Habitat and behavioural associations of *Aipysurus* group sea snakes in Western Australia

Interim report to Marine Species Conservation, Department of the Environment, Commonwealth of Australia.

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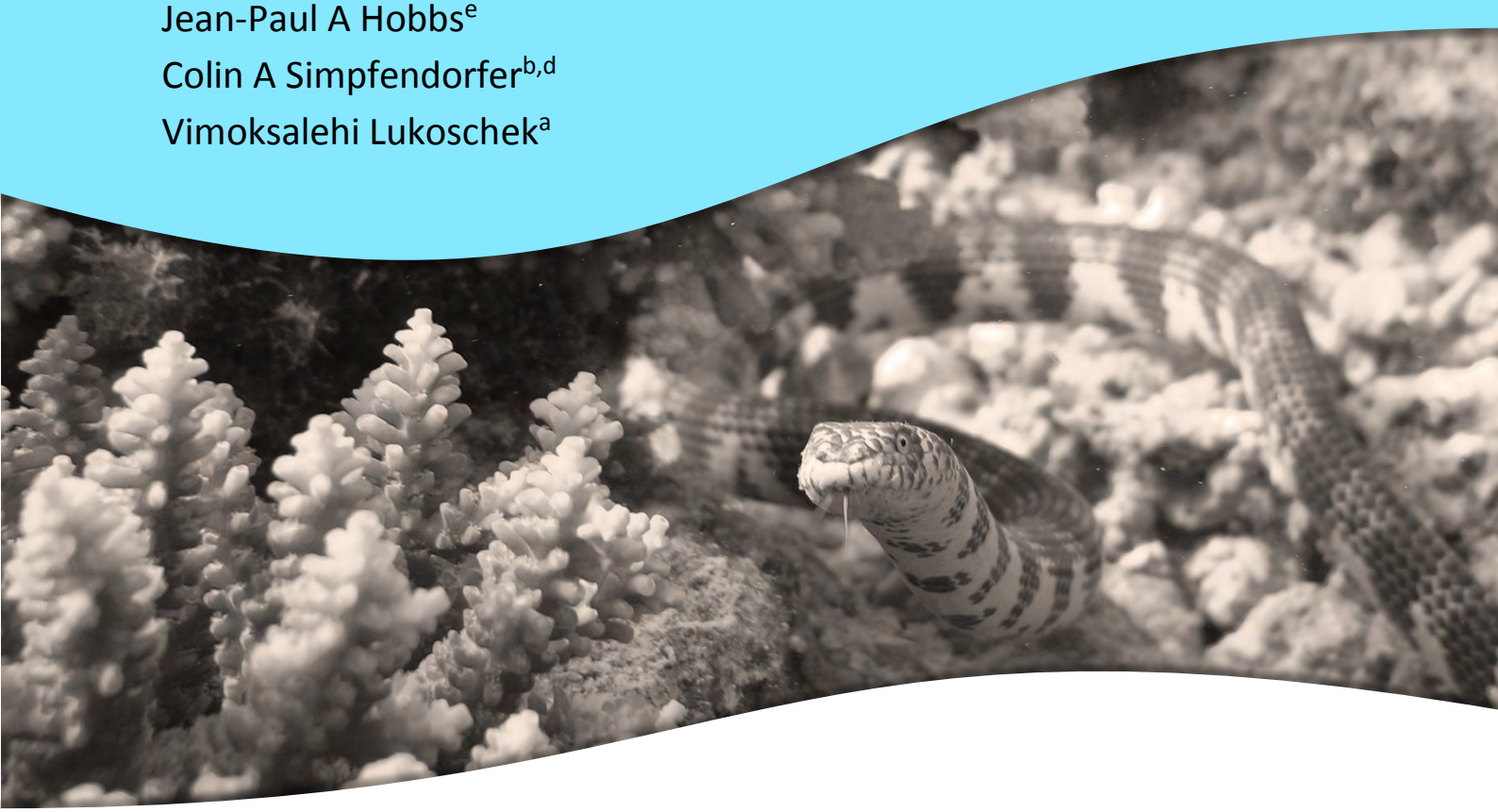

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Cover Image: *Aipysurus duboisii* foraging amongst scleractinian coral and coral rubble at Scott Reef. **Current page image:** Lead study author Blanche D'Anastasi aboard AIMS RV Solander tender releasing *Aipysurus laevis*, the Olive sea snake, at Scott Reef. Image courtesy of Graeme Petrie. **Back cover Image:** *Aipysurus pooleorum* resting under Denham Jetty, Shark Bay, at dusk.

Executive Summary

Western Australia is a biodiversity hotspot for true sea snakes, with 22 of the ~70 species found globally. Little is known about the conservation status of sea snakes compared with other marine vertebrates (e.g. fish, mammals, and turtles) and major knowledge gaps prohibit informed status assessments. For example the distribution, habitat use and connectivity of *Aipysurus* group sea snakes in coastal Western Australia (WA), including five WA endemics, remains chronically understudied.

Serious and unexplained population declines have occurred in Australian marine reserves in WA, providing incentive to address key knowledge gaps. Our aim was to conduct surveys in WA to clarify the distribution and habitat use of sea snakes from the genus *Aipysurus*, including small-range endemics listed as Critically Endangered (CR) (IUCN Red List Criteria and the *Environment Conservation and Biodiversity (EPBC)* Act).

Our study documented 15 of WA's 22 sea snake species. Our data extends the known distributions of species including *A. apraefrontalis* and *A. foliosquama* and extends the known habitats used by four species (*A. apraefrontalis, A. foliosquama, A. pooleorum,* and *A. tenuis*). Key findings include:

- Coastal breeding populations of two CR small range endemic species, *A. apraefrontalis* and *A. foliosquama*, thought to be restricted to the offshore Ashmore Reef complex, were confirmed, extending the known ranges for both species to include coastal WA locations:
    - *Aipysurus foliosquama* - Shark Bay.
    - *Aipysurus apraefrontalis* - Ningaloo Reef and in Exmouth Gulf.

- *A. foliosquama*, thought to be a tropical coral reef specialist, was found in a sub-tropical coastal embayment (Shark Bay), associated with seagrass, sand over limestone, silt and sponges.

- The habitat use of two data deficient small range WA endemics, *Aipysurus pooleorum* and *Aipysurus tenuis*, was extended as follows:
    - *Aipysurus pooleorum* uses limestone reef, seagrass, rocky rubble, marine pavement, stromatolite, macroalgae, sand and man-made jetty and rock wall habitat.
    - *Aipysurus tenuis* uses sandy bottom, seagrass, shallow coastal rock platform, rocky reef, man-made jetty and rock wall habitats.

Key research recommendations include conducting further research on the distribution, genetic connectivity, abundance, habitat use, demography and life history of sea snake populations; the effects of trawling, and extreme weather events on sea snakes; and an assessment of the cumulative impacts of threatening processes. Future research should focus on the newly discovered populations of CR sea snake species (A. *foliosquama* and *A. apraefrontalis*) and poorly studied species (*A. pooleorum* and *A. tenuis*).

Key management actions include ensuring that future developments that may/will have a significant impact on populations of sea snakes listed as CR under the EPBC Act are referred to the Commonwealth Environment Minister to determine whether the proposal is a controlled action. The Minister's determinations should be informed by a cumulative impacts assessment of threatening processes throughout the distribution of each species. Finally, a prioritised research and conservation strategy for WA sea snakes should be developed and funded to facilitate an informed management approach to sea snakes. Data will be combined in the longer term to improve capacity to assess the conservation status of sea snakes.

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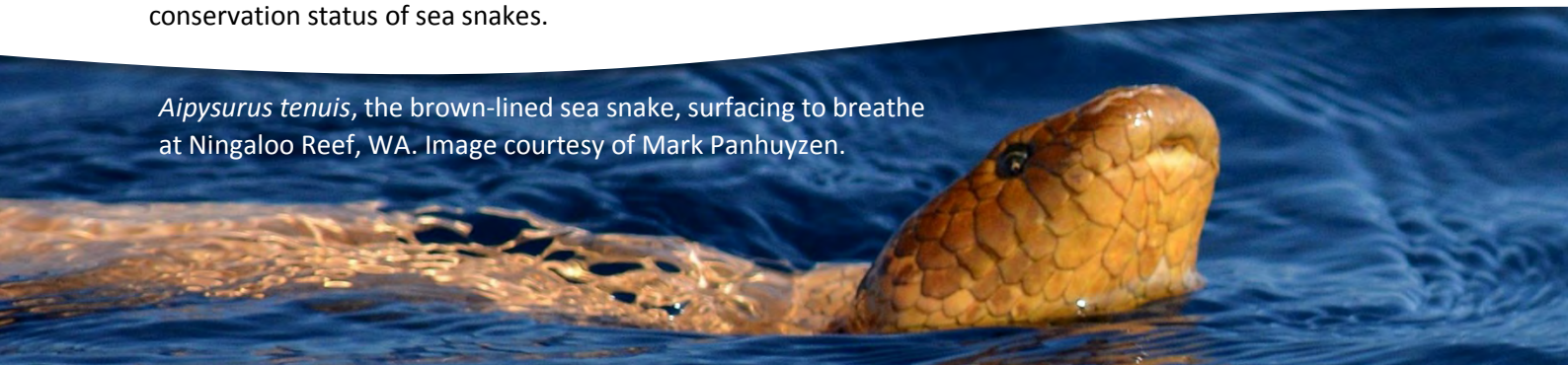
Introduction

True sea snakes (Family Elapidae: Subfamily Hydrophiinae) are predatory, live bearing, fully marine reptiles that form the most biodiverse group of marine reptiles on earth. There are ~70 species in two evolutionary lineages, the typically reef-associated *Aipysurus* group (11 species) and the typically inter-reefal *Hydrophis* group (>50 species) (Lukoschek and Keogh, 2006). True sea snakes inhabit shallow-water tropical and sub-tropical habitats throughout the Indo-West Pacific (Lukoschek et al., 2013a). Australia is a biodiversity hotspot for true sea snakes, with ~35 species (including 11 endemic species) representing both groups. WA hosts 22 species, including nine *Aipysurus* group species, of which five are WA endemics, making it a global hotspot of sea snake endemism.

Despite being large, charismatic and easily observable, little is known about the conservation status of sea snakes compared with other marine vertebrates (e.g. fish, mammals, and turtles) and major knowledge gaps prohibit informed status assessments. For example, the recent description of three new species from northern Australia (Sanders et al., 2014, Ukuwela et al., 2013, Ukuwela et al., 2012) highlights the lack of basic taxonomic knowledge, which is needed to underpin status assessments. Global IUCN Red List assessments of extinction risk of 69 true sea snake species in 2009 classified 34% as Data Deficient (DD), highlighting the need for more knowledge about this group (Elfes et al., 2013). Four species (9%) were classified as threatened with extinction (Critically Endangered, CR; or Endangered, EN). Three of these, *Aipysurus foliosquama* (CR), *A. apraefrontalis* (CR) and *A. fuscus* (EN), are Australian endemics, previously thought to be restricted to a limited number of offshore reefs in the Timor Sea (Fig. 1). The assessment of high extinction risk for these three species was primarily a consequence of the precipitous decline and largely unexplained extirpation of sea snakes at Ashmore Reef between the mid-1990s and 2010 (Lukoschek et al., 2013a, Guinea, 2007). Indeed, *A. foliosquama* and *A. apraefrontalis,* thought to be restricted to Ashmore and neighbouring Hibernia Reef (Lukoschek et al., 2013a), have not been recorded from either reef since 1998 and were listed as CR under Red List Criteria in 2010 and under *Australia's Commonwealth Environment Protection and Biodiversity Conservation (EPBC)* Act (1999) in 2011. Moreover sea snake species in Australian waters are protected as Listed Marine Species under the *EPBC Act*, in recognition of their significant contribution to biodiversity and the general status of data deficiency for the group.

Whilst the sea snake assemblage in the Ashmore Reef complex has been relatively well studied (Guinea, 2013, Lukoschek et al., 2013a), the assemblage in coastal WA remains chronically understudied. The aim of this study was to conduct surveys in coastal and offshore WA locations to clarify the distribution, habitat and behavioural associations of *Aipysurus* sea snakes, focusing on *Aipysurus* group WA endemics. Tissue samples were obtained from captured sea snakes to genetically confirm the morphological species identity, using mitochondrial DNA (ND4 and ATPase). Future work will examine genomic and genetic connectivity, taxonomy and species distributions of the WA sea snake assemblage using mitochondrial DNA sequences and nuclear single nucleotide polymorphisms (SNPs) (~2000 high quality loci), the results of which will be presented in a follow-up report. Data will be combined in the longer term to improve capacity to assess the conservation status of sea snakes.



Aipysurus tenuis, the brown-lined sea snake, surfacing to breathe at Ningaloo Reef, WA. Image courtesy of Mark Panhuyzen.

Methods

A range of methods were used to record sea snakes during > 200 hours of field surveys in Shark Bay, Ningaloo Reef, Exmouth Gulf, and the Thevenard Region in coastal WA, and the Scott Reef Complex in the Timor Sea (Fig. 1 and Table 1). In-water surveys were conducted on SCUBA (>30 hr), snorkel (>30 hr), and manta tow (>25 hr) (Table 1). Survey effort amongst habitat types varied significantly and habitats where sea snakes were more likely to occur were targeted for the purpose of catching snakes (snorkel surveys) and collecting tissues for genetic analyses. Opportunistic sightings (e.g. travelling between study sites) were recorded during fieldwork, and during low tide walks (~120 min). In addition, geo-referenced, *in situ* photo-verified sightings were obtained via collaborations with WA Department of Fisheries (WA DoF) and WA Department of Parks & Wildlife (WA DPaW). Public reports to the Australian Sea Snakes sightings program via Facebook also provided an important source of *in situ* photo-verified sightings (see Australian Sea Snakes sighting program) (Table 1). Major study sites included Shark Bay and the Scott Reef Complex.

Major Study Site Descriptions

Shark Bay

Shark Bay is a semi-enclosed, sub-tropical embayment on the central coast of WA. Its waters range from oceanic salinity to hypersaline. The predominant habitat in Shark Bay is seagrass meadows dominated by a large (>1 m) canopy-forming seagrass *Amphibolus antarctica* (Berry et al., 1990) and other seagrasses such as *Posidonia australis* and *Halodule univervis*. The majority of Shark Bay contains little coral cover. There are coral covered platforms at 1-2m depth around Dirk Hartog, Dorre and Bernier Islands, and patchy coral colonies found in deeper waters in outer Shark Bay (Berry et al., 1990).Other habitats include sand over hard substrate, sand/silt banks, carbonate sills, sponge and mollusc beds, microbial communities (microbial mats and Stromatolites) and extensive beds of mobile seagrass wrack (Berry et al., 1990).

Shark Bay experienced an unprecedented increase in sea surface temperature in 2010/2011 of 2-4°C for ~10 weeks, resulting in a catastrophic (>90%) loss of *A. antarctica* in a number of regions of Shark Bay's Western and Eastern Gulfs (Thomson et al., 2015). *A. antarctica* has been documented as a critical habitat for *Hydrophis* group sea snakes, providing shelter and foraging habitat (Kerford et al., 2008, Wirsing and Heithaus, 2009).

Denham jetty

Denham jetty is an inshore, metahaline boat harbour in the Western Gulf of Shark Bay consisting of three small wooden jetties. There is a large, mobile expanse of seagrass wrack, which typically consists of a mass of torn off *Posidonia australis* leaf straps that can stretch for 10s of metres. The seagrass wrack varies in thickness from a few centimetres to ~1 m deep and is moved around by waves, tides and currents. Fish, sharks, rays, turtles and dugongs are regularly sighted at this study site.

Jetty structures are used extensively for recreational fishing activities and boat mooring. Fishers regularly reported catching sea snakes on hand lines. Since the completion of our study, major construction works have occurred at Denham Jetty, including the deconstruction of one wooden jetty and the construction of a new jetty and boating facilities.

Hamelin Pool

Hamelin Pool is a highly protected, hypersaline embayment, enclosed by a carbonate (Faure) sill. Entry to the pool and its surrounding coastline is strictly prohibited without WA DPaW approval. Hamelin Pool

contains globally significant stromatolite reefs and microbial mats. It also contains seagrass (*A. antartica*) near the Faure sill, extensive sand and shell beds, pavement, tabular pavement, stromatolites, microbial mats and macroalgae. Freshwater upwellings also occur within the marine environment of Hamelin Pool. Fish were common in the study site. Rare sightings of sea turtles, dolphins, dugongs and whales occurred. Sharks and rays were not sighted during sea snake surveys, with the exception of one shovel nosed ray sighted near the Faure sill.

Scott Reef Complex

The Scott Reef Complex is a series of three reefs in the Timor Sea, situated on the Scott Plateau, rising up from abyssal plains (up to 2000 m deep) (Collins et al., 2011). Fish, turtles and dolphins were regularly sighted, however sharks were rare.

North and South Scott Reefs

North Scott Reef is a pear shaped reef characterized by a deep lagoon, submerged sand and emergent reef, with two narrow channels and large scattered boulders in some areas (Collins et al., 2011). South Scott Reef is crescent shaped, open to the north and is 27 km wide (Collins et al., 2011). It is characterized by submerged sand, back reef, emergent reef habitats, with reef flats up to 6 km wide, sand flats, seagrass and rubble beds (Collins et al., 2011). Sandy Islet, near the west hook of Scott Reef, is a small unvegetated sand cay surrounded by coral reef (Collins et al., 2011).

Seringapatam Reef

Seringapatam Reef is a small circular reef approximately 9.4 km in diameter that lies ~23 km north of Scott Reef, with a narrow rim, deep lagoon, a steep reef slope, emergent areas and scattered boulders in some areas (Berry, 1986). All three reefs are listed as National Natural Heritage under the *EPBC Act* (Francis, 2009).

Species identification

Sea snakes were identified using morphological characteristics (shape and number of cephalic scales, head/body shape and colour) following Storr et al. (1986) and Cogger (2000). When possible, snakes were captured and a small tissue sample was collected non-destructively and aseptically from the tail for genetic analyses. Morphological identifications were confirmed using molecular identification (mitochondrial markers ND4 and ATPase) for all available specimens.

Species distributions

Species distributions were estimated using the results of field surveys and by collating information and records from the following sources: Atlas of Living Australia (ALA, 2015); IUCN Red List assessments (IUCN, 2015); Species Profile and Threats Database (DoE, 2015b) and literature records. Georeferenced records were mapped in ARC GIS 10.2. Literature records without accurate location data are included in text descriptions, but not on maps to avoid the creation of inaccurate data points.

Habitat and behavioural associations

Habitat and behavioural associations were recorded during in-water surveys for five species (*A. pooleorum*, *A. laevis*, *A. duboisii, A. fuscus*, and *Emydocephalus annulatus*) using point sampling. Specifically, for each snake the predominant habitat where it was located and the snake's behavior was recorded at the first instance the snake was observed. Habitat and behavioural observations were also recorded from georeferenced, *in situ* photographs. Habitats were characterized based on general substrate composition (Fig. 2). Three basic behaviours were recorded: travelling (moving across a particular habitat type); foraging (putting head into crevices or structures); resting (motionless, either concealed, out in the open, or with part of the body, such as the tail, exposed). Snakes observed at the surface, or travelling to the surface,

were excluded as this was not informative for assessing habitat use. Two sites in Shark Bay (Hamelin Pool and Denham Jetty) had a high numbers of observations and the data are presented for individual sites. Habitat observations for the Scott Reef complex have been aggregated, due to the low numbers of observations at individual reefs (although this is not reflective of snake abundance).

In addition, habitat data for *A. foliosquama* (n = 4) from Shark Bay were obtained from WA DPaW's Remote Sensing and Spatial Analysis branch (courtesy Kathy Murray) and included in our results and species accounts. Habitat associations for species and locations with few observations and other records are described in the text.

