Seagrass habitat characteristics of seahorses in Selayar Island, South Sulawesi, Indonesia

[1]Rohani Ambo-Rappe, [1]Yayu A. La Nafie, [2]Andi Assir Marimba, [3]Richard K. F. Unsworth

[1] Marine Science Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar 90245, Indonesia; [2] Fisheries Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar 90245, Indonesia; [2] Seagrass Ecosystem Research Group, College of Science, Wallace Building, Swansea University, UK. Corresponding author: R. Ambo-Rappe, rohani.amborappe@mar-sci.unhas.ac.id

Abstract. Seagrass beds are an important habitat for seahorses, a group of small-sized fishes that are named for the horse-like shape of their heads. This study paid attention to the role of seagrasses in seahorse occurrence and their size distribution because this habitat plays a crucial role in their life cycle providing food and shelter from predators. Seagrass characteristics of the habitat of two seahorses, *Hippocampus barbouri* and *H. kuda*, in Selayar Island were mapped and determined based on field observations. There were three main seagrass beds used as seahorse fishing grounds around the island, namely Labuang, Jahi-Jahi, and Binanga Benteng, with seagrass percentage cover of 33.14±2.44%, 29.02±1.90%, and 4.73±1.43%, respectively. Seagrass species occurring in the seahorse fishing areas were *Enhalus acoroides*, *Thalassia hemprichii*, *Cymodocea rotundata*, *C. serrulata*, *Halophila ovalis*, and *Halodule uninervis*. A high percentage cover of macroalgae (37.22±5.75%) was found in the seagrass beds of Binanga Benteng. Macroalgae found were *Padina*, *Halimeda*, and *Dictyota*. During the study, we found in total 142 individual *H. barbouri* and 19 *H. kuda*, with the highest abundance in the seagrass beds of Binanga Benteng followed by Jahi-Jahi, and the lowest abundance in Labuang. Moreover, the size of both male and female of *H. barbouri* was also consistently larger in Binanga Benteng, followed by Jahi-Jahi, and then Labuang, suggesting the importance of habitat complexity for this species. The male: female sex ratio was 1:1.2 for *H. barbouri* and 1:0.4 for *H. kuda*. In addition to the seagrass meadows, this study also revealed the importance of macroalgal beds in providing habitat for seahorses. This finding provides the basis for future research on the population status of two vulnerable species, *H. barbouri* and *H. kuda* in different seagrass habitat complexity in order to determine management priorities for conservation.

Key Words: endangered species, habitat complexity, seahorse fisheries, seagrass, macroalgae.

Introduction. Seagrasses are marine angiosperms that have adapted to live fully submerged in the marine environment. There are about 72 species of seagrass globally (Short et al 2011). Sixteen species of seagrass have been recorded in the Indonesian Archipelago (Fortes et al 2018), of which 12 species are found in Sulawesi waters: *Enhalus acoroides*, *Thalassia hemprichii*, *Thalassodendron ciliatum*, *Halophila ovalis*, *H. spinulosa*, *H. sulawesii*, *H. tricostata, Halodule uninervis*, *H. pinifolia*, *Cymodocea rotundata*, *C. serrulata*, and *Syringodium isoetifolium* (Ambo-Rappe & Moore 2019). Most seagrass species live in the coastal area, but *H. sulawesii* is considered a deep water seagrass, which was found at 10-30 m depth around islands in the Spermonde Archipelago, South Sulawesi (Kuo 2007). The seagrass beds are mostly composed of more than one species of seagrass (i.e. multispecific beds), while a few beds are monospecific with only one species of seagrass (Ambo-Rappe & Moore 2019).

Seagrass meadows support high biodiversity and provide at least 24 different types of ecosystem services (Nordlund et al 2016), which includes providing habitat and nursery grounds for seahorses (Mason & Zengel 1996; Loh et al 2016; Harasti 2016). Seahorses are members of the family Syngnathidae and belong to the genus *Hippocampus* (Kuiter 2000). There are 33 extant seahorses species according to Lourie et al (2004): *H. abdominalis*, *H. algiricus*, *H. angustus*, *H. barbouri*, *H. bargibanti*, *H.*

barboniensis, *H. breviceps*, *H. camelopardalis*, *H. capensis*, *H. comes*, *H. coronatus*, *H. denise*, *H. erectus*, *H. fisheri*, *H. fuscus*, *H. guttulatus*, *H. hippocampus*, *H. histrix*, *H. ingens*, *H. jayakari*, *H. kellogi*, *H. kuda*, *H. lichstensteinii*, *H. minotaur*, *H. mohnikei*, *H. reidi*, *H. sindonis*, *H. spinosissimus*, *H. subelongatus*, *H. trimaculatus*, *H. whitei*, *H. zebra*, *H. zosterae*. However, Kuiter (2009) presents about 80 species of seahorses worldwide.

