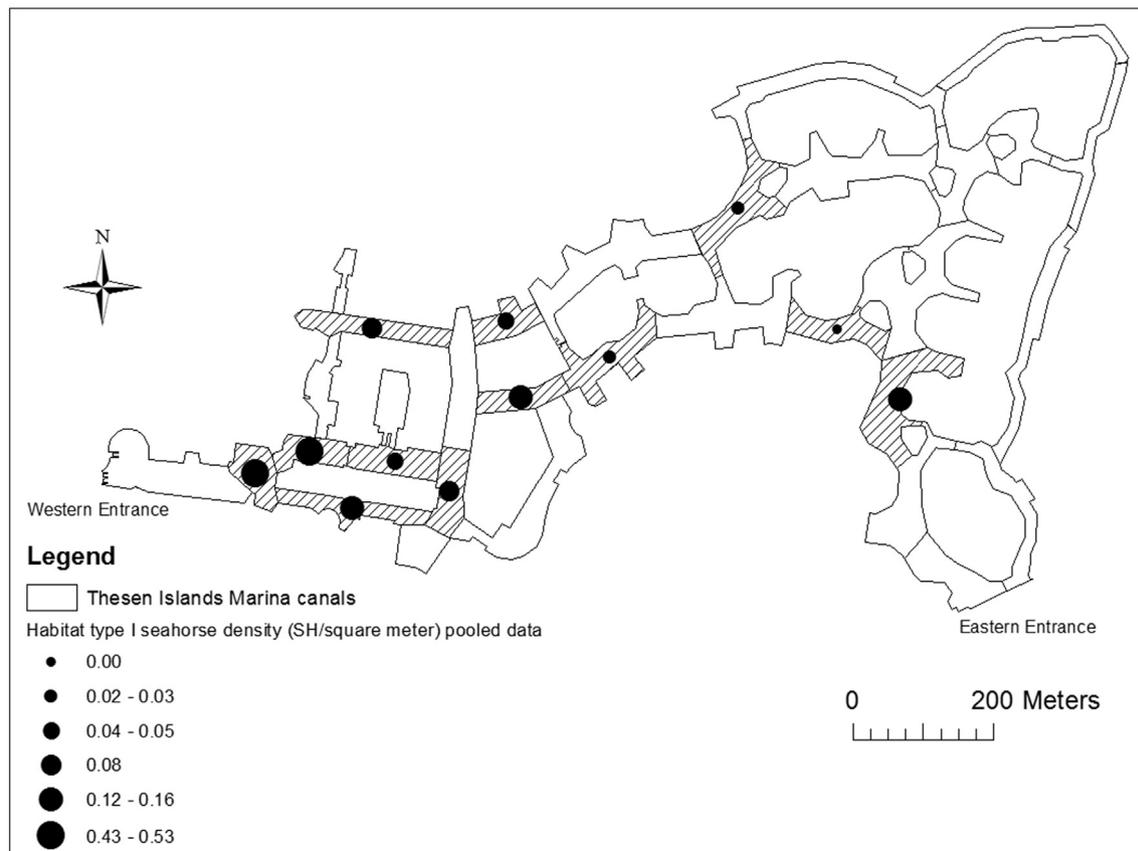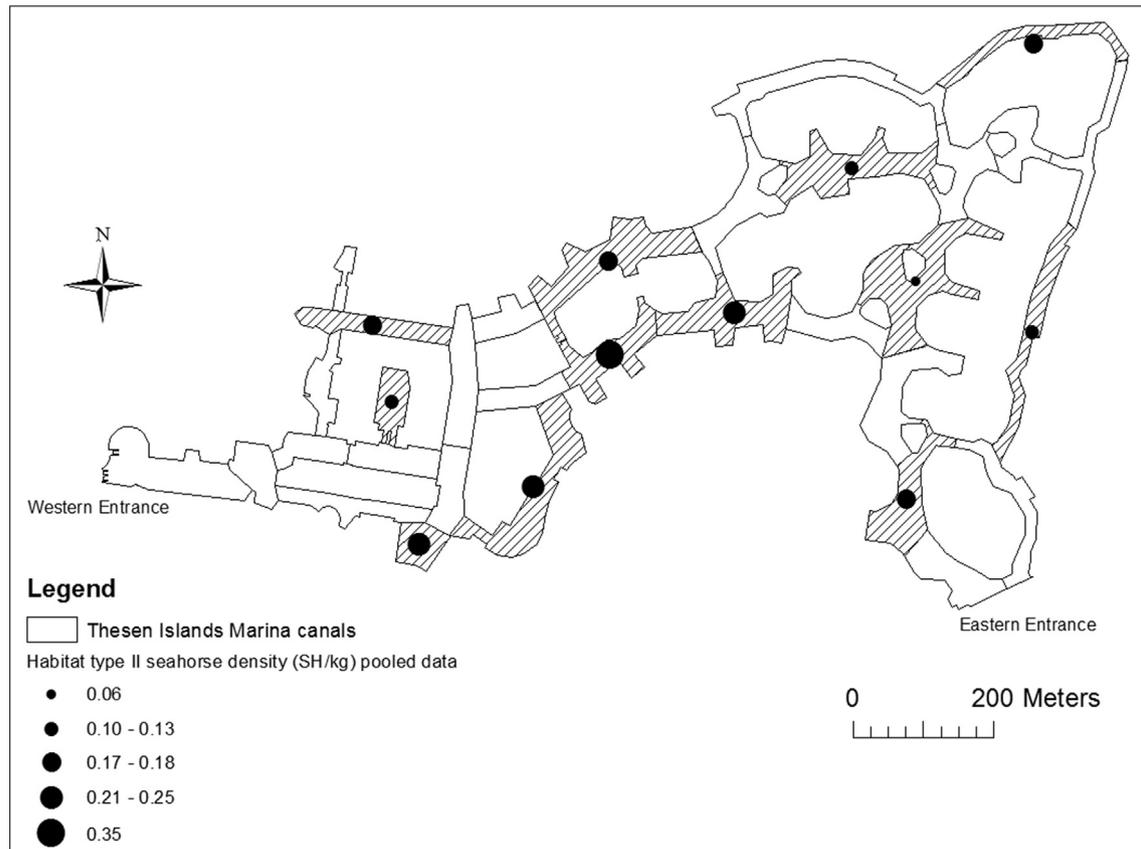

Fig. 5. Seahorse density and distribution within Habitat type I (Reno mattress habitat) for all survey data.

Table 3
Summary of the summer (February 2015) and winter (June 2015) seahorse survey within Habitat II. Densities were calculated as seahorses per kilogram of *Codium tenue*.

Date	Habitattype	Habitat description	Seahorse abundance	Females	Males	Juveniles	Average seahorse density (Indv/ kg)	Max seahorse density (Indv/ kg)	Kg *Codium* surveyed
Feb 15	II	Dense *C. tenue* beds	82	38	44	0	0.17	0.31	470.7
June 15	II	Dense *C. tenue* beds	68	32	36	0	0.19	0.44	365.5

Fig. 6. Seahorse density and distribution within Habitat type II (*Codium tenue* beds) for all survey data.

Hippocampus capensis was found to occur throughout this system. The most important habitat type in terms of seahorse use was the artificial reno mattress habitat (Habitat type I). The functionality of this habitat type is related to current velocity and in areas with reduced current velocity (dead-end canals), an increase in sedimentation or the presence of *Codium tenue* which cover the reno mattress make the habitat unsuitable for use by seahorses. The largest extent of Habitat type I was found within the western zone of the marina characterised by higher current velocities. An overall change in habitat type dominance from Habitat type I (reno mattress) and III (mixed vegetation on sediment) within the western zone to Habitat type II (*C. tenue* beds) within the eastern zone of the marina was found. This change could be ascribed to the