Journal of FISH BIOLOGY

fsbi An International Society for Fish Biology

Journal of Fish Biology (2016) **88**, 751–759
doi:10.1111/jfb.12818, available online at wileyonlinelibrary.com

An assessment of West African seahorses in fisheries catch and trade

A. M. Cisneros-Montemayor*†, K. West‡, I. S. Boiro§ and A. C. J. Vincent‡

**Fisheries Economics Research Unit & Project Seahorse, Fisheries Centre, The University of British Columbia, 2202 Main Mall, Vancouver, BC, V6T 1Z4 Canada, ‡Project Seahorse, Fisheries Centre, The University of British Columbia, 2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada and §Independent Researcher, Touba Damba, Fulladu West District, Central River Division, The Gambia*

(Received 2 June 2015, Accepted 16 September 2015)

This study provides the first assessment of a heavily traded West African seahorse species, *Hippocampus algiricus*, and the first information on short-snouted seahorse *Hippocampus hippocampus* biology in Africa. A total of 219 seahorses were sampled from fisher catch in Senegal and The Gambia, with estimated height at reproductive activity for *H. algiricus* (161 mm) larger than mean ± s.d. catch height (150 ± 31 mm). Catch composition, height at reproductive activity and potential biases in fishery retention are discussed with regard to the current Convention on International Trade of Endangered Species (CITES) guidelines.

Key words: CITES; *Hippocampus algiricus*; life history; morphometry.

Seahorses are listed in Appendix II of the Convention on International Trade of Endangered Species (CITES), requiring countries to guarantee that seahorse exports do not damage wild populations (Vincent *et al.*, 2013). This is challenging due to limited ecological and fisheries information, yet global seahorse extraction amounts to 15–20 million individuals annually (Foster *et al.*, 2014) gravely affecting many populations (Vincent *et al.*, 2011). Targeted seahorse fisheries are predominantly for aquaria (Evanson *et al.*, 2011), yet by-catch, particularly by bottom-trawl fisheries, helps supply traditional Asian medicine markets (Lawson *et al.*, 2015). Recognizing potential sustainability issues, CITES issued a recommendation to Senegal and Guinea in May 2014 requiring data on the West African seahorse *Hippocampus algiricus* Kaup 1856 (Vincent, 2014), prompting this study.

The range of *H. algiricus* is reported from Senegal to Angola (Afonso *et al.*, 1999; Lourie *et al.*, 2004; Mamonekene *et al.*, 2006), but the species was known primarily from museum specimens (Wirtz *et al.*, 2007) until 2002. This is concerning given that

†Author to whom correspondence should be addressed. Tel.: +1 604 822 2731; email: a.cisneros@fisheries.ubc.ca

CITES documents annual exports of around 700 000 individuals (2004–2010; World Conservation Monitoring Centre, www.unep-wcmc.org), making this one of the most traded seahorse species. The short-snouted seahorse *Hippocampus hippocampus* (L. 1758) also occurs in this region (Lourie *et al.*, 2004; West, 2012), yet the only specimens attributed to West Africa (Senegal) in known analyses were obtained in Hong Kong markets (Woodall *et al.*, 2011).

Data on the biology and life history of these species were collected during roving creel (followed by snowball sampling) surveys ($n > 200$) of fishers and traders along the marine coastlines of Senegal and The Gambia (Fig. 1) during May to June 2012 and June to July 2013. When possible, fishers were accompanied to observe their operation and sample catch. Surveys thus included artisanal catches and industrial landings. Catch by industrial vessels that was not landed, but directly (*i.e.* illegally) exported, was evidently not sampled and should be included in future assessments.

Six sites were surveyed underwater for habitat description, including (as numbered in Fig. 1) rocky reef (4), sand and seagrass (5), sand (6), shelf reef and algae (13), sheltered mangrove (17) and exposed mangrove (20). Based on habitat and fishery types, the study area was divided into three regions (as numbered in Fig. 1): North Coast (1–3), Dakar (4–9), Open Coast (10–17) and Deltas (18–27). Due to safety concerns, extensive sampling was not conducted in the Ziguinchor region (sites 28–34), or south of Senegal.

Seahorses were caught incidentally by fishers using 35–45 mm mesh beach seines, monofilament (or occasionally cotton) gillnets and (seldom) scuba gear. They also appeared in cuttlefish traps on seagrass beds, hiding within vegetation used to camouflage the traps (West, 2012). Industrial vessels used bottom-trawl gear.

