Marine Biodiversity Hub

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Conservation Status of Tropical Inshore Dolphins

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Important Disclaimer

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EXECUTIVE SUMMARY

Over the course of the last decade, the Australian Government has received several nominations to list tropical inshore dolphins, namely the now recognised endemic Australian humpback (*Sousa sahulensis*) and snubfin (*Orcaella heinsohni*) dolphins, as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). These nominations have not been progressed by the Threatened Species Scientific Committee, based largely upon there being a lack of data available to support each nomination. Since the development of a coordinated national research framework to inform the conservation and management of Australia's tropical inshore dolphins, however, numerous research and monitoring projects have been completed. Accordingly, there now exists markedly more in the way of baseline data. This project aimed to update and synthesize current knowledge on Australia's tropical inshore dolphins, and the anthropogenic threats they face, in order to inform subsequent assessments of their conservation status.

Long uncertain taxonomic status has been largely resolved for the Australian humpback, snubfin and Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in tropical inshore waters, but the data deficient/priority listed spinner dolphin (*Stenella longirostris* sp.) complex remains unstudied. There has been advancement in knowledge of distribution, abundance and trends, habitat use and social and population structure of the former three species, but this applies primarily to discrete study areas or, at best, some regional levels. At a national scale, the priority objectives outlined in the coordinated national research framework remain somewhat unfulfilled. Broader data sharing and a nationwide assessment of abundance, trends or genetic population structure are yet to occur. At some sites where rigorous sampling has taken place, low abundance or movements over scales larger than the study areas have precluded mark-recapture modelling of abundance, movements and trends.

Although Australia's tropical inshore waters are recognised as being some of the least impacted by human activities on a global scale, they have nonetheless been identified as a global hotspot for extinction risk in marine mammals. Anthropogenic threats to dolphins in the region align with those ranked as the greatest to marine ecosystems globally, the main three being: (*i*) habitat loss, degradation and contamination through coastal development; (*ii*) bycatch in fishing gear and shark nets set for bather protection; and (*iii*) climate change, including both gradual ocean warming and acidification, as well as extreme weather events.

In terms of assessing conservation status, a key challenge that remains is the estimation of the number of animals in areas not yet surveyed. Scenario modelling/sensitivity analysis of the likely number of mature individuals in the national 'population' of each species, based on existing knowledge of subpopulation sizes, distribution modelling of suitable habitat and assumptions about numbers in unsurveyed areas, should be given due consideration. The integration of multiple data sources to estimate areas of occupancy and national population sizes will inform conservation listings in the face of uncertainty.

1. BACKGROUND

In 2013, the (now) Department of Agriculture, Water and the Environment (DAWE) received a nomination to list the (now) Australian humpback dolphin *Sousa sahulensis* as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The nomination was not progressed by the Threatened Species Scientific Committee (TSSC) due to a lack of available data. In consultation with an expert panel, the DAWE then developed a coordinated national research framework to inform the conservation and management of Australia's tropical inshore dolphins (Department of the Environment, 2013).

This framework was updated in 2015 (Department of the Environment, 2015), when funding became available through the *Whale and Dolphin Protection Plan*. Administered by James Cook University, Queensland (Qld), a number of research projects were then undertaken across northern Australia through this plan. Other research and monitoring projects targeting tropical inshore dolphins were being completed through the formerly funded competitive tender process via the *Australian Marine Mammal Centre*. Additionally, research was being carried out as part of offset and post-approval monitoring programmes required for projects approved under the EPBC Act. The most significant of these was INPEX's "Ichthys LNG Project" on Darwin Harbour, which included long-term monitoring in the harbour and adjacent waterways, as well as one-off surveys across the broader coast of the Northern Territory (NT). A similar programme involving boat-based and aerial surveys was conducted around Chevron's "Wheatstone LNG Project" off Onslow in Western Australia (WA).

In March 2019, a second nomination to list the Australian humpback dolphin as Vulnerable under the EPBC Act was received, and the TSSC is in need of updated information to assess whether or not the Australian humpback or, indeed, the Australian snubfin dolphin *Orcaella heinsohni* might now qualify for listing under the Vulnerable category. As a result of these research and monitoring efforts, there now exists markedly more in the way of data and subsequent reporting available to inform an assessment the conservation status of Australian tropical inshore dolphin species.

1.1 Aims

This project thus aims to synthesize the outcomes of numerous tropical inshore dolphin research and monitoring efforts completed since 2013, in order to improve our understanding of their current threats and inform any subsequent assessments of their conservation status. This review updates and summarises current knowledge on Australian humpback dolphins ('humpback dolphins' hereafter), Australian snubfin dolphins ('snubfin dolphins' hereafter) and Indo-Pacific bottlenose dolphins *Tursiops aduncus* ('bottlenose dolphins' hereafter), as well as the priority listed but still little-known complex of spinner dolphins *Stenella longirostris* sp. ('spinner dolphins' hereafter) in Australian coastal waters.

The geographical focus remains on where humpback, snubfin and bottlenose dolphins co-occur, i.e., in and around Moreton Bay, Qld, around the northern Australian coastline to Shark Bay, WA.