decrease in current velocity along the west-east gradient of the marina which favours the growth of *C. tenue*. This pattern persisted across seasons although the respective abundance of the different habitat types changed. The impact of this habitat dominance change on *Hippocampus capensis* is noted by the change in the habitat type used (reno mattress vs *C. tenue* beds) by the seahorses in the different marina zones. The eastern side of the marina showed similarities to typical dead-end canal systems such as high

turbidity, which have been shown to effect syngnathid prey capture rates (James and Heck, 1994) and mating behaviour (Sundin et al., 2010). By contrast the western marina zone showed similar physico-chemical characteristics to historical data for the bay regime of the Knysna Estuary (Allanson et al., 2000).

The maximum seahorse density within Habitat type 1 (0.64 individuals/m^2) exceeded historic seahorse densities within the Knysna Estuary (0.25 individuals/m^2 in 2000 and 0.33 individuals/ m^2 in 2001) (Bell et al., 2003; Lockyear et al., 2006). Conventional transect surveys (Curtis et al., 2004) were not suitable to use within Habitat type II. Lockyear et al. (2006) used push net sampling in very dense (>80% cover) vegetation stands, but this method was also deemed unsuitable. An alternative method was established which allowed a seahorse density estimate per kilogram of *C. tenue*. Seahorse densities were found to be similar across all sites within Habitat type II. It is proposed that this method be considered during seahorse surveys in dense, unattached macro-algal beds.