Seahorses (*Hippocampus* spp.) are rare and data-poor marine species. Unlike many other marine fishes, seahorses have relatively low fecundity, mate fidelity, and lengthy parental care (Foster & Vincent 2004; Vincent et al 2005). These factors, combined with the main habitat of the seahorses in shallow waters such as in seagrass beds, have made these fishes highly exposed to various human activities such as fishing, either as a fisheries target (Vincent et al 2007) or non-target (Baum et al 2003; Meeuwig et al 2006). Furthermore they are threatened by seagrass habitat loss/degradation (Hughes et al 2009). A few studies have showed the decline of seahorse population size in relation to seagrass destruction/decline/loss (Masonjones et al 2010; Vincent et al 2011; Zhang & Vincent 2019). The human population of Sulawesi is the third largest in Indonesia after Java and Sumatera, and a significant proportion of the people in Sulawesi live in the coastal areas; therefore, the seagrasses are at risk due to the close proximity of this system to the land (human activities). The loss or degradation of seagrasses in Indonesia, including Sulawesi, has been reported as mainly due to coastal development, deterioration of water quality, and fishing activities (Unsworth et al 2018). Moreover, an ongoing increase in the population of Indonesia coupled with limited infrastructure for waste management have been resulted in oceans smothered with marine debris which has negative effects on wildlife and marine ecosystems (Sur et al 2018), including seahorses and dugongs together with their main habitat, the seagrass meadows (Moore et al 2017).

In addition, the seahorses are one type of marine ornamental fish that is in great demand; apart from aesthetic purposes as an aquarium decoration, they are also dried and used as raw material for medicines (TCM; Traditional Chinese Medicine) (Martin-Smith et al 2003; Kumaravel et al 2012). Therefore, all seahorse species have been listed in CITES Appendix II in response to serious population declines attributed to trade in ornamental species and for traditional medicine, loss of seagrass habitat, bycatch, and small-scale fisheries (Martin-Smith & Vincent 2005; Hughes et al 2009). According to IUCN (2020), seventeen seahorse species are data deficient (DD), two endangered (EN; *H. capensis* and *H. whitei*), and twelve vulnerable (VU; including *H. barbouri* and *H. kuda*), ten are least concern (LC), and one is near threatened (NT; *H. reidi*). Nine seahorse species have been found in Indonesia: *H. barbouri*, *H. bargibanti*, *H. comes*, *H. histrix*, *H. kelloggi*, *H. kuda*, *H. spinosissimus*, *H. trimaculatus*, and *H. pontohi* (Lourie et al 2004), of which seven are classified as vulnerable (VU) with the exceptions being *H. pontohi* (LC; least concern) and *H. bargibanti* (DD; data deficient) (IUCN 2020).

The concept of charismatic species to be used as flagship species has been proposed for addressing threats and promoting solutions in the context of marine conservation; such species should have the ability to capture public attention and induce people to donate funds and/or support conservation action (Walpole & Leader-Williams 2002). Moreover, as summarised by Smith & Sutton (2008), an ideal flagship species should be fall into one or more of certain categories, such as: (1) endemic to one area but known far beyond that region; (2) has economic importance within the culture; (3) can act as an umbrella species; and (4) has a declining population. Seahorses have high potential flagship species because they could raise public support for conservation efforts and meet most of the above criteria (Vincent et al 2011; Yasue et al 2012); this could be one approach to conserving these endangered species. Since seagrass meadows are the main habitat of the vulnerable seahorses, seagrass conservation is closely linked to the protection and survival of these species.

The two vulnerable species, *H. barbouri* and *H. kuda*, became the focus of interest for this study due to the widespread occurrence of these species in the seagrass meadows of South Sulawesi (Lourie et al 2005); however, the range and habitats are not well known. Furthermore, there are few studies on the population structure of these species in the wild in Indonesia (Mulyawan & Saokani 2015; Putri et al 2019). The main objective of this study was to characterize and map the seagrass areas serving as habitat for the seahorses in three seahorses fishing areas around Selayar Island, South Sulawesi, Indonesia. In addition, we also determined the population structure of the seahorses collected *in situ* during the study in order to examine possible associations between the seahorses and the seagrass in the region. This study will improve our understanding of seahorse critical habitats and support the development of means for holistic conservation of seahorses and their seagrass habitat.