The review provides updated, relevant information on:

1. Taxonomic status, Australian distribution, abundance and trends, habitat use, social structure, population structure, life history characteristics and behaviour.

2. Threats in Australian tropical inshore waters.

3. Conservation status in Australian waters.

The project falls under the National Environmental Science Program (2015-2021) Marine Biodiversity Hub's research Theme A "Threatened and Migratory Species" and aligns with the Research Priority of Marine Biodiversity 2 (Matters of National Environmental Significance).

2. SPECIES INFORMATION

2.1 Australian humpback dolphin

2.1.1 Taxonomic status

After several centuries of taxonomic uncertainty, the humpback dolphin genus *Sousa* has been better resolved using multiple lines of evidence, including skeletal morphology, external morphology, colouration, molecular genetics and biogeography. Jefferson and Rosenbaum (2014) clarify the existence of four species: the West African *S. teuszii*; *S. plumbea* which occurs from the coastal waters of South Africa to Myanmar; *S. chinensis* which ranges from eastern India to central China and throughout Southeast Asia; and finally, separated by a distributional gap coincident with Wallace's Line, the Australian humpback dolphin *S. sahulensis,* which is found in the waters of the Sahul Shelf from southern New Guinea and across northern Australia (Fig. 1).

Figure 1: An Australian humpback dolphin in tropical inshore waters.

2.1.2 Australian distribution

Humpback dolphins are widely distributed in subtropical and tropical inshore waters from around the Queensland-New South Wales border in the south-east, around northern Australia to Shark Bay in Western Australia (Allen et al., 2012; Palmer et al., 2014; Palmer, 2015; Parra and Cagnazzi, 2016; Fig. 2). It should be noted here that sightings of humpback dolphins as far south as Port Stephens on the east coast and Kalbarri on the west coast have also been documented in recent years.

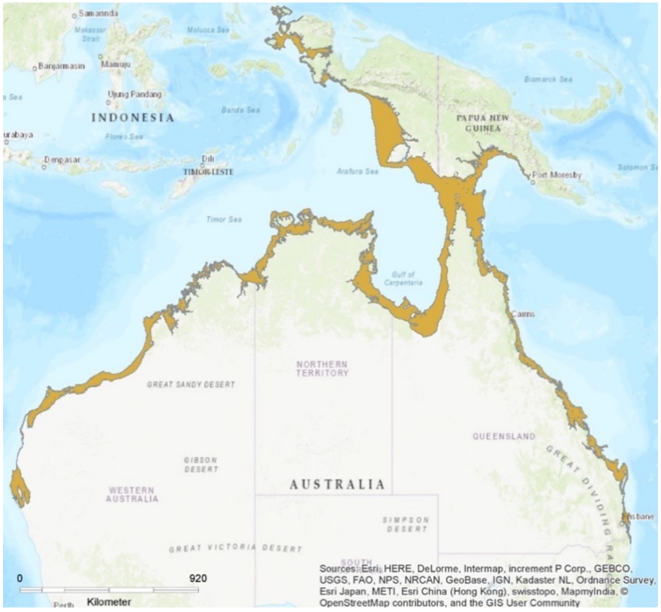

Figure 2: Humpback dolphin distribution (from IUCN Red List; Parra et al., 2017).

2.1.3 Abundance and trends

Obtaining estimates of the total number of mature individuals in the (national) population of humpback and snubfin dolphins was ranked as a high priority for research in the 2013 *Coordinated National Research Framework to Inform the Conservation and Management of Australia's Tropical Inshore Dolphins* (Department of the Environment, 2013). Nevertheless, there remains no national population estimate available for humpback dolphins, or indeed any tropical inshore dolphin species. There are estimates for discrete populations/study areas (Table 1), at which humpback dolphins occur in generally low numbers (typically <100 individuals) and at low densities (0.07-0.17 individuals per km^2) (Brown et al., 2016; Parra and Cagnazzi, 2016; Brooks et al., 2017). An exceptional upper population estimate was reported from Port Essington in the NT (207, at a density of 0.64), although estimates fluctuated widely over time (Palmer et al., 2015), and the highest density thus far reported occurs around the North West Cape in WA (with a super population estimate of 129 individuals in a 130 km^2 study area) (Hunt et al., 2017).

Few studies have been long-term or resolute enough to detect trends in abundance, although Cagnazzi (2013) reported declining abundance estimates in Keppel Bay and the Curtis Coast regions, Qld, from 115 and 84 individuals in 2007 to 104 and 45 in 2011, respectively. Extending the data collection and analyses through 2016, Cagnazzi et al. (2020b) reported on declines of 56 to 32 adult females at both Fitzroy River and Port Curtis sites in 2011, coinciding with a major flood and the expansion of Port Curtis facilities. The number of females in Port Curtis returned to original levels once development activity had ceased, but the declining trend continued in the Fitzroy River (Cagnazzi et al., 2020b). In the NT, Brooks et al. (2017) documented a steady decline in humpback dolphin abundance in Darwin Harbour over time, with a concomitant increase in two neighbouring sites.