The low observations of juvenile seahorses in this study is a concern. Bell et al. (2003) recorded three juvenile observations during her 2000 transect survey which correlates with the juvenile sightings of this study. Push net sampling used by Lockyear et al.
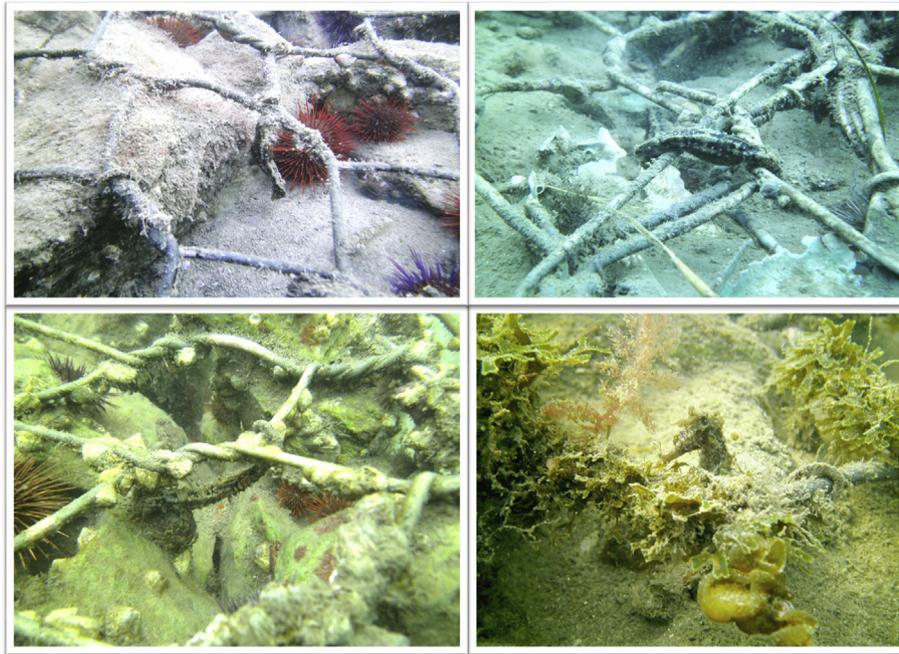
Fig. 7. Artificial habitat (reno mattress), found within the canals of Thesen Islands Marina, utilized by *H. capensis*. In each instance the wire of the mattress is used as a holdfast by the seahorse.

(2006) in 2001 resulted in higher juvenile observations (31 juveniles). No juveniles were however found in the Habitat type II sampling method used in dense *Codium tenue* beds (a method similar to that of Lockyear et al., 2006). Juvenile sightings in seahorse population surveys are known to vary and range from 21% to 80% for *Hippocampus guttulatus* in the Mar Piccolo of Taranto (Gristina et al., 2015); 34% for *Hippocampus breviceps* in Australia (Moreau and Vincent, 2004); 12% for *H. denise* and *H. bargibanti* (Smith et al., 2012) to 8% for *Hippocampus comes* in the central Philippines (Marcus et al., 2007). The size of juvenile seahorses plays a role in their visibility during surveys. Larger seahorse species such as *H. guttulatus* (maximum height of 18 cm) are considered juvenile at < 50% size at maturity (Gristina et al., 2015) and would consequently be easier to see during a transect survey. The dearth of juvenile observations during the present study could be ascribed to ontogenetic differences in habitat use by *H. capensis*. Ontogenetic differences in habitat use by seahorses have been found for *H. comes* in the Philippines (Foster and Vincent, 2004; Morgan and Vincent, 2007) and *H. guttulatus* (Foster and Vincent, 2004). According to Whitfield (1989, 1995) *H. capensis* juveniles are planktonic and dispersal via currents is likely. *Ex situ* studies on the reproduction of *H. capensis* (Grange and Cretchley, 1995; Lockyear et al., 1997) lack any data on habitat use of juvenile *H. capensis*. Teske et al. (2007) found that juveniles preferred *Zostera capensis* as a holdfast as opposed to adults who showed a preference for *Caulerpa filiformis* where a choice in vegetation types was available. Further research is required to ascertain the suitability of different habitat types within the marina to all life stages of *H. capensis*.