Material and Method

Description of the study sites. This research was conducted from September to October 2018 around Selayar Island, which is one of the areas in South Sulawesi where seahorses are known to occur. The seahorse fishing points were even considered by some fishermen who have been done the fishing for seahorses intermittently. Based on this information, we selected three locations for this study, namely Labuang, Jahi-Jahi, and Binanga Benteng (Figure 1).

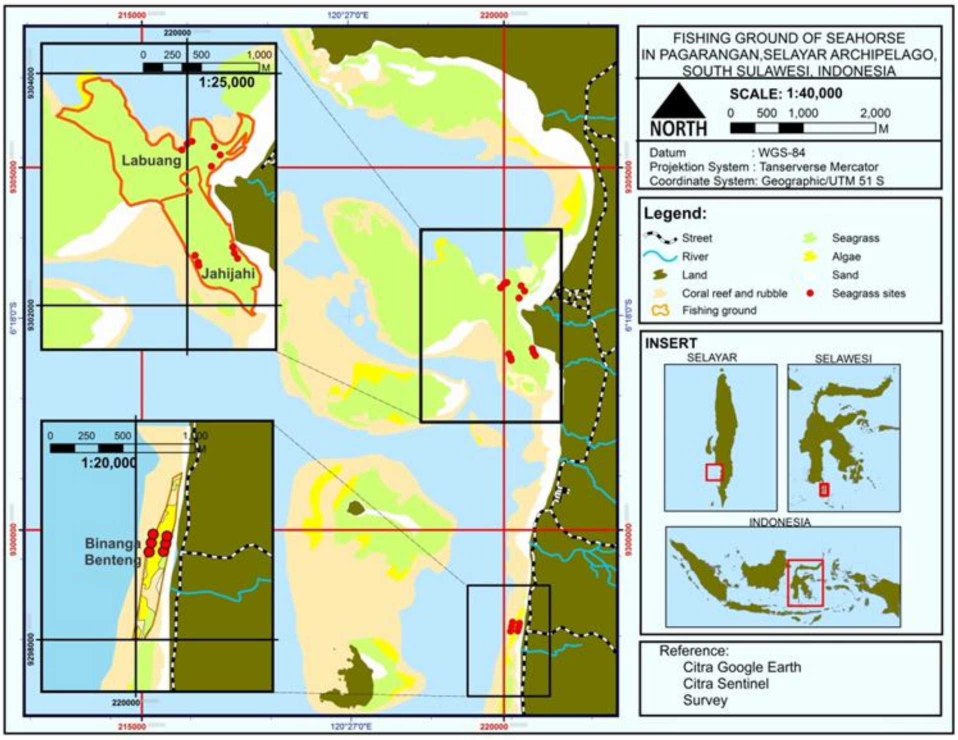

Figure 1. Study area in the coastal waters of Selayar Island showing the three observation sites (seahorse fishing points): Labuang, Jahi-Jahi and Binanga Benteng.

Measurement of seagrass condition and estimation of areal extent. A systematic line transect method was used to determine the seagrass distribution area at the three selected sites and to characterize the seagrass condition (English et al 1997; McKenzie et al 2007). At each site we laid three line transects spaced 50 m apart perpendicular to the coastline. The length of each transect was adjusted by the width of the seagrass bed, running seawards from the shoreward boundary of the seagrass beds to the point where seagrasses were no longer found. Therefore, the length of the line transects varied between sites, being 300 m at Labuang and Jahi-Jahi but only 100 m at Binanga Benteng. We then placed a quadrat (0.5m x 0.5m) every 10 m along the line transect, starting from the 0 m point on the beach. In each quadrat we recorded seagrass presence and absence and species composition; we also estimated percentage cover of seagrasses and macroalgae present in the quadrat. At each site we recorded the geographical coordinates at the start and end of each transect using a GPS (Geographical Positioning System) unit (Garmin eTrex30, datum WGS 84). In addition, one person walked around the seagrass area for ground truthing in order to determine the areal extent of seagrass at each site, based on McKenzie (2003).

Seahorse collection. Seahorse collection at each site was done by hand while walking in the seagrass beds during low tide. We conducted parallel data collection at each of the three sites by assigning two people to each site. In total, we collected 161 seahorses which were identified to species level according to Lourie et al (2004, 2016) and sexed (distinguished externally based on the presence or absence of a brood pouch). Total length was measured from the tip of the coronet to the tip of the uncurled tail (to the nearest mm), and each specimen was weighed for wet mass (g).