2.1.4 Habitat use

Aerial surveys of the Great Barrier Reef, Qld, illustrated that humpback dolphins favour shallow waters close to the coast, though they are also seen in relatively sheltered offshore areas near reefs or islands (Corkeron et al., 1997). These tendencies have more recently been corroborated by research from a variety of platforms in the NT and WA (Allen et al., 2012; Brown et al., 2012; Palmer et al., 2014). By way of example, all age/sex classes have been observed despite relatively limited effort in the shallow waters around the Montebello Islands, some 80km from the WA mainland coast (Raudino, Hunt and Waples, 2018). Analysis of humpback dolphin spatial distribution in three adjacent bays in the northern section of the Great Barrier Reef Marine Park indicated that they occur primarily in waters <15 m deep, within 10 km of the coast and within 20 km of the nearest river mouth (Parra, Corkeron and Marsh, 2006; Parra, Schick and Corkeron, 2006). In more recent, systematic, boat-based research on humpback dolphins around the North West Cape, WA, Hunt et al. (2020) also identified water depth and distance to coast as the most important variables influencing humpback dolphin presence, with the dolphins showing a preference for shallow waters (5–15 m) less than 2 km from the coast.

Some 25 years of systematic surveys and government datasets in the near-urban Moreton Bay, Qld, were interrogated to investigate long-term site fidelity and habitat use by humpback dolphins (Meager et al., 2018). Fidelity and consistency in use were evident at the industrialised port at the mouth of the Brisbane River, indicative of at least some communities using heavily anthropogenically modified habitats (Fig. 3). Patterns of habitat use were more dynamic elsewhere, with a marked shift away from the north-western side of Moreton Bay evident after 1999, attributed to a decline in habitat integrity exacerbated by periodic floods (Meager et al., 2018). In the Capricorn-Curtis coast and Great Sandy Strait study sites, the majority of the identified humpback dolphins were long-term residents (Cagnazzi et al., 2011; Cagnazzi, 2013). In Cleveland Bay, Qld, most individual humpback dolphins did not reside in the study area permanently but, rather, used it regularly from year to year, with sighting patterns suggesting that movements followed a model of emigration and re-immigration into the bay (Parra, Corkeron and Marsh, 2006).

Figure 3: A group of humpback dolphins travels by the industrialised coastline of Port Hedland, WA.

The variation in abundance estimates detected among seasons in Port Essington, NT, likely indicates many individuals moving at scales larger than the study area (Palmer et al., 2015), a finding not uncommon in mark-recapture studies of coastal delphinids (Nicholson et al., 2012; Brooks et al., 2017). In central Queensland, a male adult humpback dolphin was tracked with a satellite-linked GPS tag for four months and ranged along a 75 km stretch of coastline (J. Meager, unpub. data). Similarly, and indicative of the ease of quite distant movements, a humpback dolphin mother-calf pair were photo-identified off the open coast of WA, then re-sighted three days later within the Cambridge Gulf, >50 km distant (Brown et al., 2017). Around the North West Cape, there was considerable variation in dolphin sighting frequencies, but 63% of identified individuals exhibited high levels of site fidelity, and dolphins used the study area regularly, in a movement model also characterised by emigration and re-immigration (Hunt et al., 2017).

2.1.5 Social structure

The social system of many delphinid species is characterised by a fission-fusion grouping pattern, in which school size and composition changes frequently, but also in which differentiated relationships exist. Humpback dolphins are no exception, with numerous studies now quantifying non-random associations between individuals, same sex preferred affiliations, modular clustering of connected groups of individuals and, in some cases, potentially key individuals with a disproportionate influence on connectivity between clusters (Parra, Corkeron and Arnold, 2011; Hunt et al., 2019; Hawkins et al., 2020). There now also exists a growing body of evidence that adult male humpback dolphins may form temporary coalitions, perhaps even longer term alliances, for the purposes of gaining access to receptive females (Allen et al., 2017; Hunt et al., 2019; Fig. 4). Alliance formation is well documented in bottlenose dolphins (Connor et al., 2017, 2019), occurs in at least some Risso's dolphin populations (Hartman, van der Harst and Vilela, 2020), and these findings point to a hitherto unrecognised level of social complexity in humpback dolphins (Allen et al., 2017).

2.1.6 Population structure

Although no national assessment of humpback dolphin population structure exists, four putative populations were identified along the Qld east coast, with little contemporary gene flow among them (Parra et al., 2018). Genetic divergence followed an isolation-by-distance model, with an apparent restriction in gene flow occurring at scales of ~400-500 km, and estimates of contemporary effective population size were low (Parra et al., 2018). Similarly, significant genetic differentiation was detected between humpback dolphins sampled in the Dampier Archipelago and those ~300 km distant around the North West Cape, WA (Brown et al., 2014). Additional, although limited, sampling further east later suggested very little gene flow between the Kimberley and Pilbara coasts of WA (Brown et al., 2017). Available data point toward humpback dolphins existing as a metapopulation of small and relatively isolated populations with limited gene flow among them (Brown et al., 2014, 2017; Parra et al., 2018).