In situ measurements included: height (tip of tail to top of coronet), torso length (top of coronet to posterior end of dorsal fin), head (tip of snout to posterior end of operculum) and tail (posterior end of dorsal fin to tip of tail) (Lourie *et al.*, 2004; Loh *et al.*, 2014). A height and mass relationship was estimated as $M = \alpha H^{\beta}$ (Schneider *et al.*, 2000), where α and β are constants calculated using observed masses (M) and heights (H). When unable to measure all samples on-site, specimens were weighed and later measured from scale-referenced photographs (Image J; http://rsb.info.nih.gov/ij/). Normality tests (Shapiro–Wilk), comparisons between means (two-sample t-test) and all other quantitative analyses were performed using R (www.r-project.org).

Male maturity was noted following Vincent (1994). A dark oval patch indicative of immature male seahorses (Boisseau, 1967) could not be distinguished because of their dark pigmentation, particularly for dry specimens. Males were therefore categorized into reproductive stages as non-reproductive (pouch undeveloped and flush with body), reproductive (pouch slightly distended from body, lined and possibly filled with material, or pouch empty but recently pregnant) and pregnant (pouch clearly distended and full).

All sampled males were physically mature (had developed or undeveloped brood pouches), so the size at reproductive activity was calculated (*i.e.* engaging in reproduction) rather than the size at physical maturity (*i.e.* physically able to reproduce) (Morgan & Vincent, 2013; Lawson *et al.*, 2015). This assumed a logistic relationship between height (H) and reproductive activity (R) as:

$$R_{\mathrm{H}} = 1\left[1 + \mathrm{e}^{-\gamma(H - H_{50})}\right]^{-1} \quad (1)$$