Data analysis. Data on seagrass bed condition, areal extent, and seahorse population structure were analysed descriptively. We compared the results between locations in order to examine the habitat characteristics which might be of particular importance for the seahorses.

Results

Seagrass bed characteristics. Seagrass species found in the seahorse fishing areas around Selayar Island were *Enhalus acoroides*, *Thalassia hemprichii*, *Cymodocea rotundata*, *C. serrulata*, *Halophila ovalis*, and *Halodule uninervis*. All these seagrasses occurred in both Labuang and Jahi-Jahi; however, only three species of seagrass were found in Binanga Benteng (Figure 2). Moreover, the seagrass beds in Binanga Benteng were associated with a high percentage of macroalgae dominated by *Padina* sp.

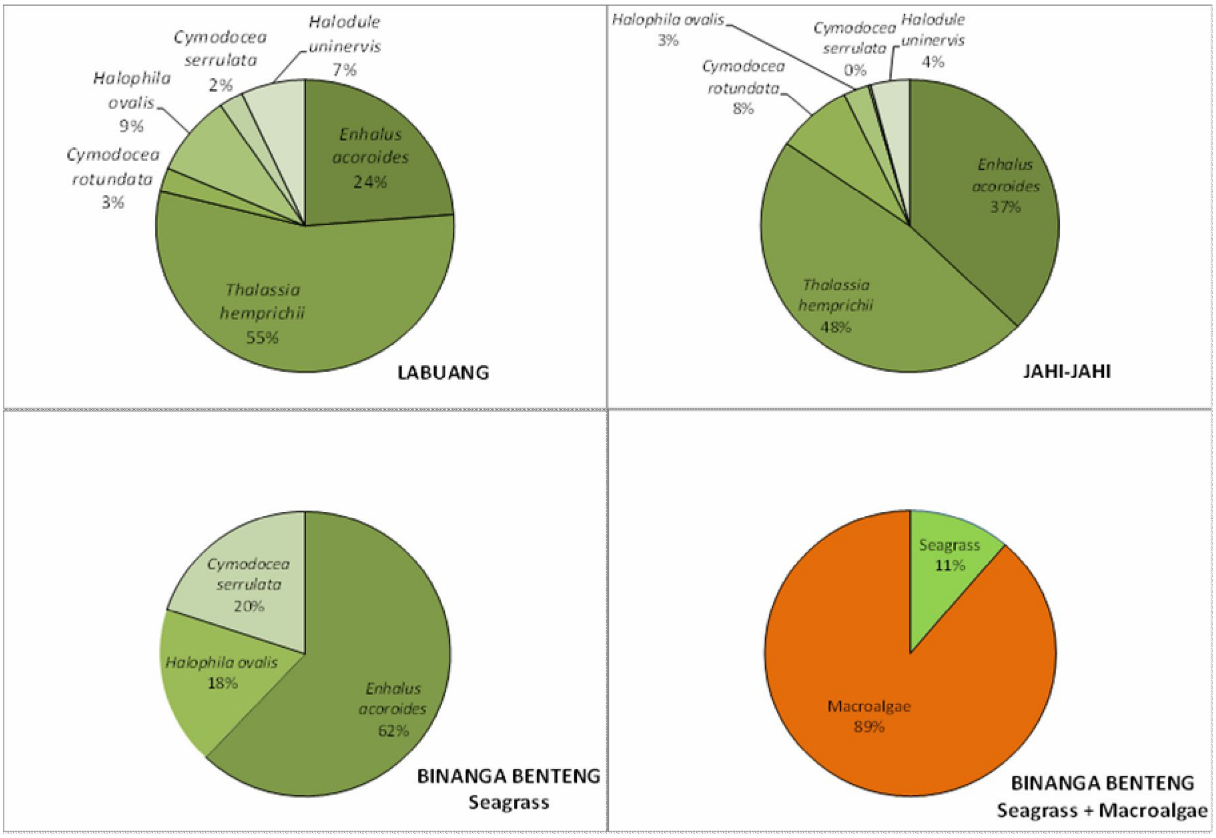

Figure 2. Species composition of the seahorse seagrass meadow habitat in three fishing grounds around Selayar Island, South Sulawesi, Indonesia.

Seagrass percentage cover was higher in Labuang (33.14±2.44%) than Jahi-Jahi (29.02±1.90%), and the lowest seagrass cover was in Binanga Benteng (4.73±1.43%). In Binanga Benteng, the macroalgal percentage cover was 37.22±5.75%, far higher than the seagrass cover (Figure 3).