2.1.7 Life history characteristics

Life history characteristics are poorly known for the Australian humpback dolphin, though they are likely to approximate those of the congeneric Indo-Pacific humpback dolphin (Parra and Cagnazzi, 2016). Gestation lasts 10-12 months; lactation may last more than 2 years; female sexual maturity is reached at 9-10 years of age and males mature at 12-14 years; Generation length is estimated at between 20 and 25 years; and longevity of over 40 years is expected (Taylor et al., 2007; Parra and Cagnazzi, 2016).

2.1.8 Behaviour

Humpback dolphins exhibit a broad suite of foraging and socialising behaviours similar to bottlenose dolphins. They are generalist-opportunistic predators, some engaging in intentional stranding in pursuit of prey (Beasley, Allen and Parra, 2012, and references therein). The manipulation of objects in their environment, particularly marine sponges, has now been observed across their range and appears to form part of multi-modal sexual displays by adult males, highly unusual in the context of mammalian behaviour (Allen et al., 2017; Fig. 4).

Figure 4: (*i*) Adult male humpback dolphin allies, showing characteristic loss of dorsal fin pigment (Brown et al., 2016), and (*ii*) an adult male carrying a large marine sponge toward a female.

2.2 Australian snubfin dolphin

2.2.1 Taxonomic status

Cranial morphometrics, external morphometrics, colouration and molecular comparisons facilitated the separation of the genus *Orcaella* into two species: *O. brevirostris*, distributed throughout Southeast Asia over the Sunda Shelf; and the Australian snubfin dolphin *O. heinsohni*, which occurs in the Kikori Delta of southern Papua New Guinea and throughout northern Australia (Beasley, Robertson and Arnold, 2005; Fig. 5).

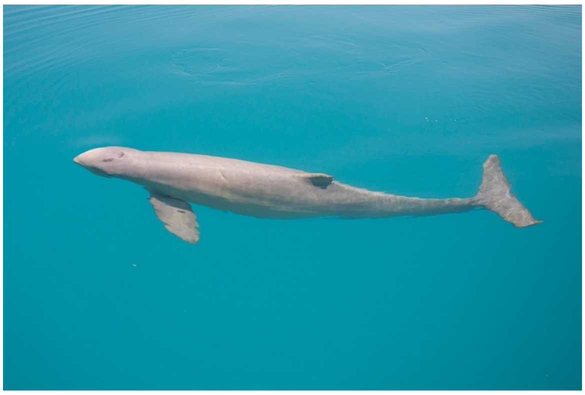

Figure 5: An Australian snubfin dolphin in tropical inshore waters.

2.2.2 Australian distribution

Snubfin dolphins occur from Port Alma/Fitzroy River, Qld, in the southeast, north along the Qld coast and across the NT to Roebuck Bay, WA (Grech et al., 2014; Palmer et al., 2014; Palmer, 2015; Beasley and Brown, 2018; Fig. 4). Extralimital records extend as far south as the Brisbane River on the east coast and the North West Cape and Exmouth Gulf on the Pilbara coast of WA (Allen et al., 2012; Beasley and Brown, 2018).

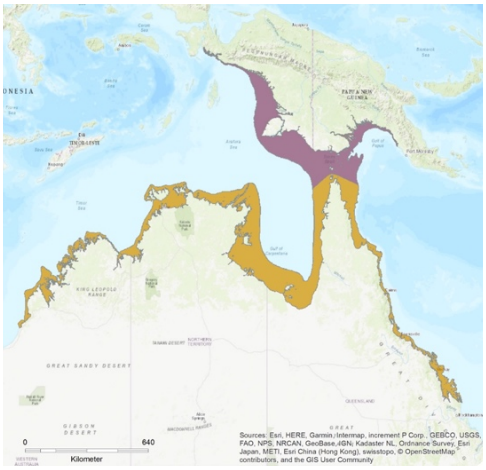

Figure 6: Snubfin dolphin distribution (area shaded yellow) and possible Papua New Guinean distribution (area shaded purple) (from IUCN Red List; Parra, Cagnazzi and Beasley, 2018).

2.2.3 Abundance and trends

No national population estimates are available for snubfin dolphins. They occur in relatively small populations (typically <100 individuals) in low densities (0.02-0.42 individuals per km^2) across their distribution (Table 1). Exceptional upper population estimates have been reported from Port Essington, NT (222 individuals at a density of 0.68 individuals per km^2), and the highest density thus far reported was in Roebuck Bay, WA (133 and density 1.33) (Palmer et al., 2014; Brown et al., 2016). Despite a spatially and temporally intensive sampling regime across three adjacent NT embayments, low snubfin dolphin recapture rates precluded capture-recapture modelling (Brooks et al., 2017). Most likely indicative of differential habitat preferences between tropical inshore dolphin species, just two groups totalling four snubfin dolphins were encountered despite considerable effort in Beagle Bay, WA, which lies between populations of ~50 and 130 snubfins (Brown et al., 2016). In terms of trends, Beasley (2016) reported over double the abundance of snubfin (and humpback) dolphins in Cleveland Bay from earlier research (Parra, Corkeron and Marsh, 2006), but this apparent increase might be attributed to differences in sampling areas, analytical approaches or a genuine increase in abundance. No broader trend data are available.