Trawl surveys

Sea snakes were recorded during scientific demersal prawn trawl surveys conducted by WA DoF in Shark Bay (>10 hrs) during the months of August and November, 2014 and February, March, April, May and June in 2015; and Exmouth Gulf (>12.5hrs) during the months of August, 2014 and March, April and May, 2015. The percentage represented by each species of the total number of sea snakes recorded was calculated using aggregated counts for each region, from all scientific surveys conducted by WA DoF using the formula:

Percentage of sea snakes represented by each species = [sea snake species count/total sea snake count] x 100

Two sea snakes which were not identified to species level have been excluded from analyses. We emphasize that an estimate of sampling effort was not quantified, therefore percentages are not scaled for effort.

Aipysurus pooleorum, the Shark Bay sea snake, foraging at dusk in Shark Bay, WA.

Results

Sea snake diversity

A total of 330 snakes were recorded in this study across all survey types (Table 1, Fig. 1). Fifteen of the 22 species of true sea snakes known from WA were recorded (n=330) comprising nine species from the genus *Aipysurus* (*A. apraefrontalis* (n=7)*, A. duboisii* (n=12)*, A. foliosquama* (n=19)*, A. fuscus* (n=5)*, A. laevis* (n=42)*, A. mosaicus* (n=1)*, A. pooleorum* (n=64)*, A. tenuis* (n=11)*)* plus a ninth species from the *Aipysurus* group (*E. annulatus* (n=13)); five species from the genus *Hydrophis* (*H. coggeri* (n=1)*, H. elegans* (n=33)*, H. major* (n=109)and *H. platurus* (n=1), *H. stokesii* (n=3)*,*); and *Hydrelaps darwiniensis* (n=2), one of three so-called 'primitive' species. Seven snakes were classified as unknown.

Sea snake distributions

Aipysurus apraefrontalis, *A. foliosquama* and *Hydrophis major* were documented in locations outside their previously known ranges. In each case, the new locations recorded in this study extended the species' distribution further south along the WA coastline as follows:

The range of *A. apraefrontalis* is extended to include Ningaloo Reef and Exmouth Gulf, in coastal WA (latitudes -22.08 to -22.24) (Fig. 3A). Our records are the first on Ningaloo Reef and represent a 1100 km southward extension of its known range (1500 km minimum seaward distance) from the Ashmore Reef Complex (see D'Anastasi et al., 2016).

The range of *A. foliosquama* is extended to include Shark Bay, in coastal WA (latitudes -20.90 to -26.35) (Fig. 3B), which is 450 km southward of any previous sighting (500 km minimum sea ward distance) and 1400 km southward (1700 km minimum seaward distance) of the Ashmore Reef Complex, which was thought to be the only location maintaining breeding populations (see D'Anastasi et al., 2016).

A single *Hydrophis major* stranded in Albany, on the south coast of WA, and subsequently died. This individual may represent a vagrant animal or a range extension 800 km southward of Kalbarri (1000km minimum seaward distance).

All other species encountered were documented within their existing known ranges or range limits (Fig 3. D-N) based on mapped, georeferenced records and general location data from the literature (see Species accounts for further details on *Aipysurus* group snakes; *Hydrophis* group snakes not presented in Species accounts).

Habitats and behavioural associations

Aipysurus apraefrontalis

Three *A. apraefrontalis* were observed in WA DoF Scientific demersal prawn trawl bycatch surveys in Exmouth Gulf (Table 1, Fig. 3A) at depths of 10-15 m. Coarse habitat data obtained from Lyne et al. (2006) indicates the snakes occurred on sandy bottom habitats with pavement and occasional coral heads. Two courting *A. apraefrontalis* were photographed offshore from Turquoise Bay, on the seaward side of Ningaloo Reef by WA DPaW Wildlife Officer Grant Griffin during a routine boat patrol. *A. apraefrontalis* was not observed during in-water surveys.

Aipysurus foliosquama

A. foliosquama (n = 16) were recorded exclusively in WA DoF Scientific demersal prawn trawl bycatch surveys, from Geographe Channel and the Western Gulf of Shark Bay in waters ranging from 10-19 m deep and Henri Freycinet Estuary (Table 1, Fig. 3C). Habitat data was available for four of the *A. foliosquama*

recorded in our study. Three of the *A. foliosquama* were collected from outer Shark Bay, east of Bernier and Dorre Islands, in seagrass habitats, within 10 km of fringing reef habitat (see Berry et al., 1990), in depths of 15-19 m. A fourth animal was collected from the metahaline waters of the southern-most extent of the Western Gulf of Shark Bay, in Henri Freycinet Harbour, amongst habitat containing sparse seagrass, sand over limestone, silt and sponges, at a depth of 10 m. Habitat data for the remaining 12 georeferenced trawl by-catch records of *A. foliosquama* are being obtained through WA DPaW's Remote Sensing and Spatial Analysis branch (courtesy Kathy Murray). These data will be available in mid-2016.

Aipysurus pooleorum

A. pooleorum were recorded during in water surveys (n=57) and WA DoF Scientific demersal prawn trawl bycatch surveys and (n=7) from outer Shark Bay, Useless Loop, the Western and Eastern Gulfs and Hamelin Pool (Table 1, Fig. 3F).

Denham Jetty, Shark Bay

At Denham Jetty, *A. pooleorum* (n =19) were observed using seagrass wrack (42 % of observations), sand (16 %), jetty (16 %), rock wall (11 %), seagrass wrack-rock (5 %), rocky rubble (5 %) and wooden debris (5 %) (Figs. 2(a-c,e,f), 4). *A. pooleorum* used seagrass wrack extensively for foraging (11%), travelling (above and below the wrack - 21%) and resting (11%). Snakes also used man-made rock wall, seagrass wrack and rock for foraging; jetty, sand and rock wall for travelling; and wooden debris and rocky rubble for resting (Fig. 5). A small (54 cm) *A. pooleorum* was found stranded on the shore, trapped in beached seagrass wrack.

Hamelin Pool, Shark Bay

A. pooleorum in Hamelin Pool (n = 27) were observed on tabular pavement-sand edge (59 % of observations), stromatolite-sand edge (7 %), stromatolite-macroalgae-sand edge (7 %), sand (7 %), pavement edge (7 %), stromatolite (4 %), stromatolite-macroalgae (4%) and tabular pavement-macroalgae-sand edge (4 %) (Figs. 2(e,m,o,p-s), 4). Tabular pavement-sand edge was the main *A. pooleorum* foraging habitat (59 %); sand was the main habitat over which sea snakes travelled (7 %); and snakes were observed resting under pavement edge (4 %) (Fig. 5).

Monkey Mia, Shark Bay

A. pooleorum in the Monkey Mia region (n = 6) were observed using seagrass beds of *A. antartica*, *P. australis* and *H. uninervis* (Fig. 2(g-i)). *A. pooleorum* were also observed travelling over sand in nearshore habitats.

There appears to have an overall decline in sea snake abundance in Monkey Mia region - an area that experienced up to 90% losses in seagrass cover after a 2010 heat wave (see Methods section and Thomson et al., 2015). Anecdotal evidence from the Shark Bay Ecosystem Research Project (Florida International University) indicates that the number encounters between sea snakes and researchers conducting boat based research declined from several snakes per day (10 hrs) to encountering approximately one snake every few days (pers. comm. J. A. Thompson, 2014).

Useless Loop, Shark Bay

One *A. pooleorum* was observed at Useless Loop, in the outer Western Gulf of Shark Bay, where it was foraging near a rock wall, on rocks surrounded by sand, adjacent to a *P. australis* bed.

Aipysurus tenuis

Eleven *A. tenuis* were observed in total, from trawl bycatch (n = 4), georeferenced photos from WA DPaW staff and the Australian Sea Snakes sighting program (n = 4), and from boats whilst travelling between study sites (n = 3) (Table 1, Fig. 3G). Habitat information from georeferenced, *in situ* photos show that A. *tenuis* uses sandy bottom habitats near large, hard coral reef/rock structures (n = 3) (Fig. 2y), shallow (<1cm deep) water on rocky platform (inshore and adjacent to Ningaloo Reef) (Fig. 2z), and shallow-water jetty with

sand, rocky reef and an artificial rock wall in Exmouth Gulf (Table 1, Figure 2(c,e,zz)). A single *A. tenuis* washed up in the Lowendall Islands, on Veranus Island in the Pilbara Region, which hosts an oil and gas processing facility. Habitat data is not available for this snake as it was stranded alive. Apache Energy staff reported the snake, which subsequently died, and submitted it to WA DPaW's Karratha office for use in this study. The specimen has been sampled and lodged with the Western Australian Museum (accession number not available yet).

Other *Aipysurus* group species

In the Scott Reef complex, *A. laevis* (n = 15), *A. duboisii* (n = 5), *A. fuscus* (n = 4), and *E. annulatus* (n = 3) used coral reef, sand and coral rubble habitats (Figs. 2(t-x), 5). *A. laevis* was most commonly observed over coral reef (60 % of observations), which it used for travelling and foraging, whilst coral reef-coral rubble-sand edges were most commonly used for resting (Figs. 2(t,x), 5, 6). *A. duboisii* was most commonly sighted on coral rubble (60 %), which was used for foraging and travelling (resting not observed) (Figs. 2(u), 5, 6). *A. fuscus* was observed travelling, resting and foraging on coral reef-sand edge (100 %)(Figs. 2(w), 5, 6). *E. annulatus* was sighted once foraging and travelling in each of coral reef (33 %), coral reef-coral rubble-sand edge (33 %) and coral reef-coral rubble edge (33%) habitats (Figs. 2(v,x) 5, 6). A single *E. annulatus* was observed in Shark Bay near Dirk Hartog Island in sand and sparse coral habitat by WA DPaW staff.

Scientific Demersal Prawn Trawl surveys

A total of 78 sea snakes were recorded in WA DoF scientific demersal prawn trawl surveys from WA DoF in Shark Bay and Exmouth Gulf (>12.5hrs). In Shark Bay, 60 snakes were recorded comprising: H. *elegans* (55 %), *A. foliosquama* (23 %), *A. pooleorum* (12 %), *H. major* (8 %) and unidentified (due to poor image quality) *Aipysurus* spp. (2 %) (Fig. 7). In Exmouth Gulf, 18 sea snakes were recorded. *A. apraefrontalis* was the most commonly encountered species (31 %), followed by *A. tenuis* (25 %), *A. duboisii* (13 %), *H. major* (13 %), *H. elegans* (6 %), *H. stokesii* (6 %) and *A. mosaicus* (6 %) (Fig. 8).

Aipysurus apraefrontalis, short nosed sea snakes, courting at Ningaloo Reef. Image courtesy of Grant Griffin and WA Department of Parks and Wildlife.

Discussion

Species accounts: distributions, habitats and behaviours

Aipysurus apraefrontalis - Short-nosed sea snake

Status: Listed Marine Species (EPBC Act), Critically Endangered (EPBC and IUCN Red List)

A. apraefrontalis, is an endemic, previously recognised only the Ashmore Reef Complex, and thought extinct after it disappeared from the Ashmore and Hibernia Reefs (Lukoschek et al., 2010c). In our study, *A. apraefrontalis* was recorded from Ningaloo Reef (n = 2) for the first time; and in Exmouth Gulf (n = 5), from where there are four previous records between 1965 and 2004 (ALA, 2015, Kangas et al., 2007), representing a 1100 km southward extension of its known range (1500 km minimum seaward distance) from the Ashmore Reef Complex (Fig. 3A). Molecular and morphological data confirm the distinctiveness of coastal populations (D'Anastasi et al., 2016, Sanders et al., 2015). Moreover, the two *A. apraefrontalis* sighted on Ningaloo Reef were courting. Taken together, these findings provide strong support for the presence of a distinct breeding population in coastal WA. The Ningaloo Reef and Exmouth Gulf population(s) are highly significant and enable application of the recommendations outlined in the Conservation Advice for *Aipysurus apraefrontalis* (Short-nosed Sea Snake) (TSSC, 2011a).

Previous data indicates that *A. apraefrontalis* is associated with reef flats and edges, in depths up to 10 m (DoE, 2016d, McCosker, 1975, Lukoschek et al., 2010c). Our study extends the habitats used by *A. apraefrontalis* to include sandy bottom with pavement and occasional coral bommies, in up to 15 m depth.

Aipysurus duboisii - Dubois' sea snake

Status: Listed Marine Species (EPBC Act), Least Concern (IUCN Red List)

A. duboisii is known from Hervey Bay on the central east coast of Australia around northern Australia to Exmouth Gulf, WA (ALA, 2015, DoE, 2016a). Records from our study are consistent with this distribution (Fig. 3B). *A. duboisii* is known from coral reefs, sea grass beds, gorgonians, coral rubble and sand habitats (Lukoschek et al., 2010d). Our study found that *A. duboisii* primarily uses coral rubble and coral reef/sand edges for foraging and travelling.

Aipysurus foliosquama - Leaf scaled sea snake

Status: Listed Marine Species (EPBC Act), Critically Endangered (EPBC and IUCN Red List)

Aipysurus foliosquama, like *A. apraefrontalis*, was previously thought to be extinct due to its disappearance from Ashmore and Hibernia Reefs, the only locations from which it was recognised (Lukoschek et al., 2013a). Our study revealed a previously unknown population in Shark Bay (n = 16), extending their known distribution from the Ashmore Reef Complex, to include the WA coastline, 1400 km southward (1700 km minimum seaward distance) to Shark Bay (see D'Anastasi et al., 2016, Lukoschek and Guinea, 2010a) (Fig. 3C). Molecular and morphological data confirm the distinctiveness of coastal populations, strongly suggesting the occurrence of distinct breeding populations in coastal WA (D'Anastasi et al., 2016, Sanders et al., 2015). The Shark Bay population of *A. foliosquama* is highly significant and enables application of the recommendations outlined in the Conservation Advice for *Aipysurus foliosquama* (Leaf-scaled Sea Snake) (TSSC, 2011b).

A. foliosquama was previously characterised as a tropical coral reef specialist (Lukoschek and Guinea, 2010b, McCosker, 1975, Smith, 1926, DoE, 2016b). Our study indicates that *A. foliosquama* can be found in sub-tropical metahaline and hypersaline waters ranging from 10-19 m deep, in habitats including seagrass areas with sparse coral cover, sand over limestone, silt and sponges. Further data on the habitat

associations of *A. foliosquama* will become available in 2016 through collaboration with WA DPaW, which will more clearly define the *A. foliosquama* habitat associations in Shark Bay.

Aipysurus fuscus - Dusky sea snake

Status: Listed Marine Species (EPBC Act), Endangered (IUCN Red List)

Historic records indicate that *A. fuscus* has been regularly identified from both the Scott and Ashmore Reef complexes (Francis, 2006, Guinea, 2007, Guinea, 2006, Guinea and Whiting, 2005), where it is known to hybridise with *A. laevis* (Sanders et al., 2014). In our study *A. fuscus* was recorded from south Scott Reef and north Scott Reef (Fig. 1, Fig. 3D), but not at nearby Seringapatam Reef. *A. fuscus* has previously been found at Seringapatam Reef (Sanders et al., 2014, Guinea, 2013). This absence may be due to a lack of detection or a genuine absence and ongoing monitoring is required. *A. fuscus* was not recorded in coastal WA in our study, consistent with historic records. One record from Atlas of Living Australia, from the Torres Strait, cannot be verified as the sample has been destroyed (accession number R1762), but may represent misidentification *A. laevis*, which is morphologically similar.

A. fuscus is considered a reef specialist and is found on reef flats, slopes and edges in habitats containing coral, coral rubble and sand (Smith, 1926, Francis, 2006, Guinea, 2007, Lukoschek et al., 2010e, DoE, 2016c). This is consistent with our observations of *A. fuscus* near hard coral (branching Acroporids), adjacent to sand habitat, on reef edges.

Aipysurus laevis - Olive sea snake

Status: Listed Marine Species (EPBC Act), Least Concern (IUCN Red List)

A. laevis is distributed from the central east Australian coast, to the Coral Sea; to the north coast of Australia; and out to isolated reefs in the Timor Sea including the Ashmore and Scott Reef Complexes (ALA, 2015, DoE, 2016d, Lukoschek et al., 2010a), with limited genetic connectivity throughout its verified range (Lukoschek et al., 2008, Lukoschek et al., 2007b). Our published (D'Anastasi et al., 2016) and unpublished molecular data confirm *A. laevis* from the Scott Reef complex, but not coastal WA. We are aware of a single coastal WA record verified by sea snake expert M. Guinea.

The numerous unverified records of *A. laevis* in coastal WA may represent misidentifications of two closely related and morphologically similar small range WA endemics, *Aipysurus tenuis* and *A. pooleorum* (see Storr and Harold, 1990, Wilson and Swan, 2008). It remains unclear whether *A. laevis*, *A. tenuis* and *A. pooleorum* co-occur; and whether breeding populations of *A. laevis* occur in coastal WA. The uncertainty around the distribution of *A. laevis* is a major barrier to assessing the status of WA endemics *A. pooleorum* and *A. tenuis*. Additional molecular sampling is underway to evaluate the distribution of these three species and data will be available mid-2016.

A. laevis is considered a generalist species, primarily associated with coral reef and nearby sandy bottoms, and inter-reefal habitats to a lesser extent (Burns and Heatwole, 1998, Lukoschek et al., 2010b, DoE, 2016e). Our findings, that *A. laevis* was found to use dense coral reef habitat (flat, crest and slope) for travelling and foraging, is consistent with previous data.

Aipysurus pooleorum - Shark Bay sea snake

Status: Listed Marine Species (EPBC Act), unassessed (EPBC and IUCN Red List)

Historically, *A. pooleorum* has been treated as both a subspecies of the Australo-Papuan endemic *A. laevis*, and as a small range endemic species (Lukoschek et al., 2010a). Recent molecular data indicates that *A. pooleorum* is a distinct species rather than a subspecies of *A. laevis* (D'Anastasi et al., 2016), therefore, *A. pooleorum* will be treated as an endemic species in this report. Our study indicates that the main distribution of *A. pooleorum* is restricted to Shark Bay (Fig. 3F), consistent with previous data (DoE, 2015a, ALA, 2015). Shark Bay is the only location known to contain breeding populations of *A. pooleorum*.

Very little has been published on the habitat use of *A. pooleorum*. Existing information indicates that *A. pooleorum* is associated with limestone reefs and adjacent rocky and sandy habitats (DoE, 2015a). Our research extends the description of habitat used by *A. pooleorum* to include systems that contain a mixture of hard structures, marine flora and sand. At Denham Jetty in the Western Gulf, *A. pooleorum* used sand, seagrass wrack and hard structures including rock, rock wall, rocky rubble, wood debris and jetty. In Hamelin Pool, which contains globally significant stromatolite reefs, *A. pooleorum* used macroalgae, sand and hard structures including stromatolites, marine pavement and tabular marine pavement.

A. pooleorum were most often observed foraging or resting in habitats with high structural complexity that provide space for both prey and sea snakes to shelter in. This is consistent with previous hypotheses indicating that structural complexity is important for sea snakes (Lukoschek et al., 2007a, Kerford et al., 2008). For example, seagrass, the dominant canopy forming structure in Shark Bay (Thomson et al., 2015), was identified as important for *Hydrophis elegans* (Kerford et al., 2008), *Hydrophis major* (Wirsing and Heithaus, 2009) and *A. pooleorum* and *A. foliosquama* in the present study.

Aipysurus tenuis - Brown-lined or Mjöberg's sea snake

Status: Listed Marine Species (EPBC Act), data deficient (IUCN Red List)

The geographic distribution and habitat use of *A. tenuis* is extremely poorly known (Guinea et al., 2010) and is further confused by the existence of closely related and morphologically similar sister taxa, *A. pooleorum* and *A. laevis,* in WA, leading to ongoing misidentification and reduced detection. Verified historic records indicate that *A. tenuis* is reliably known from the North-western coast of Australia, from Broome to the Dampier Archipelago on the Pilbarra Coast, with vagrants found as far south as Shark Bay (Storr et al., 1986, Guinea et al., 2010, ALA, 2015, DoE, 2016f). Our data suggest that *A. tenuis* can be reliably found as far south as Ningaloo Reef and Exmouth Gulf.

