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DIVERSITY, DISTRIBUTION, ECOLOGY AND CONSERVATION STATUS OF THE FAMILY SYNGNATHIDAE IN SUB-SAHARAN AFRICA AND ADJACENT ISLANDS

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Abstract The charismatic Syngnathidae occur in coastal and freshwater environments across the globe and play an important role by acting as flagship species for conservation. Despite this status, many syngnathids are threatened by a range of anthropogenic impacts including exploitation and habitat destruction. In addition, the cryptic nature and generally low population densities of syngnathids make research and related conservation action difficult, which can lead to data gaps. The gap in knowledge of the biology and status of syngnathids is especially acute within Africa. This review provides the first synthesis of syngnathid diversity, biogeography, ecology, threats and conservation in sub-Saharan Africa and adjacent islands. Research focus and effort are biased towards the southeast coast of Africa, with limited research specifically on syngnathids. A total of 63 species of syngnathids in 26 genera are recorded in Africa, with higher syngnathid diversity on the east coast of Africa. Ecological research focused on population trends and diversity is identified as priorities, specifically for those species listed as Data Deficient on the IUCN Red List. Other priorities identified include research on the extent and impact of illegal catch and trade and the development of local capacity and expertise. These findings provide an important resource that can be used for the future conservation of this iconic group of fishes.

Keywords: seahorse, pipefish, pipehorse, synganthids, South Africa, ecology, diversity, conservation

Introduction

Syngnathidae (seahorses, pipefish, pipehorses and seadragons) are charismatic fishes and, as such, are effective flagship species for the conservation of threatened habitats (Shokri et al. 2009, Vincent et al. 2011). Yet, many species are harvested for use in traditional Chinese medicine and as curios, caught as by-catch in industrial and artisanal fisheries, and threatened by habitat loss (Pollom et al. 2021). Unfortunately, little is known about the biology and ecology of the majority of syngnathid species, and this is especially true of those inhabiting the waters of sub-Saharan Africa and adjacent

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islands. If syngnathid populations in sub-Saharan Africa and adjacent islands are to be conserved and sustainably managed, a better understanding of the status of this group of fishes is needed. Available data on the diversity, distribution, threats and conservation status of syngnathids in this region are scattered and need to be synthesized to provide a current overview, which will help identify research and conservation priorities.

Syngnathids, comprising over 300 species in 57 genera, are widely distributed in temperate and tropical habitats, predominantly among shallow coastal areas of the Atlantic and Indo-Pacific Oceans, including soft sediment habitats, seagrass beds, estuaries, coral and rocky reefs, and mangroves (Foster & Vincent 2004, Kuiter 2009). Members of this family are uniquely characterised by male pregnancy, cryptic morphology and behaviour, and a fused jaw that allows for suction feeding. All 45 extant species of seahorses currently belong to the genus *Hippocampus* (IUCN 2021). There are over 300 species of pipefish in 50 genera, with only three species of seadragon in two genera and eight species of pipehorse in four genera (IUCN 2021). Seahorses are found between latitudes 50° north and 50° south (Lourie et al. 2004, 2016), pipefish occur circumglobally in nearshore habitats (Dawson 1985), whilst seadragons are confined to southern Australia (Stiller et al. 2015). Pipehorses are less commonly observed and occur in both the Atlantic and Indo-Pacific, including in the western Indian Ocean (Dawson 1985, Kuiter 2004, 2009). Mitochondrial and nuclear sequence data from a broad diversity of syngnathid genera strongly support the geographic origin of the seahorse genus *Hippocampus* in the Indo-Pacific and its sister clades as a grouping of morphologically diverse Indo-Pacific genera, including the Indo-Pacific pygmy pipehorses (Hamilton et al. 2017). The data also revealed speciose clades that originated in southern Australia and the western Atlantic, with no large clades originating in Africa (Hamilton et al. 2017).

Syngnathids are generally found in complex habitats that provide suitable cover and protection from predators. The habitats include seagrasses (e.g. Choo & Liew 2003, Dias & Rosa 2003, MasonJones et al. 2010, Choi et al. 2012, Filiz & Taskawak 2012, Correia et al. 2015a, Otero-Ferrer et al. 2015, Manning et al. 2018), algal beds (e.g. Moreau & Vincent 2004, Curtis & Vincent 2005), mangroves (e.g. Dias & Rosa 2003), muck habitats (de Brauwer & Burton 2018) and coral reefs (Marcus et al. 2007, Vincent et al. 2011). In addition to protection against predators, the availability of holdfasts (structures that a seahorse is able to curl its tail around for support) is a critical component in seahorse habitats. Various studies have found that seahorse presence and abundance are positively associated with the number of available holdfasts (Curtis & Vincent 2005, Aylesworth et al. 2015, Lazic et al. 2018). A decrease in available holdfasts has been linked to population declines of the long-snouted seahorse, *Hippocampus guttulatus*, in the Ria Formosa, Portugal (Correia et al. 2015a), as well as White's seahorse, *H. whitei*, in Port Stephens, Australia (Harasti 2016). In addition to natural habitats, many syngnathids use, and in some instances even prefer, artificial structures (Dias & Rosa 2003, Correia et al. 2015b, Gristina et al. 2015, Otero-Ferrer et al. 2015, Lazic et al. 2018), such as wall- and mattress-type gabions (Claassens 2016, Munro 2017, Claassens et al. 2018), swimming nets (Harasti et al. 2010) as well as structures specifically designed for seahorse conservation, e.g. 'seahorse hotels' (Simpson et al. 2019, 2020).

Estuaries are particularly important coastal systems for some syngnathids (Rosa et al. 2007, MasonJones et al. 2010, Aylesworth et al. 2015, Whitfield et al. 2017). According to Lourie et al. (2016), the Knysna seahorse *Hippocampus capensis* is the only known true estuarine seahorse species, found in only three South African estuaries (Bell et al. 2003, Lockyear et al. 2006). However, *H. whitei* also occurs exclusively in estuarine habitats in eastern Australia, including Sydney Harbour and Port Stephens, New South Wales and Moreton Bay, Queensland (Harasti et al. 2012, Short et al. 2019). Members of the Indo-Pacific *Hippichthy*s move between rivers and estuaries (Dawson 1985, Ishihara & Tachihara 2009, Lim et al. 2011, Paller et al. 2011, Jayaneththi et al. 2014, Moore et al. 2014), whilst pipefish in the west African genus *Enneacampus* occur exclusively in freshwater systems (Dawson 1985).

Syngnathids are vulnerable to anthropogenic impacts because they occur in shallow, coastal systems and within threatened habitats (Lim et al. 2011, Vincent et al. 2011). In addition, syngnathids have various characteristics (uneven distribution, low mobility, small home-ranges, monogamy and low fecundity) that leave them susceptible to habitat destruction and overexploitation (Foster & Vincent 2004, Lim et al. 2011, Vincent et al. 2011). Within the Syngnathidae, research examining threats has been biased towards seahorses (Foster & Vincent 2004, Vincent et al. 2011), and only species of *Hippocampus* is listed in CITES Appendix II (Vincent et al. 2013, Foster et al. 2016). Regardless of this bias, many threats faced by seahorses also apply to pipefish, pipehorses and seadragons, as these groups are found in similar habitats to seahorses and are used for similar purposes by humans (Martin-Smith & Vincent 2006, Lim et al. 2011, Vincent et al. 2011). The three most important anthropogenic threats to syngnathids are as follows: overexploitation by targeted fisheries, incidental capture in non-selective fishing gear (by-catch) and habitat degradation and loss (Martin-Smith & Vincent 2006, Lim et al. 2011, Vincent et al. 2011, Harasti 2016).

The overarching aim of this review is to evaluate the current state of knowledge of syngnathids in sub-Saharan Africa and adjacent islands. Here, all available literature on southern African syngnathids and adjacent islands has been collated to investigate research effort and focus across this part of the African continent. This is followed by a detailed review of syngnathid diversity in sub-Saharan Africa and adjacent islands to verify occurrence records and distributions. Ecological information on syngnathids within the region is synthesized on habitat use, life histories, reproduction, feeding and predation, and behaviour. Major threats and conservation actions will be reviewed within an African context. Lastly, research gaps and future priorities for African syngnathids will be identified.

Geographic scope and literature review

Whilst the focus of this review is on sub-Saharan African syngnathids, we have extended the geographic boundaries north of the equator to include countries located south of Western Sahara on the Atlantic coast, and south of Somalia on the Indian Ocean coast. In addition, several neighbouring western Indian Ocean islands (Europa, Madagascar, Réunion, Mauritius, Seychelles, Comoros and Zanzibar) are also covered. Many syngnathid species that occur in the Mediterranean Sea and the Red Sea range across Europe (with a suite of resources and information available on these species), and to maintain the focus on Africa, those countries bordering the Red Sea and the Mediterranean Sea were excluded from this review. Most of the area under review lies within the tropics and subtropics. However, around the coast of South Africa, there are four distinct biogeographic regions: a tropical north-east region on the east coast close to the border with Mozambique; a subtropical east coast; a warm temperate south coast; and the cold temperate west coast that extends into Namibia.

Extent and type of syngnathid research

To determine the geographic extent and type of research on syngnathids in southern Africa, a literature search using online databases was conducted that included specific syngnathid-focused search terms including generic, species and common names, as well as more general marine-related searches. Key word searches were also conducted using Google Scholar and Rhodes University

Library Catalogue searching words such as "syngnathids", "seahorse", "pipefish", "pipehorse", "estuary" as well as variations of these words. The literature search was focused on research from sub-Saharan Africa and adjacent islands, syngnathid ecology, reproduction, conservation and taxonomy, in which the literary sources included both peer-reviewed articles and grey literature. In addition to sub-Saharan African-focused research, general searches were conducted on those syngnathid species that are found in Africa, but also occur in other regions globally.

Scuba divers and citizen scientists can provide important information on species diversity and distributions, especially in areas where scientific research is limited, on social platforms designed for observational input via photographic records of species and associated habitat. One such network, iNaturalist (2021), is a social network for naturalists, citizen scientists and biologists and is built on the concept of mapping and sharing observations of biodiversity across the globe. To gain a better understanding of the distribution patterns of African syngnathids, the lead author created a project entitled "Syngnathids of Africa" on iNaturalist (https://www.inaturalist.org/projects/syngnathids-of-africa) with the aim of collating citizen science syngnathid observations from Africa. However, such data do have limitations. For example, it is extremely difficult to identify many syngnathid species correctly, both *in situ* and from photographs, owing to morphological similarities across species and their cryptic nature. In addition, owing to the threatened status of many syngnathid species, only general locality information is provided for most observations on iNaturalist.

A total of 147 scientific publications and unpublished reports, dating from 1900 to the present, were found that referenced, recorded, listed or mentioned syngnathids in Africa, with a clear geographic bias to the south-eastern coast and in particular South Africa. The earliest publication found was the description of *Hippocampus capensis* in 1900 (Boulenger 1900).

A similar pattern in terms of geographic focus was found for ecological publications that included specific locality information. Various species descriptions and a detailed overview of Indo-Pacific pipefish by Dawson (1985) provided extensive information on this group.

The majority of articles (71%) on syngnathids had an ecological focus (Ecological in Figure 1), ranging from field surveys to genetics research; studies which targeted a specific syngnathid species were only found for *Hippocampus capensis* and *Syngnathus watermeyeri* in South Africa, and *Hippocampus hippocampus* and *H. algiricus* along the west coast of Africa. Only 41 publications (28%) were exclusively focused on syngnathids, whilst the rest consisted of general fish surveys, biodiversity assessments and species lists. Species lists (Lists in Figure 1) and reviews (Review in Figure 1) mostly depend on other primary sources for the inclusion of syngnathid-related data and were considered secondary sources. The remaining publications included species descriptions (Figure 1) using specimens originating from sub-Saharan Africa and adjacent islands and management-focused publications (Figure 1). The dependence on unverified historic sources can lead to the perpetuation of misinformation, owing to incorrect species identification. For example, in various reports (Cyrus 2001, Weerts & Cyrus 2002, Whitfield 2005, Kleynhans 2007, Perera et al. 2011, Weerts et al. 2014, Máiz-Tomé et al. 2018, Cutler et al. 2020), the pipefish *Microphis millepunctatus* is mistakenly recorded as *M. brachyurus*, which does not occur in Africa (Dawson 1985). In addition, members of the pipefish genus *Corythoichthys*, as well as larval syngnathids, are extremely difficult to identify to species. Misidentification to species level in these instances is thus likely (Harris et al. 1999, Pattrick & Strydom 2008, Mwaluma et al. 2010, Jaonalison et al. 2016).

Hippocampus capensis, *Syngnathus watermeyeri*, *S. temminckii* and *Hippichthys spicifer* were the species with the highest number of ecological publications, whilst *Microphis millepunctatus* had the greatest number of records in species lists and reviews (Figure 1). Genetic research on syngnathids in Africa is limited to a few studies from South Africa, mostly focused on *Hippocampus capensis* and studies investigating the evolutionary history of *Hippocampus* spp. (Toeffie 2000, Teske et al. 2003, 2004, 2005, Galbusera et al. 2007, Mkare et al. 2017, 2021), *Syngnathus temminckii* and *S. watermeyeri* (Mwale et al. 2013).

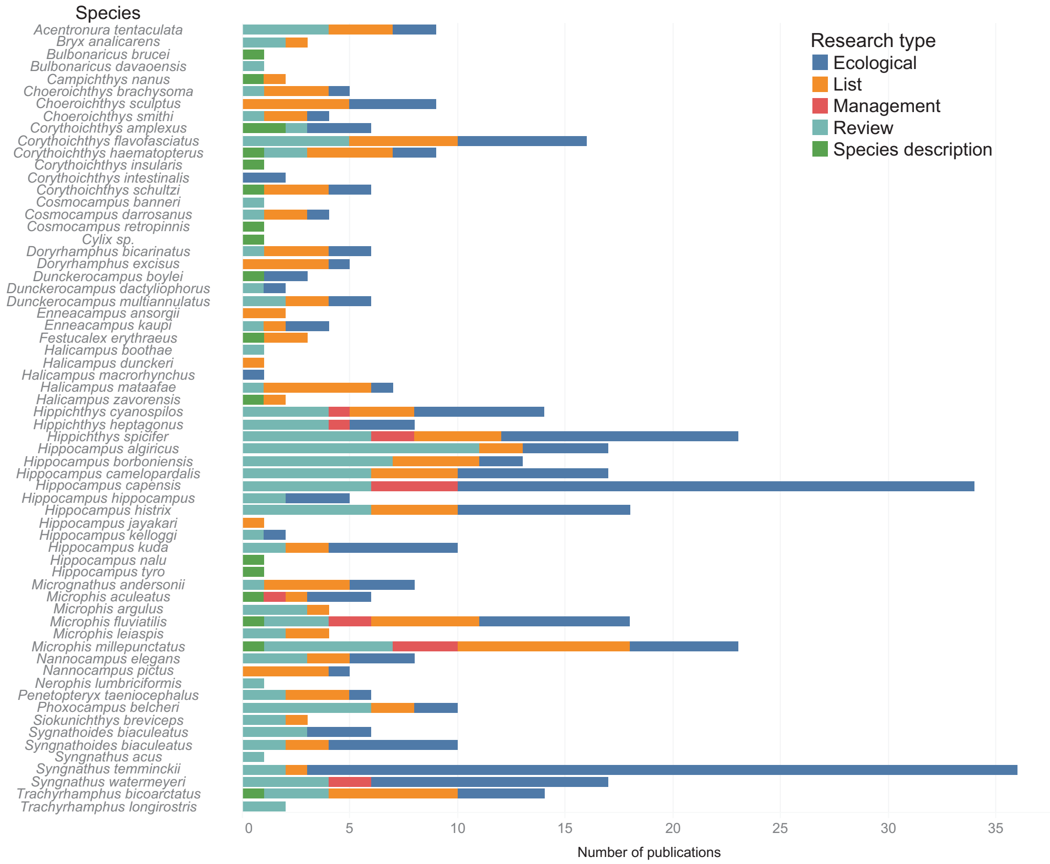

Figure 1 Number of publications relating to different species: publications are divided into ecological research, species lists and reviews, and species descriptions using specimens that originated from Africa. Note that one publication or report can provide a record for multiple species.

A total of 668 syngnathid observations were logged from the region on iNaturalist between April 2002 and March 2021. Of these records, 58% of observations were Research Grade (an observation is considered to be "Research Grade" when the community agrees on species-level identification, i.e. when more than two-thirds of identifiers agree on the identification) and 32% of species required identification. The observations from iNaturalist provided data for Cameroon (*Hippocampus algiricus*), which were not available in the published literature, as well as a first record for *Halicampus macrorhynchus* in Kenya.

Diversity and biogeography

To determine the species richness of African syngnathids, data from the literature review, observations from iNaturalist and information provided by diving schools, divers and non-governmental organisations (NGOs) were used. In addition, collection records from the South African Institute of Aquatic Biodiversity (SAIAB), Grahamstown, and Iziko Museum, Cape Town, were reviewed.

