Received: 25 March 2020 | Accepted: 3 May 2020

DOI: 10.1111/jfb.14371

BRIEF COMMUNICATION

JOURNAL OF FISH BIOLOGY fsbi

Field studies of seahorse population density, structure and habitat use in a semi-closed north-eastern Mediterranean marine area (Stratoni, North Aegean Sea)

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Funding information
This study received Portuguese national funds from FCT - Foundation for Science and Technology through project UIDB/04326/2020, and from the operational programmes CRESC Algarve 2020 and COMPETE 2020 throughproject EMBRC.PT ALG-01-0145-FEDER-022121

Abstract

The present study was carried out in the marine area of Stratoni, Greece, where two seahorse species are present (*Hippocampus hippocampus* and *Hippocampus guttulatus*). Two surveys were conducted (September 2016 and May 2019) to gather information regarding seahorse species' abundance, distribution and habitat characteristics. Four different seahorse natural and artificial habitat types were identified. The results revealed that the presence of *H. hippocampus* was relatively high, especially at sites with artificial structures, whereas the presence of *H. guttulatus* was rare. Data collected can provide baseline information for future population assessments.

KEYWORDS

artificial structure, scoastal area, habitat use, Mediterranean Sea, threatened species

Seahorses (*Hippocampus* spp.) are charismatic and iconic marine fishes, often used as flagship species for conservation issues, that live in some of the most vulnerable marine habitats in shallow areas around the world, where anthropogenic disturbances are most frequent (Vincent *et al*., 2011). They are characterized by sparse distribution, low mobility, small home ranges, low fecundity, lengthy parental care and mate fidelity (Foster & Vincent, 2004). Seahorse life history and behaviour render them vulnerable to population decline (Vincent *et al*., 2011), which leads to the inclusion of all seahorse species in the Convention on International Trade in Endangered Species of Wild Fauna and Flora and in the IUCN Red List of Threatened Species.

The short-snouted seahorse *Hippocampus hippocampus* Linnaeus, 1758, and the long-snouted seahorse *Hippocampus guttulatus* Cuvier, 1829, are two species present in the Mediterranean Sea. Although both species have been assessed as "data deficient" at a global level, they have recently been reassessed as "near threatened" in the Mediterranean Sea (Pollom, 2016, 2017). They are both typically present in coastal environments and associated with habitats of different complexities (Correia *et al*., 2015a; Correia *et al*., 2018; Woodall *et al*., 2018). Despite the extended geographical distribution of both species, there are only a few inshore locations where seahorse abundance, distribution and habitat use have been studied within the Mediterranean Sea (Ape *et al*., 2019; Gristina *et al*., 2015; Louisy, 2011). To the authors' knowledge, ecological data have been rare in Greek waters and especially in the Aegean Sea focusing on wild seahorse population structure (Kitsos

et al., 2008; Woodall *et al*., 2018), including ichthyofaunal assessments (Koutrakis *et al*., 2005; Lamprakis *et al*., 2008).

The present study was carried out in the marine area of Stratoni (Chalkidiki Peninsula, North Aegean Sea) which seems to be a refuge for seahorse populations, initially reported by professional divers during fieldwork activities in November 2007. The objectives of the present study were to (a) describe the seahorses' habitat types in the Stratoni marine area, (b) estimate the seahorses' population density and describe the population structure and (c) investigate seahorses' habitat use.