Previously available habitat data indicates that *A. tenuis* occurs on sandy bottom and seagrass habitats (Guinea et al., 2010). Our study indicates that *A. tenuis* is also found in association with shallow, coastal rock platforms adjacent to reefs; and rocky reef habitat associated with man-made jetties and rock walls.

Emydocephalus annulatus – Turtle headed sea snake

Status: Listed Marine Species (EPBC Act), Least Concern (IUCN Red List)

E. annulatus has exceptionally high site fidelity (at scales of <1 km) (Lukoschek and Shine, 2012). This species has a disjunct distribution, from the central east coast of Australia, including the southern Great Barrier Reef, north to the Torres Strait, but not in adjacent waters of the Gulf of Carpentaria (ALA, 2015, Lukoschek et al., 2010f). On the north coast of Australia, *E. annulatus* occurs in van Diemens Gulf (ALA, 2015), where its range extends west to the Kimberleys, Broome, the Pilbarra Coast, Shark Bay and offshore Timor Sea reefs (ALA, 2015, Lukoschek et al., 2010f). Records from our study are consistent with this distribution.

E. annulatus is known to use coral, coral rubble, rock and sand (Minton and Heatwole, 1975, Shine et al., 2004, Lukoschek et al., 2010f, DoE, 2016g). This is consistent with our findings, in which *E. annulatus* was observed foraging along edge habitats between coral reef, coral rubble and sand.

Potential impacts on true sea snakes

With ongoing, unexplained patterns of decline in sea snakes in the Timor Sea (Lukoschek et al., 2013a) and in the Pacific Ocean (New Caledonia, Goiran and Shine, 2013, Great Barrier Reef, Lukoschek, 2007), identifying impacts on sea snakes is essential for the successful conservation of sea snakes, especially the newly discovered WA populations of Critically Endangered species. Extreme weather events and demersal trawling were identified as threats to sea snakes.

Extreme weather events

Extreme weather events, such as cyclones and marine heat waves are linked to a wide range of marine ecosystem impacts. Impacts include damage and mortality of habitat forming organisms such as coral (Moore et al., 2012, Lukoschek et al., 2013b) and seagrass (Thomson et al., 2015, Pollard and Greenway, 2013), as well as vertebrates (Caputi et al., 2014). Such events are also linked to major ecosystem shifts in tropical (Roff et al., 2015) and sub-tropical environments (Thomson et al., 2015).

Since 1970, average sea surface temperature in areas between Shark Bay and Ningaloo Reef in WA have been warming by 0.16-0.2^{o}C, per decade (BoM, 2016). Until 2010, widespread coral bleaching had not been documented in coastal WA (see Moore et al., 2012). In 2010/2011, parts of Western Australia's coastline experienced unprecedented sea surface temperatures at 2-4^{o}C above average for ~10 weeks, resulting in a marine heat wave (Thomson et al., 2015). The heat wave resulted in widespread impacts on marine life (Pearce et al., 2011, Moore et al., 2012, Wernberg et al., 2013, Thomson et al., 2015). Ningaloo Reef and Exmouth Gulf experienced severe impacts on coral communities, including widespread coral bleaching (Moore et al., 2012, Depczynski et al., 2013). Shark Bay experienced severe habitat degradation including seagrass cover declines of up to 90% (Thomson et al., 2015).

Since the 2010/2011 heatwave, anecdotal evidence indicates that overall sea snake abundance has declined in Shark (pers. comm. J. A. Thomson, 2014). Three untested hypotheses may explain the sea snake declines – death due to physiological stress at increased temperatures; increased predation due to the loss of seagrass shelter; and sea snake emigration (e.g. to cooler water). The impact of the 2010/2011 heat wave on Ningaloo Reef sea snakes is unknown. Cyclones may also affect sea snakes, which were reported washing ashore and dying in Shark Bay after a cyclone in 2008 (pers. comm. J. A. Thomson, 2014).

Whilst it is not within the scope of this report to examine the occurrence or cause of sea snake declines, extreme weather events, such as marine heat waves and cyclones, may clearly have serious impacts on sea snake habitats and populations. The persistence of small range endemic sea snakes such as *A. pooleorum* is particularly vulnerable to such widespread stressors. Extreme weather events are projected to intensify as the climate warms (Cai et al., 2014, Hobday et al., 2016), suggesting that climate change is a potential threat to sea snakes.

WA DoF Scientific Demersal Prawn Trawl surveys

Trawling is a documented threat to sea snakes (Milton et al., 2008, Wassenberg et al., 2001, Wassenberg et al., 1994). The data indicate that a diversity of *Aipysurus* group sea snakes are susceptible to demersal trawl gear in WA. Interactions between trawlers and a range of sea snakes reported here include Critically Endangered species (*A. foliosquama* and *A. apraefrontalis*), small range endemics (*A. pooleorum* and *A. tenuis*) and more widely distributed species (*A. duboisii* and *A. mosaicus)*.

Aipysurus apraefrontalis WA DoF

Aipysurus foliosquama

Recommendations

True sea snakes are chronically understudied and major knowledge gaps remain about their basic biology, ecology, dispersal, recruitment, and capacity for recovery from population declines. Research to date on *Aipysurus* group sea snakes suggests limited connectivity (Burns and Heatwole, 1998, Guinea and Whiting, 2005, Lukoschek and Shine, 2012, Lukoschek et al., 2008, Lukoschek et al., 2007b) and therefore, limited capacity for replenishment following declines. *Aipysurus* group sea snakes therefore appear vulnerable and conserving them requires a multifaceted approach to research and management.

Research

Research that supports and/or improves status assessment, monitoring of population dynamics and understanding threatening processes for sea snakes should be prioritised. For Aipysurus group sea snakes the following types of research should be prioritised:

1) Ongoing taxonomic and species distribution studies combining molecular sampling (e.g. hand collection of tissues or e-DNA) and field surveys are necessary for accurate assessment of species ranges and status assessments.
2) Studies of genetic connectivity, demographic structure and life history characteristics are necessary to improve knowledge of the susceptibility of sea snakes to depletion and capacity for recovery following declines.
3) Habitat use studies are required to identify critical habitats and support habitat protection planning. This research should include an assessment of how differences or changes in habitat composition and structural complexity affect sea snake abundance and diversity.
4) Studies of abundance and population dynamics are necessary to provide insight into: long term trends in sea snake abundance; population status; the effects of impacts and any implemented conservation measures.
5) Determination of threatening processes and the level of impact on sea snake populations including:
    a. Determining species-specific by-catch and mortality rates in demersal trawling in coastal WA and the effectiveness of by-catch reduction devices for each species (also see Kangas et al., 2015a, Kangas et al., 2015b).
    b. Determining the effects of extreme weather events such as heat waves on sea snake populations.
    c. Assessing the cumulative effects of these and other threatening processes on sea snake species identified as being impacted.

Newly confirmed coastal WA populations of the Critically Endangered species *A. foliosquama* and *A. apraefrontalis,* should be prioritised for research and conservation actions, in accordance with the Conservation Advices provided to the Commonwealth (TSSC, 2011a, TSSC, 2011b). Poorly known endemic species including *A. pooleorum* and *A. tenuis* should also be given high research priority.

Conservation and management

Reducing the effects of threatening processes and preventing future declines of sea snakes will be an ongoing challenge. The largely unexplained extirpations of several sea snakes species within the Ashmore and Cartier Reef Commonwealth Marine Reserves highlight this challenge and demonstrate that marine reserves alone cannot prevent sea snake extinctions. Thus, further research is required to understand what the key threatening processes are to sea snakes and how they cause populations to decline. Whilst further

research is required, there are a number of interim management actions that can be used to minimise and/or prevent impacts on sea snakes:

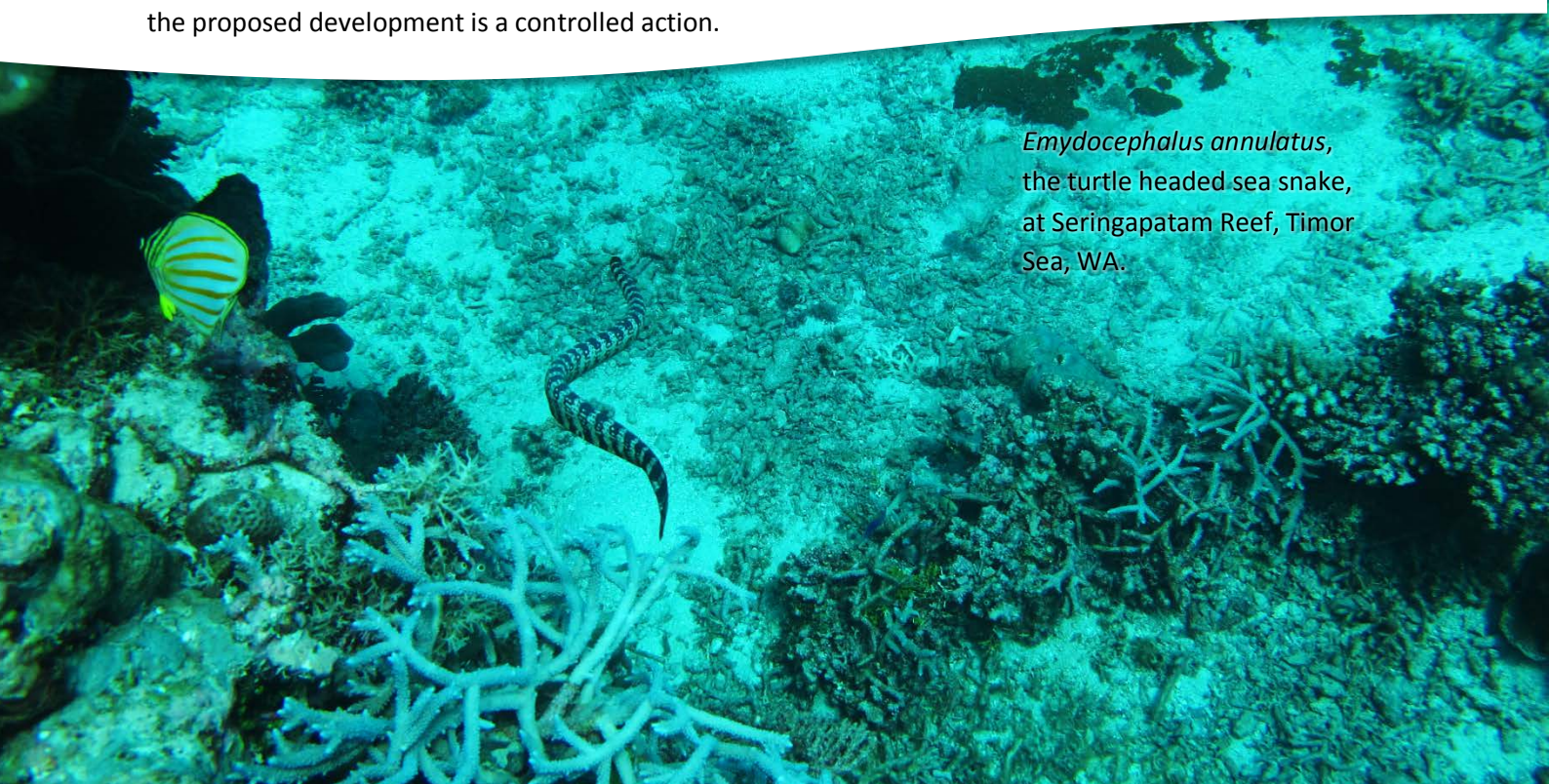
1) *A. foliosquama* and *A. apraefrontalis* are Critically Endangered Matters of National Environmental Significance (MNES). Under the EPBC Act, all new development proposals, marine and coastal, that can, will or may have a significant impact on these threatened species are required by law to be referred to the Commonwealth Environment Minister, to determine if the proposal constitutes a controlled action. This applies to areas where these species have been confirmed to or may occur. This should be communicated explicitly to development proponents and government staff dealing with existing and new development proposals in WA.
2) An interim desktop study of the cumulative impacts of known threatening processes should be conducted based on existing knowledge to help determine:
    a. The estimated scale of impacts that may be affecting sea snakes
    b. Whether offsets are appropriate (or inappropriate) where statutory obligations to prevent significant impacts on CE MNES sea snakes cannot be met by proponents of, in a context of cumulative impacts.
3) A prioritised research and conservation strategy for sea snakes in WA should be developed, funded and implemented as soon as practicable.

Conclusion

This study has made a significant contribution to our understanding of the habitat use and distribution of *Aipysurus* group sea snakes in WA. Our study has extended the known habitats used by four sea snake species (*A. apraefrontalis, A. foliosquama, A. pooleorum, and A. tenuis*) and extended the known distribution of two species (*A. apraefrontalis, A. foliosquama*).

Key recommendations about future research include a focus on: a) determining the distribution, genetic connectivity, abundance, habitat use, demography and life history of sea snake populations; b) understanding the effects of trawling, and extreme weather events on sea snakes; c) assessing the cumulative impacts of threatening processes on sea snakes; d) developing and funding a research and conservation strategy for *Aipysurus* group sea snakes in WA to facilitate a science based management approach to sea snake conservation.

Key management actions include ensuring that future developments that may significantly impact on threatened sea snakes, are referred to the Commonwealth Environment Minister to determine whether the proposed development is a controlled action.



Emydocephalus annulatus, the turtle headed sea snake, at Seringapatam Reef, Timor Sea, WA.

Figures and Tables

Table 1a. Location data for 330 sea snakes encountered during >200 hrs of surveys at 151 locations from 8 regions on the WA coast and three reefs in the Timor Sea. In water surveys were conducted on snorkel, manta tow and SCUBA. In addition, boat surveys were conducted opportunistically and some shallow water habitats were surveyed on foot. Lat=Latitude in decimal degrees, Long=Longitude (AGD1994), WADPaW= Western Australian Department of Parks and Wildlife, WADoF=WA Department of Fisheries, JCU=James Cook University, WAM=Western Australian Museum, n/a=not available.

Region and Location	Lat	Long	Record No.	*Aipysurus apraefrontalis*	*Aipysurus duboisii*	*Aipysurus foliosquama*	*Aipysurus fuscus*	*Aipysurus laevis*	*Aipysurus mosaicus*	*Aipysurus pooleorum*	*Aipysurus tenuis*	*Emydocephalus annulatus*	*Aipysurus unknown*	*Hydrelaps darwiniensis*	*Hydrophis coggeri*	*Hydrophis elegans*	*Hydrophis major*	*Hydrophis platurus*	*Hydrophis stokesii*	*Unknown*	*No snakes sighted (sites)*
Scott Reef Complex					10		5	42				10	1		1						7
North Scott Reef, North-East, slope	-13.93	121.92	83		1			3													
	-13.92	121.92	54					6													
North Scott Reef, South, slope	-14.02	121.86	56																		1
	-14.02	121.85	55																		1
Scott Reef, East Hook, reef flat	-14.08	121.95	57		1			5				2									
	-14.08	121.95	58		1		1	4													
Scott Reef, East Hook, reef lagoon slope	-14.08	121.95	63																		1
	-14.08	121.95	62									2									1
	-14.08	121.95	60																		1
	-14.08	121.95	61																		1
	-14.07	121.95	59																		1
Scott Reef, East Hook, slope	-14.09	121.98	84		1			1													
Scott Reef, Sandy Islet, lagoon slope	-14.07	121.78	65		1			4				1									
	-14.07	121.78	44					1													
	-14.06	121.77	64				1	8				2									
Scott Reef, South, lagoon slope	-14.19	121.81	85		1			1													
	-14.19	121.81	67				3								1						
	-14.19	121.80	66									1	1								
Seringapatam Reef, North-east, slope	-13.65	122.03	53		1			7				1									
	-13.64	122.03	52		1			1				1									
	-13.64	122.03	43		2			1													
Pilbarra Coast						1					2			2		1			2		9
Eighty Mile Beach, Cape Keraudren	-20.08	119.57	183											1							
	-19.99	119.74	182											1							
Pilbarra Coast, Central, Bandicoot Bay, Barrow Island	-20.90	115.30	186			1															
Pilbarra Coast, Central, Lowendal Islands, Veranus Island	-20.65	115.57	38																		
Pilbarra Coast, Central, Sholl Is	-20.95	115.90	184																1		
Pilbarra Coast, Thevenard Region, Gorgon	-21.55	115.08	77																		1
Thevenard Region, Airlie Island	-21.33	115.17	80																		1
Thevenard Region, Ashburton	-21.59	114.94	74																		1
Thevenard Region, Bessieres Island	-21.53	114.79	78																		1
	-21.53	114.76	40								2										
Thevenard Region, Direction Island	-21.53	115.14	79																		1
Thevenard Region, Fly Island	-21.80	114.55	72																		1
Thevenard Region, Fly Island, West of	-21.83	114.47	129																1		
Thevenard Region, Herald Island	-21.57	115.06	75																		1
Thevenard Region, Murion Islands, South-East	-21.76	114.37	130													1					
Thevenard Region, Paroo	-21.56	115.01	76																		1
Thevenard Region, Roller Reef	-21.65	114.93	73																		1

Table 1a (ctd). Location data for 330 sea snakes encountered during >200 hrs of surveys at 151 locations from 8 regions on the WA coast and three reefs in the Timor Sea.

Region and Location	Lat	Long	Record No.	*Aipysurus apraefrontalis*	*Aipysurus duboisii*	*Aipysurus foliosquama*	*Aipysurus fuscus*	*Aipysurus laevis*	*Aipysurus mosaicus*	*Aipysurus pooleorum*	*Aipysurus tenuis*	*Emydocephalus annulatus*	*Aipysurus unknown*	*Hydrelaps darwiniensis*	*Hydrophis coggeri*	*Hydrophis elegans*	*Hydrophis major*	*Hydrophis platurus*	*Hydrophis stokesii*	*Unknown*	*No snakes sighted (sites)*
Ningaloo Reef				2							4	2									7
Blizzard Ridge, Lighthouse Bay	-21.80	114.13	68								1	1									
Lakeside	-22.04	113.91	87																		1
	-22.04	113.91	86																		1
Lighthouse Bay	-21.80	114.13	69								1										
	-21.80	114.13	70								1										
	-21.80	114.13	71									1									
Lighthouse Sanctuary Zone, North West Cape	-21.80	114.14	181								1										
Osprey Bay	-22.25	113.83	89																		1
	-22.24	113.83	88																		1
Tantabiddi	-21.89	113.95	47																		1
	-21.88	113.97	46																		1
	-21.88	113.98	45																		1
Turquoise Bay	-22.10	113.87	180	2																	
Exmouth Gulf				5	2				1		5						1		1		9
Badjirrajirra Creek	-22.16	114.09	39																		1
Bay of Rest	-22.30	114.13	42																		1
Bundegi	-21.89	114.20	90																1		
	-21.83	114.18	91																		1
	-21.83	114.18	48																		1
	-21.83	114.18	179																		1
Central Exmouth Gulf	-22.24	114.28	118	2																	
	-22.24	114.28	119	1																	
	-22.15	114.28	120	1																	
	-22.08	114.28	121	1																	
	-22.06	114.26	122														1				
Exmouth Harbour	-21.96	114.14	92																		1
Learmonth Jetty	-22.21	114.10	116								1										
Navy Pier	-21.82	114.19	93																		1
	-21.82	114.19	94																		1
Pebble Beach	-22.04	114.12	95																		1
West Exmouth Gulf	-22.21	114.17	123								1										
	-22.17	114.14	124								1										
	-22.16	114.17	125								1										
	-22.13	114.17	126						1												
	-22.13	114.17	127		1																
	-22.11	114.14	128		1						1										

Table 1a (ctd). Location data for 330 sea snakes encountered during >200 hrs of surveys at 151 locations from 8 regions on the WA coast and three reefs in the Timor Sea.