High species richness, with a total of 63 species of syngnathids in 26 genera (Table 1), is recorded in African waters (excluding the African countries bordering the Mediterranean and Red Sea) and the nearby island countries and territories of São Tomé and Príncipe, Zanzibar, Comoros, Mayotte, Madagascar, Europa Island, Seychelles, Mauritius and Réunion Island. The total includes

Table 1 All syngnathid species and the countries in which they are found within sub-Saharan Africa and adjacent Indian Ocean islands

Species	Country	Reference
Acentronura tentaculata Günther, 1870	Madagascar	Dawson (1985), McKenna & Allen (2006), Fricke et al. (2018)
	Mozambique	Smith (1963), Dawson (1985), De Boer et al. (2001), Pereira (2008)
	Kenya	iNaturalist (2021)
	Tanzania	iNaturalist (2021)
	Comoros	Smith (1963)
Bryx analicarens (Duncker, 1915)	Madagascar	Fricke et al. (2018)
	Seychelles	Dawson (1985)
	Zanzibar	Dawson (1985)
Bulbonaricus brucei Dawson, 1984	Tanzania	Dawson (1984a)
Bulbonaricus davaoensis (Herald, 1953)	Kenya	Dawson (1985)
Campichthys nanus (Dawson, 1977)	Mozambique	Dawson (1977a), Pereira (2008)
Choeroichthys brachysoma (Bleeker, 1855)	Madagascar	Fricke et al. (2018)
	Mauritius	Smith (1963), Arndt & Fricke (2019)
	Réunion	Letourneur et al. (2004), Fricke et al. (2009)
Choeroichthys sculptus (Günther, 1870)	Madagascar	McKenna & Allen (2006), Weis et al. (2009), Jaonalison et al. (2016), Fricke et al. (2018)
	Mozambique	Pereira (2000), De Boer et al. (2001), Pereira (2008)
	Réunion	Letourneur et al. (2004), Fricke et al. (2009)
Choeroichthys smithi Dawson, 1976	Europa Island	Fricke et al. (2013)
	Madagascar	McKenna & Allen (2006)
	Mozambique	Dawson (1985), Pereira (2008)
Corythoichthys amplexus Dawson & Randall, 1975	Kenya	Huxham et al. (2008), Mwaluma et al. (2010)
	Seychelles	Dawson & Randall (1975), Dawson (1977b)
	Zanzibar	Tyler et al. (2009), Berkström et al. (2012)
Corythoichthys flavofasciatus (Rüppell, 1838)	Madagascar	McKenna & Allen (2006), Jaonalison et al. (2016), Fricke et al. (2018)
	Mauritius	Arndt & Fricke (2019)
	Mozambique	Smith (1963), Gell & Whittington (2002), Pereira (2008)
	Réunion	Letourneur et al. (2004), Fricke et al. (2009)
	Zanzibar	Smith (1963), Tyler et al. (2009), Berkström et al. (2012), Kloiber (2013), Palmqvist (2013)
	Kenya	Smith (1963)
	Seychelles	Smith (1963)
Corythoichthys haematopterus (Bleeker, 1851)	East coast of Africa/ Seychelles	Dawson (1977b)
	Madagascar	McKenna & Allen (2006), Fricke et al. (2018)
	Mozambique	Smith (1963), Gell & Whittington (2002), Pereira (2008)
	Mozambique	Gell & Whittington (2002)
	Seychelles	Smith (1963)
	Réunion	Letourneur et al. (2004), Fricke et al. (2009)

(*Continued*)

Table 1 (*Continued*) All syngnathid species and the countries in which they are found within sub-Saharan Africa and adjacent Indian Ocean islands

Species	Country	Reference
Corythoichthys insularis Dawson, 1977	Comoros	Dawson (1977b)
Corythoichthys intestinalis (Ramsay, 1881)	Madagascar	Ory (2008)
	Mozambique	Fordyce (2016)
Corythoichthys schultzi Herald, 1953	Kenya	Cowburn et al. (2018)
	Mozambique	Gell & Whittington (2002), Pereira (2008)
	Réunion	Letourneur et al. (2004), Fricke et al. (2009)
	Seychelles	Dawson (1977b)
Cosmocampus banneri (Herald & Randall, 1972)	South Africa	Dawson (1985)
Cosmocampus darrosanus (Dawson & Randall, 1975)	Madagascar	McKenna & Allen (2006), Fricke et al. (2018)
	Mozambique	Pereira (2008)
Cosmocampus retropinnis Dawson, 1982	Gambia	Dawson (1982)
Cylix sp.	South Africa	G. Short, unpublished data.
Doryrhamphus bicarinatus Dawson, 1981	Madagascar	Fricke et al. (2018)
	Mauritius	Arndt & Fricke (2019)
	Mozambique	Pereira (2008)
	Réunion	Fricke et al. (2009), Pinault et al. (2013)
	South Africa	Dawson (1981, 1985)
Doryrhamphus excisus Kaup, 1856	Kenya	Cowburn et al. (2018)
	Madagascar	Fricke et al. (2018)
	Mozambique	Pereira (2000, 2008)
	Réunion	Letourneur et al. (2004)
Dunckerocampus boylei Kuiter, 1998	Mauritius	Forget et al. (2020)
	Seychelles	Daly et al. (2018)
	South Africa	Kuiter (1998)
Dunckerocampus dactyliophorus (Bleeker, 1853)	South Africa	Dawson (1985)
	Mozambique	Fordyce (2016)
Dunckerocampus multiannulatus (Regan, 1903)	Mauritius	Forget et al. (2020)
	Réunion	Letourneur et al. (2004), Fricke et al. (2009), Tea et al. (2020)
	South Africa	Dawson (1985)
	Mauritius	Smith (1963)
Enneacampus ansorgii (Boulenger, 1910)	Angola	Skelton (2019)
Enneacampus kaupi (Bleeker, 1863)	Angola	Skelton (2019)
	Côte d'Ivoire	Kamelan et al. (2013)
	Gabon	Mamonekene et al. (2006)
	Western and central African tropical estuaries	Whitfield (2005)
Festucalex erythraeus (Gilbert, 1905)	Mozambique	Dawson (1977a), Pereira (2000), Pereira (2008)
Halicampus dunckeri (Chabanaud, 1929)	Madagascar	Fricke et al. (2018)

(*Continued*)

Table 1 (*Continued*) All syngnathid species and the countries in which they are found within sub-Saharan Africa and adjacent Indian Ocean islands

Species	Country	Reference
Halicampus macrorhynchus Bamber, 1915	Kenya	Ewout Knoester pers. comm., iNaturalist (2021)
	Madagascar	Alain Rassat pers. comm.
Halicampus mataafae (Jordan & Seale, 1906)	Madagascar	Fricke et al. (2018)
	Mauritius	Arndt & Fricke (2019)
	Mozambique	Pereira (2000, 2008)
	Réunion	Letourneur et al. (2004), Fricke et al. (2009)
	South Africa	Dawson (1985)
Halicampus zavorensis Dawson, 1984	Mozambique	Dawson (1984b), Pereira (2008)
Halicampus boothae (Whitley, 1964)	Kenya	Dawson (1985)
Hippichthys cyanospilos (Bleeker, 1854)	Eastern African tropical estuaries	Whitfield (2005)
	Kenya	Okeyo (1998), Crona & Rönnbäck (2007)
	Madagascar	McKenna & Allen (2006), Fricke et al. (2018)
	Madagascar and Indian Ocean islands	Máiz-Tomé et al. (2018)
	Mauritius	Arndt & Fricke (2019)
	Mozambique	Dawson (1985), De Boer et al. (2001), Pereira (2008)
	South Africa	Forbes et al. (2013), Van Niekerk et al. (2019a)
Hippichthys heptagonus Bleeker, 1849	South Africa	Dawson (1985), Skelton et al. (1989), Harris et al. (1995, 1999), Van Niekerk et al. (2019a)
	South-eastern African subtropical estuaries and eastern African tropical estuaries	Teugels et al. (1994), Whitfield (2005)
	Kenya	Dawson (1985)
Hippichthys spicifer (Rüppell, 1838)	Kenya	Van der Velde et al. (1995), Seegers et al. (2003), Mirriam (2010)
	Madagascar	Smith (1963), Fricke et al. (2018), Máiz-Tomé et al. (2018)
	Mauritius	Arndt & Fricke (2019)
	Mozambique	Pereira (2008)
	South Africa	Cyrus & McLean (1996), Mbande (2003), Harrison & Whitfield (2006), O'Brien et al. (2009), Forbes et al. (2013), Van Niekerk et al. (2019a)
	South-eastern African warm-temperate estuaries and south-eastern African subtropical and eastern African tropical estuaries	Teugels et al. (1994), Whitfield (2005)
	Mozambique	Smith (1963)

(*Continued*)

Table 1 (*Continued*) All syngnathid species and the countries in which they are found within sub-Saharan Africa and adjacent Indian Ocean islands

Species	Country	Reference
	Tanzania	Smith (1963), Mwandya et al. (2009), Mwandya (2019)
	Zanzibar	Lugendo (2007), Berkström et al. (2012), Palmqvist (2013)
Hippocampus algiricus Kaup, 1856	Gabon	Mamonekene et al. (2006)
	São Tomé	Afonso et al. (1999), Lourie et al. (2004), Wirtz et al. (2007)
	Senegal	West (2012), Lourie et al. (2004), Cisneros-Montemayor et al. (2016)
	Angola	Lourie et al. (2004)
	Benin	Lourie et al. (2004)
	Côte d'Ivoire	Lourie et al. (2004)
	Gambia	Lourie et al. (2004), Cisneros-Montemayor et al. (2016)
	Ghana	Lourie et al. (2004)
	Guinea	Lourie et al. (2004)
	Liberia	Lourie et al. (2004)
	West Africa	Otero-Ferrer et al. (2017)
	Nigeria	Lourie et al. (2004)
	Western and central African tropical estuaries	Whitfield (2005)
Hippocampus borboniensis Duméril, 1870	Madagascar	Lourie et al. (2004), Fricke et al. (2018)
	Mozambique	Lourie et al. (2004), Pereira (2008), Warnell et al. (2013), Fordyce (2016)
	Réunion	Smith (1963), Lourie et al. (2004), Fricke et al. (2009)
	Mauritius	Lourie et al. (2004)
	South Africa	Lourie et al. (2004)
	Tanzania	Lourie et al. (2004), McPherson & Vincent (2004)
Hippocampus camelopardalis Bianconi, 1854	Eastern African tropical estuaries	Whitfield (2005)
	Madagascar	McKenna & Allen (2006), Fricke et al. (2018)
	Mozambique	Smith (1963), Almeida et al. (1999, 2001), De Boer et al. (2001), Lourie et al. (2004), Teske et al. (2004), Pereira (2008), Warnell et al. (2013), Fordyce (2016)
	Réunion	Letourneur et al. (2004)
	Mauritius	Smith (1963)
	Tanzania	Lourie et al. (2004), McPherson & Vincent (2004)
	South Africa	Lourie et al. (2004)

(*Continued*)

Table 1 (*Continued*) All syngnathid species and the countries in which they are found within sub-Saharan Africa and adjacent Indian Ocean islands

Species	Country	Reference
Hippocampus capensis Boulenger, 1900	South Africa	Boulenger (1900), Smith (1963), Riley (1986), Whitfield (1989), Russell (1994), Teugels et al. (1994), Grange & Cretchley (1995), Whitfield (1995a), Le Cheminant (2000), Toeffie (2000), Bell et al. (2003), Teske et al. (2003), Lourie et al. (2004), Teske et al. (2005), Whitfield (2005), Harrison & Whitfield (2006), Lockyear et al. (2006), Galbusera et al. (2007), Teske et al. (2007), Claassens (2016), Claassens & Hodgson (2018a), Mkare et al. (2017), Western Cape Government (2017), Claassens & Hodgson (2018b), Claassens et al. (2018), De Villiers et al. (2019), Van Niekerk et al. (2019b), Claassens & Harasti (2020), Claassens et al. (2020), Arendse & Russell (2020), SANParks (2020), Mkare et al. (2021)
Hippocampus hippocampus (Linnaeus, 1758)	Senegal	Lourie et al. (2004), West (2012), Cisneros-Montemayor et al. (2016)
	The Gambia	Cisneros-Montemayor et al. (2016)
	Guinea	Lourie et al. (2004)
	West Africa	Otero-Ferrer et al. (2017)
Hippocampus histrix Kaup, 1856	Kenya	Van der Velde et al. (1995), McPherson & Vincent (2004), Cowburn et al. (2018)
	Mozambique	Almeida et al. (1999), Pereira (2000), Almeida et al. (2001), Gell & Whittington (2002), Pereira (2008), Warnell et al. (2013), Fordyce (2016)
	Réunion	Letourneur et al. (2004)
	Kenya	McPherson & Vincent (2004)
	Zanzibar	Smith (1963), Lugendo (2007), Berkström et al. (2012)
	South Africa	Lourie et al. (2004)
	Tanzania	Lourie et al. (2004)
	Mauritius	Lourie et al. (2004)
Hippocampus jayakari Boulenger, 1900	Réunion	Fricke et al. (2009)
Hippocampus kelloggi Jordan & Snyder, 1901	Tanzania	Lourie et al. (2004), Teske et al. (2005), McPherson & Vincent (2004)
Hippocampus kuda Bleeker, 1852	Madagascar	McKenna & Allen (2006)
	Mozambique	Smith (1963), Almeida et al. (2001), Teske et al. (2005), Pereira (2008), Warnell et al. (2013), Fordyce (2016)
	South Africa	Teske et al. (2004, 2005)
	Zanzibar	Smith (1963)

(*Continued*)

Table 1 (*Continued*) All syngnathid species and the countries in which they are found within sub-Saharan Africa and adjacent Indian Ocean islands

Species	Country	Reference
Hippocampus nalu Short, Claassens, Smith, De Braauwer, Hamilton, Stat & Harasti, 2020	South Africa	Short et al. (2020)
Hippocampus tyro Randall & Lourie, 2009	Seychelles	Randall & Lourie (2009)
Micrognathus andersonii (Bleeker, 1858)	Kenya	Sindorf et al. (2015), Cowburn et al. (2018)
	Madagascar	Dawson (1985), McKenna & Allen (2006), Fricke et al. (2018)
	Mozambique	Pereira (2000, 2008)
Microphis aculeatus (Kaup, 1856)	Angola	Dawson (1984c), Skelton (2019)
	Benin	Adite et al. (2013)
	Côte d'Ivoire	Kamelan et al. (2013)
	Gabon	Cutler et al. (2020)
	Nigeria	Ukaonu et al. (2011)
	Senegal	Dawson (1984c)
Microphis argulus (Peters, 1855)	Comoros	Smith (1963), Dawson (1985)
	Madagascar	Dawson (1985), Fricke et al. (2018)
Microphis fluviatilis (Peters, 1852)	Kenya	Dawson (1985), Okeyo (1998), Seegers et al. (2003)
	Madagascar	Dawson (1985), Fricke et al. (2018), Máiz-Tomé et al. (2018)
	Mozambique	Smith (1963), Dawson (1985), Desai et al. (2019)
	South Africa	Cyrus (2001), Weerts & Cyrus (2002), Kyle (2002), Du Preez et al. (2007), Kleynhans (2007), Perera et al. (2011), Weerts et al. (2014), Evan (2017), Van Niekerk et al. (2019a)
	South-eastern African subtropical estuaries and eastern African tropical estuaries	Whitfield (2005)
Microphis leiaspis (Bleeker, 1854)	Madagascar	Smith (1963), Dawson (1985), Fricke et al. (2018), Máiz-Tomé et al. (2018)
Microphis millepunctatus (Kaup, 1856)	Réunion	Dawson (1984c, 1985), Letourneur et al. (2004), Fricke et al. (2009)
	Gabon	Cutler et al. (2020)
	Madagascar	Smith (1963), Dawson (1984c, 1985), Keith (2002), Fricke et al. (2018), Máiz-Tomé et al. (2018)
	Mauritius	Dawson (1984c, 1985), Arndt & Fricke (2019)
	Mozambique	Pereira (2008)
	São Tomé	Wirtz et al. (2007)

(*Continued*)

Table 1 (*Continued*) All syngnathid species and the countries in which they are found within sub-Saharan Africa and adjacent Indian Ocean islands

Species	Country	Reference
	South Africa	Cyrus (2001), Weerts & Cyrus (2002), Perera et al. (2011), Kleynhans (2007), Weerts et al. (2014), Evan (2017), Van Niekerk et al. (2019a)
	Kenya	Dawson (1985)
	South-eastern African subtropical estuaries and eastern African tropical estuaries and western and central African tropical estuaries	Whitfield (2005)
Nannocampus elegans Smith, 1953	Mozambique	Smith (1963), Pereira (2000, 2008)
	South Africa	Smith (1963), Christensen & Winterbottom (1981), Bennett (1987), Pattrick & Strydom (2008)
Nannocampus pictus (Duncker, 1915)	Mauritius	Arndt & Fricke (2019)
	Mozambique	Pereira (2000, 2008)
	South Africa	Dawson (1985)
	Réunion	Letourneur et al. (2004), Fricke et al. (2009)
Nerophis lumbriciformis (Jenyns, 1835)	Western Sahara	Dawson (1986a)
Penetopteryx taeniocephalus Lunel, 1881	Madagascar	Dawson (1985), McKenna & Allen (2006), Fricke et al. (2018)
	Mozambique	Pereira (2008)
	Mauritius	Smith (1963)
	Réunion	Letourneur et al. (2004)
Phoxocampus belcheri (Kaup, 1856)	Madagascar	McKenna & Allen (2006), Fricke et al. (2018)
	Mauritius	Arndt & Fricke (2019)
	Kenya	Dawson (1985), Smith (1963)
	Mozambique	Smith (1963), Pereira (2000)
	Zanzibar	Smith (1963)
	Mafia Island	Smith (1963)
	Seychelles	Smith (1963)
Siokunichthys breviceps Smith, 1963	Mozambique	Smith (1963), Dawson (1985), Pereira (2008)
Syngnathoides biaculeatus (Bloch, 1785)	Kenya	Van der Velde et al. (1995), Crona & Rönnbäck (2007), Mirriam (2010), Gajdzik et al. (2014)
	Madagascar	McKenna & Allen (2006), Fricke et al. (2018)
	Mozambique	Smith (1963), Almeida et al. (1999, 2001), Gell & Whittington (2002), Pereira (2008)
	Eastern African tropical estuaries	Whitfield (2005)

(*Continued*)

Table 1 (*Continued*) All syngnathid species and the countries in which they are found within sub-Saharan Africa and adjacent Indian Ocean islands

Species	Country	Reference
	Comoros	Smith (1963)
	Seychelles	Smith (1963)
	Zanzibar	Lugendo (2007), Berkström et al. (2012)
Syngnathus acus Linnaeus, 1758	Western Sahara	Dawson (1986)
Syngnathus temminckii Kaup, 1856	Namibia	Mwale et al. (2013)
	South Africa	Beckley (1984), Wallace et al. (1984), Bennett (1989), Whitfield (1989), Bennett & Branch (1990), Ter Morshuizen & Whitfield (1994), Teugels et al. (1994), Clark et al. (1996), Whitfield & Bruton (1996), Harris et al. (1999), Paterson & Whitfield (2000), Strydom (2003), Teske et al. (2004), Strydom & Wooldridge (2005), Harrison & Whitfield (2006), Pattrick et al. (2007), Pattrick & Strydom (2008), Wasserman et al. (2010), Sheppard et al. (2011), Becker et al. (2012), Mwale et al. (2013, 2014), Strydom (2015), Whitfield et al. (2017), Ntshudisane et al. (2021)
Syngnathus watermeyeri Smith, 1963	South Africa	Smith (1963), Dawson (1985), Ter Morshuizen & Whitfield (1994), Teugels et al. (1994), Whitfield & Bruton (1996), Cowley & Whitfield (2001), Whitfield (2005), Harrison & Whitfield (2006), Vorwerk et al. (2007), Sheppard et al. (2011), Mwale et al. (2013, 2014), Whitfield et al. (2017), Van Niekerk et al. (2019b), Ntshudisane et al. (2021)
Trachyrhamphus bicoarctatus (Bleeker, 1857)	East Africa	Dawson (1985)
	Madagascar	Dawson (1985), McKenna & Allen (2006), Weis et al. (2009), Fricke et al. (2018)
	Mozambique	Almeida et al. (1999), Pereira (2000, 2008), Fordyce (2016)
	Réunion	Letourneur et al. (2004), Fricke et al. (2009)
	Mauritius	Dawson (1985)
	South Africa	Dawson (1985)
	Zanzibar	Nordlund et al. (2013)
Trachyrhamphus longirostris Kaup, 1856	Zanzibar	Dawson (1985)
	Madagascar	Dawson (1985)

Species highlighted in grey are endemic either to a specific country or to the region.

11 species of seahorses, 50 pipefish and two pygmy pipehorse (Table 1). The syngnathids occurring in Africa represent 40% and 20% of the world's known genera and species, respectively. Countries with the highest number of syngnathid species are located along the south-east African coast and include South Africa, Mozambique, Tanzania and Madagascar, with a total of 40 species (Figure 2). Countries with nine syngnathid species or more include Seychelles, Mauritius, Réunion, Tanzania, Kenya, South Africa, Madagascar and Mozambique. In contrast, the lowest numbers of syngnathid species per country occur mostly along the west African coast, including Namibia, Benin, Ghana and Liberia, and in Europa Island in the Mozambique Channel off the east African coast, with only one species recorded in each of these countries (Figure 2). When considering the number of syngnathid species per kilometre of coastline, east African countries dominate. An exception to this trend is The Gambia on the west coast, which has the fourth highest species density out of 23 countries (Figure 2).