2.2.4 Habitat use

The combination of stranding records, museum specimens, sighting databases and unpublished data from aerial surveys demonstrated that snubfin dolphins are found primarily in protected, shallow, coastal waters close to creeks and river mouths (Beasley, Allen and Parra, 2012, and references therein). A review of all available sightings data and stranding information indicated that the Fitzroy River snubfin dolphin population is the southernmost in Australian waters; composed of less than 100 individuals; with a decrease in representative range, core area and preferred habitat between 14 and 25% projected to occur following industrial port development (Cagnazzi et al., 2013). Boat-based photo-identification in Cleveland Bay, Qld, revealed that, like humpback dolphins, most individual snubfin dolphins did not reside in the study area permanently, but rather used it regularly from year to year, with movement patterns following a model of emigration and re-immigration (Parra et al., 2006). Within the representative ranges identified in Cleveland Bay, snubfin dolphins preferred shallow (1–2 m) waters and areas with seagrass (Parra, 2006). Spatial distribution of snubfin dolphins in three adjacent bays in the far northern Great Barrier Reef Marine Park indicated that most snubfins were sighted primarily in waters <15 m deep, within 10 km of the coast and within 20 km of the nearest river mouth (Beasley, Allen and Parra, 2012).

One extended small boat survey detected snubfin (and humpback) dolphins beyond the 30 m depth contour and >30 km from the remote Kimberley coast (Brown et al., 2017). Most recently, Bouchet et al. (2021) assessed 17 years of snubfin sightings data from various platforms in the Kimberley region, finding they were consistently encountered in shallow (<21 m) waters and close (<15 km) to freshwater outflows. Estimates of their area of occupancy were small relative to their extent of occurrence (~700 km^2 cf. ~38,300 km^2).

After a most intensive sampling regime undertaken for coastal dolphins, Brooks et al. (2017) concluded there was little basis for understanding coastal dolphin movements in northern Australia. While dolphins may be responding to seasonal influences or variation in prey abundance, their study period (3.5 years) and study area (>1000 km^2) did not encompass the ranging patterns of snubfin, humpback and bottlenose dolphins, which appear larger than assumed (Palmer et al., 2014; Brown et al., 2016; Brooks et al., 2017).

2.2.5 Social structure

Limited research has been conducted on snubfin dolphin social structure, though social network analyses based on photo-identification data suggests dynamic fission-fusion grouping patterns (Parra et al., 2011), similar to other coastal delphinids (Connor et al., 2019; Hunt et al., 2019). Association patterns among identifiable individuals in Cleveland Bay, Qld, were non-random and highly structured, with social networks characterised by strong associations among specific clusters of individuals. Modelling of the temporal patterns of association indicated that long-lasting associations were an important feature of snubfin fission-fusion dynamics (Parra et al., 2011). In Cygnet Bay, WA, Brown (2016) used photo-identification and genetic data from biopsy samples to investigate snubfin dolphin social structure, documenting evidence of sex-segregation, although at least 42% of groups were of mixed-sex. There were also pronounced sex-differences in individual sociability, males forming stronger associations and being far more gregarious than females, and there was significant evidence of non-random associations within the sexes (Brown, 2016). Overall, males appeared to form a single, large network of frequently associating individuals, some of which associated more frequently than others, while most females were relatively solitary. Associations were not correlated with genetic relatedness, and individuals which associated more frequently were no more related than expected by chance (Brown, 2016; Fig. 7).

Figure 7: A trio of snubfin dolphins associating in Cygnet Bay, WA.

2.2.6 Population structure

Despite many years of sampling efforts and a dire outlook for the congeneric Irrawaddy dolphin (Krützen et al., 2018), an Australia-wide assessment of snubfin dolphin population genetic structure has yet to be completed. Research along the east coast of Qld found low levels of haplotype and nucleotide diversity, and marked genetic differentiation between snubfin populations separated by ~350 km (Beasley and Brown, 2018). Similarly, Brown et al. (2014) analysed nuclear and mitochondrial DNA from snubfin dolphins sampled ~250 km apart in Cygnet and Roebuck Bays, WA, detecting significant genetic differentiation. The estimated proportion of migrants was low, and preliminary evidence indicated low effective population sizes (Brown et al., 2014; Brown, 2016). Follow up sampling in both bays, as well as further east in the Kimberley region, WA, further supported low levels of gene flow between Roebuck and Cygnet Bays, but no differentiation was detected between Cygnet and Cone Bays (~60 km distant). Results suggest that north-western Australian snubfin dolphins may exist as metapopulations of small, largely isolated population fragments (Brown et al., 2017). A hybrid was sampled at Cygnet Bay, confirmed by molecular analyses as having a snubfin mother and humpback dolphin father (Brown et al., 2014; Fig. 8), and two further hybrids with similar parentage have been sampled further east (Allen et al., unpub. data).