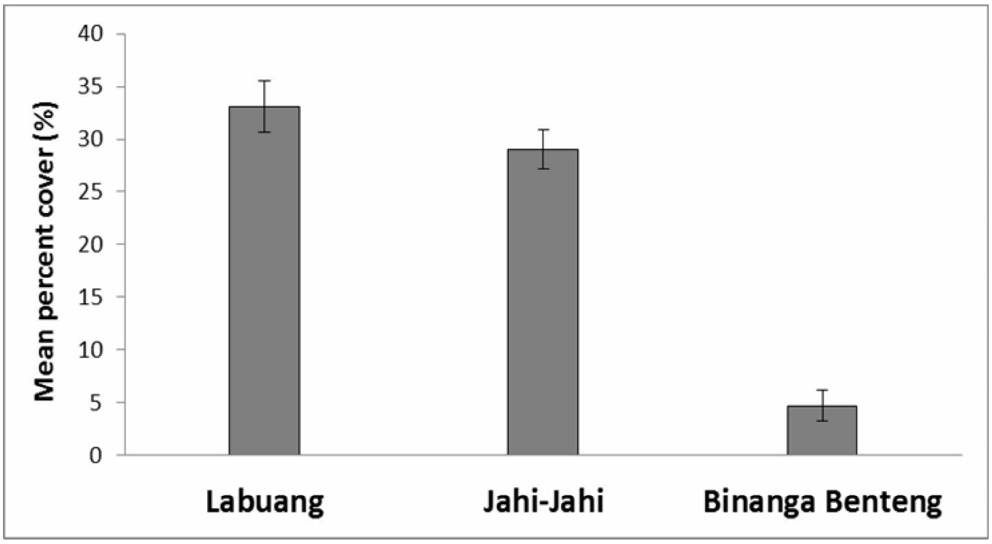

Figure 3. Seagrass percentage cover in three seahorse fishing grounds around Selayar Island, South Sulawesi, Indonesia.

Seagrass areal extent. The greatest seagrass extent was in Labuang, followed by Jahi-Jahi, and then Binanga Benteng (Table 1). In addition to the extent, seagrass distribution patterns also varied between sites. In Jahi-Jahi seagrasses were evenly distributed, even though the overall percentage cover was lower than in Labuang, despite the sandy patches at the latter site. In Binanga Benteng the seagrass beds were very patchy, with a very low percentage cover and they also occupied the smallest areal extent. Apart from this patchy nature, the seagrass beds in Binanga Benteng look more complex than those at the other two sites due to a greater variety of benthic form.

Table 1

Seagrass bed areal extent and benthic cover at three seahorse fishing grounds around Selayar Island, South Sulawesi, Indonesia

Location	*Benthic cover*	*Area (m^2)*
Labuang	Seagrass	690725.60
	Sand	782.55
		691508.15
Jahi-Jahi	Seagrass	432600.68
		432600.68
Binanga Benteng	Algae	53459.56
	Coral and rubble	45863.83
	Seagrass	19086.14
	Sand	3566.82
		121976.36

Seahorse population structure. Two species of seahorse were found during the study, namely *Hippocampus barbouri* and *H. kuda*. In total, we found 142 individual *H. barbouri* and 19 *H. kuda*. The highest number of seahorses was found in Binanga Benteng (72 *H. barbouri* and 10 *H. kuda*). Seahorses found in Jahi-Jahi were 53 *H. barbouri* and 5 *H. kuda*. Despite having the most extensive seagrass beds, only 17 *H. barbouri* and 4 *H. kuda* were found in Labuang. The male:female sex ratio was 1:1.2 for *H. barbouri* and 1:0.4 for *H. kuda* (Figure 4).

The *H. barbouri* seahorses found in this study ranged from 56 to 130 mm in length and 1 to 9 g in weight. On average, the *H. kuda* specimens tended to be somewhat larger, ranging from 100 to 155 mm in length and 4 to 10 g in weight. Overall, the size distribution of the seahorses *H. barbouri* and *H. kuda* in terms of length and width showed a similar pattern across the stations (Figure 5A and 5B); especially for *H. barbouri,* both male and female seahorses tended to be larger in Binanga Benteng, followed by Jahi-Jahi, and smallest in Labuang (Table 2).