South Africa currently exhibits a high degree of endemism, which may be due to higher research efforts in the country, relative to all other African countries that were reviewed (Table 1). This endemism comprises 4 out of 63 species of syngnathids occurring nowhere else in Africa: the temperate *Hippocampus capensis* and *Syngnathus watermeyeri*, and two new tropical species from Sodwana Bay, a pygmy pipehorse belonging to the new genus *Cylix* (Short, unpublished data; https://www.inaturalist.org/observations/11120680) and the pygmy seahorse *Hippocampus nalu* (Short et al. 2020, https://www.inaturalist.org/observations/31815098). The two new species of syngnathids from Sodwana Bay are remarkable for South African syngnathid endemism and overall African syngnathid biodiversity in that they were the first newly described species since *Syngnathus watermeyeri* in 1963 (Smith 1963). Other single-country endemics include *Bulbonaricus brucei* from Tanzania, *Campichthys nanus* from Mozambique, and *Hippocampus tyro* from the Seychelles, all of which are currently found nowhere else in eastern Africa and offshore islands.

African syngnathid endemicity can be also be assessed regionally on a broader scale with respect to marine provinces and ecoregions. For example, the pipefish *Choeroichthys smithi* has been recorded only in Réunion Island, Mauritius, the Seychelles, Madagascar, Tanzania, Mozambique and South Africa, yet this range spans the subtropical-tropical Agulhas and western Indian Ocean marine provinces in eastern Africa (Table 1; Spalding et al. 2007). Similarly, the pipefish *Doryrhamphus bicarinatus*, *Microphis millepunctatus*, *M. fluviatilis* and *Nannocampus elegans* have all been recorded in eastern Africa and nowhere else in the Indo-Pacific (Table 1). Additionally, the seahorse *Hippocampus algiricus* and the freshwater pipefish *Enneacampus ansorgii, E. kaupi* and *Microphis aculeatus* occur only in the western Africa and Gulf of Guinea provinces (Spalding et al. 2007) in the tropical eastern Atlantic (Table 1). In contrast, the temperate pipefish *Syngnathus temminckii* occurs only in the temperate marine environments of Namibia and South Africa.

Seahorses

Eleven species of seahorses are recorded in sub-Saharan Africa and adjacent islands, three of which are endemic to Africa, including *Hippocampus algiricus*, *H. capensis* and *H. nalu* (Table 1). The West African *H. algiricus* occurs from north to south in the following eastern Atlantic countries: the Canary Islands (Spain), Senegal, The Gambia, Guinea, Sierra Leone, Liberia, Ivory Coast, Ghana, Benin, Nigeria, São Tomé and Príncipe and Angola. The Knysna seahorse *H. capensis* is endemic to the temperate south coast of South Africa, where it has been recorded from three estuaries: Keurbooms, Knysna and Swartvlei estuaries (Bell et al. 2003, Lockyear et al. 2006). Lastly, *H. nalu* is the first recorded species of pygmy seahorse for continental Africa and is currently known only from Sodwana Bay in KwaZulu-Natal, South Africa (Short et al. 2020). This species, however, may occur further north into Mozambique and Tanzania, and further ichthyofaunal surveys, diver

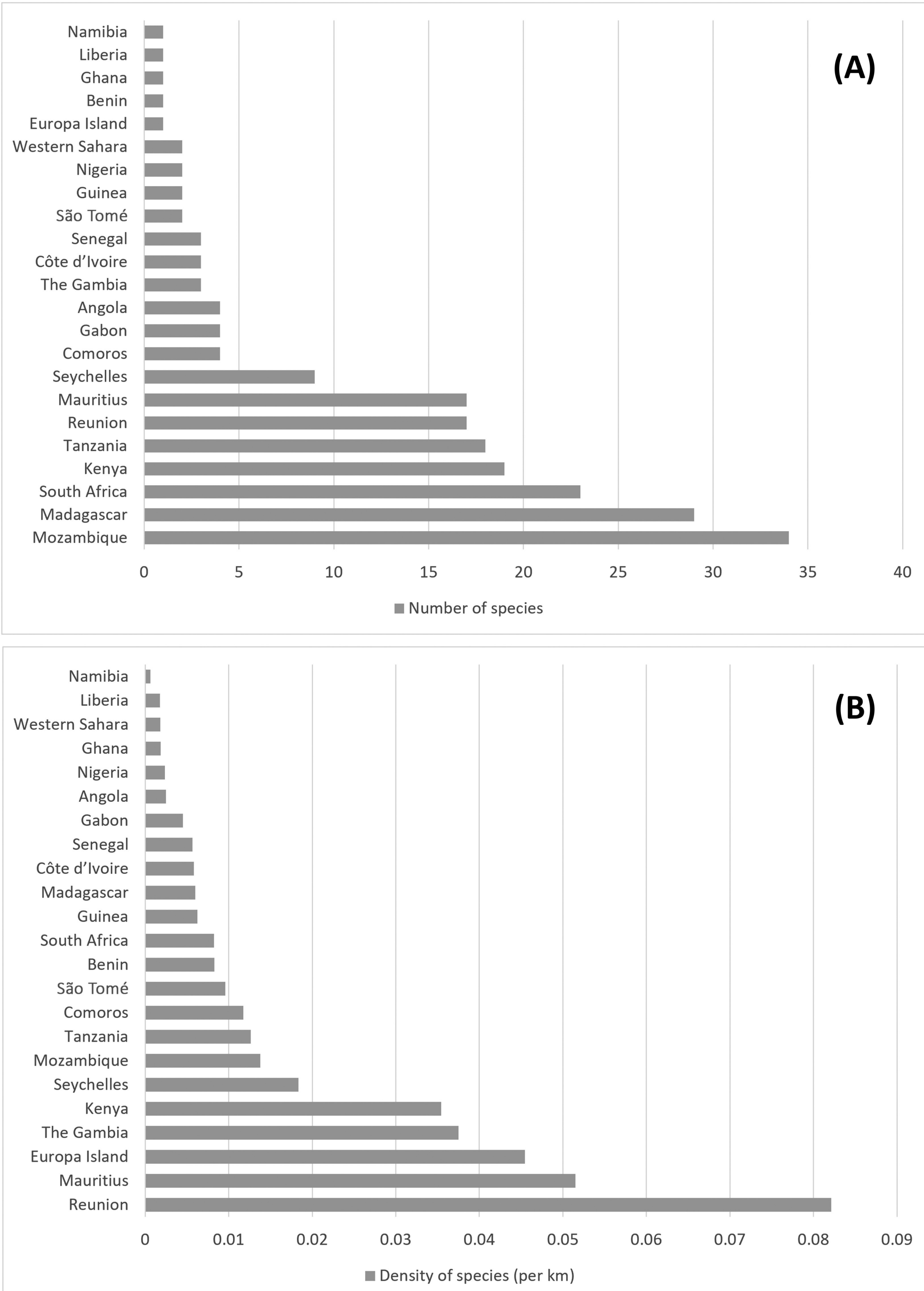

Figure 2 (A) Total number of syngnathid species per country and (B) number of species per kilometre of coastline for each country.

observations and a better understanding of the distribution of sandy coral reefs, which it inhabits, are needed.

The broadly distributed Indo-Pacific species, *H. histrix*, *H. kelloggi*, *H. kuda* and *H. jayakari*, have been recorded in South Africa, Mozambique, Madagascar, Mauritius, Tanzania and Kenya (Table 1) (Lourie et al. 2004). The exception is *H. hippocampus*, which has a distribution that includes the Mediterranean, British Isles, Wadden Sea, the Gulf of Guinea, the Azores and the Canary Islands. The Réunion seahorse *H. borboniensis* and the giraffe seahorse *H. camelopardalis* exhibit a regional East African distribution that covers South Africa, Mozambique, Tanzania, Madagascar, Mauritius and Réunion Island (Table 1); however, new distributional records for these seahorses in Indian waters have recently been published (Krishnan et al. 2011, Subburaman et al. 2014). The description of *H. borboniensis* was based on seven individuals taken as by-catch from the Gulf of Mannar, India, indicating that there may be a local breeding population of this species. In contrast, the description of *H. camelopardalis* is based on the occurrence of a single specimen collected in fishing by-catch in the vicinity of the Mithapur reef in the Gulf of Kachchh Marine National Park, Gujarat, India (Subburaman et al. 2014). The collected individual is presumed to have drifted in the prevailing equatorial currents to the eastern Arabian Sea (Subburaman et al. 2014).

In a revision of the genus *Hippocampus*, *H. borboniensis* has been synonymised with *H. kuda* due to a lack of distinguishable morphological, genetic or geographic differences (Lourie et al. 2016). However, we find the results of the revisional study inconclusive as preliminary examinations of specimens of *H. borboniensis* and *H. kuda* by Graham Short and Louw Claassens revealed several morphological differences in the presence of diagnostic characters of the eye and snout spines. Similarly, the partial cytochrome c oxidase subunit I (COI) DNA sequences generated from the single individual of *H. borboniensis*, which were sourced from the Barcode of Life Data (BOLD) and used to calculate genetic divergences in the study, were also examined by the co-authors and deemed to be of low quality due to messy chromatogram data. Therefore, it appeared that the low-quality DNA sequences were not suitable for meaningful genetic analyses. A phylogenomic study of the family Syngnathidae based on next-generation sequencing of ultra-conserved elements (UCE) is currently underway, and the results strongly support *H. borboniensis* as a distinct evolutionary unit from *H. kuda* (Josefin Stiller pers. comm.).

Several seahorse specimens collected in Mozambique and South Africa between 1954 and 1989, and housed in the fish collections at the South African Institute for Aquatic Biodiversity (SAIAB), have been identified as *H. whitei*, the south-west Pacific seahorse endemic to New South Wales and Queensland, Australia (Short et al. 2019) (catalogue numbers 5631, 12285, 12286, 12287 and 36140, and identified as *H. novaehollandae* or *H. whitei*). However, this species designation has often been given to members of *Hippocampus* of unknown identity at the time based on superficial similarity in appearance to *H. whitei*, including *H. camelopardalis* in Mozambique and South Africa, *H. kelloggi* in Papua New Guinea and Solomon Islands, and *H. breviceps* in South Australia (Lourie et al. 2016).

Pipefishes

Fifty species of pipefish are recorded in Africa, eight of which are endemic to western, southern and eastern Africa, respectively (Table 1): the freshwater pipefishes *Enneacampus ansorgii* and *E. kaupi*, and the brackish water pipefish *Microphis aculeatus* from western Africa; the obligate *Galaxea* sp. coral dweller *Bulbonaricus brucei* from Tanzania; *Campichthys nanus* from Mozambique; *Nannocampus elegans* from Mozambique and South Africa; and the temperate estuarine pipefishes *Syngnathus temminckii* and *S. watermeyeri* from Namibia and South Africa. The distribution records of Pereira (2008) and Mwaluma et al. (2010) that record *S. temminckii* in Mozambique and Kenya, respectively, are probably based on misidentification, as this is a temperate species. The non-endemic pipefish species listed in Table 1 have an Indo-Pacific distribution and have been recorded in eastern Africa, including Kenya, Madagascar, Mozambique, Mauritius, Réunion, Seychelles and South Africa. The exceptions are *Nerophis lumbriciformis*, a species recorded in Western Sahara, and in the north-eastern Atlantic, the Baltic, Mediterranean and Black Seas (Dawson 1986a, 1986b); and *Syngnathus acus*, which is recorded in Western Sahara and in the eastern Atlantic (British Isles, Norway, and the Faroe Islands) (Dawson 1986a). The wide-ranging coral rubble- and sand-associated Indo-Pacific winged pipefish, *Halicampus macrorhynchus*, has recently (2020) been recorded in south-eastern Kenya and Madagascar (Alain Rassat, pers. comm., Ewout Knoester, pers. comm., https://www.inaturalist.org/observations/41930021, https://www.inaturalist.org/observations/81180257).

Some taxonomic authorities show the distributions of *Syngnathus acus* extending into Namibia and South Africa (Dawson 1985, 1986a, Kuiter 2009); however, recent studies revealed that *S. acus* is replaced by the temperate *S. temminckii* in these countries (Mwale et al. 2013). Morphological data show that *S. temminckii* is distinct from the broadly distributed European pipefish *S. acus*, and a molecular phylogeny reconstructed using mitochondrial DNA recovered *S. temminckii* and *S. watermeyeri* as sister taxa to the North Atlantic members of *Syngnathus* (Mwale et al. 2013). Similarly, the flagtail pipefish, *Doryrhamphus bicarinatus*, which occurs in Mozambique, South Africa and Réunion Island, was recorded in the Maldives (Anderson et al. 1998) with identification based on meristic and diagnostic characters of the snout spine of one individual. However, we regard the individual of flagtail pipefish observed in the Maldives as an undescribed species of *Doryrhamphus*. Although morphologically similar to *D. bicarinatus* in meristic characters and the number and placement of spines present on the snout, it has a colour pattern on the tail that is highly distinct from that observed in *D. bicarinatus* from South Africa (Dawson 1981, 1985). The distinct coloration patterns present on the tail in members of *Doryrhamphus* appear to distinguish populations with large genetic distances among them throughout the Indo-Pacific (Dawson 1981, Lessios & Robertson 2016, Rudie Kuiter 2020 pers. comm.). Therefore, we retain *D. bicarinatus* as a regional eastern African species.

Pygmy pipehorses

Only one species of pygmy pipehorse has been definitively identified in African waters, the Indo-Pacific *Acentronura tentaculata*, which has been recorded in Kenya, Madagascar, Mozambique, South Africa and Tanzania (Table 1). Observations of an undescribed species, provisionally identified as a member of *Hippocampus*, were recorded in Sodwana Bay, South Africa, in 2009 on iNaturalist.org (https://www.inaturalist.org/observations/11120680, https://www.inaturalist.org/observations/11120683). Subsequently, further examinations of preserved specimens by the co-authors placed them in the genus *Cylix*, which has recently been described from New Zealand (Short & Trnski 2021). Pygmy pipehorses superficially resemble seahorses and share many morphological synapomorphies, including the head at an angle to the body axis, fully enclosed brood pouch and prehensile tail, and hence are often misidentified as seahorses by recreational scuba divers. There are currently eight described species of pygmy pipehorses that occur in the Indo-Pacific in the genera *Acentronura*, *Cylix*, *Idiotropiscis* and *Kyonemichthys* (Short & Trnski 2021). It therefore seems a matter of time before new genera and species are discovered in eastern and southern Africa.

Ecology

Data from the literature search and information from diving schools, divers and NGOs across Africa were used to review the ecology of African syngnathids. iSeahorse, a seahorse-focused citizen science initiative developed by Project Seahorse, is available from within iNaturalist and provides an opportunity to log additional ecological data with a seahorse record, such as depth, abundance and habitat. Empirical data from field surveys conducted by the lead author are also included.

Habitats

Most syngnathids occurring in sub-Saharan Africa and adjacent islands inhabit shallow coastal environments in water depths of 1–30 m (Table 2), and several species are recorded from intertidal rock pools, such as *Micrognathus andersonii* (Sindorf et al. 2015, Cowburn et al. 2018), *Nannocampus elegans* (Christensen & Winterbottom 1981), *N. pictus* (Brian Sellick pers. comm.), *Cosmocampus darrosanus* (Dawson 1985), *Choeroichthys sculptus* (Fricke et al. 2009), *C. smithi* (Fricke et al. 2009, 2013), *Doryrhamphus bicarinatus* (Fricke et al. 2009), *Halicampus zavorensis* (Adrian Pearton pers. comm.) and *Phoxocampus belcheri* (Arndt & Fricke 2019).

Some species are known to occur in deeper, offshore environments: *Hippocampus algiricus* (West 2012), *Syngnathus acus* (Dawson 1986), *Hippocampus tyro* (only known from a dredged sample at 48 m depth, Randall & Lourie 2009), *Trachyrhamphus longirostris* (Dawson 1985) and *Dunckerocampus multiannulatus* recorded at 80–90 m depth on mesophotic reefs at Réunion (Tea et al. 2020), although these species also occur in shallow coastal environments. *Dunckerocampus multiannulatus* has also been observed in caves in reef habitats in South Africa at 25 m and in Madagascar at 16 m (Brian Sellick pers. comm., Adrian Payton pers. comm., Alain Rassat pers. comm.). Kuiter (1998) concluded that *D. boylei*, a sister species to *D. multiannulatus*, only occurs in depths greater than 25 m. However, Daly et al. (2018) recorded the first observation of this species in the Seychelles at 18 m. Furthermore, a study on fish aggregation device (FAD) arrays in the western Indian Ocean recorded these two species together on a FAD in Mauritius at a depth of 15 m (Forget et al. 2020). It should be noted; however, it is difficult to distinguish between these two species, and there is a possibility that the fish were misidentified.

The majority (61%) of syngnathids (39 species) that occur in sub-Saharan Africa and adjacent islands inhabit shallow reef habitats, ranging from smooth volcanic reefs (Pinault et al. 2013) to coral rubble and boulders (Dawson 1985, Fricke et al. 2009, Mwaluma et al. 2010). In most instances, syngnathids are found in complex habitats, although some species occur in less complex habitats such as sandy or muddy bottoms (Goran & Spanier 1985, Golani & Lerner 2007, Ali et al. 2020). *Hippocampus histrix*, in particular, is commonly found in sandy habitats with sparse coral, sponge and sea pen cover (Adrian Pearton pers. comm., Alain Rassat pers. comm., Ewout Knoester pers. comm.).

Limited information is available on habitat specialisation by African species. The type specimens of *Bulbonaricus brucei* were collected from the coral *Galaxea astreata* in Tanzania (Dawson 1984a), and species in this genus are known to live in obligate associations with dendrophyllid corals, including those of the genus *Galaxea*, which provide refuge from predators (Araki et al. 2020). *Bulbonaricus brucei* is, however, only known from its type specimen, and no published observations of this species could be found other than its initial description in 1971. *Corythoichthys flavofasciatus* has been recorded associating with the corals *Acropora formosa*, *A. pulchra*, *Echinopora mammiformis* and *Heliopora coerulea* in the Indo-Pacific; it seems likely that this species inhabits similar habitats in Africa (Coker et al. 2014).