The marine area of Stratoni (Figure 1, latitude from 40° 30′ to 40° 32.5′ and longitude from 23° 45′ to 23° 32.5′) lies within the Ierissos Gulf, a semi-closed water body, affected by small river inputs, characterized also by soft sediments and high biodiversity (Koutrakis *et al*., 2003). A first pilot survey of the area was conducted in September 2016 to gather information regarding seahorse abundance, distribution and habitat characteristics using scuba underwater visual census. Transects (15,100 m long and 4 m wide) transects were laid parallel to the shoreline, at three different depths (5, 7.5 and 10 m), covering 6000 m^2. Whenever an individual of a seahorse was found, species, sex and size (height, according to Lourie *et al*., 1999) were recorded along with four environmental variables: water depth, water temperature at depth, holdfast at first sighting (structure grasped by a seahorse's tail) and the predominant habitat (*i.e*., benthos observed within a 1 m^2 quadrat centred around the seahorse). This data was used to identify and classify the most representative habitats found according to the European Nature Information System (EUNIS) habitat code (http://eunis.eea.europa.eu). In May 2019, four sites were chosen per habitat type and registered in a GPS unit: (a) sand (*Cymodocea* beds, EUNIS A5.5313), characterized by substrates of fine sand, previously covered by *Cymodocea nodosa* beds; (b) *Sabella* sp. (infralittoral mixed sediments, EUNIS A5.432), dominated by *Sabella* sp. in soft-bottom substrates; (c) *Posidonia oceanica* (*Posidonia* beds, EUNIS A5.535); and (d) artificial structures (ropes) deployed a few months before the first pilot survey. Each site was surveyed by laying a 50 m belt transect, following a bearing parallel to the shoreline to allow constant depth, and a 2 m wide strip on each side was covered by two divers. Overall, 16 sites were surveyed for 3200 m^2 (Figure 1). The same data were collected as described in the previous survey. In addition, information regarding predominant habitat type was recorded every 10 m along the transect line.

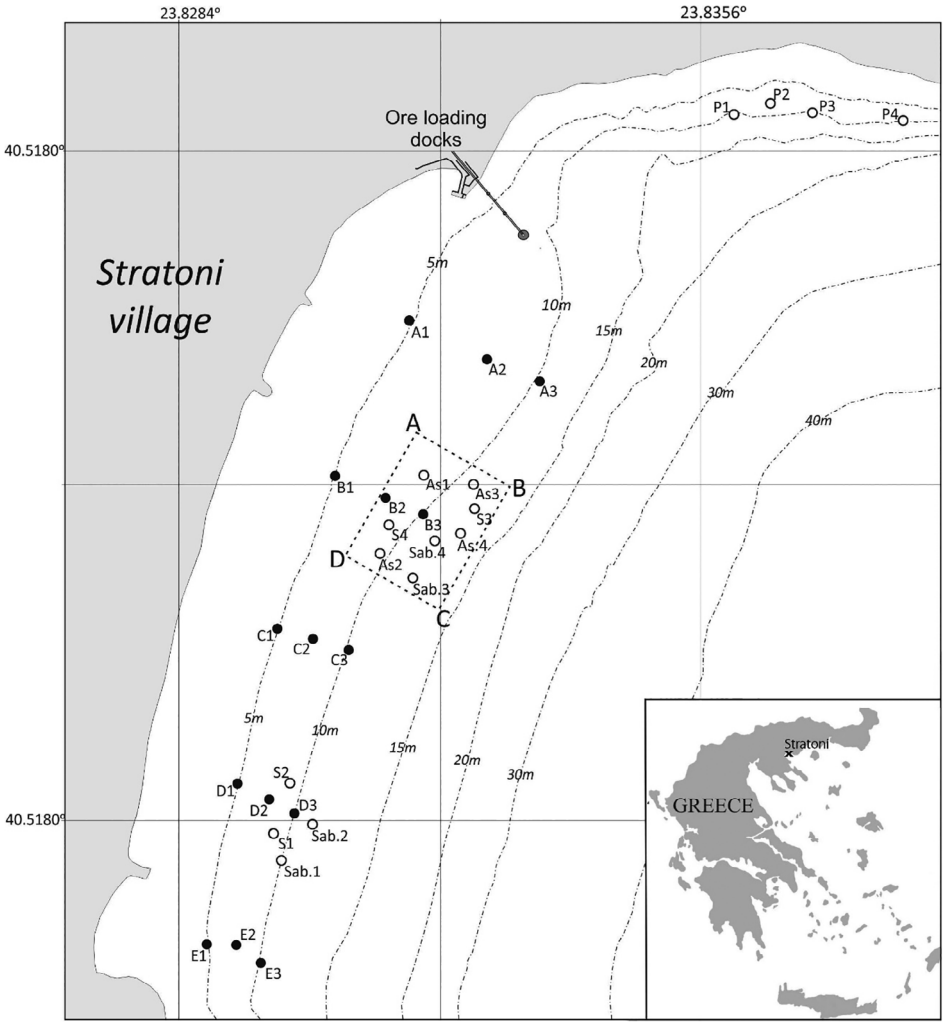

FIGURE 1 Map of the study area of Stratoni (Chalkidiki Peninsula, North Aegean Sea) depicting the arrangement and the code numbers of sampling visual census stations-transects (ABCD delimits the area selected for the deployment of artificial structures)