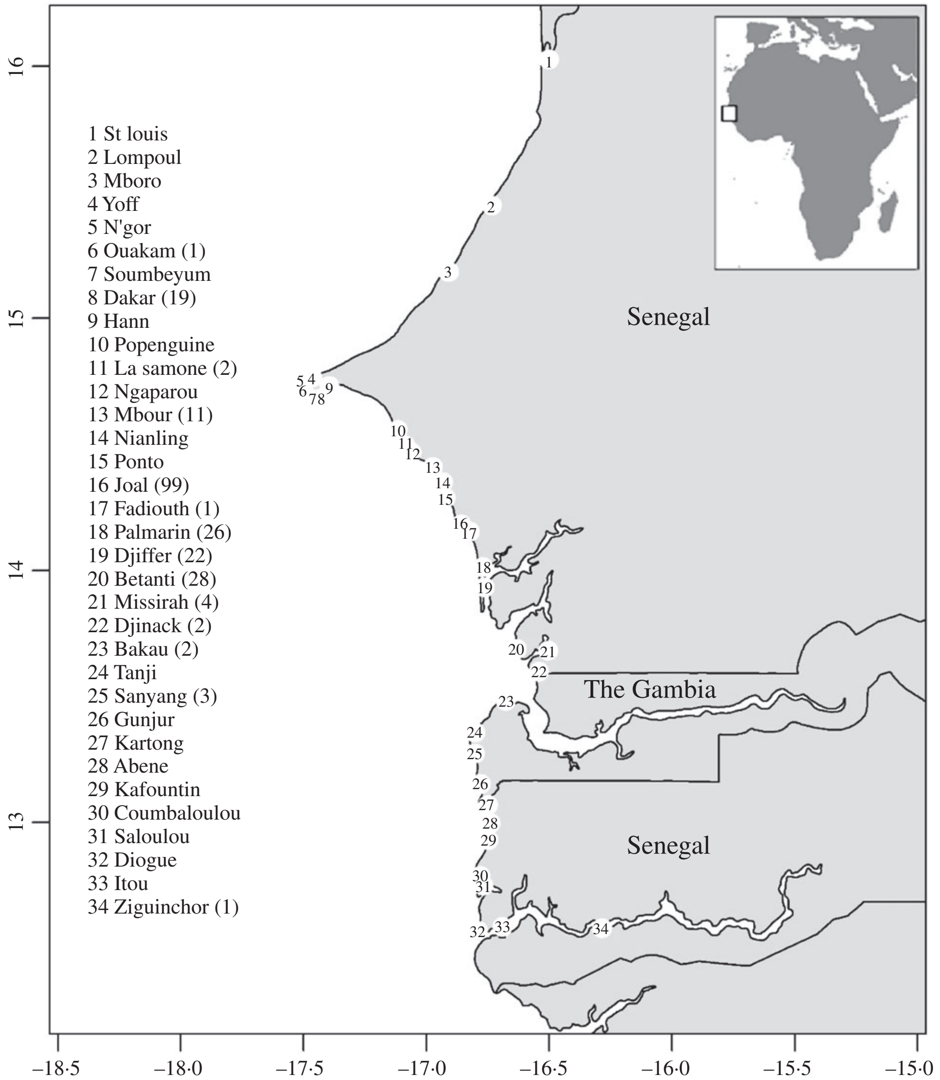

FIG. 1. Study area in Senegal and The Gambia, West Africa. Survey sites are numbered from 1 to 34. Numbers in parentheses denote seahorses sampled at a given site.

where γ is the slope of a logistic curve and H_{50} is the height at 50% reproductive activity. These parameters were estimated by fitting equation (1) to observed data using a non-linear least squares approximation.

To determine the ratio between wet and dry mass, fresh seahorses obtained from fishers were dried in the local manner (hanging in a well-ventilated and lit area avoiding direct sunlight) and weighed daily.

A total of 219 seahorses were sampled, 205 (94%) *H. algiricus* and 14 (6%) *H. hippocampus*; most specimens ($n = 200$) were dry. Seahorses were found at 13 of the 34 survey sites (40%) (Fig. 1); most were sampled in the Open Coast (139), followed by

TABLE I. Summary statistics for *Hippocampus algiricus*, *Hippocampus hippocampus* and aggregated seahorse samples in West Africa. Size and mass data are mean ± S.D. values for each category. Wet:dry mass represent the average for specimens where both measurements were available. Torso length is also referred to as trade height

	H. algiricus				
	Female	Male	All	*H. hippocampus*	All
n	67	138	205	14	219
Height (mm)	137 ± 32	153 ± 29	148 ± 31	100 ± 19	145 ± 32
Torso length (mm)	51 ± 12	55 ± 11	54 ± 12	38 ± 6	53 ± 12
Head length (mm)	28 ± 7	31 ± 5	30 ± 6	21 ± 5	29 ± 6
Tail length (mm)	86 ± 22	98 ± 21	94 ± 22	62 ± 17	92 ± 23
Dry mass (g)	5 ± 3	6 ± 2	6 ± 3	2 ± 1	5 ± 3
Wet mass (g)	11 ± 7	18 ± 11	15 ± 10	4 ± 2	12 ± 9
Wet:dry mass	3·1 ± 0·3	3·2 ± 0·1	3·1 ± 0·2	3·0 ± 0·6	3·1 ± 0·3
Sex ratio (male:female)	–	–	2	1·3	2
Reproductive males (%)	–	39	39	25	38
Pregnant males (%)	–	10	10	12	10

n, sample size.

the Deltas (60) and Dakar (20). According to interviews, few seahorses are caught by fishers north of Dakar (North Coast), and none were encountered in surveys.

Heights of *H. algiricus* (mean ± S.D. = 148 ± 30 mm) were normally distributed (Shapiro–Wilk, $P > 0·05$) (Table I and Fig. 2). Males (mean ± S.D. = 150 ± 30 mm) were significantly larger (height) ($P < 0·001$) than females (mean ± S.D. = 134 ± 32 mm). There were no significant height differences ($P > 0·05$) between seahorses in Dakar (mean ± S.D. = 156 ± 31 mm), Open Coast (mean ± S.D. = 143 ± 31 mm) and Deltas (mean ± S.D. = 145 ± 35 mm) regions.

A height and mass relationship was calculated for *H. algiricus* (Fig. 3). Low sample size impeded separate analysis for *H. hippocampus* (Fig. 3). The sub-sample of freshly