2.2.7 Life history characteristics

Very little is known of the life history characteristics of snubfin dolphins. Age was determined for 18 individuals from north Qld waters, suggesting that snubfin dolphins may live for at least 30 years (Beasley and Brown, 2018). Based on data from closely related small cetaceans, it is likely that life expectancy might be at least 30-40 years (Taylor et al., 2007). Age of first reproduction has been reported as nine years; gestation has been estimated at ~11 months; and generation length has been estimated at ~16 years, based on an age at first reproduction and oldest age of a reproducing female (Taylor et al., 2007). Greater certainty around these basic parameters to aid in conservation and management efforts should be gained through long-term study of readily accessible populations at, for example, Cleveland Bay, Qld, and Roebuck Bay, WA (Fig. 8; Parra et al., 2011; Brown et al., 2016).

Figure 8: (*i*) Snubfin-humpback dolphin hybrid; (*ii*) snubfin dolphins foraging in Roebuck Bay, WA.

2.2.8 Behaviour

Snubfin dolphins are considered opportunistic generalist feeders, and they exhibit behavioural specialisations including spitting jets of water in apparent attempts to manipulate prey behaviour (Beasley and Brown, 2018). This species can be difficult to detect during boat-based fieldwork due to their frequently inconspicuous and unpredictable surfacing behaviour, as well as a tendency to occupy turbid, riverine and coastal waterways. On the other hand, some populations are somewhat habituated to boating traffic and can be approachable and, thus, amenable to detailed observation and sampling (pers. obs.).

2.3 Indo-Pacific bottlenose dolphin

2.3.1 Taxonomic status

There has long been controversy over the taxonomy of the genus *Tursiops*, both globally and, more recently, in Australian waters. Despite some remaining uncertainty and disagreement between researchers, the Society for Marine Mammalogy's Committee on Taxonomy currently recognises only two species (https://marinemammalscience.org/species-information/list-marine-mammal-species-subspecies/): *T. truncatus*, globally distributed in tropical and temperate waters; and the Indo-Pacific bottlenose dolphin *T. aduncus*, which occurs in shallow waters around the coastlines of the Indian Ocean and western Pacific, throughout southeast Asia and around much of the Australian coastline. Competing arguments remain on species assignment in south-eastern Australian *Tursiops* (e.g. (Charlton-Robb et al., 2011; Jedensjö et al., 2020), but Australia's tropical inshore regions are occupied by *T. aduncus* only, being replaced by its congener *T. truncatus* offshore (Allen et al., 2016). This update/review thereby focuses on *T. aduncus* accordingly.

Figure 9: An Indo-Pacific bottlenose dolphin in tropical inshore waters.

2.3.2 Australian distribution

Bottlenose dolphins are distributed widely around the Australian coastline, with some contention over species delineation/composition in South Australia, Victoria and Tasmania (e.g. Kemper, 2004; Möller et al., 2008; Charlton-Robb et al., 2011; Jedensjö et al., 2017, 2020). In northern tropical and sub-tropical Australia, however, bottlenose dolphin distribution is more resolute, with *T. aduncus* occupying shallow (typically <50 m deep) inshore regions in waters fringing the coastline, reefs and offshore islands, generally being replaced by *T. truncatus* in deeper waters (e.g. Palmer et al., 2014; Allen et al., 2016; Fig. 10).

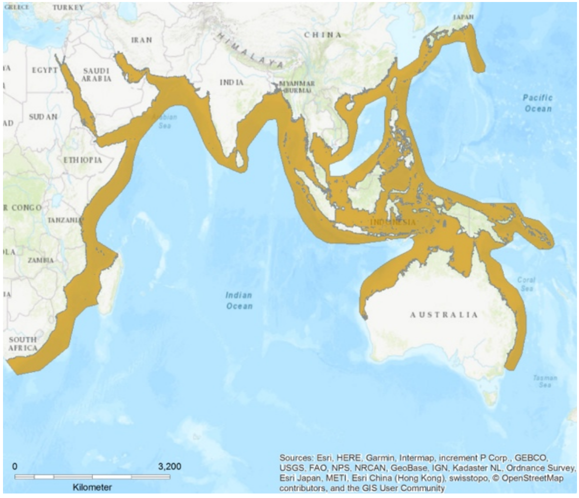

Figure 10: Bottlenose dolphin distribution (from Braulik et al., 2019).*

*While it does not impact upon a tropical inshore dolphin review, it should be noted that *T. aduncus* is also well-documented around southwestern WA (Sprogis et al., 2016; Manlik et al., 2019; Jedensjö et al., 2020; Chabanne et al., 2021), potentially extending into SA.