Seagrass is another important habitat for African syngnathids, with 15 species recorded in seagrass beds along the east African coast (Van der Velde et al. 1995, Almeida et al. 2001, De Boer et al. 2001, Gell & Whittington 2002, Bell et al. 2003, Vorwerk et al. 2007, Fricke et al. 2009, Mwaluma et al. 2010, Berkström et al. 2012, West 2012) (Table 2). Species that depend on seagrass habitat consequently occur in areas suitable for development of seagrass beds, especially in bays and estuaries (De Boer et al. 2001, Gell & Whittington 2002, Weerts & Cyrus 2002, Mamonekene et al. 2006, Lugendo 2007, Mwandya et al. 2009, Palmqvist 2013, Mwandya 2019). For some species,

Table 2 A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
Acentronura tentaculata	Coastal	1 m (De Boer et al. 2001)	Seagrass (*Halodule wrightii*, *Cymodocea serrulata*, *Zostera capensis*) in Inhaca Island, Mozambique (De Boer et al. 2001)	No global habitat data found
		<5 m (Louw Claassens unpublished data)	Weeds in Inhaca Island, Mozambique (Smith 1963)	
			Seagrass beds in Vilankulo, Mozambique (Louw Claassens unpublished data)	
Bryx analicarens	Coastal	Shallow tide pools up to 45 m (Dawson 1985)	No habitat data found for sub-Saharan Africa and adjacent islands	First record of *B. analicarens* in India found underneath a dead coral boulder overgrown with macroalgae, in a pool on an intertidal reef flat (Chandran et al. 2020)
				Shallow tide pools with macroalgal cover (including the brown alga *Cystoseira* spp.), but has also been captured by trawl at 45 m depth (Dawson 1985)
Bulbonaricus brucei	Coastal	1 m (Dawson 1984a)	Type specimen collected from the coral *Galaxea astreata* in Tanzania (Dawson 1984a)	Endemic to Tanzania
Bulbonaricus davaoensis	Coastal	1–8 m (Dawson 1985)	East African specimens found among the coral *Galaxea fascicularis*, and planktonic specimens collected from upper 200 m to depths of 610–7120 m (Dawson 1985)	*Galaxea* sp. coral polyps in Japan (Araki et al. 2020)
		6–15 m (Araki et al. 2020)		
Campichthys nanus	Coastal	3–11 m (Dawson 1985)	Coral knolls (Dawson 1985)	Endemic to Africa
Choeroichthys brachysoma	Coastal	Found up to 25 m deep, but mostly <5 m (Dawson 1985)	Tide pools in northern Mozambique (Smith 1963)	Seagrass, reef and coral reef habitats (Dawson 1985)
			Coral reef and rocky shore habitats in Réunion (Letourneur et al. 2004)	
Choeroichthys sculptus	Coastal	<1 m (Weis et al. 2009)	Shallow mangrove (*Avicennia*, *Sonneratia*, *Rhizophora*, *Bruguiera*) pools in western Madagascar (Weis et al. 2009)	Intertidal reef flats and seagrass beds up to a few metres in depth (Kuiter 2009)

(*Continued*)

Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
		<3 m (Dawson 1985)	Coral reefs in southwest Madagascar (Jaonalison et al. 2016)	Shallow rock pools in Japan (Murase 2015)
		1.4 m (De Boer et al. 2001)	Tide pools in East Africa (Smith 1963)	Shallow reefs (Dawson 1985)
		0–9 m (Fricke et al. 2009)	Mud flats and beds of seagrass (*Zostera capensis*) in Inhaca Island, Mozambique (De Boer et al. 2001)	
			Reef flats and seagrass areas, including tidal pools, in Réunion (Fricke et al. 2009)	
Choeroichthys smithi	Coastal	<1 m (Fricke et al. 2013)	Reef flat with tidal pools in Europa Island (Fricke et al. 2013)	No global habitat data found
		0–25 m (Fricke et al. 2009)	Coral reefs and seagrass areas, including tidal pools, in Réunion (Fricke et al. 2009)	
Corythoichthys amplexus	Coastal	Recorded depth range is 0–30 m, and 15 of 32 collections are from confirmed water depths greater than 9 m; only 7 are from less than 5 m (Dawson 1977b)	Coral reefs in Zanzibar (Berkström et al. 2012)	Associated with hard substrata in Australia (Moore et al. 2014)
		3–14 m (Berkström et al. 2012)	Mangroves (*Sonneratia alba*) in Kenya (Huxham et al. 2008)	Mangrove habitat in New Caledonia (Thollot 1996)
		<2 m (Huxham et al. 2008)	Larvae found in reef lagoons along the Kenyan coast, characterised by coral outcrops interspersed with seagrass beds, sand and coral rubble of varying cover (Mwaluma et al. 2010)	Shallow coastal waters in Malaysia (see Lim et al. 2011)
		<3 m (Mwaluma et al. 2010)	Coral reefs in Zanzibar (Tyler et al. 2009)	
		<30 m (Moore et al. 2014)		
		<15 m (Tyler et al. 2009)		

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
Corythoichthys flavofasciatus	Coastal	Depth range of 0–24 m; 25 of 36 collections were from 0 to 5 m, six were from 5 to 10 m and only five lots were from confirmed depths exceeding 10 m (Dawson 1977b)	Coral reefs in southwest Madagascar (Jaonalison et al. 2016)	*Acropora formosa*, *A. pulchra*, *Echinopora mammiformis*, *Heliopora coerulea* in the Indo-Pacific (Coker et al. 2014)
		3–14 m (Berkström et al. 2012)	Coral reefs in Zanzibar (Berkström et al. 2012)	Sandy bottom habitat with low knolls consisting of coral in the Red Sea (Goran & Spanier 1985)
		2–5 m (Palmqvist 2013)	*Thalassodendron ciliatum* in Zanzibar (Palmqvist 2013)	Associated with hard substrata in Australia (Moore et al. 2014)
		<30 m (Moore et al. 2014)	Seagrass beds dominated by *Enhalus acoroides*, *Thalassodendron ciliatum* and *Cymodocea serrulata* in Mozambique (Gell & Whittington 2002)	Shallow coastal waters in Malaysia (see Lim et al. 2011)
		2–5 m depth (Gell & Whittington 2002)		
Corythoichthys haematopterus	Coastal	2–5 m depth (Gell & Whittington 2002)	Seagrass beds dominated by *Enhalus acoroides*, *Thalassodendron ciliatum* and *Cymodocea serrulata* in Mozambique (Gell & Whittington 2002)	Found in mangrove habitats in Australia (Blaber 1986)
		7–9 m (Matsumoto & Yanagisawa 2001)	Reefs in East Africa (Smith 1963)	Rubble bottom in Japan (Matsumoto & Yanagisawa 2001)
		2–10 m; <1 m; 0–7 m (Sogabe & Takagi 2013)		Steep boulder and bedrock slopes, shallow seagrass beds and on a vertical wharf structure in Japan (Sogabe & Takagi 2013)
		0.5–2 m (Nakamura et al. 2003)		*Enhalus acoroides*-dominated seagrass beds in Japan (Nakamura et al. 2003)

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
		Data from 27 collections indicate a 0–19 m depth range; 18 samples were from 0 to 3 m, four were from 3 to 10 m, and five were from SCUBA collections in 10–19 m (Dawson 1977b)		
Corythoichthys insularis	Coastal	Depths of 20–42 m (Dawson 1977b)	No habitat data found for sub-Saharan Africa and adjacent islands	No global habitat data found
Corythoichthys intestinalis	Coastal	<30 m (Moore et al. 2014)	Shallow reefs in Madagascar (Ory 2008)	Associated with hard substrata in Australia (Moore et al. 2014)
		0–3 m depth (Dawson 1977b)		Sand, coral or seagrass (Dawson 1977b)
Corythoichthys schultzi	Coastal	2–5 m (Gell & Whittington 2002)	Seagrass beds dominated by *Enhalus acoroides*, *Thalassodendron ciliatum* and *Cymodocea serrulata* in Mozambique (Gell & Whittington 2002)	Sandy, trench habitat with coral knolls and branched corals (Goran & Spanier 1985)
		9–12 m (Goran & Spanier 1985)	Reefs in Mozambique (Cowburn et al. 2018)	Associated with hard substrata in Australia (Moore et al. 2014)
		<30 m (Moore et al. 2014)		Shallow, coastal waters in Malaysia (Lim et al. 2011)
		Depth range of 0–30 m; 15 collections were in 0–9 m, eight in 10–16 m and seven from confirmed depth greater than 16 m (Dawson 1977b)		Seagrass beds in Jordan (Khalaf et al. 2012)
Cosmocampus banneri	Coastal	<30 m (Dawson 1985)	No habitat data found for sub-Saharan Africa and adjacent islands	Shallow coastal waters in Malaysia (Lim et al. 2011)
		<30 m (Moore et al. 2014)		Associated with hard substrata in Australia (Moore et al. 2014)
				Coral reef habitats (Dawson 1985)

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
Cosmocampus darrosanus	Coastal	<3 m (Dawson 1985)	No habitat data found for sub-Saharan Africa and adjacent islands	Reef flats and tide pools (Dawson 1985)
				Shallow coastal waters in Malaysia (Lim et al. 2011)
Cosmocampus retropinnis	Coastal	Depths to 79 m (Dawson 1982)	No habitat data found for sub-Saharan Africa and adjacent islands	No global habitat data found
Cylix sp.	Coastal	Still being described	Still being described	Still being described
Doryrhamphus bicarinatus	Coastal	<5 m (Louw Claassens unpublished data)	Rocky reefs and artificial reefs in Vilankulo, Mozambique (Louw Claassens unpublished data)	No global habitat data found
		0–20 m (Fricke et al. 2009)	Shallow lagoon and coral and rocky reef areas, including tidal pools in Réunion (Fricke et al. 2009)	
		5–30 m (Pinault et al. 2013)	Compact lava substrata with high algal cover and *Pocillopora verrucosa*, *P. eydouxi*, *P. damicornis* and *P. meandrina* corals in Madagascar (Pinault et al. 2013)	
		<28 m (Dawson 1985)		
Doryrhamphus excisus	Coastal	45–49 m (Dawson 1985)	No habitat data found for sub-Saharan Africa and adjacent islands	Rock or coral bottoms (Dawson 1985)
		<30 m (Moore et al. 2014)		Associated with hard substrata in Australia (Moore et al. 2014)
		1.5 m (Goran & Spanier 1985)		Mangrove habitat in New Caledonia (Thollot 1996)
				Sandy bottom habitat with low knolls consisting of coral in the Red Sea (Goran & Spanier 1985)
Dunckerocampus boylei	Coastal	18 m (Daly et al. 2018)	Recorded on a chain of 0.2 m diameter rigid buoys as part of a FAD array in Mauritius (Forget et al. 2020)	Deeper water and associated with reef habitats and caves (Kuiter 1998)

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
		20–95 m (Kuiter 1998)		
		<15 m (Forget et al. 2020)		
Dunckerocampus dactyliophorus	Coastal	<30 m (Moore et al. 2014)	Coral reefs in Mozambique (Fordyce 2016)	Associated with hard substrata in Australia (Moore et al. 2014)
		Maximum recorded depth of 56 m with records from tide pools and intermediate depths (Dawson 1985)		Shallow coastal waters in Malaysia (Lim et al. 2011)
Dunckerocampus multiannulatus	Coastal	Depths to 45 m (Dawson 1985)	Recorded within a chain of 0.2 m diameter rigid buoys as part of a FAD array in Mauritius (Forget et al. 2020)	Coral and rocky reefs and associated caves (Dawson 1981, 1985)
		<15 m (Forget et al. 2020)	Mesophotic reefs in Réunion (Tea et al. 2020)	Flat coral reefs and artificial structures in the Red Sea (Rilov & Benayahu 2000)
		25 m (Brian Sellick pers. comm.)		
		<35 m (Kuiter 1998)		Oil terminal jetties in the Red Sea (Rilov & Benayahu 1998)
		20–30 m (Rilov & Benayahu 2000)		
		80–90 m (Tea et al. 2020)		
Enneacampus ansorgii	Freshwater	<6 m depth (Mamonekene et al. 2006)	Rivers in Angola (Skelton 2019)	Endemic to western Africa
			Estuaries in Nigeria (Kone et al. 2021)	
			Ndogo Lagoon in Gabon (Mamonekene et al. 2006)	
Enneacampus kaupi	Freshwater	No depth information	Rivers in Angola (Skelton 2019)	Endemic to western Africa
			River systems in the Democratic Republic of the Congo (Walsh et al. 2014)	
			Estuaries in Nigeria (Kone et al. 2021)	

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
			Tidal flats in Mauritania (Wolff et al. 2006)	
			Estuarine lake in Ivory Coast (Ecoutin et al. 2005)	
			Mangrove creek in Nigeria (Allison et al. 1997)	
			River delta in Nigeria (Onwuteaka 2015)	
Festucalex erythraeus	Coastal	18–43 m (Dawson 1985)	No habitat data found for sub-Saharan Africa and adjacent islands	Reef habitats (Dawson 1985)
				Shallow coastal waters in Malaysia (Lim et al. 2011)
Halicampus dunckeri	Coastal	<30 m (Moore et al. 2014)	No habitat data found for sub-Saharan Africa and adjacent islands	Associated with hard substrata in Australia (Moore et al. 2014)
		<13 m (Dawson 1985)		Sand, rubble and reef habitats (Dawson 1985)
Halicampus mataafae	Coastal	Generally found at depths of <9 m, but have been recorded as deep as 15 m (Dawson 1985)	No habitat data found for sub-Saharan Africa and adjacent islands	Rock and coral habitats and reef pools (Dawson 1985)
Halicampus zavorensis	Coastal	15 m (Ziyadi et al. 2018)	Holotype collected from a tide pool in Mozambique (Dawson 1984b)	Two specimens collected from Oman in sandy rocky reef over rocky sand with some coral (Dawson 1984b)
		4 m (Dawson 1984b)	Shallow reefs and also in intertidal rock pools in Durban (Adrian Pearton pers. comm.)	
Halicampus macrorhynchus		3–25 m (Dawson 1985)	Sandy area with isolated patches of algae and sponges in Kenya (Ewout Knoester pers. comm.)	Seagrass, coral rubble and algae-covered rocks (Dawson 1985)
	Coastal	10–15 m (Ewout Knoester pers. comm.)	Sandy area with patches of algae in Madagascar (Alain Rassat pers. comm.)	Shallow coastal habitats in Malaysia (Lim et al. 2011)
Halicampus boothae	Coastal	3–30 m (Dawson 1985)	No habitat data found for sub-Saharan Africa and adjacent islands	Rock and coral habitats (Dawson 1985)

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
Hippichthys cyanospilos	Coastal and estuarine	1 m (De Boer et al. 2001)	*Sonneratia alba* mangroves in Gazi Bay, Kenya. Juveniles found in estuaries; adults found further upstream (Crona & Rönnbäck 2007)	Coastal and brackish water (Dawson 1985)
		<1 m (Weerts & Cyrus 2002)	Of 81 fish sampled in Inhaca Island, Mozambique, most were found within channel habitat covered by old coral debris and rocks, with patches of *Halodule wrightii* seagrasses. Most fish caught at night and during summer. Also recorded within sandflat, mudflat, mangrove, sandbank and *Zostera capensis* habitats (De Boer et al. 2001)	Larvae found in mangrove habitats in Malaysia (Azmir et al. 2017)
		<30 m (Moore et al. 2014)	Recorded within *Z. capensis* within the Mhlathuze Estuary, South Africa (Weerts & Cyrus 2002)	*Halophila ovalis* and *H. uninervis* beds in Malaysia (Jani et al. 2019)
			Associated with moderate to large, closed estuaries and predominantly open estuaries (Harrison & Whitfield 2006)	Associated with mangroves and estuaries in Australia (Moore et al. 2014)
				Rivers and estuaries within seagrass in Malaysia (Lim et al. 2011)
Hippichthys heptagonus	Coastal and estuarine	<1 m (Jayaneththi et al. 2014)	Associated with predominantly open estuaries (Harrison & Whitfield 2006)	Estuarine seagrass beds and mangroves in Australia (Blaber 1986)
			Lower swamp habitat in the Mkuze swamps, South Africa (Skelton et al. 1989)	Found resting underneath overhanging roots of Ficus benghalensis in a Sri Lankan lake (Jayaneththi et al. 2014)
			South African estuaries (Harris et al. 1995, 1999, Harris & Cyrus 2000)	Rivers in the Philippines (Paller et al. 2011)
				Lower reaches of rivers and estuaries (Dawson 1985)

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
Hippichthys spicifer	Coastal	3–14 m (Berkström et al. 2012)	Mangroves in Zanzibar, but also recorded in seagrass (Berkström et al. 2012)	Shallow coastal waters and estuaries and sometimes in mangroves (Dawson 1985)
		<1 m (Mirriam 2010)	Mangrove creek (*Rhizophora mucronata* and *Avicennia marina*) in Kenya (Mirriam 2010)	Abandoned aquaculture ponds in the Philippines (Ikejima et al. 2006)
		2–5 m (Palmqvist 2013)	*Thalassodendron ciliatum* in Zanzibar (Palmqvist 2013)	Mangroves in Japan (Ishihara & Tachihara 2009)
		Average depth of 3 m (Lugendo 2007)	Mangrove creeks and channels (*Rhizophora mucronata*) with a muddy substratum with prop roots as well as in Enhalus acoroides interrupted by small patches of *Thalassodendron ciliatum* and the calcareous algae *Halimeda* spp. in Kenya (Lugendo 2007)	
		<1 m (Mwandya et al. 2009)	Found within mangrove creeks (*Avicennia marina* and *Xylocarpus granatum*) in Kenya. Substrate varied between mud, seagrass and sand (Mwandya et al. 2009, Mwandya 2019)	
			Recorded in estuaries in South Africa (O'Brien et al. 2009, Forbes et al. 2013)	
			Recorded in mangroves and seagrass beds in Kenya (Van der Velde et al. 1995)	
Hippocampus algiricus	Coastal and estuarine	1–50 m (West 2012)	Ndogo Lagoon, Gabon (Mamonekene et al. 2006)	Endemic to western Africa
		1–25 m (Wirtz et al. 2007)	Found frequently holding onto sponges (Wirtz et al. 2007)	
		<6 m (Mamonekene et al. 2006)	Seagrass beds and also on soft bottom habitats in deeper water on the west African coast (West 2012)	

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
		2–24 m (Afonso et al. 1999)	Mixed bottom and muddy plain in São Tomé Island (Afonso et al. 1999)	
Hippocampus borboniensis	Coastal	<5 m (Louw Claassens unpublished data)	Shallow seagrass beds in Vilankulo, Mozambique (Louw Claassens unpublished data)	Indian record only with no habitat data
		5–60 m (McPherson & Vincent 2004)	Associated with seagrass, soft bottom, sponges on the east African coast (McPherson & Vincent 2004)	
Hippocampus camelopardalis	Coastal	2 m (Subburaman et al. 2014)	Seagrass beds (*Thalassodendron ciliatum/ Cymodocea serrulata* and *Thalassodendron ciliatum/Cymodocea serrulata*) in Inhaca Island, Mozambique (Almeida et al. 2001)	Reefs in India (Subburaman et al. 2014)
		<5 m (Louw Claassens unpublished data)	Seagrass beds in Mozambique (Louw Claassens unpublished data, Teijema 2020)	
		Up to 45 m (McPherson & Vincent 2004)	'Weeds' from Inhaca Island and Inhambane estuary, Mozambique (Smith 1963)	
			Seagrass beds, algal beds and shallow reefs (McPherson & Vincent 2004)	
Hippocampus capensis	Estuarine	<1 m (Arendse & Russell 2020)	Seagrass (*Zostera capensis*, *Ruppia cirrhosa*, *Halophila ovalis*) and macroalgae (*Caulerpa filiformis*, *Codium extricatum*) – predominantly *Zostera capensis* (Lockyear et al. 2006, Teske et al. 2007)	Endemic to South Africa
		1–3 m (Claassens 2016)	Bare sediment habitats and among vegetation (*Z. capensis*, *Halophila ovalis*, *Caulerpa filiformis*) (Bell et al. 2003)	

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
		1–2 m (Claassens & Hodgson 2018)	*Codium tenue* (De Villiers et al. 2019)	
		<1.5 m (Whitfield 1989)	Reno mattress, *Zostera capensis*, *Caulerpa filiformis*, *Asparagopsis taxiformis*, *Codium tenue* (Claassens 2016, Claassens et al. 2018, Claassens & Hodgson 2018b, Claassens & Harasti 2020)	
Hippocampus histrix	Coastal	2–5 m (Gell & Whittington 2002)	Seagrass beds dominated by *Enhalus acoroides*, *Thalassodendron ciliatum* and *Cymodocea serrulata* in Mozambique (Gell & Whittington 2002)	*Euplexaura* sp. gorgonian fan in Port Stephens, Australia (Harasti 2015)
		Up to 20 m (McPherson & Vincent 2004)	Seagrass beds, weedy rocky reefs, sponges and sea squirts in areas of sparse or no seagrass, soft bottoms with soft corals and sponges (McPherson & Vincent 2004)	Mangroves in New Caledonia (Thollot 1996)
		Average depth of 3 m (Lugendo 2007)	Mangrove creeks and channels (*Rhizophora mucronata*) with a muddy substratum with prop roots in Kenya (Lugendo 2007)	
		30 m depth (Dave Harasti unpublished data)	Shallow reefs in Mozambique (Fordyce 2016)	
			Mangrove and seagrass habitats in Kenya (Van der Velde et al. 1995)	
		25–30 m (Adrian Pearton pers. comm.)	Deeper reef habitat in South Africa (Adrian Pearton pers. comm.)	
		22 m (Alain Rassat pers. comm.)	Sandy substrata and among macroalgae, hard or soft coral, dead corals, sponges in Madagascar (Alain Rassat pers. comm.)	