Region and Location	Lat	Long	Record No.	*Aipysurus apraefrontalis*	*Aipysurus duboisii*	*Aipysurus foliosquama*	*Aipysurus fuscus*	*Aipysurus laevis*	*Aipysurus mosaicus*	*Aipysurus pooleorum*	*Aipysurus tenuis*	*Emydocephalus annulatus*	*Aipysurus unknown*	*Hydrelaps darwiniensis*	*Hydrophis coggeri*	*Hydrophis elegans*	*Hydrophis major*	*Hydrophis platurus*	*Hydrophis stokesii*	*Unknown*	*No snakes sighted (sites)*
Shark Bay, Outer						9				4		1	1			18	2	1		5	
Carnarvon, Town Beach	-24.88	113.65	117															1			
Dirk Hartog Island, North tip	-25.48	112.98	81									1									
Geographe Channel	-25.66	113.26	160			1															
	-25.38	113.42	159													1					
	-25.38	113.42	20							1											
	-25.38	113.44	19							1											
	-25.34	113.56	158			1															
	-25.34	113.41	157													1					
	-25.33	113.43	18							1											
	-25.33	113.44	156													1					
	-25.33	113.38	155													2					
	-25.31	113.42	154																	1	
	-25.28	113.52	17							1											
	-25.26	113.45	153			1															
	-25.25	113.63	152													1	1				
	-25.22	113.63	151													1					
	-25.22	113.57	150			1															
	-25.22	113.57	149			1											1				
	-25.19	113.42	148													1					
	-25.19	113.61	147																	1	
	-25.16	113.58	146			1															
	-25.14	113.37	145													1					
	-25.13	113.43	144			1										1					
	-25.13	113.42	143													1					
	-25.13	113.47	142													1					
	-25.11	113.33	141													1					
	-25.10	113.29	140													1					
	-24.97	113.39	139																	1	
	-24.96	113.27	138										1								
	-24.95	113.20	137			1															
	-24.94	113.27	136													1					
	-24.93	113.41	135													1					
	-24.92	113.36	134																	1	
	-24.88	113.27	133																	1	
	-24.67	113.37	132													2					
	-24.59	113.21	131			1															

Table 1a (ctd). Location data for 330 sea snakes encountered during >200 hrs of surveys at 151 locations from 8 regions on the WA coast and three reefs in the Timor Sea.

Region and Location	Lat	Long	Record No.	*Aipysurus apraefrontalis*	*Aipysurus duboisii*	*Aipysurus foliosquama*	*Aipysurus fuscus*	*Aipysurus laevis*	*Aipysurus mosaicus*	*Aipysurus pooleorum*	*Aipysurus tenuis*	*Emydocephalus annulatus*	*Aipysurus unknown*	*Hydrelaps darwiniensis*	*Hydrophis coggeri*	*Hydrophis elegans*	*Hydrophis major*	*Hydrophis platurus*	*Hydrophis stokesii*	*Unknown*	*No snakes sighted (sites)*
Shark Bay, Eastern Gulf						3				34						8	62				
Eastern Gulf, Monkey Mia	-25.69	113.65	169														1				
Eastern Gulf, North	-25.53	113.58	178													1					
	-25.53	113.63	177													1					
	-25.51	113.54	176													1					
	-25.47	113.62	175													1					
	-25.44	113.69	174													1					
	-25.40	113.64	173			1										1					
	-25.39	113.59	172			1															
	-25.39	113.59	171			1															
	-25.32	113.65	170													1					
Guichenault Pt to Monkey Mia/Dubaut Pt	-25.75	113.66	37							6						1	11				
Hamelin Pool, Booldah Well Shelf	-26.40	114.04	33							3											
	-26.40	114.05	16							1							1				
	-26.39	114.02	25							2							2				
	-26.38	114.03	2							1											
	-26.38	114.03	1							1							2				
	-26.37	114.01	32							3											
Hamelin Pool, Carbala Point	-26.27	114.22	49														2				
	-26.27	114.22	113														1				
	-26.27	114.22	114														2				
Hamelin Pool, Flagpole Landing	-26.38	114.19	3							1											
Hamelin Pool, Nilemah Bank	-26.28	113.99	36							6											
	-26.28	113.99	4							1							1				
Hamelin Pool, Nilemah Embayment	-26.44	114.09	115														3				
Hamelin Pool, Petit Bank	-26.08	113.91	24							2											
Hamelin Pool, Snake Bank	-26.40	114.04	7							1											
	-26.24	113.98	6							1							4				
	-26.24	113.98	27							2							7				
	-26.24	113.98	26							2							10				
	-26.23	113.97	51														1				
	-26.23	114.00	5							1							11				
	-26.22	113.99	50														2				
	-26.21	113.99	41														1				

Table 1a (ctd). Location data for 330 sea snakes encountered during >200 hrs of surveys at 151 locations from 8 regions on the WA coast and three reefs in the Timor Sea.

Region and Location	Lat	Long	Record No.	*Aipysurus apraefrontalis*	*Aipysurus duboisii*	*Aipysurus foliosquama*	*Aipysurus fuscus*	*Aipysurus laevis*	*Aipysurus mosaicus*	*Aipysurus pooleorum*	*Aipysurus tenuis*	*Emydocephalus annulatus*	*Aipysurus unknown*	*Hydrelaps darwiniensis*	*Hydrophis coggeri*	*Hydrophis elegans*	*Hydrophis major*	*Hydrophis platurus*	*Hydrophis stokesii*	*Unknown*	*No snakes sighted (sites)*
Shark Bay, Western Gulf						6				26						5	43				2
Denham Jetty	-25.93	113.53	96														2				
	-25.93	113.53	97														2				
	-25.93	113.53	98														3				
	-25.93	113.53	99														1				
	-25.93	113.53	100														4				
	-25.93	113.53	8							1							2				
	-25.93	113.53	101														2				
	-25.93	113.53	102														1				
	-25.93	113.53	9							1							2				
	-25.93	113.53	10							1							1				
	-25.93	113.53	28							2							3				
	-25.93	113.53	103														2				
	-25.93	113.53	104														3				
	-25.93	113.53	29							2											
	-25.93	113.53	11							1											
	-25.93	113.53	105														2				
	-25.93	113.53	35							4											
	-25.93	113.53	30							2							1				
	-25.93	113.53	31							2											
	-25.93	113.53	106														1				
	-25.93	113.53	34							3											
	-25.93	113.53	12							1							2				
	-25.93	113.53	107														3				
	-25.93	113.53	13							1							2				
	-25.93	113.53	14							1											
	-25.93	113.53	108														1				
	-25.93	113.53	109														1				
	-25.93	113.53	110														2				
Henri Freycinet Estuary	-26.35	113.71	168			1										1					
Useless loop	-26.13	113.42	112																		1
	-26.13	113.42	111																		1
	-26.12	113.42	15							1											
Western Gulf, North	-25.92	113.22	167			1															
	-25.75	113.22	23							1											
	-25.75	113.17	22							1											
	-25.63	113.16	21							1											
	-25.58	113.07	166													1					
	-25.55	113.20	165			1															
	-25.46	113.41	164													1					
	-25.44	113.38	163			1															
	-25.42	113.38	162													1					
	-25.41	113.42	161			2										1					
Albany																	1				
Fremantle																1					
Grand Total				7	12	19	5	42	1	64	11	13	2	2	1	33	109	1	3	5	34

Table 1b. Meta data for 330 sea snakes encountered during >200 hours of surveys at 151 locations from 8 regions on the WA coast and three reefs in the Timor Sea. Search times for SCUBA, snorkel and manta-tow were approximated by subtracting three minutes per snake from the total session time (to account for processing time). n/a: indicates that search time was not recorded. Lat=Latitude in decimal degrees, Long=Longitude (AGD1994), WADPaW= Western Australian Department of Parks and Wildife, WADoF=WA Department of Fisheries, JCU=James Cook University, WAM=Western Australian Museum, n/a=not available.

Region and Location	Lat	Long	Date (DD/MM/YYYY)	Record type	Search time (mins)	Record or survey type	Record Source	Institution	Record No.
Scott Reef Complex									
North Scott Reef, North-East, slope	-13.93	121.92	13/10/2014	Scientific survey	142	Snorkel	Blanche D'Anastasi	JCU	83
	-13.92	121.92	10/10/2014	Scientific survey	98	SCUBA dive	Blanche D'Anastasi	JCU	54
North Scott Reef, South, slope	-14.02	121.86	17/10/2014	Scientific survey	65	SCUBA dive	Blanche D'Anastasi	JCU	56
	-14.02	121.85	19/10/2014	Scientific survey	79	SCUBA dive	Blanche D'Anastasi	JCU	55
Scott Reef, East Hook, reef flat	-14.08	121.95	6/10/2014	Scientific survey	59	SCUBA dive	Blanche D'Anastasi	JCU	57
	-14.08	121.95	7/10/2014	Scientific survey	159	SCUBA dive	Blanche D'Anastasi	JCU	58
Scott Reef, East Hook, reef lagoon slope	-14.08	121.95	6/10/2014	Scientific survey	32	SCUBA dive	Blanche D'Anastasi	JCU	63
	-14.08	121.95	6/10/2014	Scientific survey	81	SCUBA dive	Blanche D'Anastasi	JCU	62
	-14.08	121.95	5/10/2014	Scientific survey	63	SCUBA dive	Blanche D'Anastasi	JCU	60
	-14.08	121.95	5/10/2014	Scientific survey	80	SCUBA dive	Blanche D'Anastasi	JCU	61
	-14.07	121.95	6/10/2014	Scientific survey	50	SCUBA dive	Blanche D'Anastasi	JCU	59
Scott Reef, East Hook, slope	-14.09	121.98	16/10/2014	Scientific survey	79	Snorkel	Blanche D'Anastasi	JCU	84
Scott Reef, Sandy Islet, lagoon slope	-14.07	121.78	14/10/2014	Scientific survey	63	SCUBA dive	Blanche D'Anastasi	JCU	65
	-14.07	121.78	14/10/2014	Scientific survey	59	Manta tow	Blanche D'Anastasi	JCU	44
	-14.06	121.77	15/10/2014	Scientific survey	159	SCUBA dive	Blanche D'Anastasi	JCU	64
Scott Reef, South, lagoon slope	-14.19	121.81	9/10/2014	Scientific survey	58	Snorkel	Blanche D'Anastasi	JCU	85
	-14.19	121.81	8/10/2014	Scientific survey	68	SCUBA dive	Blanche D'Anastasi	JCU	67
	-14.19	121.80	7/10/2014	Scientific survey	63	SCUBA dive	Blanche D'Anastasi	JCU	66
Seringapatam Reef, North-east, slope	-13.65	122.03	13/10/2014	Scientific survey	130	SCUBA dive	Blanche D'Anastasi	JCU	53
	-13.64	122.03	14/10/2014	Scientific survey	46	SCUBA dive	Blanche D'Anastasi	JCU	52
	-13.64	122.03	11/10/2014	Scientific survey	66	Manta tow	Blanche D'Anastasi	JCU	43
Pilbarra Coast									
Eighty Mile Beach, Cape Keraudren	-20.08	119.57	22/05/2015	Georeferenced photo	n/a	Low tide walk	Kathy Murray	WADPaW	183
	-19.99	119.74	22/05/2015	Georeferenced photo	n/a	Low tide walk	Kathy Murray	WADPaW	182
Pilbarra Coast, Central, Bandicoot Bay, Barrow Island	-20.90	115.30	2/10/2010	Museum record	n/a	Stranding	WAM	WAM	186
Pilbarra Coast, Central, Lowendal Islands, Veranus Island	-20.65	115.57	2/07/2015	Georeferenced specimen	n/a	Stranding	Tony Doyle	Apache Energy	38
Pilbarra Coast, Central, Sholl Is	-20.95	115.90	14/11/2014	Georeferenced photo	n/a	Stranding	Grant Griffin	WADPaW	184
Pilbarra Coast, Thevenard Region, Gorgon	-21.55	115.08	19/02/2014	Scientific survey	68	SCUBA dive	Blanche D'Anastasi	JCU	77
Thevenard Region, Airlie Island	-21.33	115.17	21/02/2014	Scientific survey	82	SCUBA dive	Blanche D'Anastasi	JCU	80
Thevenard Region, Ashburton	-21.59	114.94	18/02/2014	Scientific survey	81	SCUBA dive	Blanche D'Anastasi	JCU	74
Thevenard Region, Bessieres Island	-21.53	114.79	21/02/2014	Scientific survey	n/a	SCUBA dive	Blanche D'Anastasi	JCU	78
	-21.53	114.76	21/02/2014	Scientific survey	29	Boat	Blanche D'Anastasi	JCU	40
Thevenard Region, Direction Island	-21.53	115.14	20/02/2014	Scientific survey	56	SCUBA dive	Blanche D'Anastasi	JCU	79
Thevenard Region, Fly Island	-21.80	114.55	21/02/2014	Scientific survey	60	SCUBA dive	Blanche D'Anastasi	JCU	72
Thevenard Region, Fly Island, West of	-21.83	114.47	26/03/2015	Scientific survey	60	Trawl survey	Invertebrate Trawl Section	WADoF	129
Thevenard Region, Herald Island	-21.57	115.06	20/02/2014	Scientific survey	46	SCUBA dive	Blanche D'Anastasi	JCU	75
Thevenard Region, Murion Islands, South-East	-21.76	114.37	26/03/2015	Scientific survey	60	Trawl survey	Invertebrate Trawl Section	WADoF	130
Thevenard Region, Paroo	-21.56	115.01	19/02/2014	Scientific survey	109	SCUBA dive	Blanche D'Anastasi	JCU	76
Thevenard Region, Roller Reef	-21.65	114.93	18/02/2014	Scientific survey	66	SCUBA dive	Blanche D'Anastasi	JCU	73

Table 1b (ctd). Meta data for 330 sea snakes encountered during >200 hours of surveys at 151 locations from 8 regions on the WA coast and three reefs in the Timor Sea.

Region and Location	Lat	Long	Date (DD/MM/YYYY)	Record type	Search time (mins)	Record or survey type	Record Source	Institution	Record No.
Ningaloo Reef									
Blizzard Ridge, Lighthouse Bay	-21.80	114.13	11/07/2012	Georeferenced photo	n/a	SCUBA dive	Huw Dilley	JCU	68
Lakeside	-22.04	113.91	2/04/2014	Scientific survey	15	Snorkel	Blanche D'Anastasi	JCU	87
	-22.04	113.91	2/04/2014	Scientific survey	15	Snorkel	Blanche D'Anastasi	JCU	86
Lighthouse Bay	-21.80	114.13	12/08/2001	Georeferenced photo	n/a	SCUBA dive	Dani Rob	JCU	69
	-21.80	114.13	24/02/2006	Georeferenced photo	n/a	SCUBA dive	Dani Rob	JCU	70
	-21.80	114.13	15/10/2007	Georeferenced photo	n/a	SCUBA dive	Dani Rob	JCU	71
Lighthouse Sanctuary Zone, North West Cape	-21.80	114.14	15/12/2015	Georeferenced photo	n/a	Low tide walk	Keely Markovina, Adam Thompson	WADPaW	181
Osprey Bay	-22.25	113.83	2/04/2014	Scientific survey	15	Snorkel	Blanche D'Anastasi	JCU	89
	-22.24	113.83	2/04/2014	Scientific survey	15	Snorkel	Blanche D'Anastasi	JCU	88
Tantabiddi	-21.89	113.95	27/03/2014	Scientific survey	60	Manta tow	Blanche D'Anastasi	JCU	47
	-21.88	113.97	27/03/2014	Scientific survey	120	Manta tow	Blanche D'Anastasi	JCU	46
	-21.88	113.98	29/03/2014	Scientific survey	70	Manta tow	Blanche D'Anastasi	JCU	45
Turquoise Bay	-22.10	113.87	29/04/2013	Georeferenced photo	n/a	Boat,	Grant Griffin	WADPaW	180
Exmouth Gulf									
Badjirrajirra Creek	-22.16	114.09	4/04/2014	Scientific survey	120	Boat	Blanche D'Anastasi	JCU	39
Bay of Rest	-22.30	114.13	2/04/2014	Scientific survey	120	Low tide walk	Blanche D'Anastasi	JCU	42
Bundegi	-21.89	114.20	3/03/2015	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	90
	-21.83	114.18	30/03/2014	Scientific survey	240	Snorkel	Blanche D'Anastasi	JCU	91
	-21.83	114.18	27/03/2014	Scientific survey	20	Manta tow	Blanche D'Anastasi	JCU	48
	-21.83	114.18	26/03/2014	Georeferenced photo	30	Boat	Matt Smith	WADPaW	179
Central Exmouth Gulf	-22.24	114.28	27/03/2015	Scientific survey	60	Trawl survey	Invertebrate Trawl Section	WADoF	118
	-22.24	114.28	11/05/2015	Scientific survey	60	Trawl survey	Invertebrate Trawl Section	WADoF	119
	-22.15	114.28	12/05/2015	Scientific survey	90	Trawl survey	Invertebrate Trawl Section	WADoF	120
	-22.08	114.28	19/08/2014	Scientific survey	120	Trawl survey	Invertebrate Trawl Section	WADoF	121
	-22.06	114.26	16/08/2014	Scientific survey	150	Trawl survey	Invertebrate Trawl Section	WADoF	122
Exmouth Harbour	-21.96	114.14	4/04/2014	Scientific survey	120	Snorkel	Blanche D'Anastasi	JCU	92
Learmonth Jetty	-22.21	114.10	4/04/2014	Georeferenced photo	60	Georeferenced photo	Stacy Rickard	Public	116
Navy Pier	-21.82	114.19	28/03/2014	Scientific survey	24	Snorkel	Blanche D'Anastasi	JCU	93
	-21.82	114.19	3/04/2014	Scientific survey	54	Snorkel	Blanche D'Anastasi	JCU	94
Pebble Beach	-22.04	114.12	4/04/2014	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	95
West Exmouth Gulf	-22.21	114.17	11/05/2015	Scientific survey	90	Trawl survey	Invertebrate Trawl Section	WADoF	123
	-22.17	114.14	12/05/2015	Scientific survey	90	Trawl survey	Invertebrate Trawl Section	WADoF	124
	-22.16	114.17	19/08/2014	Scientific survey	150	Trawl survey	Invertebrate Trawl Section	WADoF	125
	-22.13	114.17	14/04/2015	Scientific survey	90	Trawl survey	Invertebrate Trawl Section	WADoF	126
	-22.13	114.17	13/05/2015	Scientific survey	90	Trawl survey	Invertebrate Trawl Section	WADoF	127
	-22.11	114.14	19/08/2014	Scientific survey	150	Trawl survey	Invertebrate Trawl Section	WADoF	128

Table 1b (ctd). Meta data for 330 sea snakes encountered during >200 hours of surveys at 151 locations from 8 regions on the WA coast and three reefs in the Timor Sea.