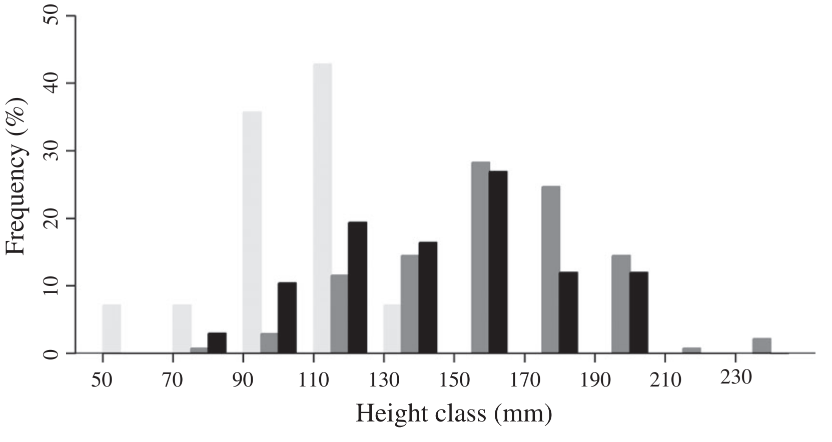

FIG. 2. Height frequency distribution for female (■), male (■) and all (■) *Hippocampus algiricus* samples.

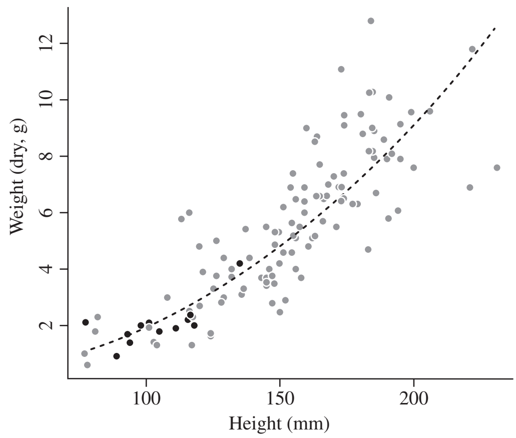

FIG. 3. Height and mass (dry) relationship for *Hippocampus algiricus* samples (●). Data for *Hippocampus hippocampus* are shown (●) but not included in the analysis because of low sample size. The curve was fitted by $y = 6 \cdot 9 \times 10^{-5} x^{2 \cdot 23}$ ($r^2 = 0{\cdot}71$).

caught seahorses ($n = 19$) had a broad range of height (mean ± S.D. = 145 ± 43 mm) and wet mass (mean ± S.D. = 12 ± 9 g). Mass was monitored up to 19 days after capture as the specimens dried; virtually all reached their final dry mass after 3 days. Mean wet:dry mass was 3·1:1 (Table I).

Sex ratio of *H. algiricus* showed a 2:1 male bias (Table I). A total of 41% of males for all species were reproductively active (Table I), with an H_{50} of 161 mm calculated for *H. algiricus* (Fig. 4). The only fresh pregnant seahorse encountered (*H. hippocampus*) had a height of 89 mm and wet mass of 3·7 g (dry mass 0·9 g) including embryo mass. A total of 175 individual embryos (together weighing 0·6 g) were counted, for an estimated total of 200 embryos including those stuck inside the pouch lining.

Seahorse colour and size were identified by fishers and traders as an important attribute for unit price, with bright yellow, red and two-toned specimens as the most valuable. Specimen colours included brown (23%), black (18%), yellow (16%), striped (13%), red (9%) and two-toned (black tail and yellow or red head and body; 4%). When fresh, spots and mottling were clearly visible on seahorses of any colour, but this mostly faded when dry. It is worth noting that the physical appearance of live seahorses, with vibrant colours and skin filaments not often seen in dry specimens, can make visual identification difficult in the field.

This study provides the first biological data on *H. algiricus* and the first data for *H. hippocampus*. Results can help establish reference points for assessing future effects of extraction and suggest potential risks. Key concerns include male-biased landings with possible population effects, significant yet unmonitored industrial catch and exports, and potential growth overfishing of *H. algiricus*. A highly useful result for management is the calculation of a wet-to-dry-mass conversion factor (3·1:1), essential for analysing trade data that overwhelmingly report dried seahorses. Similarly, morphometrics (Table I) can aid researchers that may frequently encounter incomplete individuals in trade.