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
		3–14 m (Berkström et al. 2012)	Seagrass beds (*Thalassia hemprichii/Halodule wrightii* and *Thalassodendron ciliatum/Cymodocea serrulata*) in Mozambique (Almeida et al. 2001)	
			Mainly found in seagrass in Zanzibar, but also recorded in coral reefs (Berkström et al. 2012)	
Hippocampus hippocampus	Coastal	12–15 m (Kitsos et al. 2008)	No habitat data found for sub-Saharan Africa and adjacent islands	Found in habitats with less complexity and using various holdfasts (artificial structures, the small tuft-forming bryozoan *Bugula neritina*, sea urchins and small or tuft-forming macroalgae) in Portugal (Curtis & Vincent 2005, Correia et al. 2015a)
		>3 m (Caldwell & Vincent 2012)		Found in habitats with less complexity in Italy (Gristina et al. 2015)
		2 m (Spinelli et al. 2020)		*Posidonia oceanica* meadows in the Aegean Sea (Kitsos et al. 2008)
		4–13 m (Otero-Ferrer et al. 2015)		Found holding on to various holdfasts in the Canary Islands, including *Cystoseira abies-marina, Sargassum* spp. or *Asparagopsis taxiformis* and artificial structures (Otero-Ferrer et al. 2015)
Hippocampus jayakari	Coastal	2–30 m (Fricke et al. 2009)	Rubble-algae habitats and on soft bottoms on sponges in Réunion (Fricke et al. 2009)	Reef habitat in India (Parmar et al. 2015)
				Sandy beach habitat in the Red Sea (Golani & Lerner 2007)
Hippocampus kelloggi	Coastal	Up to 90 m (McPherson & Vincent 2004)	Soft bottoms and gorgonians (McPherson & Vincent 2004)	Recorded to use sponges and soft coral *Dendronephthya australis* as holdfasts in Port Stephens, Australia (Harasti 2017)

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
		65–90 m (Choo & Liew 2003)		Associated with muddy bottoms and gorgonids (Murugan et al. 2008)
		25–30 m (Perry et al. 2020)		Sandy and rocky habitats, floating with seaweed in India (Perry et al. 2020)
		10–20 m (Murugan et al. 2008)		
		5–75 m (Balasubramanian & Murugan 2017)		
Hippocampus kuda	Coastal	<5 m (Louw Claassens unpublished data)	Seagrass beds (*Thalassia hemprichii*/ *Halodule wrightii*) in Mozambique (Almeida et al. 2001)	Seagrass and macroalgae in estuaries and shallow coastal waters in Malaysia (Lim et al. 2011)
		0–4 m (McKenna & Allen 2006)	Seagrass beds in Mozambique (Louw Claassens unpublished data, Teijema 2020)	Shallow estuarine habitats and shallow reef flats in Malaysia (Choo & Liew 2003)
		1–3 m (Choo & Liew 2003)	Coral reefs in north-west Madagascar (McKenna & Allen 2006)	Seagrass, dead coral and sponges in India (Murugan et al. 2008)
		3–10 m (Murugan et al. 2008)		
Hippocampus nalu	Coastal	12–17 m (Short et al. 2020)	Flat sandstone-based coral reefs comprising low pinnacles, shallow drop-offs and sandy gullies, the latter being exposed to wave action and strong (e.g. tidal) currents. Associated with short algae turf (Short et al. 2020)	Endemic to South Africa
Hippocampus tyro	Coastal	43–48 m depth (Randall & Lourie 2009)	Found in a dredge grab with fragments of various coral species (*Stylophora pistillata*, *Montipora digitata* and *Dendrophyllia* sp.) from the Seychelles (Randall & Lourie 2009)	Endemic to Seychelles
Micrognathus andersonii	Coastal	Rock pool depths of an average of 14 cm (Sindorf et al. 2015)	Intertidally within rocky tide pools in Mozambique (Cowburn et al. 2018)	Rock or coral tide pools within vegetation, or from reef and sand flats (Dawson 1985)

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
		0.5–1 m (Goran & Spanier 1985)	Rock pools in Mozambique (Sindorf et al. 2015)	Flat, sandy bottom habitat with flat rocks forming crevices and some coral cover in the Red Sea (Goran & Spanier 1985)
		<30 m (Moore et al. 2014)		Associated with seagrass and hard substrata in Australia (Moore et al. 2014)
		0.5 m (Randall et al. 2010)		Reef flat habitat in Tahiti (Randall et al. 2010)
		Recorded to depths of 5 m, it is most commonly found <2 m deep (Dawson 1985)		Mangroves in New Caledonia (Thollot 1996)
				Seagrass and macroalgae in Malaysia (Lim et al. 2011)
Microphis aculeatus	Freshwater	No depth data	Recorded in *Rhizophora racemosa*-dominated estuaries in Benin (Adite et al. 2013)	Endemic to West Africa
Microphis argulus	Freshwater	No depth data	Freshwater in Madagascar and Comoros (Smith 1963)	Rivers and streams (Dawson 1985)
Microphis millepunctatus	Freshwater	No depth data	Brackish estuaries and lower reaches of freshwater streams in Réunion (Fricke et al. 2009)	No global habitat data found
			Sheltered waters and estuaries (Smith 1963)	
			Inland water in Benin (Adite et al. 2013)	
Microphis fluviatilis	Freshwater	No depth data	Found in quiet water among vegetation, where they apparently adopt a head-down orientation to conceal themselves among the fronds. Can also be found in the vicinity of logs at river edge (Okeyo 1998)	Rivers (Dawson 1985)

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
			Fresh and brackish water in East Africa (Smith 1963)	
			Enters lower reaches of rivers (Seegers et al. 2003)	
Microphis leiaspis	Freshwater	No depth data	Rivers and estuaries in Madagascar (Smith 1963)	Rivers in Japan (Ishihara & Tachihara 2009)
				Found as drifting larvae in a river in Japan (Maeda & Tachihara 2010)
				Rivers and streams, although juveniles have been observed in estuaries (Dawson 1985)
Nannocampus elegans	Coastal	5 m range (Pattrick & Strydom 2008)	Tide pools in East Africa (Smith 1963)	Rock pools and shallow reefs (Dawson 1985)
		27 m (Brian Sellick pers. comm.)	Rock pool with the vertical sides covered by a short algal turf of corallines and *Hypnea spicigera* in South Africa (Christensen & Winterbottom 1981)	Tide pools and shallow reefs (Kuiter 2009)
		< 3 m depth (Christensen & Winterbottom 1981)		
Nerophis lumbriciformis	Coastal	Intertidal (Monteiro et al. 2002, 2005, 2006)	No habitat data found for sub-Saharan Africa and adjacent islands	Intertidal (Dawson 1986)
				Rocky shores (Monteiro et al. 2005, 2006)
				Intertidal seaweeds (Monteiro et al. 2002)
				Uses rocky shore boulders as refuge during low tide period (Monteiro et al. 2002)
Nannocampus pictus	Coastal	<9 m (Dawson 1985)	Tide pool in South Africa (Brian Sellick pers. comm.)	Algal beds, reefs and coral reefs (Dawson 1985)
		1 m (Brian Sellick pers. comm.)		

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Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
Penetopteryx taeniocephalus	Coastal	<1 m (Dawson 1985)	No habitat data found for sub-Saharan Africa and adjacent islands	Sampled in surface plankton samples in Indonesia (Dawson 1985)
				Gravel and coral rubble habitats (Dawson 1985)
Phoxocampus belcheri	Coastal	1–15 m (Dawson 1985)	Intertidal habitats in Mauritius (Arndt & Fricke 2019)	Tide pools and reefs (Dawson 1985)
			Intertidally associated with coral rubble and weeds in East Africa (Smith 1963)	Shallow rock pools in Japan (Murase 2015)
				Shallow coastal waters in Malaysia (Lim et al. 2011)
Siokunichthys breviceps	Coastal	< 2 m and specimens collected from surface samples were collected over 21 m (Dawson 1983)	Coral rubble in Mozambique (Dawson 1983)	Coral and coral rubble habitats – have also been found in surface samples (Dawson 1985)
		<10 m (Dawson 1985)	Coral rubble in Mozambique (Smith 1963)	
Syngnathoides biaculeatus	Coastal and estuarine	<5 m depth (Louw Claassens unpublished data)	Seagrass beds in Vilankulo, Mozambique (Louw Claassens unpublished data)	Coastal shallows. Juveniles have been recorded in offshore surface samples (Dawson 1985)
		Average depth of 3 m (Lugendo 2007)	Mangrove creeks and channels (*Rhizophora mucronata*) with a muddy substratum with prop roots as well as in *Enhalus acoroides* interrupted by small patches of *Thalassodendron ciliatum* and the calcareous algae *Halimeda* spp. in Kenya (Lugendo 2007)	Mangrove habitat in New Caledonia (Thollot 1996)

(*Continued*)

Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
		<1 m (Mirriam 2010)	Mangrove creek (*Rhizophora mucronata* and *Avicennia marina*) in Kenya (Mirriam 2010)	Shallow coastal seagrass habitats. Juveniles can occur in offshore surface waters (Dawson 1985)
		4–7 m depths (Gajdzik et al. 2014)	Mangrove and seagrass habitats in Kenya (Van der Velde et al. 1995)	*Enhalus acoroides*-dominated seagrass bed in Japan (Nakamura et al. 2003)
		3–14 m (Berkström et al. 2012)	*Sonneratia alba* mangroves in Gazi Bay, Kenya. Juveniles found in estuaries; adults found further upstream (Crona & Rönnbäck 2007)	*Zostera capricorni*, with interspersed *Halophila ovalis* and *H. spinulosa*, seagrass beds from the east coast of Australia (Takahashi et al. 2003)
		5–6 m depths (Almeida et al. 2001)	Seagrass beds (*Thalassodendron ciliatum/ Cymodocea serrulata*) in Mozambique (Almeida et al. 2001)	*Thalassia hemprichii*-dominated seagrass beds (within close proximity to mangroves) in Papua New Guinea (Barrows et al. 2009)
		2–5 m (Gell & Whittington 2002)	Mangroves (*Rhizophora mucronata* and *Ceriops tagal*) in Kenya (Gajdzik et al. 2014)	Associated with *Zostera muelleri* and *Caulerpa taxifolia* in Australia (Burfeind et al. 2009)
		20 m (Sanaye et al. 2016)	Seagrass beds dominated by *Enhalus acoroides*, *Thalassodendron ciliatum* and *Cymodocea serrulata* in Mozambique (Gell & Whittington 2002)	
		0.5–2 m (Nakamura et al. 2003)	Seagrass in Zanzibar, but also recorded in coral reefs (Berkström et al. 2012)	
		0.5–1 m (Takahashi et al. 2003)	Mainly found in weeds in East Africa (Smith 1963)	
Syngnathus acus	Coastal	<1 m (Gurkan et al. 2009)	No habitat data found for sub-Saharan Africa and adjacent islands	Found within *Zostera marina* eelgrass in Sweden (Goncalves et al. 2011)

(*Continued*)

Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
		10–90 m (Yildiz et al. 2015)		Found within eelgrass beds (*Zostera marina* and *Z. noltii*) in Portugal (Costa et al. 1994)
Syngnathus temminckii	Coastal and estuarine	<1 m (Harrison 1999)	*Zostera capensis* in estuaries in South Africa (Bekcley 1984, Hanekom & Baird 1984, Ter Morshuizen & Whitfield 1994, Becker et al. 2012, Ntshudisane et al. 2021) *Spartina maritima* in South Africa (Nel et al. 2018) *Cladophora* sp. in the Kleinemonde estuary and *Ruppia* sp., *Potamogeton* sp., Chara sp. and Cladophora sp. in the Bot estuary, South Africa (Bennett 1989) Surf zone of nearby South African estuaries (Strydom 2003) *Zostera capensis* and Codium spp. in the Bushmans and Kariega estuaries, South Africa (Paterson & Whitfield 2000, Claassens et al. 2021)	Endemic to southern Africa
Syngnathus watermeyeri	Estuarine	1–2 m (Cowley & Whitfield 2001)	Associated with predominantly open estuaries (Harrison & Whitfield 2006) *Ruppia cirrhosa* in Kleinemonde East estuary, South Africa (Cowley & Whitfield 2001)	Endemic to South Africa

(*Continued*)

Table 2 (*Continued*) A synthesis from the literature of the general environment, depth ranges and habitats used by syngnathid species in sub-Saharan Africa and adjacent islands

Species name	General environment	Depth range	Habitats (southern and western Africa specific)	General habitat information
			Codium spp. in the Bushmans and Kariega estuaries in South Africa (Claassens et al. 2021)	
			Zostera capensis habitats in estuaries in South Africa (Vorwerk et al. 2007, Whitfield et al. 2017, Ntshudisane et al. 2021, Claassens et al. 2021)	
Trachyrhamphus bicoarctatus	Coastal	2–42 m (Dawson 1985)	Reefs in Madagascar (Fordyce 2016)	Sand, rubble, reef and grass habitats (Dawson 1985)
		Shallows to 40 m (Ali et al. 2020)	Seagrass beds in Vilankulo, Mozambique (Louw Claassens unpublished data)	Muddy and sandy estuaries and bays in Yemen (Ali et al. 2020)
		15–22 m (Alain Rassat pers. comm.)	Sandy habitats in Madagascar (Alain Rassat pers. comm.)	
			Sandy habitat among sea pens in Mozambique (Georgina Jones pers. comm.)	
Trachyrhamphus longirostris	Coastal	16–91 m (Dawson 1985)	No habitat data found for sub-Saharan Africa and adjacent islands	Only recorded from deep, offshore habitats (Dawson 1985)

General habitat information for species that occur outside of Africa is also provided.

submerged vegetation is essential for their occurrence. For example, *Syngnathus watermeyeri* is dependent on available submerged vegetation habitats, such as *Ruppia cirrhosa* (Sheppard et al. 2011).

Only two species, *Hippocampus capensis* and *Syngnathus watermeyeri*, are found exclusively in estuaries along the south coast of South Africa (Bell et al. 2003, Lockyear et al. 2006, Vorwerk et al. 2007, Whitfield et al. 2017). Estuarine species can withstand high variability of environmental conditions, specifically salinity. For example, *Hippocampus capensis* can tolerate salinities of 1–59 on the Practical Salinity Scale (Riley 1986). At least six estuarine species occur in mangroves along the east coast and adjacent islands of Africa (*H. histrix*, *H. kuda*, *Choeroichthys sculptus*, *C. amplexus*, *Hippichthys spicifer* and *Microphis aculeatus*) (Van Der Velde et al. 1995, De Boer et al. 2001, Crona & Rönnbäck 2007, Lugendo 2007, Huxham et al. 2008, Mwandya et al. 2009, Weis et al. 2009, Mirriam 2010, Berkström et al. 2012, Mwandya 2019).

Several species, such as *Enneacampus* spp., *Microphis* spp. and *Hippichthys* spp., move up into rivers from estuaries (Skelton et al. 1989, Okeyo 1998, Weerts & Cyrus 2002, Seegers et al. 2003, Harrison & Whitfield 2006, Crona & Rönnbäck 2007, Fricke et al. 2009). *Hippichthys cyanospilos*, *H. spicifer* and *Microphis leiaspis* are amphidromous, and adults of these species are usually associated with freshwater streams and estuaries across the Indo-Pacific (Milton 2009). The migratory seasons for these species are not known, but migration is likely to be timed with wet and dry seasons (Milton 2009). Members of the genera *Enneacampus* and *Microphis* are truly freshwater species and occur in inland river systems in Kenya, Benin, Republic of the Congo, Lower Guinea and Angola (Okeyo 1998, Seegers et al. 2003, Adite et al. 2013, Walsh et al. 2014, Skelton 2019).

Many syngnathids, particularly seahorses, have been found globally to use artificial structures (Harasti et al. 2010, Gristina et al. 2015, Correia et al. 2015b, Otero-Ferrer et al. 2015, Claassens 2016, Gristina et al. 2016, Claassens & Hodgson 2018b). In some instances, artificial structures have been used for the conservation of syngnathid species (Hellyer et al. 2011, Correia et al. 2013, Simpson et al. 2020), and two species of seahorses (*Hippocampus capensis* and *H. whitei*) have been found to actively choose artificial habitat (seahorse hotels and Reno Mattresses) over natural seagrass habitats (Claassens et al. 2018, Simpson et al. 2019). In Mozambique, *Doryrhamphus bicarinatus* inhabits concrete blocks deployed as artificial reefs in seagrass habitats (Louw Claassens unpublished data), and both *Dunckerocampus boylei* and *D. multiannulatus* were found on rigid buoys used as FAD structures in Mauritius (Forget et al. 2020), as well as on the legs of oil rigs in the Red Sea (Rilov & Benayahu 1998).

Population parameters

Limited data are available on syngnathid populations in sub-Saharan Africa and adjacent islands (Table 3). Since most ichthyological studies have not been specifically designed to focus on syngnathids, sampling approaches and equipment utilised may not have been effective in detecting them. Abundance and density data for syngnathids in the region are therefore probably underestimates owing to the non-targeted nature of most of the research. Approaches used in the studies that recorded syngnathids include various netting methods (seine nets, fyke nets, trawl nets and plankton nets) (Whitfield 1989, Harris et al. 1995, 1999, Almeida et al. 2001, Lugendo 2007, Vorwerk et al. 2007, Pattrick & Strydom 2008, O'Brien et al. 2009, Mirriam 2010, Mwaluma et al. 2010, Ntshudisane et al. 2021), light trapping (Jaonalison et al. 2016) and underwater visual surveys (Van Der Velde et al. 1995, Bell et al. 2003, Lockyear et al. 2006, Ory 2008, Pinault et al. 2013, Claassens & Hodgson 2018b, Daly et al. 2018, Forget et al. 2020) (Table 3).