Region and Location	Lat	Long	Date (DD/MM/YYYY)	Record type	Search time (mins)	Record or survey type	Record Source	Institution	Record No.
Shark Bay, Outer									
Carnarvon, Town Beach	-24.88	113.65	21/06/2015	Georeferenced photo	n/a	Shore walk	Mary-Ann Livesy	Public	117
Dirk Hartog Island, North tip	-25.48	112.98	17/11/2014	Scientific survey	n/a	SCUBA dive	Blanche D'Anastasi	JCU	81
Geographe Channel and northern Shark Bay	-25.66	113.26	17/02/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	160
	-25.38	113.42	11/05/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	159
	-25.38	113.42	12/04/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	20
	-25.38	113.44	13/04/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	19
	-25.34	113.56	12/05/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	158
	-25.34	113.41	13/04/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	157
	-25.33	113.43	12/04/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	18
	-25.33	113.44	18/03/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	156
	-25.33	113.38	19/11/2014	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	155
	-25.31	113.42	12/06/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	154
	-25.28	113.52	13/04/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	17
	-25.26	113.45	16/02/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	153
	-25.25	113.63	17/03/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	152
	-25.22	113.63	14/11/2014	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	151
	-25.22	113.57	17/03/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	150
	-25.22	113.57	17/03/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	149
	-25.19	113.42	11/05/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	148
	-25.19	113.61	10/06/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	147
	-25.16	113.58	11/02/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	146
	-25.14	113.37	12/04/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	145
	-25.13	113.43	18/03/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	144
	-25.13	113.42	13/02/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	143
	-25.13	113.47	13/05/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	142
	-25.11	113.33	12/04/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	141
	-25.10	113.29	12/04/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	140
	-24.97	113.39	13/05/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	139
	-24.96	113.27	12/04/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	138
	-24.95	113.20	29/10/2013	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	137
	-24.94	113.27	17/11/2014	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	136
	-24.93	113.41	18/03/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	135
	-24.92	113.36	9/06/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	134
	-24.88	113.27	14/06/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	133
	-24.67	113.37	15/03/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	132
	-24.59	113.21	29/10/2013	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	131
Shark Bay, Eastern Gulf									
Eastern Gulf, Monkey Mia	-25.69	113.65	17/04/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	169
Eastern Gulf, North	-25.53	113.58	12/02/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	178
	-25.53	113.63	12/02/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	177
	-25.51	113.54	12/02/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	176
	-25.47	113.62	15/11/2014	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	175
	-25.44	113.69	12/05/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	174
	-25.40	113.64	18/08/2014	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	173
	-25.39	113.59	18/08/2014	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	172
	-25.39	113.59	12/05/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	171
	-25.32	113.65	14/11/2014	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	170
Guichenault Pt to Monkey Mia/Dubaut Pt	-25.75	113.66	2013	Scientific survey	3720	Snorkel & Boat	Blanche D'Anastasi	JCU	37
Hamelin Pool, Booldah Well Shelf	-26.40	114.04	22/04/2014	Scientific survey	51	Manta tow	Blanche D'Anastasi	JCU	33
	-26.40	114.05	8/11/2014	Scientific survey	84	Snorkel	Blanche D'Anastasi	JCU	16
	-26.39	114.02	19/03/2014	Scientific survey	36	Manta tow	Blanche D'Anastasi	JCU	25
	-26.38	114.03	20/03/2014	Scientific survey	n/a	Manta tow	Blanche D'Anastasi	JCU	2
	-26.38	114.03	23/04/2014	Scientific survey	61	Manta tow	Blanche D'Anastasi	JCU	1
	-26.37	114.01	13/04/2014	Scientific survey	29	Manta tow	Blanche D'Anastasi	JCU	32
Hamelin Pool, Carbala Point	-26.27	114.22	13/03/2014	Scientific survey	7	Manta tow	Blanche D'Anastasi	JCU	49
	-26.27	114.22	16/03/2014	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	113
	-26.27	114.22	17/03/2014	Scientific survey	27	Snorkel	Blanche D'Anastasi	JCU	114
Hamelin Pool, Flagpole Landing	-26.38	114.19	12/04/2014	Scientific survey	45	Manta tow	Blanche D'Anastasi	JCU	3
Hamelin Pool, Nilemah Bank	-26.28	113.99	11/04/2014	Scientific survey	81	Manta tow	Blanche D'Anastasi	JCU	36
	-26.28	113.99	13/04/2014	Scientific survey	102	Manta tow	Blanche D'Anastasi	JCU	4
Hamelin Pool, Nilemah Embayment	-26.44	114.09	9/03/2014	Scientific survey	43	Snorkel	Blanche D'Anastasi	JCU	115
Hamelin Pool, Petit Bank	-26.08	113.91	10/04/2014	Scientific survey	n/a	Boat	Blanche D'Anastasi	JCU	24
Hamelin Pool, Snake Bank	-26.40	114.04	23/04/2014	Scientific survey	n/a	Manta tow	Blanche D'Anastasi	JCU	7
	-26.24	113.98	10/11/2014	Scientific survey	85	Manta tow	Blanche D'Anastasi	JCU	6
	-26.24	113.98	8/11/2014	Scientific survey	176	Manta tow	Blanche D'Anastasi	JCU	27
	-26.24	113.98	10/11/2014	Scientific survey	303	Manta tow	Blanche D'Anastasi	JCU	26
	-26.23	113.97	24/04/2014	Scientific survey	n/a	Manta tow	Blanche D'Anastasi	JCU	51
	-26.23	114.00	22/03/2014	Scientific survey	209	Manta tow	Blanche D'Anastasi	JCU	5
	-26.22	113.99	11/03/2014	Scientific survey	27	Manta tow	Blanche D'Anastasi	JCU	50
	-26.21	113.99	12/11/2013	Scientific survey	n/a	Boat	Blanche D'Anastasi	JCU	41

Table 1b (ctd). Meta data for 330 sea snakes encountered during >200 hours of surveys at 151 locations from 8 regions on the WA coast and three reefs in the Timor Sea.

Region and Location	Lat	Long	Date (DD/MM/YYYY)	Record type	Search time (mins)	Record or survey type	Record Source	Institution	Record No.
Shark Bay, Western Gulf									
Denham Jetty	-25.93	113.53	21/11/2013	Scientific survey	25	Snorkel	Blanche D'Anastasi	JCU	96
	-25.93	113.53	23/11/2013	Scientific survey	25	Snorkel	Blanche D'Anastasi	JCU	97
	-25.93	113.53	27/11/2013	Scientific survey	50	Snorkel	Blanche D'Anastasi	JCU	98
	-25.93	113.53	28/11/2013	Scientific survey	30	Snorkel	Blanche D'Anastasi	JCU	99
	-25.93	113.53	28/11/2013	Scientific survey	49	Snorkel	Blanche D'Anastasi	JCU	100
	-25.93	113.53	29/11/2013	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	8
	-25.93	113.53	30/11/2013	Scientific survey	23	Snorkel	Blanche D'Anastasi	JCU	101
	-25.93	113.53	2/12/2013	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	102
	-25.93	113.53	5/12/2013	Scientific survey	63	Snorkel	Blanche D'Anastasi	JCU	9
	-25.93	113.53	6/12/2013	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	10
	-25.93	113.53	7/12/2013	Scientific survey	95	Snorkel	Blanche D'Anastasi	JCU	28
	-25.93	113.53	7/12/2013	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	103
	-25.93	113.53	8/12/2013	Scientific survey	143	Snorkel	Blanche D'Anastasi	JCU	104
	-25.93	113.53	9/12/2013	Scientific survey	15	Snorkel	Blanche D'Anastasi	JCU	29
	-25.93	113.53	10/12/2013	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	11
	-25.93	113.53	11/12/2013	Scientific survey	20	Snorkel	Blanche D'Anastasi	JCU	105
	-25.93	113.53	11/12/2013	Scientific survey	32	Snorkel	Blanche D'Anastasi	JCU	35
	-25.93	113.53	12/12/2013	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	30
	-25.93	113.53	13/12/2013	Scientific survey	95	Snorkel	Blanche D'Anastasi	JCU	31
	-25.93	113.53	13/12/2013	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	106
	-25.93	113.53	14/12/2013	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	34
	-25.93	113.53	15/12/2013	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	12
	-25.93	113.53	26/02/2014	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	107
	-25.93	113.53	27/02/2014	Scientific survey	40	Snorkel	Blanche D'Anastasi	JCU	13
	-25.93	113.53	27/02/2014	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	14
	-25.93	113.53	28/02/2014	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	108
	-25.93	113.53	2/03/2014	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	109
	-25.93	113.53	21/04/2014	Scientific survey	14	Snorkel	Blanche D'Anastasi	JCU	110
Henri Freycinet Estuary	-26.35	113.71	19/04/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	168
Useless loop	-26.13	113.42	19/04/2014	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	112
	-26.13	113.42	18/04/2014	Scientific survey	n/a	Snorkel	Blanche D'Anastasi	JCU	111
	-26.12	113.42	19/04/2014	Scientific survey	120	Snorkel	Blanche D'Anastasi	JCU	15
Western Gulf, North	-25.92	113.22	22/11/2014	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	167
	-25.75	113.22	16/08/2014	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	23
	-25.75	113.17	17/08/2014	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	22
	-25.63	113.16	20/11/2014	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	21
	-25.58	113.07	20/11/2014	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	166
	-25.55	113.20	20/11/2014	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	165
	-25.46	113.41	11/05/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	164
	-25.44	113.38	15/02/2015	Scientific survey	20	Trawl survey	Invertebrate Trawl Section	WADoF	163
	-25.42	113.38	11/05/2015	Scientific survey	30	Trawl survey	Invertebrate Trawl Section	WADoF	162
	-25.41	113.42	16/03/2015	Scientific survey	25	Trawl survey	Invertebrate Trawl Section	WADoF	161
Albany									
Albany	-35.02	117.92	11/07/2013	Georeferenced specimen	n/a	Stranding	Steve Toole	WADPaW	185
Fremantle									
Fremantle	-32.06	115.74	21/01/2014	Georeferenced photo	n/a	Shore walk	Douglas Coughran	WADPaW	82

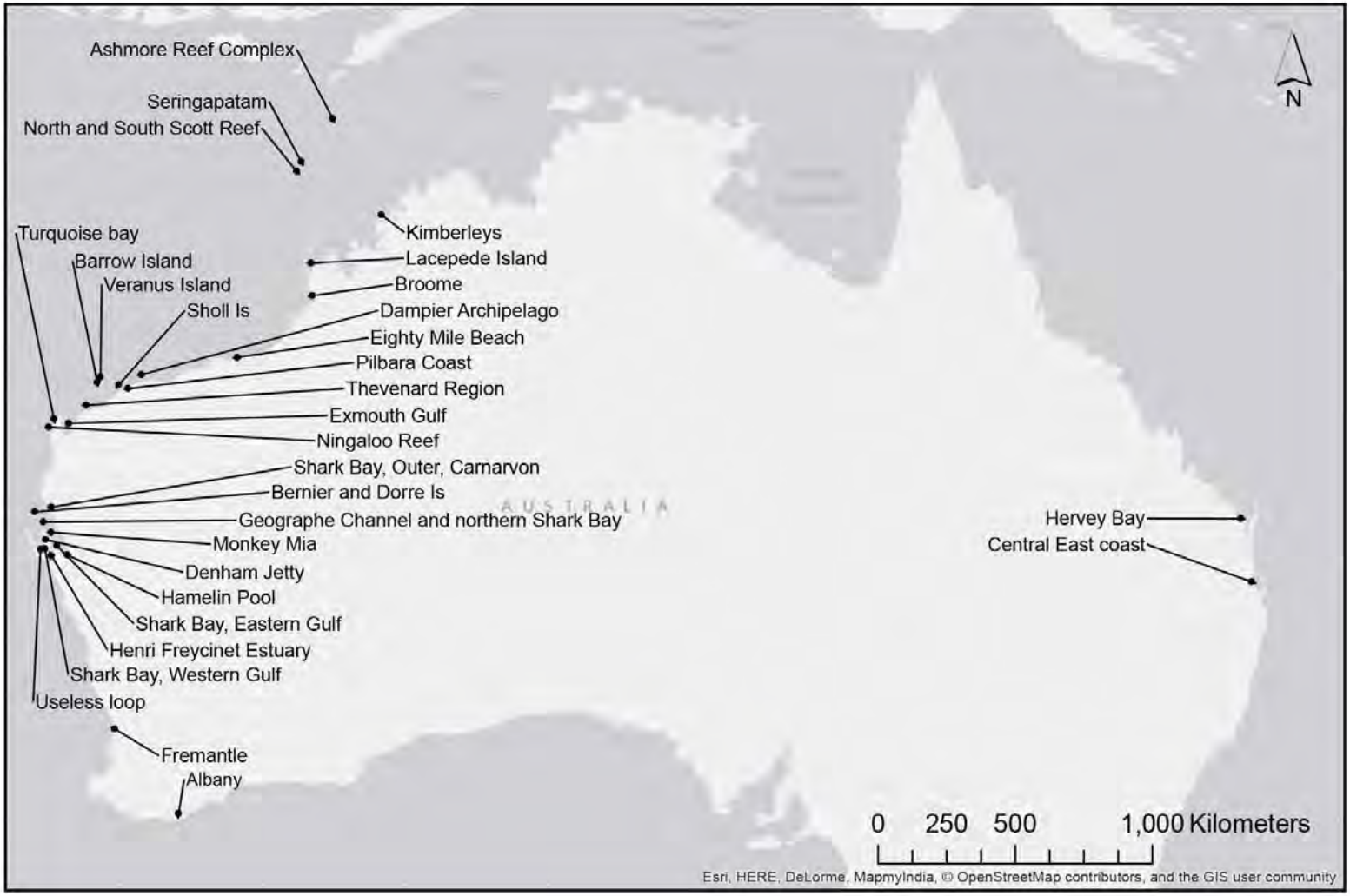
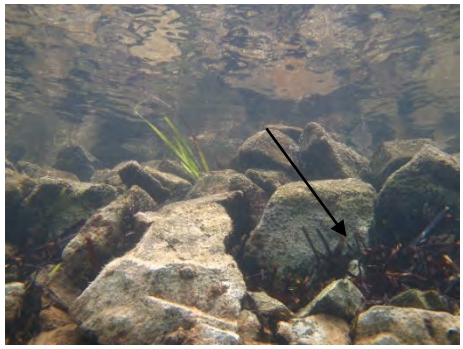


Figure 1. Map of key locations throughout the study region.

a) seagrass wrack
Mass of organic material, comprised mainly of seagrass, which creates a mobile 3D structure that can be moved by wind, tide and currents

b) rocky rubble
Aggregated rocks on the sea floor which create a 3D structure

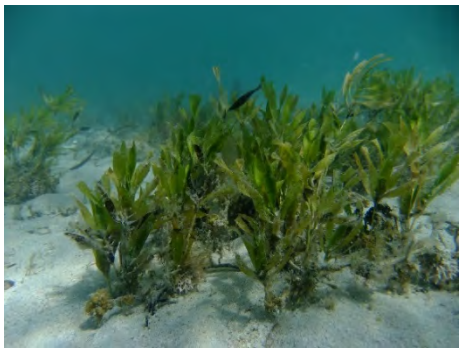


c) rock wall, with seagrass wrack
Man-made sea wall constructed from terrestrial rocks. May contain patches of sea grass wrack (see arrow) or invertebrates (bryozoans, sponges, corals etc.)

d) wooden debris
Man-made or natural pieces of wood in the marine environment, typically on the sea floor.

e) sand
Expanses of small grained sediment

f) jetty
Man-made marine structures which may consist of wood, concrete and metal structures.



g) seagrass, *Amphibolus antarctica* seagrass
Large (>1m), leafy, canopy forming seagrass.

h) seagrass, *Posidonia australis*

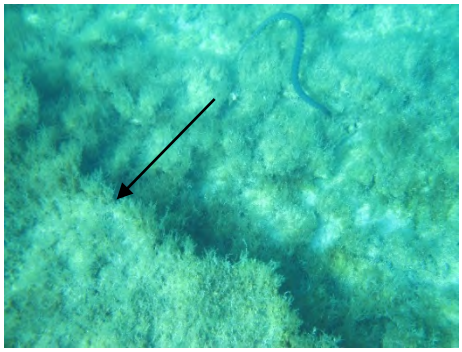
Medium (15cm) seagrass with long strap like leaves

i) seagrass, *Halodule univervis*

Medium (15cm) seagrass with long strap like leaves

Figure 2. Images and descriptions of habitat types used by six species from the *Aipysurus* lineage of sea snakes (*A. duboisii, A. fuscus, A. laevis, A. mosaicus, A. pooleorum, A. tenuis*) in Western Australia, between 2001 and 2015. Habitat records are based on in-water surveys and georeferenced images (also see Table 1). Habitat types recorded in this study for *A. foliosquama* and *A. apraefrontalis* are not included in this figure as images are not available, due to the records being obtained from trawl by-catch.

j) pavement
Marine pavement comprised of lithified carbonate sediment, including calcareous exoskeletons, produced by microbial communities.



k) pavement edge
Distinct edge of marine pavement sheet, may or may not form a ledge with space underneath

l) tabular pavement
Marine pavement broken into blocks ranging from ~0.3-2m wide, forming a 3D structure.

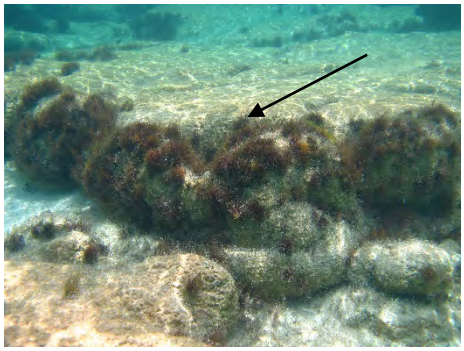
m) tabular Pavement-sand edge

Intersection between tabular pavement and sand

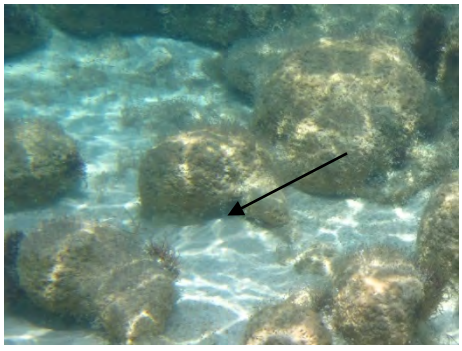
n) tabular pavement-macroalgae

Intersection between tabular pavement and macroalgae

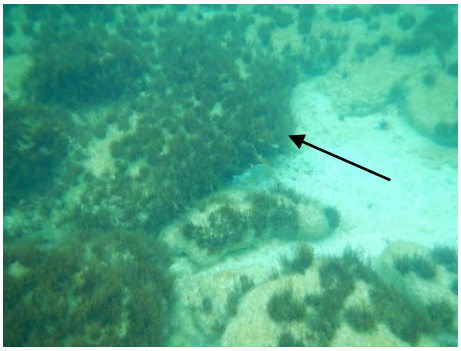
o) tabular pavement-macroalgae-sand edge
Intersection between tabular pavement, macroalgae and sand



p) stromatolite
Lithified marine and littoral structures comprised of lithified carbonate sediment and calcareous exoskeletons, produced by microbial communities.

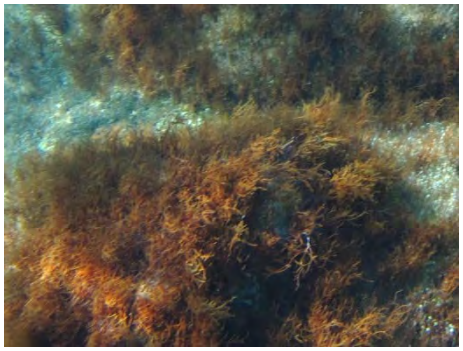


q) Stromatolite-sand edge
Intersection between stromatolite and sand



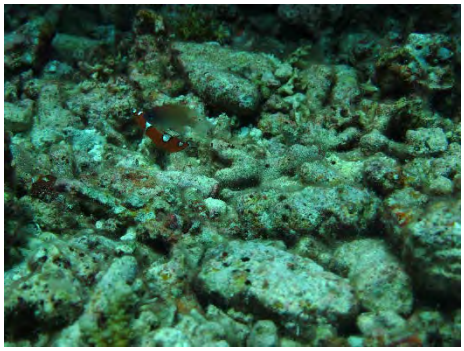
r) stromatolite-macroalgae-sand edge
Intersection between stromatolite, macroalgae and sand

Figure 2 (ctd). Images and descriptions of habitat types used by six species from the *Aipysurus* lineage of sea snakes.



s) stromatolite-macroalgae
Intersection between stromatolite and macroalgae.

t) coral reef
Reef dominated by hard coral.