TABLE 1 Abundance indices for *Hippocampus hippocampus* and *Hippocampus guttulatus*

	2016						2019				
	A	B	C	D	E	Pooled	S	Sab	P	As	Pooled
H. hippocampus											
Total number	2	0	10	4	2	18	1	5	0	15	21
Males	0	0	2	2	1	5	0	1	0	7	8
Females	2	0	8	2	1	13	0	2	0	6	8
Juveniles	0	0	0	0	0	0	1	2	0	2	5
Mean density (m^{-2})	0.002	0.000	0.008	0.003	0.002	0.003	0.001	0.006	0.000	0.019	0.007
S.E.	0.001	0.000	0.003	0.003	0.002	0.001	0.001	0.005	0.000	0.008	0.004
H. guttulatus											
Total number	0	0	0	1	0	1	0	1	0	3	4
Males	0	0	0	1	0	1	0	0	0	1	1
Females	0	0	0	0	0	0	0	1	0	2	3
Mean density (m^{-2})	0.000	0.000	0.000	0.001	0.000	0.0002	0.000	0.001	0.000	0.004	0.001
S.E.	0.000	0.000	0.000	0.001	0.000	0.0002	0.000	0.001	0.000	0.002	0.001

In 2016, 19 seahorses were sighted (Table 1). The seahorse *H. hippocampus* was the most sighted species and female biased (18 individuals: 5 males, 13 females), whereas only one *H. guttulatus* male was sighted. The maximum density for *H. hippocampus* was estimated in site C2 (0.015 individual m^{-2}). The one individual of *H. guttulatus* was found in site D3. Almost half of the seahorses were found not grasping any holdfast (52.6%), whereas 26.3% were observed grasping *Sabella* sp., 15.8% artificial structures and 5.3% shells. All seahorses were found between 5 and 10 m depth. The height of adult individuals of *H. hippocampus* varied from 4.0 to 12.0 cm (mean size 8.8 ± 2.1 cm), whereas that of *H. guttulatus* was 12 cm. The temperature of the water column was 22°C.

Along the 16 transects surveyed in 2019, 25 seahorses were sighted. The seahorse *H. hippocampus* was the most sighted species (n = 21), with a relative abundance five times higher than *H. guttulatus* (n = 4). After pooling all sites, the mean density was 0.007 (S.E. ± 0.004) individual m^{-2} for *H. hippocampus* and 0.001 (S.E. ± 0.001) individual m^{-2} for *H. guttulatus*. The maximum density for *H. hippocampus* was estimated in site As3 (0.035 individual m^{-2}), whereas that for *H. guttulatus* was estimated in site As4 (0.010 individual m^{-2}). Four juveniles of *H. hippocampus* were found, which corresponded to 19% of total observations for this species. Juveniles varied in size between 4.0 and 5.0 cm. *H. hippocampus* was marginally female biased (52.9%). The sex ratio was not calculated for *H. guttulatus* because of low sighting numbers. Adult individuals of *H. hippocampus* varied in size from 6.0 to 11.5 cm (8.9 ± 1.9 cm), whereas those of *H. guttulatus* ranged in size from 6.5 to 13.5 cm (8.6 ± 3.0 cm). The temperature varied from 16 to 17°C. Individuals of *H. guttulatus* were absent in sand and *Posidonia* habitats, whereas *H. hippocampus* were found in all habitats, excluding *Posidonia*. Most of the seahorses were sighted grasping artificial structures (73%) and *Sabella* sp. (23%), whereas a few were not grasping any holdfast (4%). Individuals of *H. hippocampus* and *H. guttulatus* were observed in artificial habitats at a mean density of 0.019 (S.E. ± 0.008) individual m^{-2} and 0.004 (S.E. ± 0.002) individual m^{-2}, respectively.