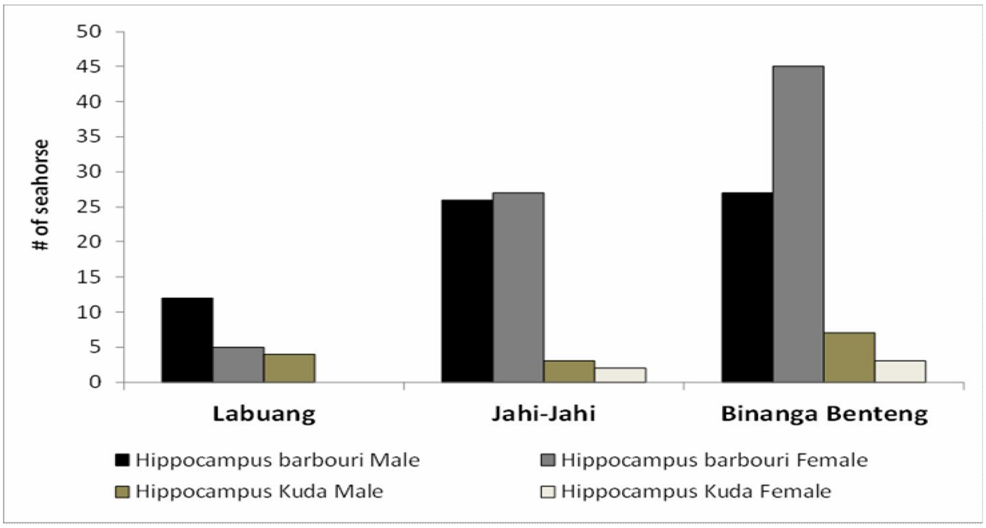

Figure 4. Number of seahorses found, by species and sex, in three fishing grounds around Selayar Island, South Sulawesi, Indonesia.