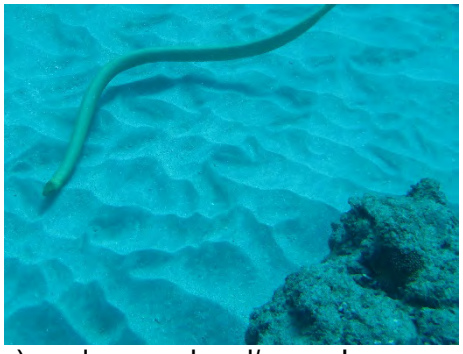


u) coral rubble
Fragments of coral skeleton on the sea floor

v) coral reef-coral rubble edge
Intersection between coral reef and coral rubble.

w) coral reef-sand edge

x) coral reef-coral rubble-sand edge



y) sand near rock and/or coral bommy
Sandy bottom habitat adjacent to hard coral reef/rock structures.

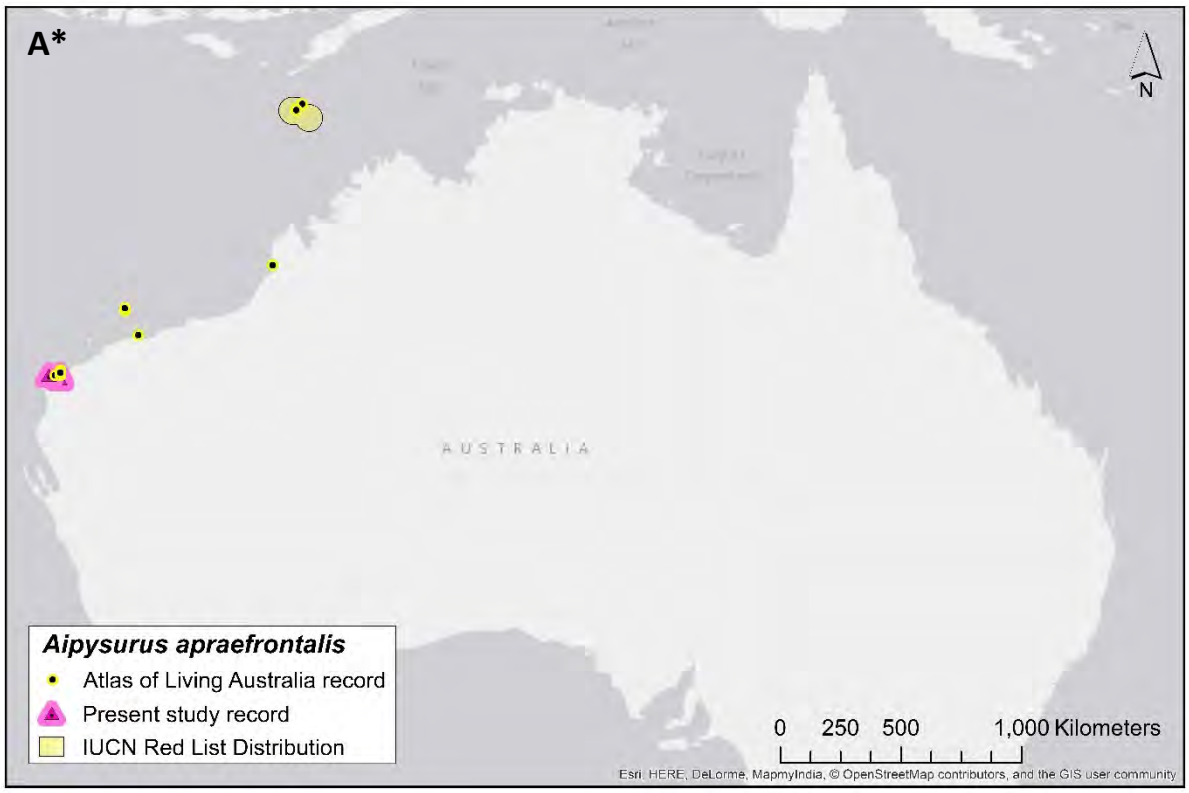
z) intertidal rocky platform

Inshore rocky platform, which is intermittently inundated with sea water.

zz) rocky reef

Reef formed on rock substrate with biota including (but not limited to macroalgae, sponges, byrozoans, ascidians and scleractinian coral, but is not dominated by scleractinian coral.

Figure 2 (ctd). Images and descriptions of habitat types used by six species from the *Aipysurus* lineage of sea snakes.



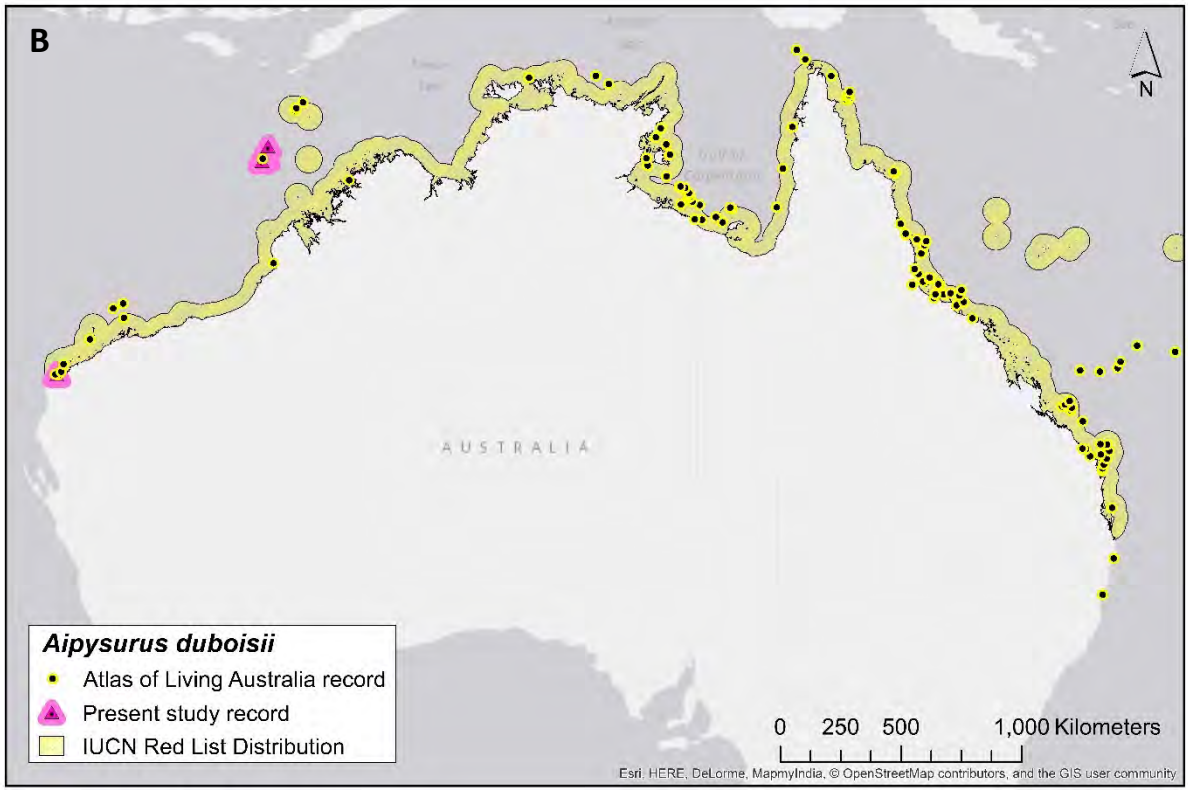
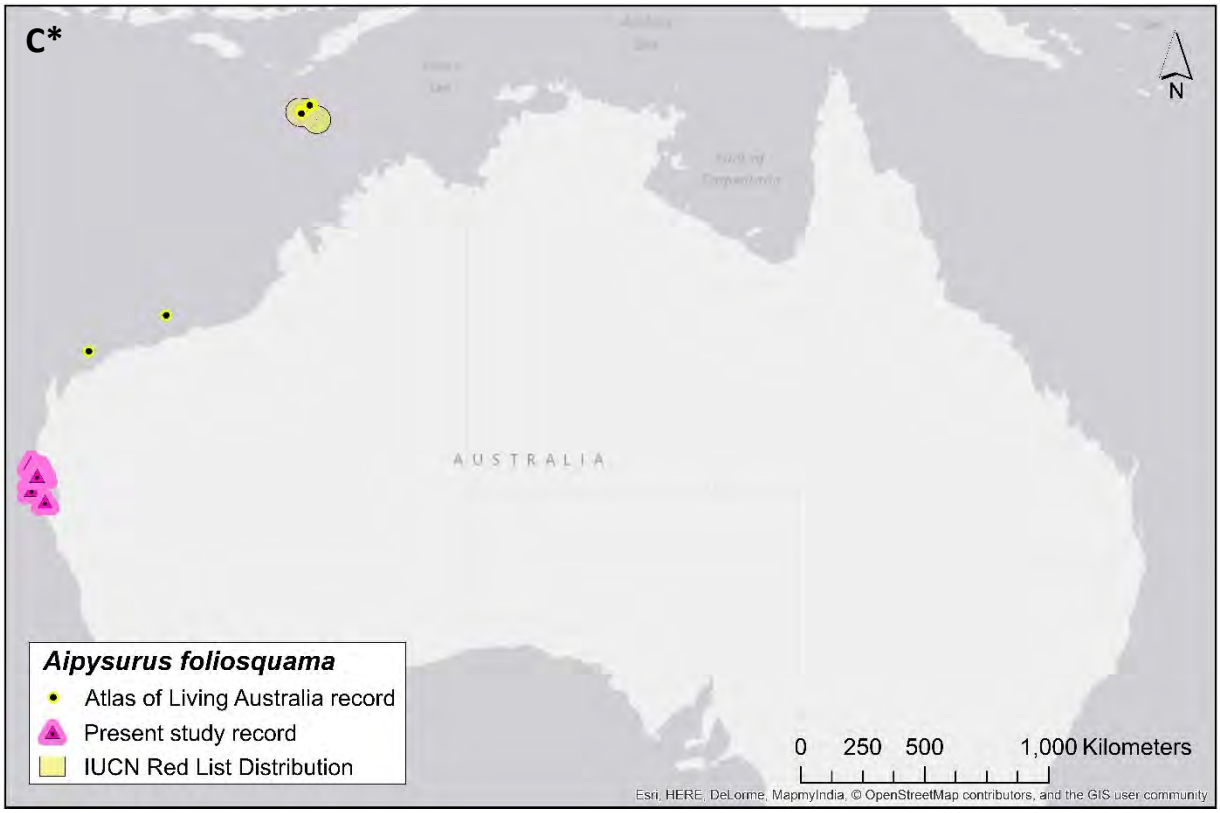


Figure 3. Sea snake distribution records from survey and sighting reports collected during the present study (pink triangles) and the Atlas of Living Australia (black dots with yellow rings) and the estimated species distribution from the IUCN Red List of Threatened species (yellow cross hatching enclosed by a black line) for A) *A. apraefrontalis*, B) *A. duboisii*, C) *A. foliosquama*, D) *A. fuscus*, E) *A. laevis*, F) *A. pooleorum*, G) *A. tenuis*, H) *E. annulatus*, I) *Hydrelaps darwiniensis*, J) *H. coggeri*, K) *H. elegans*, L) *H. major*, M) *H. platurus* and N) *H. stokesii*. Please note that text based records lacking accurate location data (e.g. a specified latitude and longitude), are not presented on these maps- see Species accounts for further details). Figure numbers marked with an asterix ('*') represent range extensions based on GPS data and literature descriptions of range.



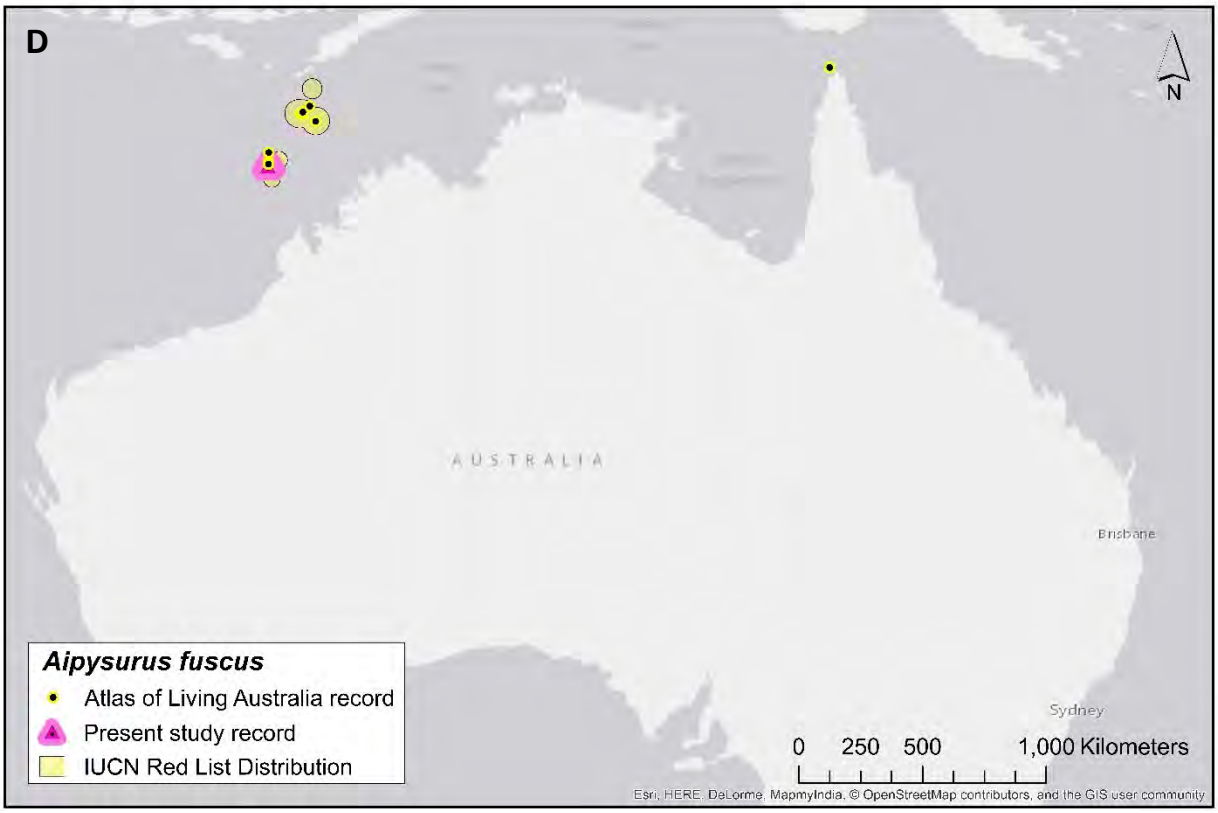
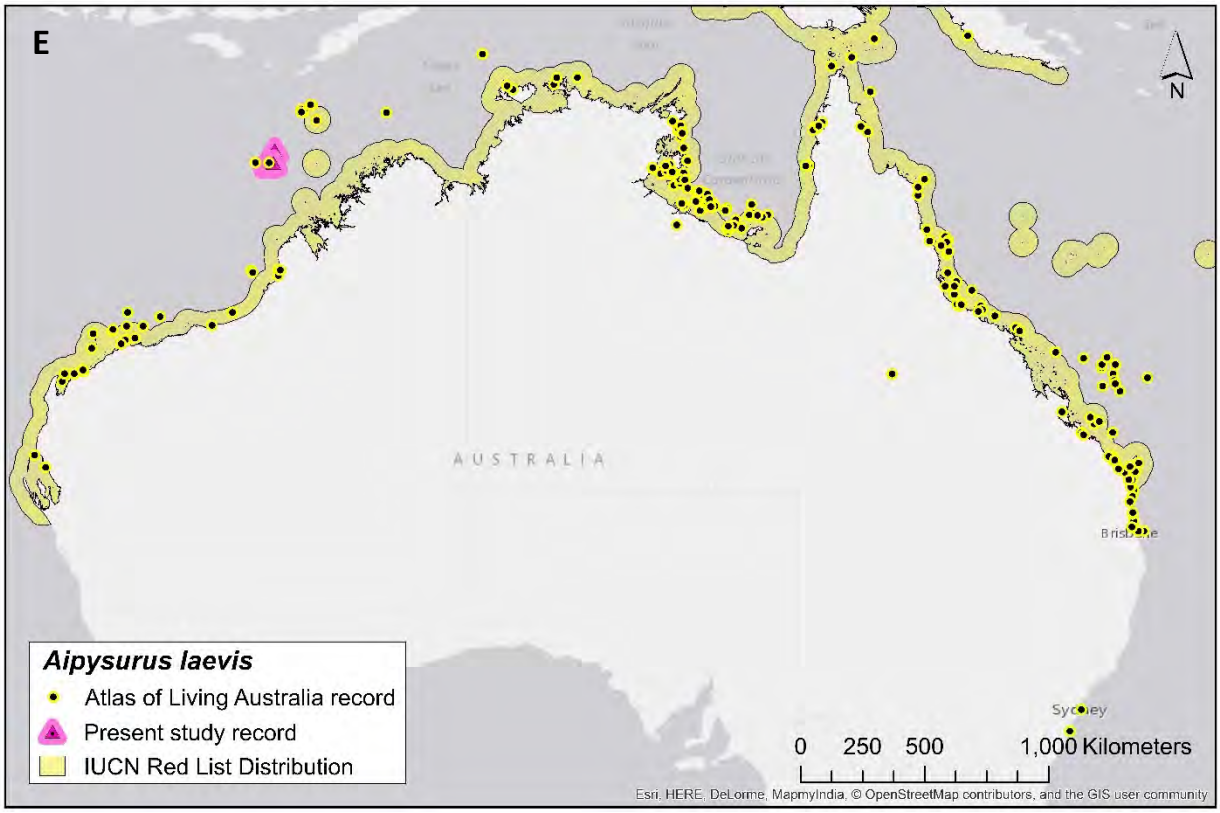


Figure 3 (ctd). Sea snake distribution records from survey and sighting reports collected during the present study (pink triangles) and the Atlas of Living Australia (black dots with yellow rings) and the estimated species distribution from the IUCN Red List of Threatened species (yellow cross hatching enclosed by a black line). Figure numbers marked with an asterix ('*') represent range extensions based on GPS data and literature descriptions of range.