The estimated height at 50% reproductive activity for *H. algiricus* was 16 cm, suggesting that the 10 cm minimum allowable catch size recommended by CITES (Foster

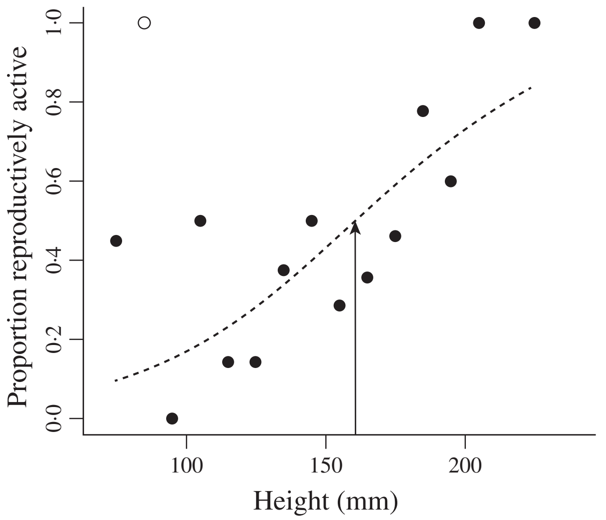

FIG. 4. Estimated height at 50% maturity for *Hippocampus algiricus* (161 mm; ⟶); $\gamma = 0{\cdot}026$. ---- is model fit to the observed data (●). ○, outlier value not included in the model.

& Vincent, 2005) is ineffective. Size at reproductive activity is useful for conservation measures, as physically mature seahorses may not have yet reproduced (Harasti *et al.*, 2012). Estimated fecundity for *H. hippocampus* was consistent with findings for species of similar size (Foster & Vincent, 2004; Harasti *et al.*, 2012). This information must also be obtained for *H. algiricus*, perhaps through focused sampling in high abundance areas (Fig. 1).

This study found that *H. algiricus* dominates artisanal catch in the region (94% of all samples) and expanded the prior confirmed distribution (Lourie *et al.*, 2004) of *H. hippocampus* to include The Gambia and, based on multiple independent interviews with fishers, Guinea-Bissau. About 11 specimens of *H. algiricus* (5% of samples) were larger than the previous maximum reported size (19 cm height; Lourie *et al.*, 2004), with the largest measuring 22 cm in height, making it the fourth largest known seahorse species in the world.

Male-biased sex ratios in sampled landings of *H. algiricus* probably stemmed from selective fishing practices. Most wild populations of seahorse species studied have equal sex ratios or, occasionally, tend towards female predominance (Strawn, 1958; Baum *et al.*, 2003; Martin-Smith & Vincent, 2006). Studies of *H. hippocampus* in Portugal and the Azores found seasonal male-biased sex ratios during breeding, which the authors link to mate-choice breeding dynamics (Naud *et al.*, 2009). Perhaps more significantly for this study, fishers indicated that they are more likely to retain colourful, larger or visibly pregnant individuals (*i.e.* males), suggesting possible strong biases in retained and traded catch.

Gear–habitat interactions may have also contributed to sampling results. It was difficult to know exactly where and how all seahorse samples were caught, so independent research on sex distributions and catch biases is needed. Clearly, sex-selective extraction is significant as many species maintain monogamous breeding pairs and male pregnancy is a rate-limiting step in some species (Vincent, 1994; Wilson *et al.*, 2003;

Harasti *et al.*, 2012). With expanding trade, retention rates for females will probably increase, as females have only slightly less value than males and vessels are not limited in holding capacity. This selectivity shift was noted by some fishers and is consistent with observed fishing behaviour as incentives for retention increase and other targeted fish populations decrease (Pauly, 1998).

Few seahorses were observed in the field or in artisanal catch during surveys around Dakar, yet were abundant at its industrial port. According to fishers, industrial catch occurs at greater depths and further south off the coasts of Guinea-Bissau and Guinea. Some seahorse species are larger at greater depths (Choo & Liew, 2003), which may support the (albeit not statistically significant) difference between these specimens and those caught in shallow (<4 m) waters by artisanal fishers. Observation of industrial catch was not possible and would be an important step for management efforts.

Fishery surveys, although inherently potentially biased, provide vital information for management. This survey sought to maximize fishers and traders contacts and seahorse samples at each site. A drawback of creel survey data is a potential memory bias (Mallison & Cichra, 2004), and snowball sampling can limit surveys to specific social networks, although it is highly useful for obtaining sensitive or private information (Biernacki & Waldorf, 1981). Nevertheless, the large number of seahorses sampled allowed for comparison between interview responses and samples, providing qualitative support for quantitative data.