The decrease in seahorse densities between the preliminary (late winter to early spring 2014) and the summer survey (2015) might be ascribed to the increase in recreational activities during the December holiday season. The occupancy of houses on the island increases from 50% to 100% during this time with a related increase in boat use. Anderson et al. (2011) found that seahorses exposed to loud noise demonstrated physiological, chronic stress

responses with reduced mass and body condition. Further research on the potential effect of increased noise on seahorses caused by boat activity is required (Vincent et al., 2011). Another explanation for the decrease in seahorse density may be the fact that seahorses hide within the crevices of the reno mattress during this time and therefore surveys were unable to account for all individuals present.

Conflicting conclusions have been reached with regards to habitat and holdfast use by *H. capensis* within the Knysna embayment. Bell et al. (2003) found no association between seahorse densities and vegetation cover, and in fact found higher densities of seahorses within low density (<20%) vegetation stands. Seahorses were also recorded on bare sediment. By contrast Teske et al. (2007) found a positive correlation between seahorse densities and dense vegetation cover (>75%) and suggested that *H. capensis* will only be found in areas with adequate vegetation cover. This fact limits the distribution of *H. capensis* in the Knysna Estuary as it was found that only 11% of the sub-tidal area in the estuary is covered by vegetation (Teske et al., 2007). In the winter of 2014, 67% of the subtidal marina area was covered by some type of vegetation (mixed vegetation on sediment, *C. tenue* beds, *A. taxiformis* on reno mattress). A recent threat to the subtidal vegetation of the embayment regime of the Knysna Estuary is an extensive and lengthy *Ulva lactuca* bloom (Allanson et al., 2016). *Ulva* spp. have been found to displace saltmarsh vegetation (Watson et al., 2015) and *Z. capensis* (Human et al., 2016). The additional habitat found in Thesen Islands Marina could thus be a refuge for *H. capensis* and related biota in a changeable estuarine environment.

The highest densities of seahorses were found in the reno mattress habitat although it is the habitat type with the least percentage cover (only 3.1% cover) within the marina. A number of seahorse species have been noted to utilise artificial holdfasts. *Hippocampus reidi* will use fish coral screens and nylon ropes (Rosa et al., 2007), both *H. guttulatus* and *Hippocampus hippocampus* use ropes, bricks and nets as holdfasts (Curtis and Vincent, 2005; Correia et al., 2013; Gristina et al., 2015) while *H. whitei* use

swimming nets within Sydney Harbour (Clynick, 2008b). Gristina et al. (2015) reports that *H. guttulatus* and *H. hippocampus* within the Mar Picco di Taranto, Italy, prefer to shelter and feed in artificial habitats such as mussel farms and rocky artificial substrata. This preference might, however, be owing to the large decline in natural seagrass beds within the area which leave artificial habitat as the only choice for seahorses. Another reason could be the exemption of such areas from fishing (Gristina et al., 2015). Hellyer et al. (2011) and Gristina et al. (2015) found that more complex artificial structures have a higher abundance of epifauna which include potential seahorse prey animals among the Amphipoda and Copepoda. This may help to explain the suggested preference of these habitats by seahorses.

Detailed experimental research on artificial habitat and holdfast use by seahorses is limited to two studies. Correia et al. (2015) found that *H. guttulatus* densities increased with the deployment of Artificial Holdfast Units (AHU) in the Ria Formosa, Portugal, while Hellyer et al. (2011) showed that more complex frayed net material supported higher densities of *H. whitei* in Sydney Harbour, Australia. *Hippocampus capensis* can be regarded as a holdfast generalist (Teske et al., 2007) as opposed to seahorse species associated with a specific type of holdfast {*H. bargibanti* and *H. denise*} (Smith et al., 2012). Their adaptability in the use of a new holdfast (reno mattress wire mesh) can thus be expected. In some transects the availability of wire mesh was patchy due to sedimentation. Seahorses found in these transects were located on the wire patches as opposed to adjacent vegetation on sediment. This observation helps to strengthen the association between *H. capensis* and the reno mattress habitat.

In conclusion, the development of the canals in Thesen Islands Marina, which have relatively stable environmental conditions, has created important new habitat for the endangered Knysna seahorse. The highest density of seahorses (0.64 individuals/m^2) were found in the western zone of Thesen Islands Marina within the reno mattress habitat, characterised by high current velocity. Seasonal variation in seahorse abundances was not significant and the decrease in numbers found during the summer 2015 survey recovered during the winter 2015 survey. Seahorses were also found within dense *C. tenue* beds and this habitat type should be regarded as important — especially in areas of low current velocities where the availability of alternative habitat is limited. This study provides a first glimpse of the current population dynamics of *H. capensis* within an artificial water body and provides insights into the usefulness of this type of development in the creation of suitable estuarine habitat. Future research will focus on long term population trends of the species as well as the process of habitat selection and use.

Acknowledgements

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