This study is the first to describe the population density and structure as well as investigate the habitat use of the two seahorse species in Greek seas. Results of the two field surveys and previous underwater observations (Mentogiannis, pers. comm.) indicate that the population of *H. hippocampus* appears to be present over time in the marine area of Stratoni, whereas individuals of *H. guttulatus* are rare. Considering that both species are classified as "near threatened" in the IUCN Red List, it is important that this baseline information is made available to contribute to appropriate location-specific conservation strategies.

The mean size of *H. hippocampus* is within the range documented for those in other areas of the Mediterranean Sea (Woodall *et al.*, 2018), whereas the juvenile fraction seems to reflect a good population status (Woodall, 2009). Furthermore, the high density of *H. hippocampus* estimated from the second survey at this site is the highest described in the Mediterranean (Woodall *et al.*, 2018), which indicates that the species might find the necessary environmental conditions to settle even in relatively limited areas. Both seahorse species occur in the study area most probably because of the high availability of food resources observed (*e.g.*, dense populations of hyperbenthic crustaceans; Koulouri, pers. comm.). Artificial structures (ropes) deployed a few months before the 2016 survey might have contributed to aggregate seahorses as they provide the much-needed holdfast. Seahorse species have been reported as typically associated with seagrass habitats (Foster & Vincent, 2004). Nonetheless, no seahorse was found in the *P. oceanica* meadows of the study area, which might indicate that other important environmental variables are at play. Considering that seagrass meadows have been found to be a very important habitat for seahorses as they provide shelter and food (Manning *et al.*, 2018; Woodall *et al.*, 2018), it is worth further exploring the presence/absence of seahorses in *Posidonia* beds of the study area while investigating the associated biotic and abiotic factors. Unlike previous studies

(Woodall *et al*., 2018), *H. hippocampus* was much more abundant than *H. guttulatus* in both surveys. This abundance might be explained by the type of low-complexity habitats in the study area, muddy substrate and water depth (Woodall *et al*., 2018). The use of artificial structures as habitat enrichment for seahorses, first observed in 2016, has apparently contributed to seahorse settlement in the deployment area, as also documented in other studies (Correia *et al*., 2013; Correia *et al*., 2015b; Simpson *et al*., 2020). In fact, most of the seahorses of both species were found grasping artificial structures (*e.g*., ropes) in the study area. Although these structures may act as fish aggregation devices (Correia *et al*., 2015b), they provide holdfasts and enhance the habitat complexity, providing a long-term beneficial effect on the recovery of seahorse populations, particularly as a major component of a wider rehabilitation and management plan.

The presence of artificial holdfasts might have contributed to the settlement of seahorses in the marine area of Stratoni, yet other variables might also be relevant. There is an urgent need for substantial further research on the local population distribution, structure and ecology of *H. hippocampus* and *H. guttulatus* through a long-term monitoring plan. Population genetic studies may also contribute to assess the genotypic health of local seahorse population, which might be facing genetic isolation. Future research will contribute to inform decision-makers and stakeholders to protect and conserve these charismatic fishes in the marine area of Stratoni, used also for other coastal areas of the Aegean Sea.

ACKNOWLEDGEMENTS

This is a contribution from Project Seahorse. This work was supported by Hellas Gold (https://www.hellas-gold.com/). aThe authors thank the contribution of a team of dedicated volunteers: Rafael Amado, Gabriela Cardoso, Logan Couraud, Regina Cunha, Christina Egger, Joan-Ignasi Llinàs, Giulia Marchioro, Maria Rakka, Friedrich Rittner, Carmen Santos, Northern Greece Underwater Explorers, UFR Team, Kostas Katsioulis and Alexandros Paschalis.

This study received Portuguese national funds from FCT - Foundation for Science and Technology through project UIDB/04326/2020, and from the operational programmes CRESC Algarve 2020 and COMPETE 2020 through project EMBRC.PT ALG-01-0145-FEDER-022121.

CONFLICTS OF INTEREST

The authors have no conflict of interest to declare.

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How to cite this article: Correia M, Paulo D, Samara E, Koulouri P, Mentogiannis V, Dounas C. Field studies of seahorse population density, structure and habitat use in a semi-closed north-eastern Mediterranean marine area (Stratoni, North Aegean Sea). *J Fish Biol*. 2020;1–4. https://doi.org/10.1111/jfb.14371