Current coastal fisheries in West Africa allow for potential mitigation of seahorse catch. Artisanal fishers bring catch-up slowly to allow for sorting, and seahorses were usually not entangled in netting but had attached themselves with their tails to nets or accompanying debris. Individuals observed at capture appeared to be in good condition and would probably have survived if released; an immediate initial policy could aim to reduce effects by promoting release rates of small or pregnant individuals. Conversely, industrial bottom-trawl vessel crew reported that seahorse by-catch was always kept, particularly by Asian crew for sale on their return home. In addition to sustained catches from artisanal fisheries, indiscriminate by-catch from bottom-trawlers worldwide represents an unsupportable pressure on wild populations of seahorses and many other less iconic species.

Fishery data were invaluable for this study, but research on wild populations of *H. algiricus* is essential. There was an evident bias in size, sex and colour selectivity in landings and trade, which should be compared with wild populations through independent sampling. Potential trade restrictions to mitigate seahorse overexploitation should aim to create incentives for fisheries sustainability in West Africa, for the benefit of marine ecosystems and fishing communities.

This is a contribution from Project Seahorse. We gratefully acknowledge the many Senegalese and Gambian individuals who participated in this study, and particularly M. Abba Sonko and the staff of Senegal's Direction des Eaux, Forêts, Chasse et de la Conservation des Sols for their assistance. We also thank J. Lawson, G. Bestbier, R. Pollom, L. Woodall and F. Otero for their assistance with sample identification and comments on the manuscript. This work was kindly funded by the People's Trust for Endangered Species, the Mohamed bin Zayed Species Fund and an Erasmus Darwin Barlow Expedition award. A.C.J.V. thanks Guylian Chocolates Belgium and an anonymous donor for their generous support through partnerships with Project Seahorse for marine conservation. This work was approved by the UBC Human Behavioural Research Ethics Board, Permit H13-00819, and animal ethics Certificate 5884-13 of the Canadian Council on Animal Care.

References

Afonso, P., Porteiro, M., Santos, R. S., Barreiros, J. P., Worms, J. & Wirtz, P. (1999). Coastal marine fishes of Sao Tome Island (Gulf of Guinea). *Arquipélago: Life and Marine Sciences* **17,** 65–92.

Baum, J. K., Vincent, A. C. J. & Meeuwig, J. J. (2003). Bycatch of lined seahorses (*Hippocampus erectus*) in a Gulf of Mexico shrimp trawl fishery. *Fishery Bulletin* **101,** 721–731.

Biernacki, P. & Waldorf, D. (1981). Snowball sampling. Problems and techniques of chain referral sampling. *Sociological Methods and Research* **10,** 141–163.

Boisseau, J. (1967). *Les régulations hormonales de l'incubation chez un Vertébré mâle: recherches sur la reproduction de l'Hippocampe*. Bordeaux: Université de Bordeaux.

Choo, C. K. & Liew, H. C. (2003). Spatial distribution, substrate assemblages and size composition of sea horses (family Syngnathidae) in the coastal waters of Peninsular Malaysia. *Journal of the Marine Biological Association of the United Kingdom* **83,** 271–276.

Evanson, M., Foster, S. J., Wiswedel, S. & Vincent, A. C. J. (2011). Tracking the international trade of seahorses (*Hippocampus* species) – the importance of CITES. *Fisheries Centre Research Reports* **19**.

Foster, S. J. & Vincent, A. C. J. (2004). Life history and ecology of seahorses: implications for conservation and management. *Journal of Fish Biology* **65,** 1–61.

Foster, S. J. & Vincent, A. C. J. (2005). Enhancing sustainability of the international trade in seahorses with a single minimum size limit. *Conservation Biology* **19,** 1044–1050.

Foster, S. J., Wiswedel, S. & Vincent, A. C. J. (2014). Opportunities and challenges for analysis of wildlife trade using CITES data – seahorses as a case study. *Aquatic Conservation: Marine and Freshwater Ecosystems*. doi: 10.1002/aqc.2493

Harasti, D., Martin-Smith, K. & Gladstone, W. (2012). Population dynamics and life history of a geographically restricted seahorse, *Hippocampus whitei*. *Journal of Fish Biology* **81,** 1297–1314.

Lawson, J. M., Foster, S. J., Lim, A. C. O., Chong, V. C. & Vincent, A. C. J. (2015). Novel life history data for threatened seahorses provides insights into fishing impacts. *Journal of Fish Biology* **86,** 1–15.

Mallison, C. T. & Cichra, C. E. (2004). Accuracy of angler-reported harvest in roving creel surveys. *North American Journal of Fisheries Management* **24,** 880–889.