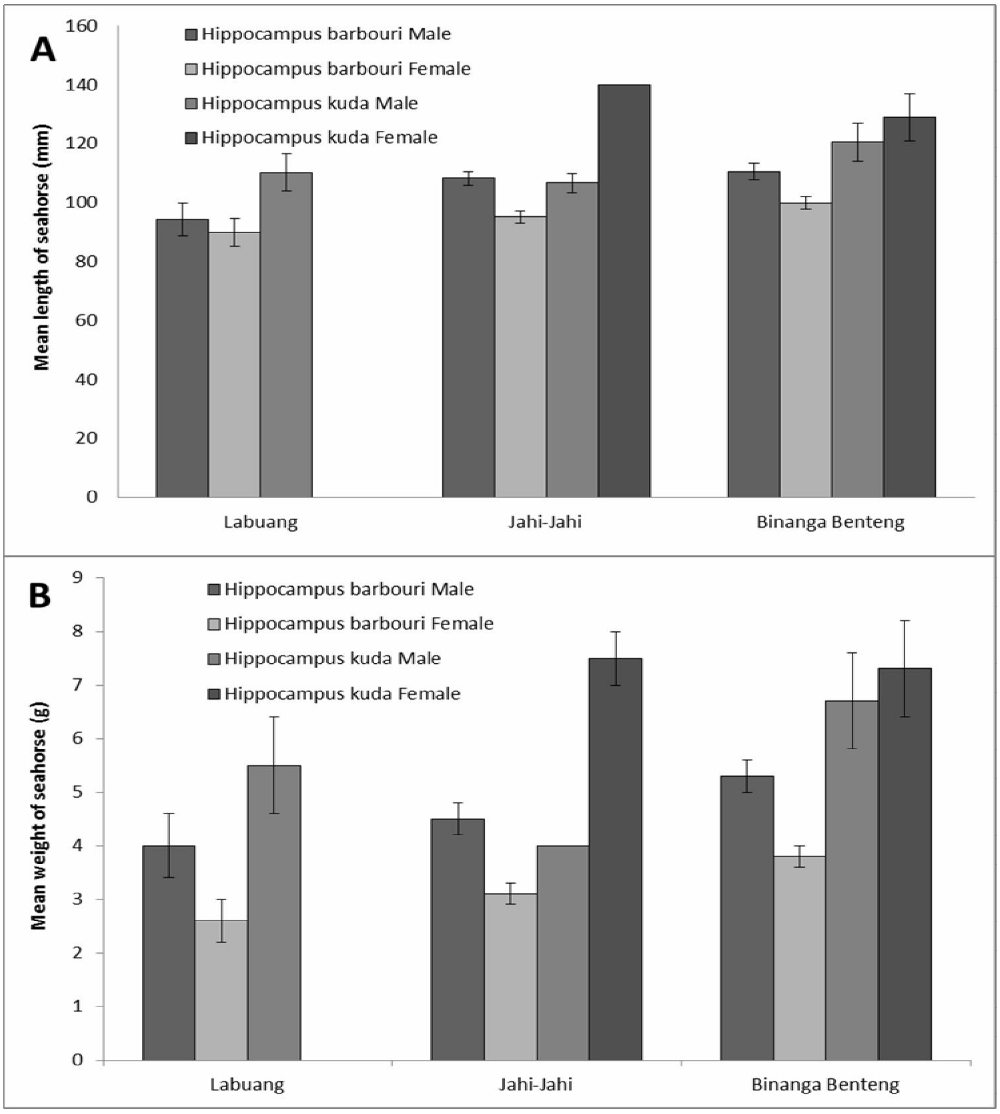

Figure 5. Length (A) and weight (B) distribution of two seahorse species (*H. barbouri* and *H. kuda*) in three fishing grounds around Selayar Island, South Sulawesi, Indonesia.

Table 2

Size distribution of the seahorses in three seahorse fishing grounds around Selayar Island, South Sulawesi, Indonesia

Location	*Hippocampus barbouri*		*Hippocampus kuda*	
	Male	*Female*	*Male*	*Female*
Mean length ± SE				
Labuang	94.2±5.6	90.0±4.7	110.3±6.3	0
Jahi-Jahi	108.3±2.4	95.2±2.0	106.7±3.3	140.0±0.0
Binanga Benteng	110.5±2.8	100.0±2.1	120.6±6.4	129.0±8.0
Mean weight ± SE				
Labuang	4.0±0.6	2.6±0.4	5.5±0.9	0
Jahi-Jahi	4.5±0.3	3.1±0.2	4.0±0.0	7.5±0.5
Binanga Benteng	5.3±0.3	3.8±0.2	6.7±0.9	7.3±0.9

Discussion. The species composition of seagrasses found in seahorse habitat at the three study sites around Selayar Island was dominated by seagrasses with strap-like leaf forms such as *E. acoroides*, *T. hemprichii*, *H. uninervis*, *C. serrulata* and *C. rotundata*. This type of seagrass leaves seems to be important for seahorses to use as a holdfast to curl their strong prehensile tail around for anchoring; this is consonant with Correia et al (2015) who found a positive correlation between the density of seahorse *H. guttatus* and the percentage of holdfast coverage. This anchoring behaviour on vegetation or other substrate is a specific characteristic of seahorses due to their weak swimming ability (Kendrick & Hyndes 2003); therefore they mostly rely on prey coming within close range instead of actively pursuing them (Foster & Vincent 2004; Felício et al 2006).

Multispecific seagrass beds are common in Indonesia (Kuriandewa et al 2003), with greater seagrass biodiversity occurring in eastern Indonesia (Sjafrie et al 2018). The seagrass species most commonly found dominating the seagrass beds of Indonesia are *T. hemprichii* followed by *E. acoroides* (Sjafrie et al 2018; Furkon et al 2020). We found multispecific seagrass beds, comprised more than one seagrass species (in this case 3 to 6 seagrass species occurring in one bed) at all stations; however the seagrass community was dominated by *T. hemprichii* in Labuang and Jahi-Jahi, and by *E. acoroides* in Binanga Benteng.

Seagrass habitat complexity was greater in Binanga Benteng due to the occurrence of a high percentage cover of macroalgae as well as other benthic components (sand, coral, and rubble), despite this site having the smallest areal extent. Habitats with greater complexity might be preferred by the seahorses found in this study (*H. barbouri* and *H. kuda*) as places to live, as the highest number individual seahorses was also collected from this site. Moreover, both males and females of *H. barbouri* were consistently larger in size in Binanga Benteng compared to Jahi-Jahi and smallest in Labuang, but *H. kuda* did not seem to follow this pattern.

Habitat complexity has been shown to have an effect on *H. guttatus* where the abundance of this seahorse was positively correlated with an index of habitat complexity, the percentage cover of flora and sessile fauna; however, an opposite pattern was observed for *H. hippocampus* which preferred to use more open spaces without vegetation and subjected to a greater swell (Curtis & Vincent 2005). Increased habitat complexity was also found to benefit *H. whitei* and *H. guttulatus* through providing more food sources (mobile crustaceans) which tend to be more abundant in more complex habitat structures, leading to a higher abundance of seahorses (Hellyer et al 2011; Ape et al 2019). However, *H. guttulatus* was also found to be able to exploit unvegetated sediment to capture prey, which lessens the effect of habitat structure on this seahorse (Ape et al 2019). In addition, Kendrick & Hyndes (2003) suggested that seahorses occupy vegetated habitats that best enable them to remain inconspicuous to predators. Moreover, habitat complexity could offer more structures that can be used as holdfasts for the seahorses; Dias & Rosa (2003) reported 18 different holdfast used by *H. reidi* including macroalgae, tunicate, and mangrove roots. It would seem that the influence of habitat complexity on seahorses is often important but tends to be species specific. The effects of increased habitat complexity might lead to an increased in the size of the seahorses, such as that observed in this study, due to higher food availability. Assessing food availability in the study area combined with gut content analysis for both *H. barbouri* and *H. kuda* would be one important way to gain a better understanding of the linkages between the seagrass habitat structure and these two seahorses, now and in the future.