Local population information exists for 37% (22 species) of African syngnathid species with seine netting being the most frequently used survey method. The most available population abundance data are for *Syngnathus temminckii* with a total of 20 studies, followed by *Hippocampus*

Table 3 Available quantitative population data on syngnathids that occur in sub-Saharan Africa and adjacent islands

Species	Country	Location	Sample approach/ gear type	Total abundance	Density	Other measures	Reference
Choeroichthys sculptus	Madagascar	Nosy Ve island and Great Reef of Toliara	Light trap	13			Jaonalison et al. (2016)
Corythoichthys amplexus	Kenya	Mombasa and Watamu	Plankton net		1.1; 0.2; 29.4 fish/100 m^2		Mwaluma et al. (2010)
	Kenya	Gazi Bay	Stake net	1			Huxham et al. (2008)
Corythoichthys flavofasciatus	Madagascar	Nosy Ve island and Great Reef of Toliara	Light trap	6			Jaonalison et al. (2016)
Corythoichthys intestinalis	Madagascar	Ankilibe Bay	Underwater visual census	14	Mean (SE) density of 0.9 (0.6) per transect		Ory (2008)
Doryrhamphus bicarinatus	Réunion	Piton de la Fournaise	Underwater visual census			0–0.08 occurrence (number of observations per total number of stations)	Pinault et al. (2013)
Dunckerocampus boylei	Mauritius	Not given	Underwater visual census			10% Frequency of occurrence	Forget et al. (2020)
	Seychelles	Not given	Underwater visual census	1			Daly et al. (2018)
Dunckerocampus multiannulatus	Réunion	Saint-Leu	Photographic survey	1			Tea et al. (2020)
	Mauritius	Not given	Underwater visual census			10% Frequency of occurrence	Forget et al. (2020)
Hippichthys cyanospilos	Kenya	Gazi Bay	Net pen	13			Crona & Rönnbäck (2007)
Hippichthys heptagonus	South Africa	St Lucia	Plankton net	11	0.05 mean density/100 m^3		Harris et al. (1999)
	South Africa	Kosi Bay	Plankton net	1			Harris et al. (1995)
Hippichthys spicifer	Kenya	Gazi Bay	Fyke net, underwater visual census, trawl net	1			Van der Velde et al. (1995)

(*Continued*)

Table 3 (*Continued*) Available quantitative population data on syngnathids that occur in sub-Saharan Africa and adjacent islands

Species	Country	Location	Sample approach/ gear type	Total abundance	Density	Other measures	Reference
	South Africa	Mngazi and Mngazana estuaries	Seine net			Large seine net: 0.3 catch per unit effort; Fry seine net: 0.1 catch per unit effort	Mbande (2003)
	Zanzibar	Chwaka Bay	Seine net		0.4 pipefish/km²		Lugendo (2007)
	Kenya	Tutor	Seine net	2			Mirriam (2010)
	South Africa	Umvoti estuary	Seine net, fyke net, gill net, cast net, electrofishing	1			O'Brien et al. (2009)
Hippocampus algiricus	Senegal and The Gambia	Not given	Surveys	205			Cisneros-Montemayor et al. (2016)
	Senegal	Not given	Surveys	35			West (2012)
Hippocampus camelopardalis	Mozambique	Inhaca Island	Beam trawl	10			Almeida et al. (2001)
Hippocampus capensis	South Africa	Swartvlei Estuary	Hand collected	3000 dead seahorses			Russell (1994)
	South Africa	Swartvlei Estuary	Plankton net	4061 juveniles exiting the estuary, 205 juveniles entering the estuary			Whitfield (1989)
	South Africa	Knysna Estuary	Scoop net		0.33 (± 0.03) and 0.23 (± 0.03) seahorses per kg of *C. tenue*		De Villiers et al. (2019)
	South Africa	Swartvlei Estuary	Seine net and hand collected	78 live specimens, 371 dead specimens			Arendse & Russell (2020)
	South Africa	Knysna Estuary	Underwater visual census	44	0–0.25 seahorses/m²; mean = 0.0089 m²		Bell et al. (2003)
	South Africa	Knysna Estuary	Underwater visual census		Reno mattress 0·26 ± 0·02 seahorses/m² Vegetation: 0·01 ± 0·002 to 0·06 ± 0·01 seahorses/m²		Claassens & Hodgson (2018b)

(*Continued*)

Table 3 (*Continued*) Available quantitative population data on syngnathids that occur in sub-Saharan Africa and adjacent islands

Species	Country	Location	Sample approach/ gear type	Total abundance	Density	Other measures	Reference
	South Africa	Knysna Estuary	Underwater visual census	279 in Knysna, 71 in Swartvlei, 102 in Keurbooms			Lockyear et al. (2006)
	South Africa	Knysna Estuary	Underwater visual census and scoop net	*Z. capensis* habitat: 23; Reno mattress habitat: 100–182; *Codium tenue* habitat: 82–68			Claassens (2016)
	South Africa	Knysna Estuary	Underwater visual survey	135–75			Claassens & Harasti (2020)
Hippocampus hippocampus	Senegal and The Gambia	Not given	Surveys	14			Cisneros-Montemayor et al. (2016)
	Senegal	Not given	Surveys	2			West (2012)
Hippocampus histrix	Mozambique	Inhaca Island	Beam trawl	1			Almeida et al. (2001)
	Kenya	Gazi Bay	Fyke net, underwater visual census, trawl net	2			Van der Velde et al. (1995)
	Zanzibar	Chwaka Bay	Seine net		0.1 seahorses/km²		Lugendo (2007)
Hippocampus kuda	Mozambique	Inhaca Island	Beam trawl	1			Almeida et al. (2001)
Micrognathus andersonii	Kenya	Watamu	Quadrats	1			Sindorf et al. (2015)
Microphis aculeatus	Benin	Not given	Seine net, gill net	5			Adite et al. (2013)
	Nigeria	Not given	Survey			200 fish in a box; $1 unit price	Ukaonu et al. (2011)
	Côte d'Ivoire	Dodo River		1			Kamelan et al. (2013)
Nannocampus elegans	South Africa	Algoa Bay	Plankton net	1	0.01 (range 0.0–0.06)		Pattrick & Strydom (2008)
	South Africa	Port Alfred	Rotenone			2% of the total sample	Bennett (1987)

(*Continued*)

Table 3 (*Continued*) Available quantitative population data on syngnathids that occur in sub-Saharan Africa and adjacent islands

Species	Country	Location	Sample approach/ gear type	Total abundance	Density	Other measures	Reference
	South Africa	Kleinemonde East	Rotenone	1			Christensen & Winterbottom (1981)
Syngnathoides biaculeatus	Mozambique	Inhaca Island	Beam trawl	35			Almeida et al. (2001)
	Kenya	Mida Creek	Fyke net	2			Gajdzik et al. (2014)
	Kenya	Gazi Bay	Fyke net, underwater visual census, trawl net	20			Van der Velde et al. (1995)
	Kenya	Gazi Bay	Net pen (Stake net?)	13			Crona & Rönnbäck (2007)
	Zanzibar	Chwaka Bay	Seine net		0.5; 02; 0.4 pipefish/km²		Lugendo (2007)
	Kenya	Tutor	Seine net	1			Mirriam (2010)
Syngnathus temminckii	South Africa	Swartvlei Estuary	Plankton net	71,000 juveniles exiting the estuary			Whitfield (1989)
	South Africa	St Lucia	Plankton net	11			Harris et al. (1999)
	South Africa	Algoa Bay	Plankton net	3	0.02 (range 0.0–0.07)		Pattrick & Strydom (2008)
	South Africa	Bushmans Estuary	Seine net	5			Ntshudisane et al. (2021)
	South Africa	Bot Estuary	Seine net		10–1 pipefish/seine net haul		Bennett (1989)
	South Africa	Bot Estuary	Seine net		0.008 pipefish/m^2		Bennett & Branch (1990)
	South Africa	Kleinemonde Estuary	Seine net		0.2 pipefish/seine net haul		Bennett (1989)
	South Africa	False Bay	Seine net	2			Clark et al. (1996)
	South Africa	Bot Estuary	Seine net	17			Harrison (1999)
	South Africa	Klein Estuary	Seine net	42			Harrison 1999
	South Africa	Kariega Estuary	Seine net		Average of 0.05 pipefish/10 m^2		Paterson & Whitfield (2000)
	South Africa	Mngazi Estuary	Plankton net	2			Pattrick et al. (2007)
	South Africa	Kariega Estuary	Otter trawl	6			Richardson et al. (2006)

(*Continued*)

Table 3 (*Continued*) Available quantitative population data on syngnathids that occur in sub-Saharan Africa and adjacent islands

Species	Country	Location	Sample approach/ gear type	Total abundance	Density	Other measures	Reference
	South Africa	Gamtoos Estuary	Plankton net	11			Strydom & Wooldridge (2005)
	South Africa	Keurbooms Estuary	Seine net	3			James & Harrison (2010a)
	South Africa	Kariega Estuary	Seine net	4			James & Harrison (2010b)
	South Africa	Gamtoos Estuary	Plankton net	11			Strydom & Wooldridge (2005)
	South Africa	Touw Estuary, Eilandvlei, Rondevlei	Seine net		Relative abundance: Touw Estuary 0.1/36 seine nets, Eilandsvlei 0.02/24 seine nets Rondevlei 0.02 /13 seine nets		Olds et al. (2016)
	South Africa	Various estuaries	Plankton net		Cool temperate estuaries: 23.03 pipefish/100 m^3, warm temperate estuaries: 6.65 pipefish/100 m^3, transition zone estuaries: 7.75 pipefish/100 m^3		Strydom (2015)
	South Africa	Kromme estuary	Seine net	22			Hanekom & Baird (1984)
	South Africa	Nxaxo-Ngqusi Estuary	Plankton net		Average density 2.5 (range 0–32.3) pipefish/100 m^3		Wasserman et al. (2010)
	South Africa	Kabeljous Estuary	Seine net	1			Strydom (2003)
	South Africa	Kariega Estuary	Seine net		0.01–0.07 pipefish/m^2		Ter Morshuizen & Whitfield (1994)
Syngnathus watermeyeri	South Africa	Bushmans Estuary	Seine net	5			Ntshudisane et al. (2021)
	South Africa	Kleinemonde East	Seine net	43			Cowley & Whitfield (2001)
	South Africa	Kariega Estuary	Seine net	1 in Kariega in 2013; 55 in Kleinemonde East			Whitfield et al. (2017)
	South Africa	Kariega Estuary	Seine net	20			Vorwerk et al. (2007)

capensis with nine studies. Studies on *Syngnathus temminckii* were, however, mostly part of general fish surveys, conducted once off and using seine nets. In contrast, the population studies on *Hippocampus capensis* were conducted using underwater visual surveys (Bell et al. 2003, Lockyear et al. 2006, Claassens & Hodgson 2018b) and on a monthly basis (Claassens 2016, Claassens & Hodgson 2018b, Claassens & Harasti 2020). A comparison of population data across studies, even for the same species, is difficult owing to the different approaches, methods and the sampling effort used during sampling (Table 3).

Most syngnathids have small home-ranges (Vincent & Giles 2003, Harasti et al. 2014). For example, in the only research investigating home-ranges for syngnathids in sub-Saharan Africa and adjacent islands, individuals of *H. capensis* were found to move an average of only 5 m over a 13-month period (Claassens & Harasti 2020). Small home-ranges and a limited ability to disperse can increase the vulnerability of syngnathid populations. For example, a major flood event in the Kleinemonde East estuary, South Africa, in 2003, resulted in the local extinction of *Syngnathus watermeyeri* in this estuary (Cowley & Whitfield 2001, Sheppard et al. 2011, Whitfield et al. 2017).

Syngnathids usually disperse as juveniles, with the duration of the juvenile stage dependent on the species (Kendrick & Hyndes 2003, Bertola et al. 2020). Whitfield (1989) observed high numbers of juvenile *Hippocampus capensis* and *Syngnathus temminckii* wash in and out of the Swartvlei estuary in South Africa, most likely as a means of dispersal. Another mode of dispersion is by attaching to drifting algae (Howard & Koehn 1985, Teske et al. 2005, Kuiter 2009). *Choeroichthys sculptus*, *Hippichthys cyanospilos*, *H. spicifer*, *Micrognathus andersonii*, *Hippocampus kuda*, *Syngnathoides biaculeatus*, *Trachyrhamphus bicoarctatus* and *T. longirostris* have all been associated with drifting algae (including *Sargassum* spp.) in Japan (Ohta & Tachihara 2004, Nishida et al. 2008), and it is possible that these species also use drifting algae as a means to disperse in African waters.

Life History

There is a dearth of data on the reproductive ecology of syngnathids within African waters. Most information is from studies in South Africa that have focused on the breeding ecology and behaviour of *Hippocampus capensis* (Grange & Cretchley 1995, Lockyear et al. 1997), *Syngnathus temminckii* and *S. watermeyeri* (Mwale et al. 2014, Whitfield et al. 2017). *Syngnathus watermeyeri* has low fecundity with small brood sizes (about 44 embryos per male; Whitfield 1995b), whereas *S. temminckii* has high fecundity and larger brood sizes (200–500 eggs in a brood pouch; Branch 1966, Mwale et al. 2014, Whitfield et al. 2017). These differences in reproduction are probably one of the reasons for the differences in vulnerability between these two species (Whitfield et al. 2017). The number of offspring produced by *Hippocampus capensis* is highly variable and was found to range from 25 to 60 (Grange & Cretchley 1995) and from 7 to 95 (Lockyear et al. 1997). Larger seahorses have greater reproductive potential (Foster & Vincent 2004), which has also been found for *Syngnathus temminckii*, which has an adult size range of 10–13 cm, and in which larger pipefish produce more embryos (Mwale et al. 2014).

Many syngnathid species form pair bonds (Rosenqvist & Berglund 2011, Brandl & Bellwood 2014) and some species are monogamous within at least a single breeding season (Vincent 1995, MasonJones & Lewis 1996), whilst *Hippocampus whitei* has been found to display long-term monogamy (Harasti et al. 2012). Monogamy has not been established for syngnathid species in African waters. However, Mwale et al. (2014) found that in *Syngnathus temmincki*, the number of eggs produced by a female was not statistically different from the number of embryos brooded by the male. This suggests that a male only mates with one female. Whether this applies to other southern African pipefishes is unknown.

Sex ratios in syngnathids are usually equal (Perante et al. 2002, Moreau & Vincent 2004, Smith et al. 2012). Female-biased sex ratios have, however, been noted for *Hippocampus hippocampus* in the Macaronesia Islands, specifically in artificial habitats (Otero-Ferrer et al. 2015); in *H. erectus* in Chesapeake Bay (Teixeira & Musick 2001); and Kvarnemo et al. (2007) found a wild population of *H. subelongatus* to be female biased with stronger sexual selection on females, a contradiction to the normal male sexual selection found in monogamous species (Vincent 1994a, b, Naud et al. 2009). Information on sex ratios for *H. capensis* varies. In 2000, a transect survey indicated male bias, but equal numbers of seahorses were recorded using a focal grid method (Bell et al. 2003). In 2001, Lockyear et al. (2006) also recorded a 1:1 sex ratio from transect surveys. During surveys between 2014 and 2017, the sex ratio varied across habitats and seasons and changed from being equal to female biased (Claassens 2016, Claassens & Hodgson 2018b). In *Codium tenue* habitats, the sex ratio for *Hippocampus capensis* remained equal over an 18-month period (De Villiers et al. 2019). Both *Syngnathus temminckii* and *S. watermeyeri* were found to have female-biased sex ratios, but only significantly so in *S. temminckii* (Mwale et al. 2014).

Extravagant courting behaviour is a common phenomenon in syngnathids (Vincent 1995). One of the most well-known courting behaviours are morning greetings, mostly considered as a means to confirm pair bonds (Vincent et al. 2005), which has been shown for *Hippocampus capensis* (Claassens & Hodgson 2018a). In Japan, the monogamous pipefish *Corythoichthys haematopterus* recognised its specific partner, with morning greetings only done with existing partners (Sogabe 2011). In addition, morning greetings were observed throughout the non-breeding season as well, which suggests that this pipefish maintains its pair bonds (Sogabe & Yanagisawa 2008).

Breeding seasons vary for different syngnathid species and are linked with seasons and weather patterns (Kendrick & Hyndes 2003). The breeding season for *Syngnathus temminckii* was thought to be limited to spring and summer (Bennett 1989), but breeding was found throughout the year except during April and May (Mwale et al. 2014). *Syngnathus temminckii* also exhibits lekking behaviour similar to the worm pipefish *Nerophis lumbriciformis* (Monteiro et al. 2017), whereby female individuals gather in temporary groups at a particular area to display their ornamentation to attract males for the sole purpose of mate choice (Georgina Jones pers. comm.; Figure 3). *Syngnathus watermeyeri* breeds in all seasons, except winter (Mwale et al. 2014). *Hippocampus capensis* breeds during spring and summer and courtship behaviour and mating occurs throughout the breeding season and the average gestation period for this species is 34 days (Lockyear et al. 1997). This means

Figure 3 *Syngnathus temminckii* aggregation in False Bay, South Africa, as part of lekking behaviour (photo: Georgina Jones).

that males can produce more than one brood during the breeding season. *Microphis aculeatus* has a gestation period that ranges between one to three weeks and gives birth to juveniles that are 1.5 cm long (Snoeks & Vreven 2008).

Feeding, prey and predators

Syngnathids have a long snout, fused jaws, lack teeth and use suction feeding to consume their prey whole in a few milliseconds (Leysen et al. 2010). Suction feeding has required the evolution of musculoskeletal specializations of the head and snout. To date, the anatomy of the feeding apparatus of species from Africa has been briefly described by Branch (1966) for *Syngnathus temminckii* (as *S. acus*) and in more detail for *Hippocampus capensis* (Leysen et al. 2010). Like other syngnathids, the snouts are composed of neurocranial and suspensorial bones in which suction feeding is accomplished by hyoid retraction followed by powerful neurocranial elevation (Leysen et al. 2010, Manning et al. 2019).

Even though there are almost no data available on the feeding behaviour of syngnathids in sub-Saharan Africa and adjacent islands, general information from a recent global review of syngnathid feeding and predation is applicable to African species (Manning et al. 2019). Syngnathids are regarded as ambush predators (Manning et al. 2019), although they will actively swim to seek prey (James & Heck 1994). Such hunting behaviour in the wild has been recorded for *Hippocampus capensis* using small action cameras (Claassens & Hodgson 2018a). Syngnathids mostly feed on small crustaceans, such as amphipods, copepods and isopods (Tipton & Bell 1988, Teixeira & Musick 2001, Woods 2002, Kendrick & Hyndes 2005, Castro et al. 2008, Yip et al. 2015). In addition, some species feed on nematodes (Castro et al. 2008) and fish larvae (Didenko et al. 2018). According to Kendrick & Hyndes (2005), syngnathids with longer snouts tend to feed on more mobile prey, whilst those with shorter snouts feed on slower moving, benthic prey. Copepods (specifically *Pseudodiaptomus hessei*) and amphipods were found to be dominant in the gut content analyses of *Syngnathus temminckii* in the Bot estuary, South Africa (Bennett 1989, Bennett & Branch 1990) and only macrurans were found in the gut of *S. temminckii* in the Kromme estuary, South Africa (Hanekom & Baird 1984). According to Bennett & Branch (1990), *S. temminckii* was the most specialised feeder of all resident fish species assessed in the Bot estuary. In addition, ontogenetic changes in prey were evident, with smaller juveniles mostly feeding on copepods and larger adults on amphipods (Bennett 1989). *Hippocampus capensis*, which has a short snout, was found to hunt actively and feed primarily on mobile epibenthos (Claassens & Hodgson 2018a). A recent study using faecal eDNA to determine the prey composition of *Syngnathus watermeyeri* and *S. temminckii* (Ntshudisane et al. 2021) found a distinct difference in the types of prey these two species feed on. The long-snouted *S. temminckii* feeds mostly on gastropod and decapod crustacean larvae, whilst the short-snouted *S. watermeyeri* mostly feeds on copepods. One reason for this difference could be the difference in gape size of these two species (*S. temminckii* has a larger body, with a wider gape size and thus an ability to feed on larger prey) (Whitfield et al. 2017, Ntshudisane et al. 2021).