Mamonekene, V., Lavoue, S., Pauwels, O. S. G., Beh, J. H. M., Mackayah, J. & Tchignoumba, L. (2006). Fish diversity at Rabi and Gamba Ogooue-Maritime Province, Gabon. *Bulletin of the Biological Society of Washington* **12,** 285–296.

Martin-Smith, K. M. & Vincent, A. C. J. (2006). Exploitation and trade of Australian seahorses, pipehorses, sea dragons and pipefishes (family Syngnathidae). *Oryx* **40,** 141.

Morgan, S. K. & Vincent, A. C. J. (2013). Life-history reference points for management of an exploited tropical seahorse. *Marine and Freshwater Research* **64,** 185.

Naud, M. J., Curtis, J. M., Woodall, L. C. & Gaspar, M. B. (2009). Mate choice, operational sex ratio, and social promiscuity in a wild population of the long-snouted seahorse *Hippocampus guttulatus*. *Behavioral Ecology* **20,** 160–164.

Pauly, D. (1998). Fishing down marine food webs. *Science* **279,** 860–863.

Schneider, J. C., Laarman, P. W. & Gowing, H. (2000). Length–weight relationships. In *Manual of Fisheries Survey Methods II: with Periodic Updates* (Schneider, J. C., ed.) Chapter 17, pp. 1–16. Ann Arbor, MI: Michigan Department of Natural Resources. Available at http://www.michigandnr.com/PUBLICATIONS/PDFS/ifr/Manual/SMII%20 Chapter17.pdf/.

Strawn, K. (1958). Life history of the pigmy seahorse, *Hippocampus zosterae* Jordan and Gilbert, at Cedar Key, Florida. *Copeia* **1958,** 16–22.

Vincent, A. C. J. (1994). Operational sex ratios in seahorses. *Behaviour* **128,** 153–167.

Vincent, A. C. J., Foster, S. J. & Koldewey, H. J. (2011). Conservation and management of seahorses and other Syngnathidae. *Journal of Fish Biology* **78,** 1681–1724.

Vincent, A. C. J., Sadovy de Mitchenson, Y. J., Fowler, S. L. & Lieberman, S. (2013). The role of CITES in the conservation of marine fishes subject to international trade. *Fish and Fisheries* **15,** 563–592.

Wilson, A. B., Ahnesjo, I., Vincent, A. C. J. & Meyer, A. (2003). The dynamics of male brooding, mating patterns, and sex roles in pipefishes and seahorses (family Syngnathidae). *Evolution* **57,** 1374–1386.

Wirtz, P. C., Ferreira, E. L., Floeter, S. R., Fricke, R., Gasparini, J. L., Iwamoto, T., Rocha, L., Sampaio, C. L. S. & Schliewen, U. K. (2007). Coastal fishes of São Tomé and Príncipe islands, Gulf of Guinea (Eastern Atlantic Ocean) – an update. *Zootaxa* **1523,** 1–48.

Woodall, L. C., Koldewey, H. J. & Shaw, P. W. (2011). Historical and contemporary population genetic connectivity of the European short-snouted seahorse *Hippocampus hippocampus* and implications for management. *Journal of Fish Biology* **78,** 1738–1756.

Electronic references

Loh, T. L., Knapp, C. & Foster, S. J. (2014). *iSeahorse Trends Toolkit*. Vancouver, BC and Chicago, IL: The University of British Columbia and John G. Shedd Aquarium. Available at http://www.acheron.com/tyler/iseahorse/trends/iSeahorse_UW_Trends_Toolkit_2014March.pdf

Lourie, S. A., Foster, S. J., Cooper, E. W. T. & Vincent, A. C. J. (2004). *A Guide to the Identification of Seahorses*. Washington, DC: Project Seahorse and TRAFFIC North America, The University of British Columbia and World Wildlife Fund. Available at www.traffic.org/species-reports/traffic_species_fish29.pdf (last accessed 28 July 2015).

Vincent, A. C. J. (2014). *Three More Countries Required to Take Action for Seahorses: Project Seahorse*. Available at http://seahorse.fisheries.ubc.ca/node/703/ (last accessed 28 July 2015).

West, K. (2012). *Investigations into the Senegalese Trade in CITES-Listed Seahorses*, Hippocampus algiricus. London: Imperial College. Available at http://www.iccs.org.uk/wp-content/thesis/consci/2012/West.pdf/ (last accessed 28 July 2015).