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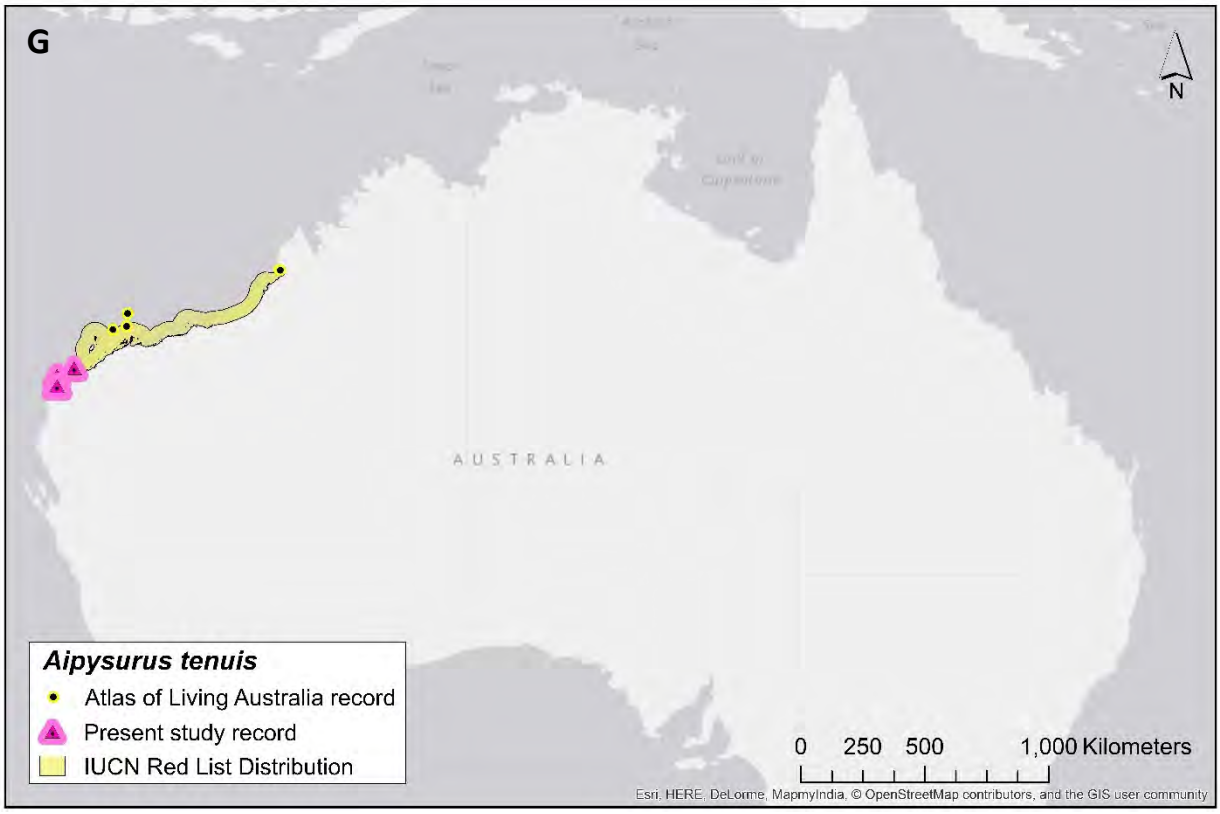

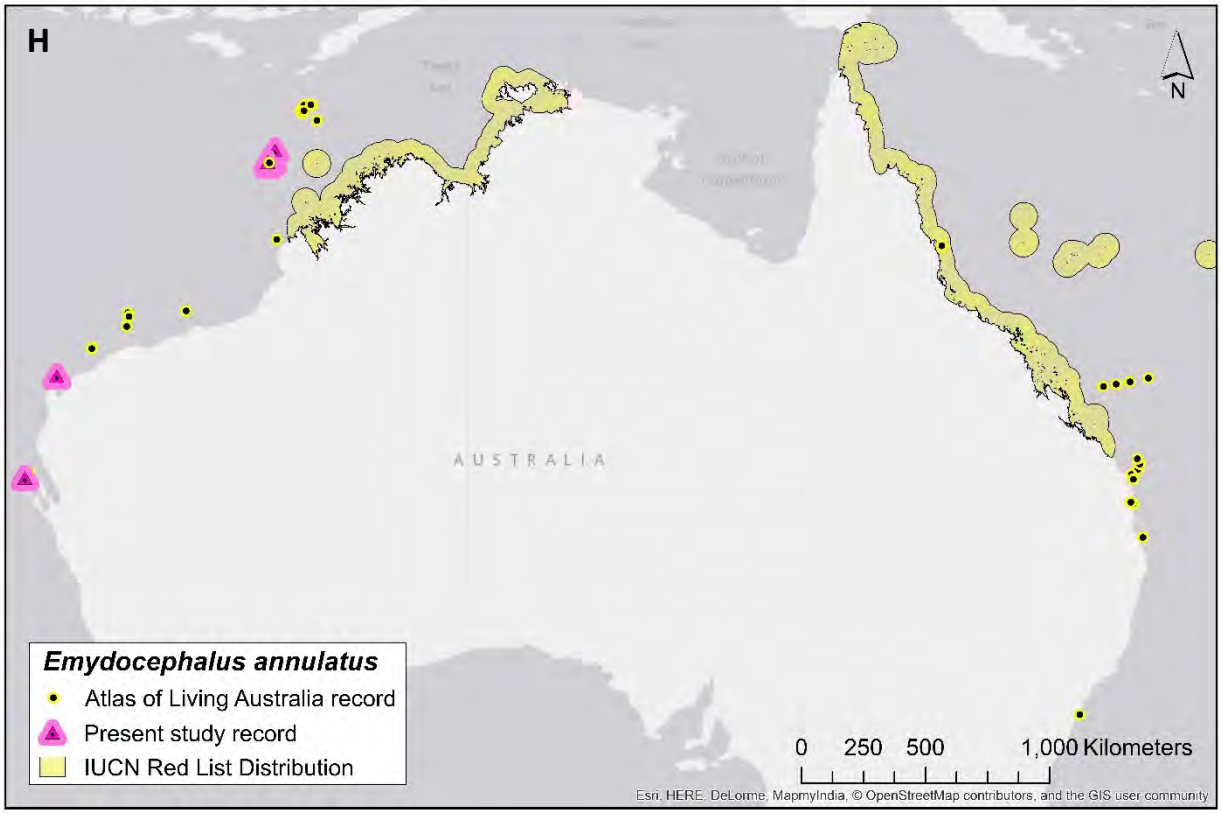

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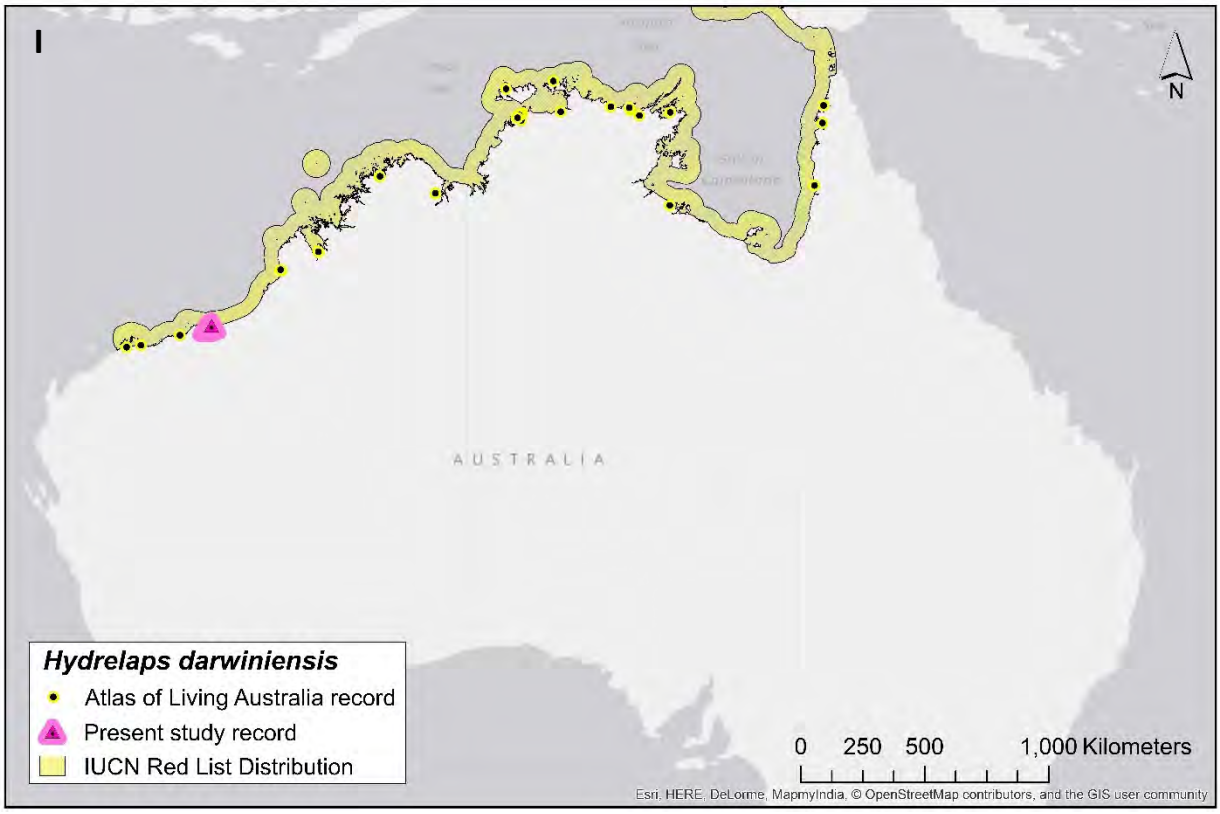

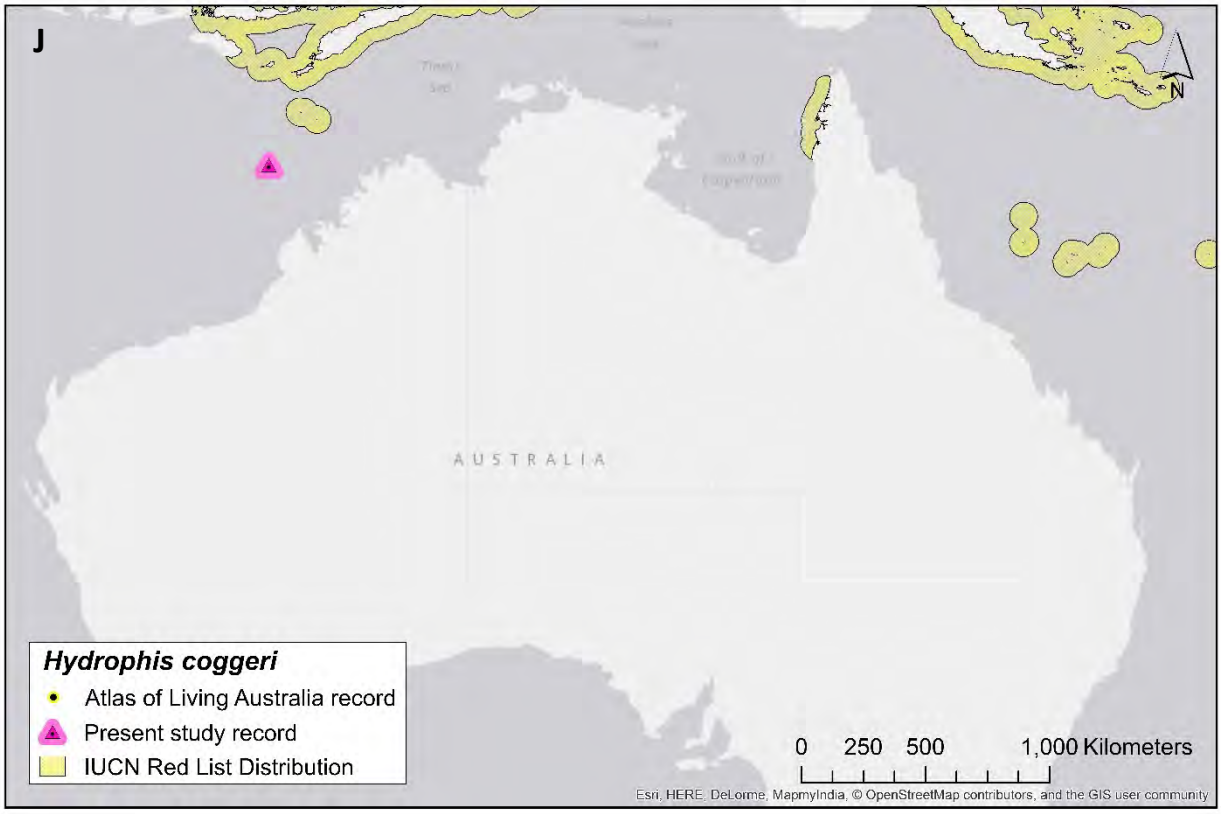

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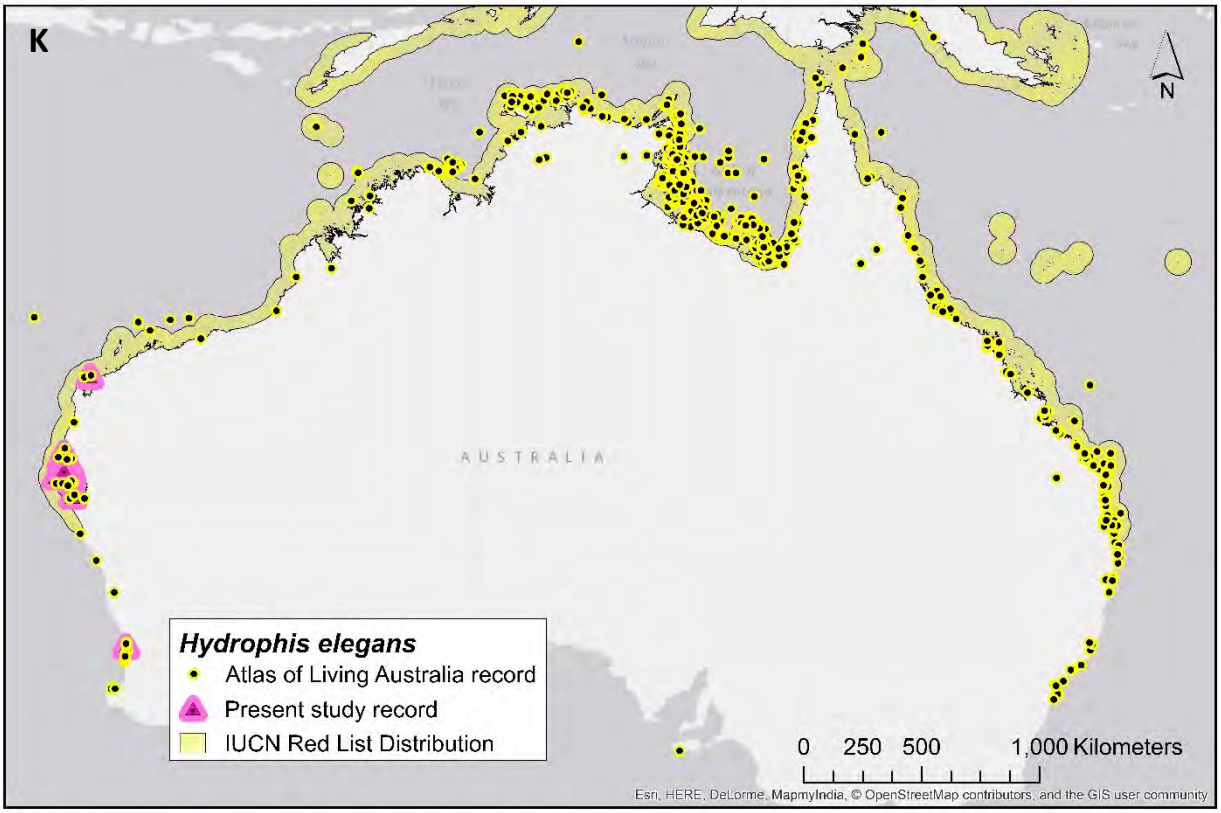

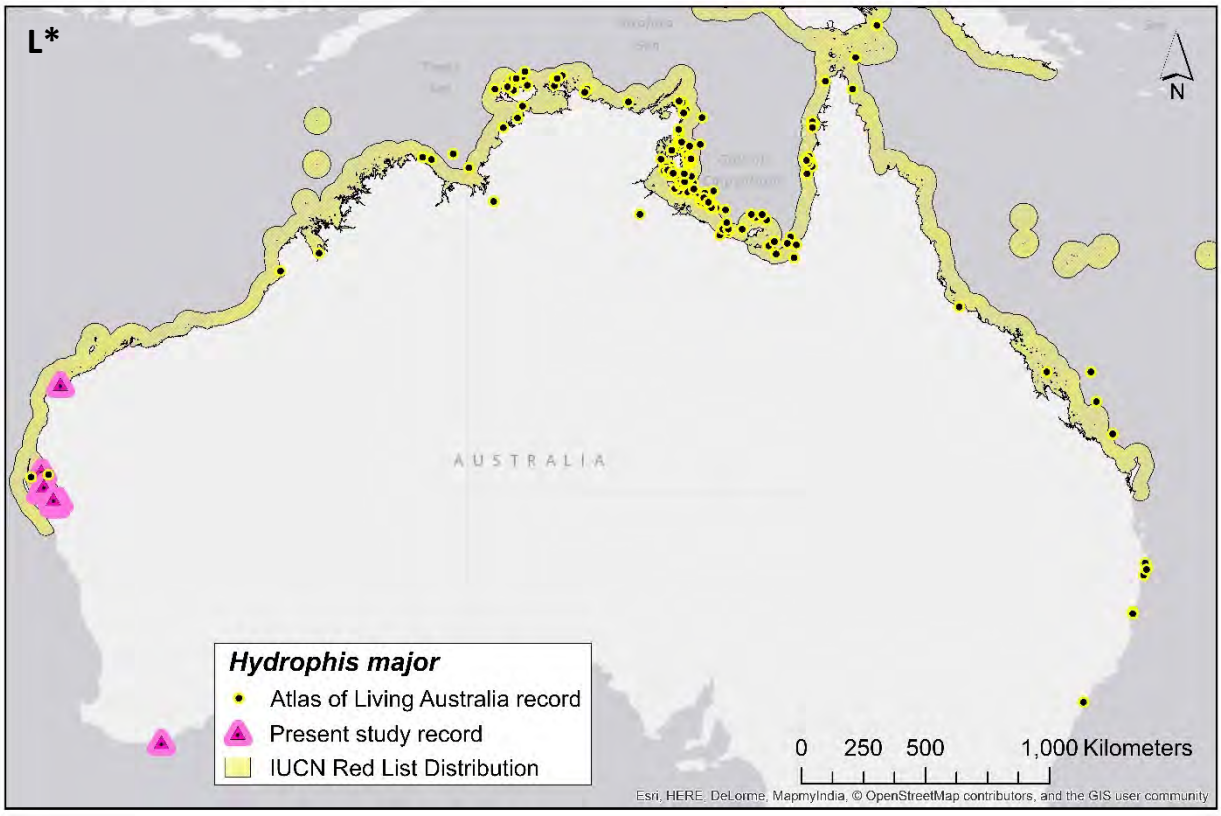

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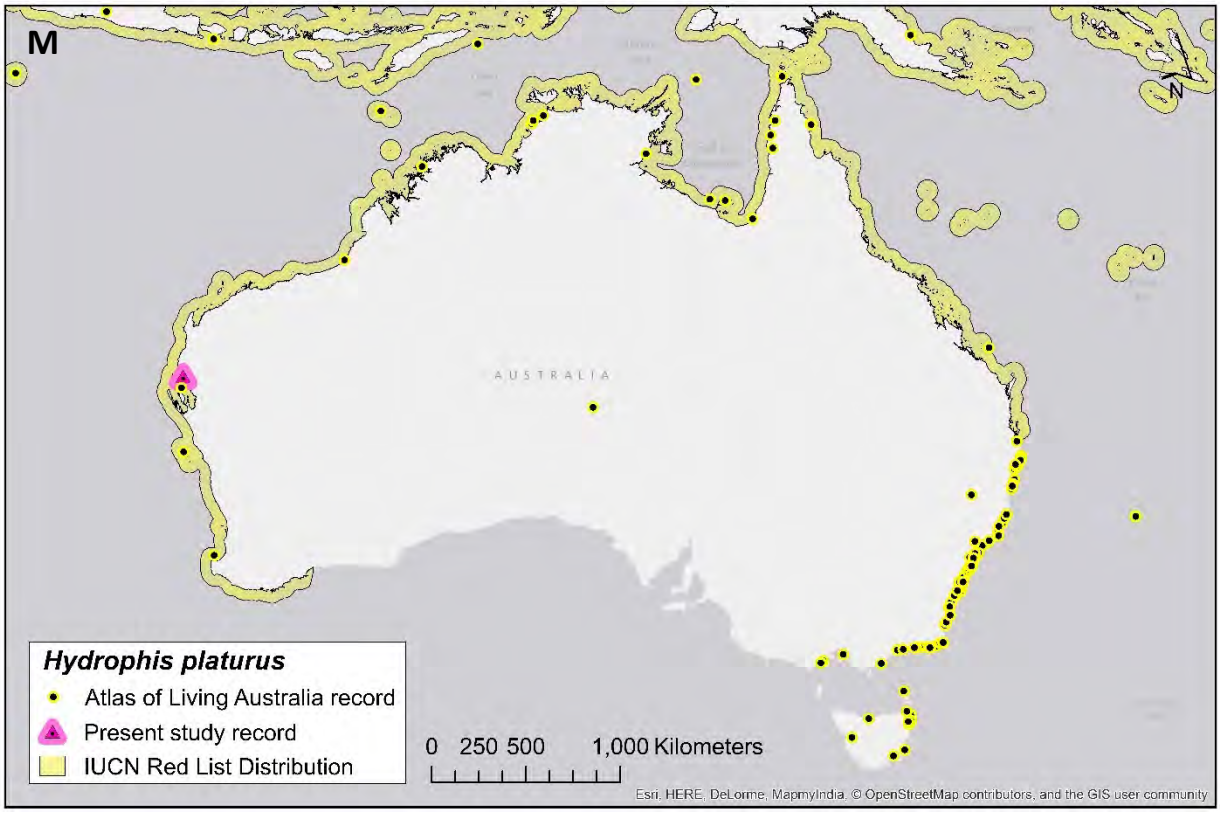