There is very little information on predators of syngnathids, and it is suggested that predation is mostly opportunistic (Kleiber et al. 2011). Cape cormorant *Phalacrocorax capensis* and the grey heron *Ardea cinera* are known to prey on *Hippocampus capensis* (https://www.youtube.com/watch?v=UyCW36HRgN4; https://www.youtube.com/watch?v=pORa8DKGcgk) (Figure 4A). Twenty *H. capensis* were found within the stomach of a spotted grunter *Pomadasys commersonnii* in the Keurbooms estuary (Figure 4B), and according to Smith (1963), *Hippocampus capensis* is eaten by some other fishes. *Syngnathus temminckii* has been recorded in the diet of the African penguin *Spheniscus demersus* in Algoa Bay (Randall & Randall 1986), bluefish *Pomatomus saltatrix* (Bennett 1989) and the Cape cormorant (Duffy et al. 1987). *Syngnathus temminckii* is preyed on by the klipvis *Clinus superciliosus* in False Bay (Georgina Jones pers. comm.; Figure 4C).

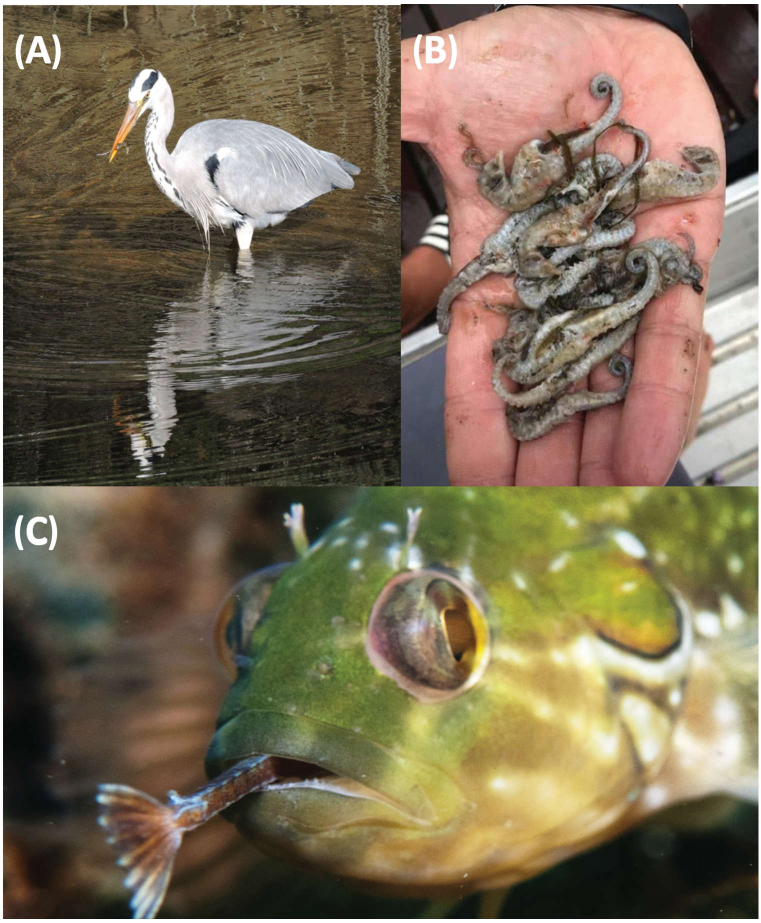

Figure 4 Examples of predation: (A) *Hippocampus capensis* in the bill of a grey heron; (B) *H. capensis* from the gut of a spotted grunter, *Pomadasys commersonnii*; (C) *Syngnathus temminckii* in the mouth of a klipvis, *Clinus superciliosus*.

Behaviour

Globally, only a handful of studies exist on the behaviour of syngnathids in the wild (MasonJones & Lewis 1996, Naud et al. 2009, Freret-Meurer et al. 2012, Harasti & Gladstone 2013), and there has been only one behavioural study in Africa, in which *Hippocampus capensis* was observed in the wild using small waterproof action cameras (i.e. GoPros) (Claassens & Hodgson 2018a). That study found that *H. capensis* was more active during the morning than midday or late afternoon and spent >80% of the active period hunting (Claassens & Hodgson 2018a). In addition, a decrease in seahorse activity during the holiday season was linked to an increase in boat noise (Claassens & Hodgson 2018a). Impacts of anthropogenic noise on seahorse behaviour have also been found in *Hippocampus erectus* (Anderson et al. 2011) and *H. guttulatus* (Palma et al. 2019).

An unusual form of behaviour is seen in *Microphis fluviatilis* in which a head-down vertical orientation is adopted in quiet water among vegetation (Okeyo 1998), which could be a means of camouflage.

Syngnathids are known for their extremely cryptic behaviour and ability to blend in with their surrounding environment (Kuiter 2009), which limits their detection by divers or researchers. For example, *Nannocampus elegans* was not detected in a visual census survey of a rock pool in

South Africa, but was found when the poison rotenone was used in the same pool (Christensen & Winterbottom 1981).

Threats and conservation

Of the 63 syngnathid species that occur in Africa, 41 are listed as Least Concern, four as Vulnerable (*Hippocampus kelloggi*, *H. kuda*, *H. histrix* and *H. algiricus*), one as Endangered (*H. capensis*) and one as Critically Endangered (*Syngnathus watermeyeri*) on the IUCN Red List (IUCN 2021). Almost 20% (12 species) are listed as Data Deficient, and four species (*Hippocampus nalu*, *Syngnathus temminckii*, *Cylix* sp. and *Hippocampus borboniensis*) have not been assessed. Limited current and regional data were used for most of the assessments, owing to the dearth of available syngnathid-focused research in Africa.

Threats

It is important to correctly identify threats that adversely affect a species (Figure 5). If a clear understanding of what threatens a species is not known or threats are misidentified, effective conservation

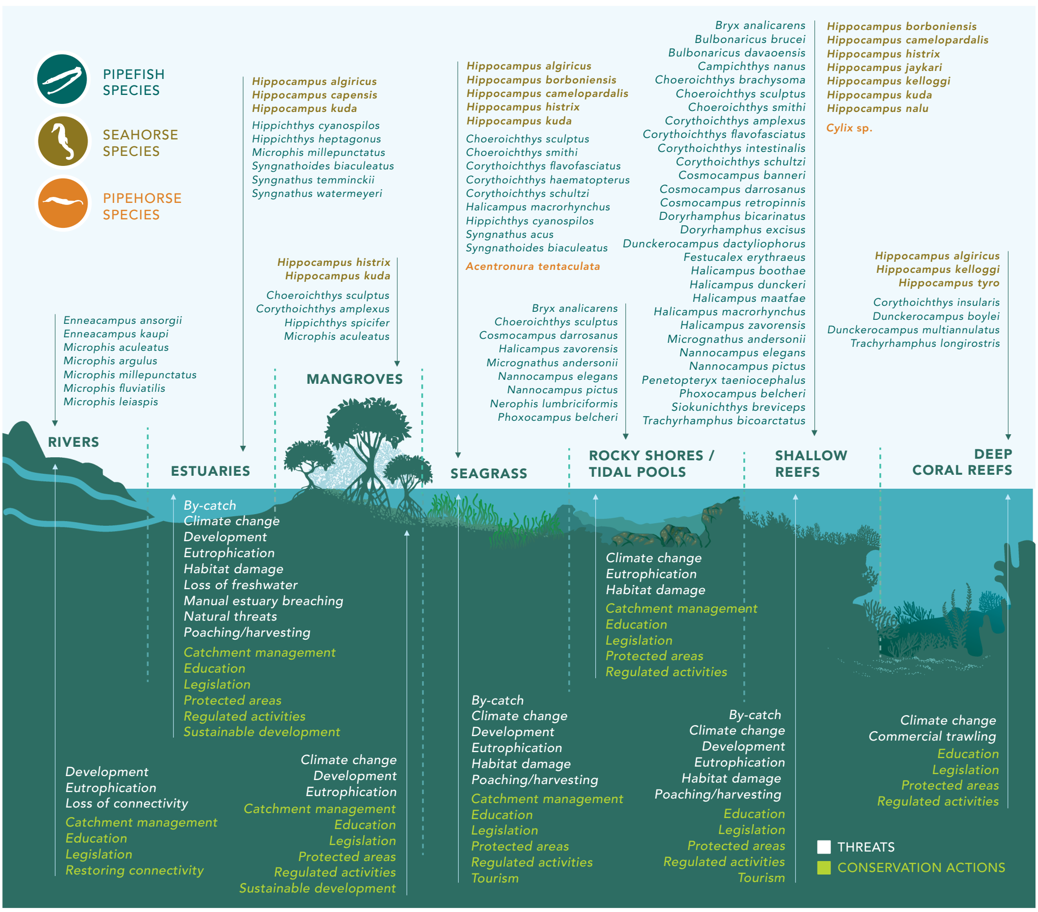

Figure 5 The distribution of syngnathid species found in sub-Saharan African and adjacent islands across their habitat ranges with a summary of habitat-specific threats and conservation actions.

actions are unlikely. Vincent et al. (2011) identified three types of threats to seahorses: (1) targeted fishing, (2) incidental capture (by-catch) and (3) habitat loss and alteration. These threats, which apply to all syngnathids, are reviewed here in the context of species that occur in Africa. The particular types of threats vary by habitat (Figure 5). For example, *Microphis* spp. are euryhaline and range from estuaries to the upper catchment of rivers (Seegers et al. 2003, Fricke et al. 2009, Weerts et al. 2014, Cutler et al. 2020). The loss of connectivity in these systems owing to dam or weir construction thus poses a direct threat to these species and their movement patterns, possibly impeding their migration upstream and downstream between rivers and the ocean (Cyrus 2001, Weerts et al. 2014, Cutler et al. 2020). Species that occur in seagrass beds face different threats than those found in deeper reef habitats. Species commonly found in seagrass beds are likely to be more vulnerable to by-catch in artisanal fisheries, impacts from recreational boating, and poaching, whereas species on deeper reefs are more vulnerable to commercial fishing (Louw Claassens pers. obs.).

Targeted fishing and trade

Syngnathids, specifically seahorses, are targeted and used for traditional Chinese medicine, the aquarium trade and curios (McPherson & Vincent 2004, Martin-Smith & Vincent 2006, Vincent et al. 2011, Stocks et al. 2017). Between 2004 and 2011, CITES reported an estimated 5.6 million seahorses were taken annually and traded internationally (Foster et al. 2016). The majority of CITES-reported seahorse trade consisted of dried specimens (98%), with a limited number (11,600 seahorses) traded live for aquaria (Foster et al. 2016). Interestingly, most seahorses in the dried trade originate from wild populations, whilst live seahorses are mostly sourced from captive breeding facilities (Foster et al. 2016). According to CITES trade data, between 2004 and 2011, *Hippocampus algiricus* made up 5.6% of total annual trade and was only sourced from wild populations along the west coast of Africa. *Hippocampus camelopardalis* and *H. capensis* made up less than 1% of annual catches, were only found in the live seahorse trade and were sourced from captive populations (Foster et al. 2016). This information is, however, questionable, because *H. capensis* is a protected species in South Africa under national legislation (see *Legislation, global agreements and regulations* section below), and all captive breeding of this species is heavily regulated and permitted in only two aquariums (Two Oceans Aquarium in Cape Town, uShaka Aquarium in Durban) and at the Garden Route National Park in Knysna. *Hippocampus histrix* and *H. kuda* made up 2.7% and 6.2%, respectively, and were used in both the dried and live trade (Foster et al. 2016).

In a recent assessment of the seahorse trade from Africa to Asia between 2008 and 2018, major discrepancies were found between total import (15,772,838) and export (11,259,098 individuals) figures (Louw & Burgener 2020). From 2004 to 2011, Senegal and Guinea were in the top three countries globally to export seahorses (Foster et al. 2016). Three African countries (Togo, Guinea and Senegal) reported seahorse exports between 2008 and 2018, and Senegal was the major exporter of seahorses during this time (Louw & Burgener 2020). However, recorded exports from these countries are less than reported imports in receiving countries, and these discrepancies highlight the limitations of CITES data to account for all trade that is taking place (Louw & Burgener 2020), especially in instances when trade is done illegally. For example, dried specimens of *H. camelopardalis,* illegally poached, probably for use in Chinese traditional medicine, have been confiscated in Mozambique en route to Asia in 2018 and 2021 (Louw Claassens unpublished data).

Between 2008 and 2018, Hong Kong was the sole importer of African seahorses, according to import records, though export records show that seahorses were also exported to mainland China and Taiwan (Louw & Burgener 2020). *Hippocampus algiricus* was the main seahorse species recorded in all African trade and was exclusively sourced from wild populations along the west coast of Africa (Louw & Burgener 2020). According to Cisneros-Montemayor et al. (2016), *H. algiricus* is one of the most traded seahorse species in the world, with an estimated annual export of 700,000 animals. It is important to note here that CITES data do not account for any animals that are captured and traded domestically.

Not much information is available for capture and trade of southern and western African pipefish and pipehorses. *Syngnathoides biaculeatus* is considered the most heavily exploited pipefish globally and is commonly used in traditional Chinese medicine (Vincent 1996, Martin-Smith & Vincent 2006, Barrows et al. 2009), probably because they are not listed under CITES. Imports of dried pipefish into Taiwan were 7500–21,300 kg per annum between 1983 and 1993 (Vincent 1996) and imports into Hong Kong in 1998–2002 were 1600–16,500 kg annually (Martin-Smith & Vincent 2006).

Seahorses caught as by-catch can be traded either in the dried seahorse trade, or as curios for tourists. In countries where seahorses and pipefish are protected species and trade only occurs illegally, the availability of accurate capture and trade data (as reported to CITES) and the extent of impacts are limited. In recent years, illegal fishing for seahorses has been recorded in a small fishing village in Vilankulo, Mozambique. A haul of 1782 dried seahorses (predominantly *Hippocampus camelopardalis* with *H. kuda*) was confiscated from local fishermen in 2018 and the fishermen were jailed. Recently, 9 kg of dried seahorses has been confiscated from a Chinese buyer in the same village (Louw Claassens unpublished data). This type of relatively small-scale unlawful harvesting and trade is not usually tracked and can have far-reaching impacts on local populations (Lawson et al. 2017). In addition, seahorses in the above two examples were targeted catch, with poachers collecting seahorses by hand from shallow seagrass beds by snorkelling or walking during low tide. In South Africa, *Syngnathoides biaculeatus* has also been confiscated together with seahorses (Louw Claassens unpublished data). In Nigeria, *Microphis aculeatus* is sold in the ornamental fish trade; a box of 200 fish can be bought for as little as 381.15 Nigerian Naira, which is equivalent to US$1 (Ukaonu et al. 2011).

By-catch and trade

As much as 95% of seahorses used in trade come from shrimp trawl by-catch (Vincent et al. 2011). Seahorse by-catch can either be used to generate a secondary income, in low-grade fishery by-products such as fishmeal, or discarded. Seahorse by-catch per vessel is generally low (Meeuwig et al. 2006), but the cumulative impact can be devastating, with 2.2 million animals caught per annum in Vietnam in the late 1990s (Giles et al. 2005). In a recent review, Lawson et al. (2017) estimated an annual seahorse by-catch of 37 million animals from the 21 countries assessed. It is especially subsistence fishermen in developing countries that turn to the sale of seahorses to make a living (McPherson & Vincent 2004). There are numerous impacts from fishing, over and above immediate reduction in population size: disruption of monogamous seahorse pairs, which can lead to reduced reproduction, alterations of population structure and habitat destruction (see Vincent et al. 2011 for a review).

Whist there are limited empirical data on syngnathid by-catch in sub-Saharan Africa and adjacent islands, there are some by-catch records for species from elsewhere in their ranges. *Corythoichthys schultzi* has been recorded as by-catch in the Nigerian *Nematopalaemon* shrimp fishery (Ambrose et al. 2016). This fishery is dominated by artisanal fishers that use conical trap nets called 'Anyima' to catch shrimps (Ambrose et al. 2016). In Sulawesi, Indonesia, *Choeroichthys sculptus* is caught as by-catch during fishing by local communities for small baitfish. The pipefish is, however, not used as bait by locals as it is considered to be poisonous (Pet et al. 2006). In addition, *Hippocampus kuda*, *H. kelloggi*, *H. histrix* and *Syngnathoides biaculeatus* have been recorded in by-catch in India, Vietnam and Malaysia (Nguyen & Do 1996, Choo & Liew 2003, Sambandamoorthy et al. 2015).

An emerging threat in East Africa is the use of mosquito nets (provided as malaria prophylaxis) by artisanal fishers (Bush et al. 2017). Mosquito nets are used to catch all edible fish in the very fine mesh and are extremely indiscriminate in the species caught, resulting in a high amount of by-catch. Unidentified species of pipefish have been recorded in mosquito net by-catch in Palma, Mozambique (Jones & Unsworth 2020). Mosquito nets are generally used in a range of shallow, coastal habitats including mangroves, estuaries, seagrass beds, intertidal mud and sand flats, rocky areas and reef platforms (Bush et al. 2017). By-catch from mosquito net fishing should thus be considered a major threat to African syngnathids, as many species occur in these habitats. This threat is, however, not limited to Africa: mosquito net fishing has also been noted in Papua New Guinea (Short et al. 2018), for example.

Habitat loss and alteration

Most habitats used by syngnathids are globally under threat and susceptible to anthropogenic impacts. In a recent study, Phair et al. (2019) found that *Zostera capensis*, the dominant seagrass species occurring in South Africa (Adams 2016), shows high clonality and low genomic diversity and concluded that this species will have limited ability to re-establish in estuarine systems once lost. The vulnerability of *Z. capensis* owing to low genetic diversity makes it a priority for protection in the context of syngnathid conservation. Unfortunately, seagrasses in Africa are threatened by growing coastal human populations and related activities such as fishing, pollution, eutrophication and sedimentation (Gullstrom et al. 2002). In addition, activities such as boating or bait digging can lead to habitat loss, especially in shallow coastal environments and estuaries (Claassens et al. 2020). First, whilst boating or bait digging is taking place, syngnathids can be disturbed within their habitats, not only by trampling or direct disturbance from a boat moving through seagrass, but noise from boats has also been found to negatively affect seahorses (Claassens & Hodgson 2018a, Palma et al. 2019). Second, seagrass can be damaged by the removal of vegetation during bait digging, anchoring or by boat propellers (Claassens et al. 2020). In areas with a high number of moored boats, damage from permanent moorings has also been found to significantly impact seagrass habitats (Glasby & West 2018).