2.3.3 Abundance and trends

No national population estimates are available for bottlenose dolphins, although several research and monitoring programmes across northern Australia have now produced abundance or relative abundance estimates (Table 1) since the previous review of tropical inshore dolphin conservation status in 2012 (Beasley, Allen and Parra, 2012). While some dedicated research efforts on bottlenose dolphins within the known distribution of humpback and snubfin dolphins have yielded no bottlenose dolphin sightings (e.g. Cone Bay and the Cambridge Gulf in the Kimberley region, WA; Brown et al., 2016, 2017), or too few recaptures of individually recognisable individuals to warrant capture-recapture modelling to estimate abundance (e.g., Brooks et al., 2017), others reveal sizeable populations of several hundreds to thousands of individuals (e.g. Moreton Bay, Qld, North West Cape and Shark Bay, WA; Preen et al., 1997; Lukoschek and Chilvers, 2008; Ansmann et al., 2013; Haughey et al., 2020).

Measures of bottlenose dolphin density per km of transect or km^2 surveyed are extremely variable, even within regions (e.g. 0.00-1.21 in the Kimberley), which is perhaps best summed up by the statement "The abundance of each species [of tropical inshore dolphin] was highly variable between different sites, likely reflecting species-specific habitat preferences" (Brown et al., 2016). High densities (2.4-2.8 dolphins per km^2) have been reported for bottlenose dolphins around the North West Cape, WA, where there is also a high density of humpback dolphins and, rarely, snubfin dolphin sightings (Allen et al., 2012; Hunt et al., 2017; Haughey et al., 2020).

No reliable national trend data are available, although one recent study documented an immediate and long-lasting (seven years) negative impact on the vital rates (survival and reproduction) of the bottlenose dolphin population in western Shark Bay, WA (Wild et al., 2019), immediately following a marine heatwave that significantly reduced the cover of foundation-forming seagrass beds (Arias-Ortiz et al., 2018; Strydom et al., 2020).

2.3.4 Habitat use

There was very limited published information on Indo-Pacific bottlenose dolphin habitat use in Australia's tropical inshore waters until the last decade or so. Research of the late 1990s in Moreton Bay, Qld (e.g., Chilvers and Corkeron, 2001), investigated the ranging patterns of individually identified bottlenose dolphins in eastern Moreton Bay, documenting two separate but overlapping dolphin communities. More recently, Ansmann et al. (2015) integrated analyses of habitat use, stable isotopes and trace elements to build upon the earlier findings and divide Moreton Bay's bottlenose dolphins into North and South subpopulations, each being adapted to different niches in deeper/offshore waters versus shallower sandbanks/nearshore waters, respectively. In the Capricorn-Bunker Group at the southern end of the Great Barrier Reef, Qld, Indo-Pacific bottlenose dolphins appear to favour the shallow waters fringing reefs, islands and atolls rather than the deeper areas between them.

Bottlenose dolphins were found in all NT sites intensively surveyed by Brooks et al. (2017), but their movements could not be modelled due to low population sizes and recapture rates. The dolphins appeared to move freely among Shoal Bay, Darwin Harbour and Bynoe Harbour, an area of over 1,000 km^2, with as many as 40 identified individuals being sighted in different sites at different times (Brooks et al., 2017).

In somewhat of a contrast, just two photographic matches of bottlenose dolphins were made between Cygnet and Beagle Bays, WA, some 120 km apart (Brown et al., 2016). Indeed, in each embayment around the Dampier Peninsula, Brown et al. (2016) documented vastly different numbers of bottlenose dolphins, and proportions of each tropical inshore dolphin species, likely reflecting differential habitat preferences. Across NW Australia, *T. aduncus* favour waters within the 50 m depth contour and/or 10 km of the coast, while their *T. truncatus* congeners replace them outside these approximate bounds (Allen et al., 2016).

Long-term research on Shark Bay's resident bottlenose dolphin population in WA has informed much of what the world knows of the species' basic biology and behavioural ecology (Connor et al., 2019). Habitat use is extremely variable among individuals and communities, home range size of adult females varying by an order of magnitude, likely linked to individual differences in learned foraging strategies (Kopps et al., 2014; Connor et al., 2019). In adult males, second-order alliances (the core social unit of adult males, see below) have extensively overlapping home ranges but exhibit marked differences in their use of these habitats (O'Brien et al., 2020).

2.3.5 Social structure

While there are no studies specifically on Indo-Pacific bottlenose dolphin social structure across most of northern Australia, long-term and detailed research has taken place at the limits of their sympatry with humpback dolphins, in Moreton Bay, Qld, and Shark Bay, WA. Indo-Pacific bottlenose dolphins typically reside in open social networks, where the social system features a fission-fusion grouping pattern, with stronger associations between adult males than adult females, and at least some populations exhibiting bisexual philopatry (Frère et al., 2010; Connor et al., 2019). Interestingly, the two separate but geographically overlapping bottlenose dolphin communities of Moreton Bay, one that fed in association with trawlers and one that did not (Chilvers and Corkeron, 2001; Chilvers, Corkeron and Puotinen, 2003), re-structured after trawling was curtailed, such that their social network became less differentiated and more compact, with more and stronger associations between individuals (Ansmann et al., 2012). The previously described partitioning into two communities disappeared, with former 'trawler' and 'non-trawler dolphins' dispersed over the entire social network and associating with each other (Ansmann et al., 2012).