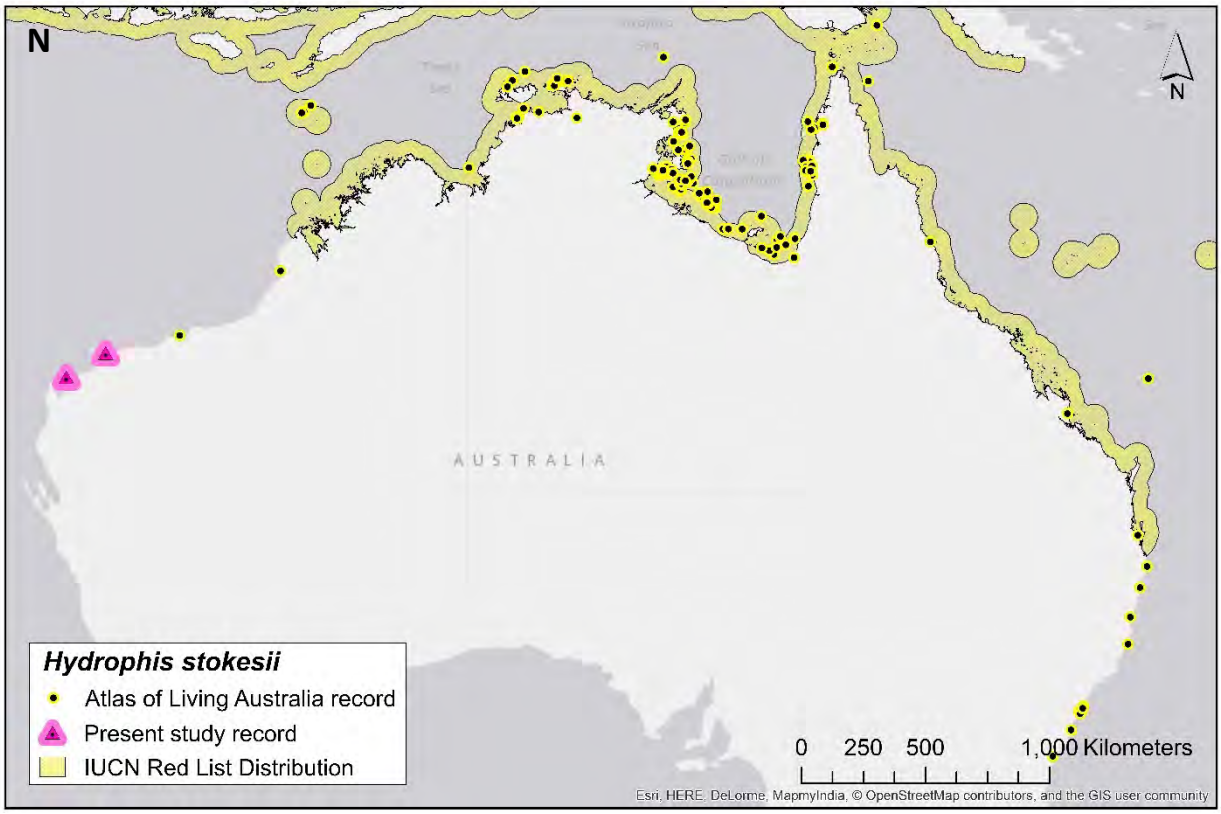

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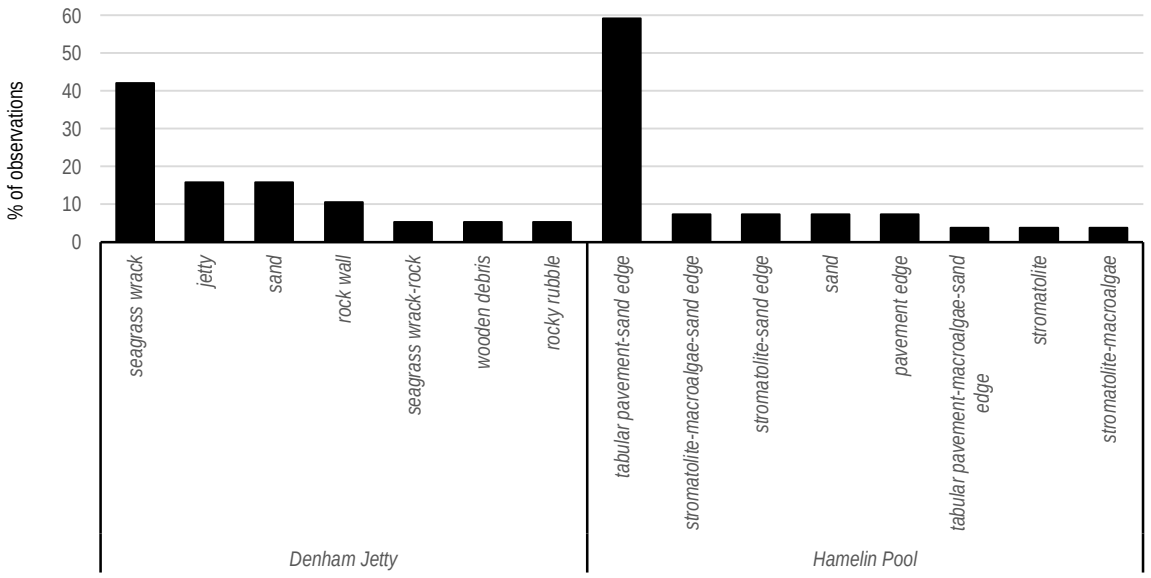

Figure 4. Habitats used by *A. pooleorum* at study sites Denham Jetty (n=19), during November and December, 2013 and February, 2014 and Hamelin Pool (n=27) during March, April and November, 2014, in Shark Bay. All surveys were conducted on snorkel and manta tow. Habitats shown represent all habitats in which *A. pooleorum* was observed in at the study sites, with observations of snakes travelling to or from the surface removed.

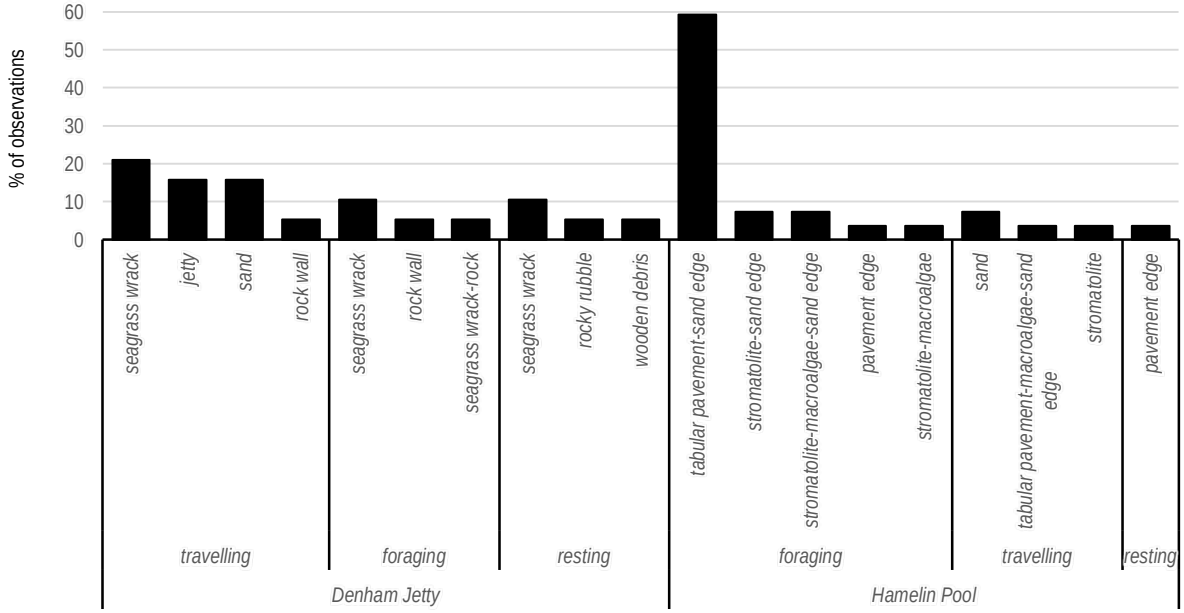

Figure 5. Behaviours associated with habitats used by *A. pooleorum* at study sites Denham Jetty (n=19) during November and December, 2013 and February, 2014 and Hamelin Pool (n=27) during March, April and November, 2014, in Shark Bay. All surveys were conducted on snorkel and manta tow. Habitats shown represent all habitats in which *A. pooleorum* was observed in at the study sites, with observations of snakes travelling to or from the surface removed. Behaviours were defined as travelling (moving across a particular habitat type); foraging (putting head into crevices or structures); resting (motionless, either concealed, out in the open, or with part of the body, such as the tail, exposed).

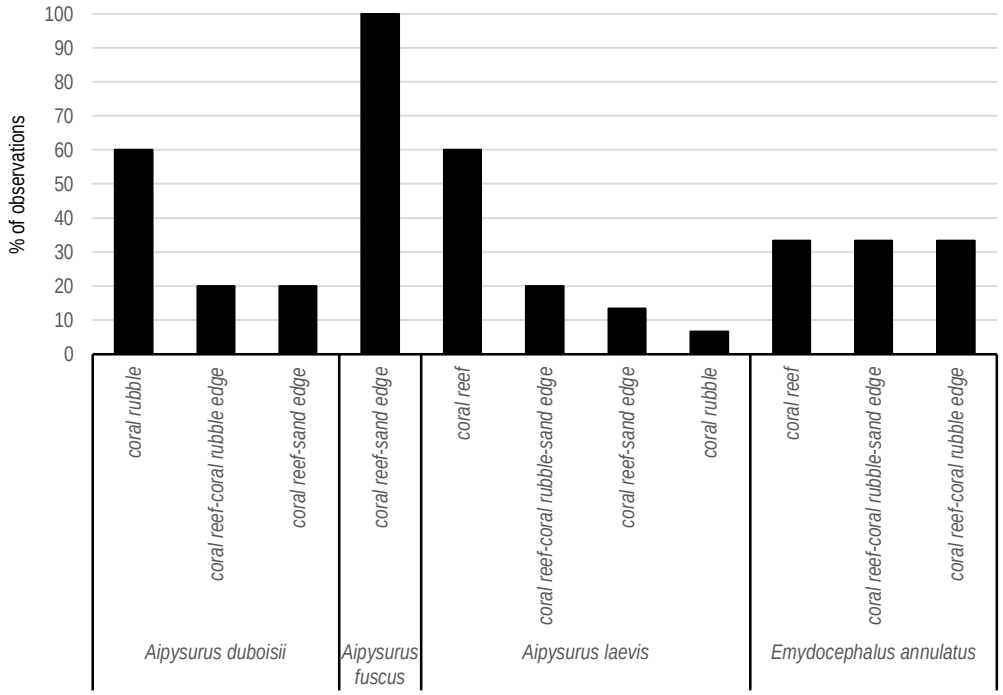

Figure 6. Habitats used by sea snake species in the *Aipysurus* lineage including *A. laevis* (n=15), *A. duboisii* (n=5), *A. fuscus* (n=4) and *E. annulatus* (n=3), in the Scott Reef Complex (North Scott, South Scott and Seringapatam reef), Timor Sea in October, 2014. Habitats shown represent all habitats in which sea snakes were observed in the study sites, with observations of snakes travelling to or from the surface removed.

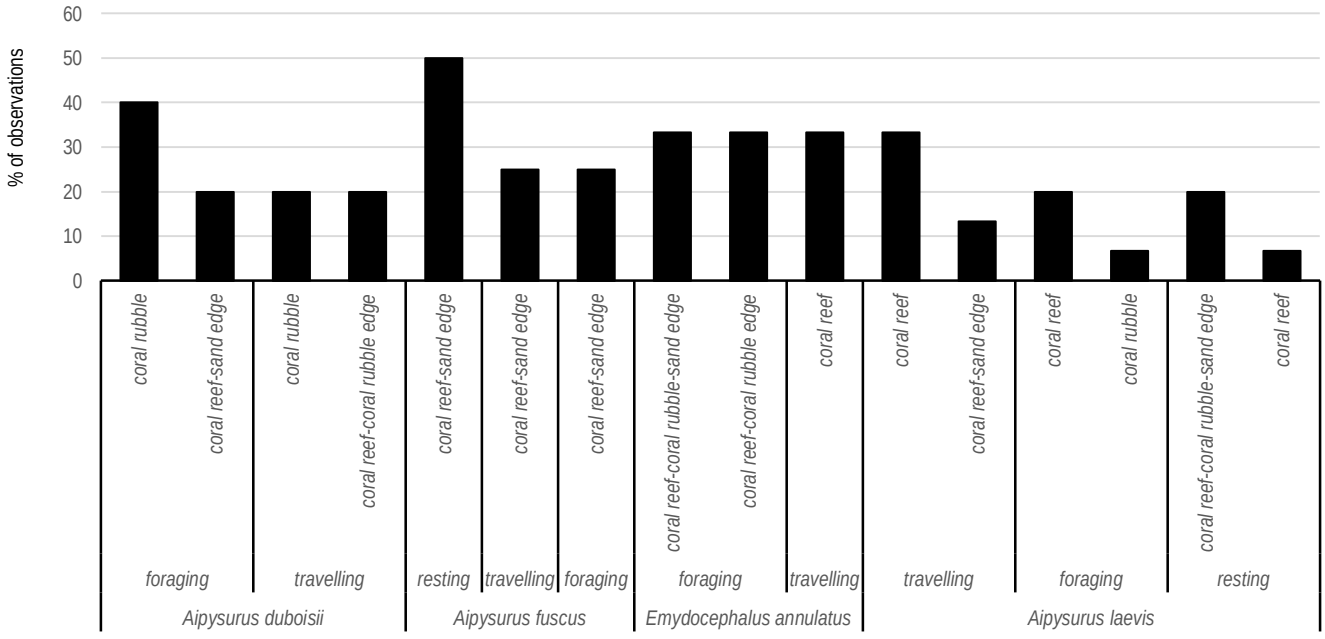

Figure 7. Behaviours associated with Habitats used by sea snake species in the *Aipysurus* lineage including *A. laevis* (n=15), *A. duboisii* (n=5), *A. fuscus* (n=4) and *E. annulatus* (n=3), in the Scott Reef Complex (North Scott, South Scott and Seringapatam reef), Timor Sea in October, 2014. Habitats shown represent all habitats in which sea snakes were observed in the study sites, with observations of snakes travelling to or from the surface removed. Behaviours were defined as travelling (moving across a particular habitat type); foraging (putting head into crevices or structures); resting (motionless, either concealed, out in the open, or with part of the body, such as the tail, exposed).

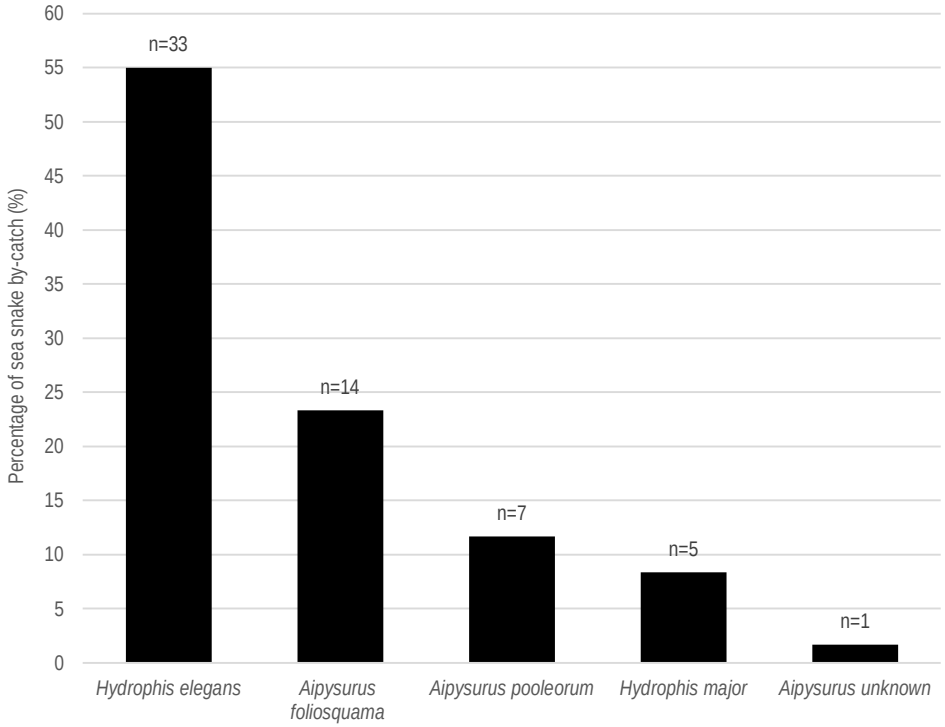

Figure 8. Sea snake by catch in Shark Bay, represented as the percentage of the total number of sea snakes (n=60) caught in combined scientific demersal prawn trawl by catch surveys, conducted by the WA DoF during the months of August and November, 2014 and February, March, April, May and June in 2015. The sample size for each species (n) is given above each bar. Two sea snakes not identified to species level have been excluded. Effort was not quantified and percentages are not scaled for effort.

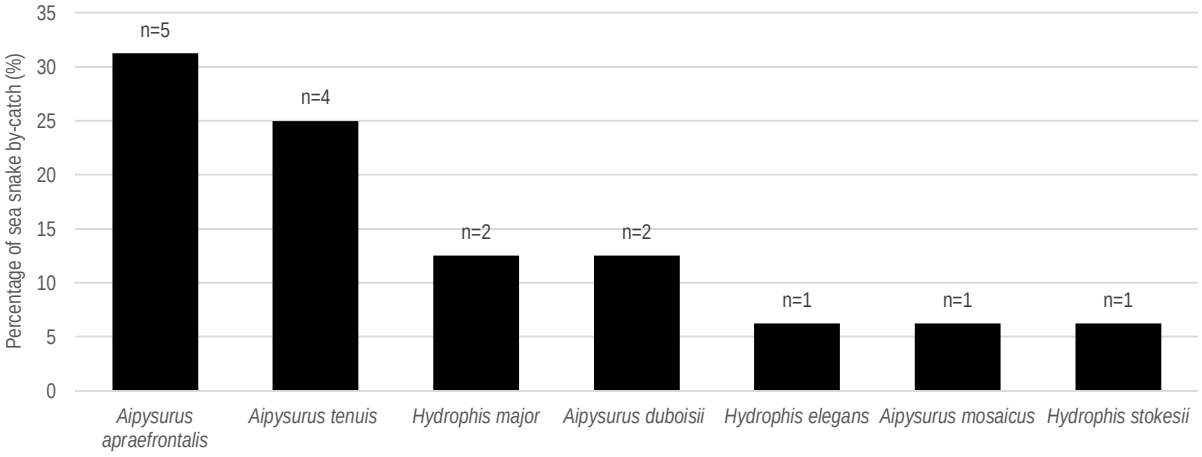

Figure 9. Sea snake by catch in Exmouth Gulf, represented as the percentage of the total number of sea snakes (n=16) caught in combined scientific demersal prawn trawl by catch surveys, conducted by the WA DoF during the months of August, 2014 and March, April and May, 2015. The sample size for each species (n) is given above each bar. Effort was not quantified and percentages are not scaled for effort.

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