In the present study, we found a total of 161 individual seahorses (142 *H. barbouri* and 19 *H. kuda*). A far greater abundance of *H. barbouri* compared to *H. kuda* was found in all sampling stations. Some previous studies also found similar trends with *H. barbouri* being more abundant and *H. kuda* being a relatively rare species in the wild (Shapawi et al 2015; Putri et al 2019). On average, in this study *H. kuda* individuals tended to be larger and heavier than *H. barbouri* with respective mean standard lengths of 119.58±3.68 mm and 101.75±1.25 mm, and respective mean weights of 6.21±0.47 g and 4.04±0.13 g. *H. kuda* is a larger species than *H. barbouri* with a maximum length of 300 mm (length at maturity 140 mm), compared to 150 mm maximum (length at maturity 80 mm) for *H. barbouri* (Froese & Pauly 2020). Based on these data, the majority of *H. barbouri* individuals found in this study were sexually mature; however, despite their generally larger size, this was not the case for *H. kuda*. Significant proportions of mature seahorses in the catch has been reported elsewhere (Perera et al 2017; Stocks et al 2019; Putri et al 2019; Correia et al 2020) and this fact has been use as evidence that this species is threatened by overexploitation, with diminished catches from seahorse fisheries due to population declines reported from several countries (Martin-Smith & Vincent 2006; Perry et al 2010). As a result, the entire genus *Hippocampus* has been added to Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to enable monitoring and determination of regulations for sustainable levels of the seahorse trade (Martin-Smith & Vincent 2006; Vincent et al 2011).

In this study a higher number of females than males was observed for *H. barbouri*, but the opposite pattern (more males than females) was seen in *H. kuda*. This result suggests that sex ratio might vary between seahorse species, although the observed patterns could also be an artefact of sampling. Equal ratios of females to males have been reported for *H. whitei* (Vincent & Sadler 1995), *H. comes* (Perante et al 2002), and *H. breviceps* (Moreau & Vincent 2004). On the other hand, female-biased sex ratios have been reported for *H. erectus* (Baum et al 2003), *H. abdominalis* (Martin-Smith & Vincent 2005), *H. coronatus* and *H. mohnikei* (Choi et al 2012).

Conclusions. This study clearly shows the importance of seagrass habitat along with its complexity in supporting the occurrence of two vulnerable seahorse species, *Hippocampus barbouri* and *Hippocampus kuda*. The seahorses seem to prefer the more complex seagrass habitat (seagrass, macroalgae, coral rubble) to live and grow, as we found more individuals and larger sized individuals in seagrass beds with a higher habitat complexity. This finding provides a basis for future research on the population status of *H. barbouri* and *H. kuda* in habitats with different complexity. In addition, assessment of food availability across the habitat combined with gut content analysis for both *H. barbouri* and *H. kuda* would be an important way to gain a better understanding of the linkage between the seagrass habitat structure and the two vulnerable seahorses in order to determine management priorities for conservation.

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Authors:
Rohani Ambo-Rappe, Marine Science Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Jl. Perintis Kemerdekaan Km.10 Tamalanrea, Makassar 90245, South Sulawesi, Indonesia, e-mail: rohani.amborappe@mar-sci.unhas.ac.id
Yayu Anugrah La Nafie, Marine Science Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Jl. Perintis Kemerdekaan Km.10 Tamalanrea, Makassar 90245, South Sulawesi, Indonesia, e-mail: yayulanafie@yahoo.com
Andi Assir Marimba, Fisheries Department, Faculty of Marine Science and Fisheries, Hasanuddin University, Jl. Perintis Kemerdekaan Km.10 Tamalanrea, Makassar 90245, South Sulawesi, Indonesia, e-mail: assirmarimba@gmail.com
Richard Kazimierz Frank Unsworth, Seagrass Ecosystem Research Group, College of Science, Wallace Building, Swansea University, UK, e-mail: R.K.F.Unsworth@swansea.ac.uk

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