Coral reefs are also vulnerable to various anthropogenic impacts ranging from destructive fishing to climate change, ocean acidification and disease (Lindén et al. 2002, Hoegh-Guldberg et al. 2017, Hughes et al. 2018). Mangroves in East Africa are threatened by activities such as logging for fuel and house building, removal to make room for urban expansion and salt and shrimp production (Godoy & De Lacerda 2015).

Development is another major threat to coastal and estuarine habitats and can result in infilling of aquatic habitats or dredging to develop and maintain artificial environments such as harbours and marinas (Claassens 2018). In the most recent South African National Biodiversity Assessment, it was found that 29% of South African estuaries have been subject to severe habitat modification owing to development and related land-use pressures (van Niekerk et al. 2019b). In Zanzibar, mangroves cleared to make space for solar power generation and fish farms have adverse effects on the trophic structure of fish communities (Mwandya 2019).

Habitat alteration and loss in rivers can be caused by the construction of dams and other structures (Cutler et al. 2020), which also results in the loss of connectivity (Weerts et al. 2014). Another related impact from increased damming and water abstraction is the loss of freshwater inflow into estuarine systems, which can lead to the loss of a salinity gradient and even hypersaline conditions (Grange et al. 2000, Van Niekerk et al. 2019b). In addition, many estuarine species depend on regular freshwater pulses for breeding and food, and the loss of regular pulses can have an adverse effect on the entire ecosystem (Ter Morshuizen & Whitfield 1994, Strydom et al. 2002, Vorwerk et al. 2008). Specifically, *Syngnathus watermeyeri* is threatened by the loss of freshwater inflow into the Kariega and Bushmans estuaries, South Africa, the only two estuaries in which this species is currently found (Whitfield et al. 2017, Claassens et al. 2021). This is because reduced freshwater inflow results in a decrease in important prey species such as copepods (Wooldridge 2010). The loss of freshwater in estuaries can, however, have a positive impact on seagrass and other macroalgal habitats and can result in the upstream expansion of these habitats (Adams 2016) and the subsequent expansion of available habitat to these estuarine species (Claassens et al. 2021).

Wastewater run-off and the resultant increase in nutrients can have adverse effects on coastal environments such as estuaries (Claassens et al. 2020) and mangrove forests (Machiwa & Hallberg 1995, Cannicci et al. 2009). Unnaturally high increases in nutrients within these systems commonly result in nuisance algal blooms and increases in turbidity, which have been found to displace seagrass (Human et al. 2016). Impacts from eutrophication can impact the behaviour of syngnathids. For example, in a choice experiment, *Nerophis ophidion* avoided *Zostera marina* overgrown with filamentous algae compared to seagrass without any algal growth (Sundin et al. 2011). Increased turbidity can also affect mate choice, either by decreasing visibility and the ability to choose a mate when using visual cues only (Sundin et al. 2010), or by enhancing sexual selection and reproductive success using alternative cues to select a mate (Sundin et al. 2017). Eutrophication has been identified as a major threat to the Knysna seahorse in the Knysna estuary owing to the displacement of eelgrass habitats by nuisance macroalgal blooms dominated by *Ulva lactuca* (Claassens et al. 2020).

Climate change is a global phenomenon which can have far-reaching effects on local and regional ecosystems. In the first instance, marine heat waves can lead to coral bleaching, which directly damages coral habitats. Extensive damage from coral bleaching has been recorded in the Seychelles, Mozambique, Tanzania and Kenya (Lindén et al. 2002). In addition, coral bleaching could also lead to a decrease in the productivity and diversity of a reef, which can result in a decrease in available prey for syngnathids. Climate change and related warming have also been found to negatively affect seagrass and macroalgae (Duarte et al. 2018) and mangroves (Gilman et al. 2008); however, the direct effects of increased water temperature on syngnathids in the wild require investigation.

Sometimes, syngnathids are impacted by natural threats such as floods or storms. Climate change is causing an increase in the frequency and severity of storms, which can directly damage coral reefs (Cheal et al. 2017) and mangroves (Godoy & De Lacerda 2015). Most estuaries in South Africa are temporarily open/closed systems, where the connection to the ocean varies over time (Whitfield 1992). Natural estuarine breaching events, where the connection between the estuary and ocean is re-established, in these types of estuaries can cause a substantial drop in water level, leaving syngnathids stranded; this happened in the Swartvlei estuary, South Africa (Russell 1994). The impacts from breaching can, however, be exacerbated when sand bars enclosing estuary mouths are deliberately breached by management authorities, usually to prevent flooding of properties (Arendse & Russell 2020). Artificial breaching can occur more frequently than natural breaching.

The deleterious impacts of microplastics on aquatic environments and a wide range of taxa have become increasingly recognised in recent years (Rochman et al. 2016, Avio et al. 2017). Even though the impacts from microplastics on syngnathids are not well known, preliminary research in the Knysna estuary found that microplastics occur in the gut of *Syngnathus temminckii* along with prey animals (Naidoo 2021). Similarly, a study conducted in Spain found that *Hippocampus reidi* ingest microplastics through trophic transfer from their prey (Dominguez 2020). The direct effects of microplastic ingestion by syngnathids is unknown, but could potentially cause harm through toxin absorption and impact on the ability to feed and digest prey.

Conservation

Successful conservation depends on the identification and implementation of actions to improve the conservation status of a species. Baseline monitoring is required to determine if specific conservation actions are necessary, and if so, to identify which actions to implement. Ongoing monitoring is required to ascertain if conservation actions are in fact effective, and if not, to determine an alternative approach. The IUCN Red List assessment provides important information on the extinction risk of species (IUCN 2012, 2021), and ecological data used to inform this assessment can be monitored over time to ascertain conservation success (Rodrigues et al. 2006). A recently developed approach, the Green Status of species, assesses the effectiveness of conservation actions (Grace et al. 2021).

This approach assesses past conservation actions for a species, estimates what the status of a species would be under different conservation scenarios and provides much-needed insight into the efficacy of conservation actions.

Legislation, global agreements and regulations

International and regional agreements are important components of successful species conservation (Figure 5). In 2004, the entire genus *Hippocampus* was one of the first groups of marine fishes to be covered by CITES trade regulations since 1976, when they were included in Appendix II (Vincent et al. 2013). Under Appendix II, all signatories to CITES must ensure that trade in seahorses does not harm or adversely affect natural populations and is done legally, and that all international trade is reported (Foster et al. 2016). Difficulty in the identification of seahorses being traded, a mismatch between export and import data, and the increasing threat from poaching and illegal trade, which are not reported, are problematic limitations of the implementation of CITES in respect of seahorses (Foster et al. 2016). Regardless of these limitations, CITES provides an integral legal platform to hold signatories to account by applying international pressure to comply with regulations. Most countries in Africa, with the exception of South Sudan, Republic of the Congo, and The Kingdom of Eswatini, are signatories of CITES. In addition to CITES, member organisations of the IUCN undertake to abide by the Motions and the resultant Resolutions and Recommendations adopted by the IUCN, which are used to guide policy and influence third parties. The latest motion specifically focused on syngnathids (Motion 111) was adopted by the IUCN and its member organisations in December 2020 and provides a key strategy for the conservation of syngnathids that can be used by member organisations (244 of which are in Africa) in the promotion of syngnathid-specific conservation actions. Regionally, on the east African coast, the Nairobi Convention (2021) is a partnership between governments, civil society and the private sector with the aim of building a prosperous western Indian Ocean region with healthy rivers, coasts and oceans. On the west coast, the Abidjan Convention (2021) was developed to focus on the cooperation, management and development of the marine and coastal environment of the Atlantic coast of West, Central and southern Africa.

All syngnathids are protected in South Africa under the National Environmental Biodiversity Act No 10 of 2004. According to this act, members of the family Syngnathidae are not allowed to be captured, collected or disturbed in any way (Government Notice No. 476 of 2017). Instances of seahorse exports from South Africa are thus concerning, especially if these animals originate from South Africa. A single *Hippocampus capensis* specimen was sampled from a Taiwanese traditional Chinese medicine market (Chang et al. 2013). Seahorses confiscated in 2017 in South Africa appear to be *H. kuda*, which are commonly found in Mozambican waters and are known to be captured for the dried seahorse trade by local communities. It is thus likely that seahorse and other syngnathid exports from South Africa originate instead from neighbouring countries, such as Mozambique, although seahorses are a protected species in that country as well. CITES as well as the IUCN Red List are used to inform the setting of the protection status of species in many countries and in Mozambique, all seahorse species are protected because they are listed under CITES.

In addition to legislation and global agreements, regulated activities can be used as a locally significant conservation tool. For example, to prevent adverse impacts on seagrass habitats in the Knysna estuary, the use of a shovel or rake to dig for bait is not permitted (Claassens et al. 2020), although these activities are still done illegally, highlighting the difficulty in enforcing regulations. Utilisation of coastal and estuarine areas can be regulated through zonation or community agreements. For example, fishing is not allowed on Sundays in Vilankulo, Mozambique (Louw Claassens unpublished data).

Marine protected areas and community conservation

Protected areas are one of the most effective ways to protect species and habitats (Halpern 2003), and marine protected areas (MPAs) are used globally to protect marine ecosystems and resources

(Kelleher & Kenchington 1992). According to the Protected Planet database (UNEP-WCMC 2021), only 12.3% of African marine and coastal areas are formally protected (UNEP-WCMC 2021). South Africa increased the total area within MPAs in 2019, with the addition of 20 new sites, which increased the extent of marine protected areas to 5% of its territorial waters (https://www.marine-protectedareas.org.za/) (Sink 2016). This network includes 17 offshore and deep-sea MPAs and 23 coastal MPAs. The coverage of MPAs for many other African countries is, however, very little, with some countries such as Angola, Benin, Liberia and Somalia having no MPAs and 14 other countries with less than 1% coverage (UNEP-WCMC, accessed 18 February 2021). The Seychelles, in contrast, has 32.8% MPA coverage, and Gabon 28.8% (UNEP-WCMC 2021). Successful protection is, however, not guaranteed with protected area demarcation. For example, despite being part of the Garden Route National Park and a protected area, the environmental health of the Knysna estuary in South Africa is deteriorating (Claassens et al. 2020). The level of protection within MPAs also varies, and not many MPAs are fully protected from extractive activities, which has been found to limit the effectiveness of an MPA (Edgar et al. 2014). In addition, consultation with and cooperation from local communities is integral in the development and implementation of MPAs (Burgoyne et al. 2017). In particular, adverse impacts on local livelihoods from MPA development should be avoided and benefits from protection should be experienced by all stakeholders (Levine 2006, Sunde & Isaacs 2008, Burgoyne et al. 2017).

Tourism

The charismatic nature of syngnathids makes them effective tourist attractions (Ternes et al. 2016, Giglio et al. 2019), which can generate significant revenue (De Brauwer et al. 2017). In some instances, seahorse tourism is being used as an alternative income generator to seahorse fishing and poaching (Ternes et al. 2016). In an attempt to deter seahorse poaching in Vilankulo, Mozambique, a seahorse tourism initiative was developed by a local NGO and community members (ParCo 2021). Through this initiative, former seahorse poachers turned seahorse tour guides take tourists on seahorse tours on a traditional boat (dhow). The programme is managed by the community fishing council, and funds generated are shared within the community (Louw Claassens unpublished data). Some organisations also use voluntourism, a form of tourism in which tourists participate in voluntary work, to promote the conservation of seahorses and conduct ongoing monitoring (Goffredo et al. 2004, Roques et al. 2018). Tourism activities face various risks, the most recent being the COVID-19 pandemic, which resulted in a significant reduction in tourism globally. It is thus important to develop robust conservation programmes that can withstand such unforeseen events.

It is, however, also important to limit adverse impacts from tourist activities, such as habitat damage or disturbance of seahorses (Giglio et al. 2019). For example, tour operators in Brazil collect *Hippocampus reidi* in glass containers for tourists to observe (Ternes et al. 2016), which can result in increased stress to the animals and adverse impacts to populations. The key aspect to prevent negative effects through tourism activities is to avoid any direct contact with the animal (De Brauwer et al. 2019, Giglio et al. 2019). With the discovery of *H. nalu* in Sodwana Bay (Short et al. 2020), the first pygmy seahorse to be found in Africa, an increase in interest from scuba divers can be expected and it will be important for local dive operators to implement sustainable practices such as a code of conduct for diving with pygmy seahorses (Smith 2021).

Catchment management and sustainable development

Good management of river catchments is an important requirement for healthy coastal and estuarine environments. In particular, effective stormwater management is needed to prevent high sediment loads and polluted run-off entering coastal areas. Wastewater is commonly discharged into coastal and estuarine environments, and this has necessitated the development of water quality standards for discharged effluent (Beher et al. 2016). Compliance with these standards is, however, lacking in many areas (Claassens et al. 2020). Connectivity across rivers and between rivers and the coastal environment is important for animal movement. In instances where connectivity has been compromised, fish ladders are used to allow for fish movement (Weerts et al. 2014), although the usefulness of such remediation for syngnathids is unknown. The reduction or loss of freshwater inflow into estuaries owing to abstraction and damming upstream can be remediated by scheduled freshwater releases from dams and minimum flow requirements (Van Niekerk et al. 2019b). In South Africa, provision has been made for an ecological reserve, which refers to the quantity of freshwater needed to sustain the environment (Adams et al. 2016).

Sustainable development is another important conservation tool that can be used to limit habitat loss and alteration within coastal environments. In South Africa, the National Environmental Management: Integrated Coastal Management Act 24 of 2008 regulates all urban and industrial development along the coast. Specifically, this act aims to: "ensure that development and the use of natural resources within the coastal zone is socially and economically justifiable and ecologically sustainable". Through this Act, a development setback line must be set by all coastal municipalities with the objective of preventing development encroaching on sensitive coastal ecosystems as well as to protect communities from risks such as flooding and shoreline erosion (Desportes & Colenbrander 2016). Despite this regulation, development continues almost randomly along shorelines, with piecemeal and unplanned management intervention resulting in wide-scale habitat fragmentation (Celliers et al. 2015, Jewitt et al. 2015).

Education

Effective education and outreach are important conservation tools and have become integral to achieving effective conservation. Citizen science is one approach, used to educate and enhance community conservation engagement and conservation (Kelly et al. 2020), and has also been used to promote syngnathid conservation globally. Novel technologies, such as facial recognition, are being used to gather data on seadragons in Australia as part of SeadragonSearch (2021). iSeahorse (Project Seahorse 2021) is a global citizen science programme which collates seahorse observations. Citizen science initiatives can be effective in assessing species distributions, changes in population abundance and habitat quality. According to a recent review of citizen science in marine conservation (Kelly et al. 2020), citizen science programmes in Africa are lacking and there is a need to develop and expand such networks both as a means to increase conservation engagement of local communities and to achieve effective species conservation. In addition, habitats such as seagrass meadows and mangrove forests, key habitats for syngnathids in Africa, are also underrepresented in citizen science programmes (Earp & Liconti 2020) and there is scope to develop additional programmes in these habitats. It is important to develop locally significant educational resources and outreach programmes, to involve local communities and to nurture local custodianship. For example, species-specific educational resources are available for the Knysna seahorse (IUCN SSC Seahorse, Pipefish and Seadragon Specialist Group 2021), and local communities in Vilankulo, Mozambique, are part of ongoing education initiatives about seahorses found along their coast (ParCo 2021).

Research priorities, conservation opportunities and conclusions

This synthesis of available information on African syngnathids provides key insights into future research, management and conservation needs for this group in Africa. Based on the gaps identified in this review, we outline the most pertinent syngnathid research priorities.

1. There is a dearth of species-specific ecological and basic biological data for most African syngnathids, and future focus should be placed on those species listed as Data Deficient on the IUCN Red List as well as those that have not yet been assessed. For example, data on reproduction, growth, movement, habitat use and other biological aspects are needed. There is a need to develop regionally and locally significant ecological research for African syngnathids that can be used to guide conservation efforts predominantly at a local level as well as contributing to conservation initiatives at national, regional and international levels.
2. Owing to the limited focus on syngnathid diversity research, it is important to investigate and confirm syngnathid species diversity across Africa. Specifically, synonymised species, such as *Hippocampus borboniensis*, should be reassessed. New research approaches such as environmental DNA and population genomics should be incorporated into future research. It is also important to develop targeted syngnathid research to ensure that survey approaches are suitable to detect these cryptic fishes. A concerted effort should be taken to find 'lost species' such as *Bulbonaricus brucei* and *Campichthys nanus* (https://www.inaturalist.org/posts/16539-lost-species). It was as recent as 2018 that *Hippocampus nalu*, the first pygmy seahorse to be found in Africa, was discovered in South Africa's most popular dive location. This discovery highlights the potential of new species discovery in Africa, even in areas that are well known.
3. The conservation of syngnathids in Africa should be highlighted and prioritized through the incorporation of syngnathid protection in national and regional legislation, regulations and policies. To aid in conservation efforts of threatened habitats such as mangroves, estuaries, seagrass and coral reefs, the use of syngnathids as 'flagship' species should be developed further, and locally significant education and outreach initiatives should be prioritized, working with citizen scientists, local dive operators and divers, and in-country partners and fishers. Endemic, threatened and range-restricted species should receive specific focus. For example, the Knysna estuary has been identified as the most important system for the long-term conservation of the endangered seahorse *Hippocampus capensis* (Mkare et al. 2017) and the successful protection of this estuary and seahorse habitats should be prioritized (Claassens et al. 2020). The tourism value of seahorses and other syngnathids should be investigated further, and ethical and sustainable tourism practices should be developed and become a requirement for any future syngnathid tourism initiatives.
4. The prevention of unsustainable fishing and poaching of syngnathids should be prioritized, and focus should be placed on compliance with CITES regulations regarding seahorse trade (and improved reporting), as well as assessing the extent of syngnathid exploitation across Africa. Management and enforcement agencies should be enabled to identify syngnathids correctly when exported or confiscated, as well as be able to determine the likely origin. This can be done by providing relevant and locally significant resources to these agencies and making use of genetic tools to verify species. Aquaculture can be a sustainable alternative source to wild-caught syngnathids, and research on the efficacy and value of syngnathid aquaculture in Africa is required.
5. Successful syngnathid research and conservation in Africa will require capacity development and training. To ensure that conservation actions are sustainable, Africa will need to develop its own in-country syngnathid experts. This will require support from global syngnathid experts, and the development of research and conservation collaborations with a focus on training and capacity development of local partners. Training should include different research fields that range from syngnathid taxonomy to trade.

Concluding remarks

This review provides the first synthesis of information for syngnathids in sub-Saharan Africa and adjacent Indian Ocean islands. Available information on syngnathids in this region are limited to a handful of species with a distinct geographical bias to South Africa. Most of the available information on this group originates from *ad hoc* and general coastal research, which limits species-specific information on ecology and conservation. In addition, piecemeal research limits the comparability of data and the application of findings.

The comprehensive literature search provides a summary of current knowledge on syngnathids in sub-Saharan Africa that can be used by researchers, managers and conservationists to assist with decision-making. The identified research priorities and conservation opportunities align future syngnathid research and conservation towards the common goal of conserving this unique group of flagship fishes and their aquatic habitats.

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