Male bottlenose dolphins in several populations form alliances. Those studied extensively in Shark Bay are long-lasting, remarkable multi-level alliances formed for the purposes of gaining and maintaining access to oestrous females. Highly differentiated but typically strong bonds exist between multiple males and can last decades (Connor et al., 2017, 2019; King et al., 2018, 2021; Bizzozzero et al., 2019; Gerber et al., 2020, 2021).

Figure 11: Three second-order male alliances with female consorts in Shark Bay, WA.

While not formally documented as yet, pairs and trios of adult males and social behaviour typical of alliances in Shark Bay have been documented during fieldwork around the North West Cape and the Dampier Peninsula, WA, for Allen et al. (2012) and Brown et al. (2016).

Having originally documented pairs and trios of adult males working together in first-order alliances, then a second level of alliance formation in the late 1980s (Connor et al., 1992), this long-term study of well-known individuals in Shark Bay subsequently revealed a third level of alliance formation, whereby two or more second-order alliances cooperate at times (Connor et al., 2011; Randić et al., 2012; King et al., 2021). Associations patterns among adult female dolphins in Shark Bay are extremely variable and depend upon the complex interplay of at least three factors: home range overlap, matrilineal kinship and biparental kinship (Frère et al., 2010).

2.3.6 Population structure

Although bottlenose dolphin species delineation and population structure remain somewhat unresolved for southern Australian waters, the story is simpler in northern tropical and sub-tropical Australia (Jedensjö et al., 2020, accepted). *T. aduncus* typically occupy shallow (<50 m depth), inshore waters fringing the coastline, reefs and islands, being replaced by common bottlenose dolphins (*T. truncatus*) in deeper waters, such as those where offshore trawlers operate (Allen et al., 2012, 2016, 2017).

Again, detailed investigations in Moreton Bay, Qld, and Shark Bay, WA, have revealed fine-scale population structure in bottlenose dolphins, despite the lack of obvious barriers to gene flow in the marine realm, but likely driven by individual and group differences in foraging strategies (e.g., Krützen et al., 2004; Ansmann et al., 2012). Across the Australian NW, Allen et al. (2016) revealed a strong pattern of isolation-by-distance among bottlenose dolphin populations. Fine-scale genetic structuring over scales of just tens of kilometres is frequently detected in bottlenose dolphins (e.g. Kopps et al., 2014; Louis et al., 2014), although Allen et al. (2016) documented the existence of a cline over some hundreds of kilometres.

2.3.7 Life history characteristics

There is little information on bottlenose dolphin life history parameters across most of northern Australia but, again, fine-scale details are known from the long-term study of individuals in Shark Bay, WA. Generation length is 21.1 years; females first conceive at 10-11 years of age, giving birth 12 months later; calves are weaned at 3-8 years of age, with last-born calves weaned later than earlier-born calves, evidence of terminal investment; median inter-birth interval is ~four years; Males typically transition from adolescence into adulthood, coalescing into alliances and consorting females at 14-15 years of age; life expectancy extends into the 40s, perhaps even 50s (Taylor et al., 2007; Karniski et al., 2018; Connor et al., 2019; Gerber et al., 2020).

2.3.8 Behaviour

There is no specific information on the behaviour of bottlenose dolphins around much of northern Australia, though they are the most frequently studied species around the coastline as a whole, and their breadth of foraging specialisations and complex social behaviours are well renowned (Connor et al., 2019). They are known to be opportunistic generalist foragers, preying on a wide variety of schooling, demersal, reef and estuary-associated fish and cephalopods, though they also exhibit striking differences between individuals, matrilines and communities, even within the same populations (e.g., Sargeant et al., 2005; Allen et al., 2011; Krützen et al., 2014; Ansmann et al., 2015). Most foraging specialisations, like sponge tool use in Shark Bay, are vertically socially transmitted from mother to offspring (Krützen et al., 2005; Wild et al., 2019; Fig. 12), although shell tool use was recently revealed as the first case of horizontal or oblique transmission of behaviour between peers in toothed cetaceans (Wild et al., 2020).

Figure 12: A bottlenose dolphin with sponge tool in Shark Bay, WA.

Bottlenose dolphins inhabit most Australian coastal waters, are gregarious and surface active, surfing coastal breaks, and most populations are habituated to boating and shipping traffic and are keen bow-riders (Fig. 13). This makes them conspicuous but also brings them into frequent contact with anthropogenic activities and their associated influences.

Figure 13: Bottlenose dolphins (*i*) surfing and (*ii*) riding the bow-wave of a transport ship.

2.4 Spinner dolphin

2.4.1 Taxonomic status

The spinner dolphins, *Stenella longirostris*, are globally divided into four subspecies: *S. l. longirostris*, the nominate 'pantropical' subspecies, distributed throughout the tropics, other than the eastern tropical Pacific (ETP); *S. l. centroamericana*, a coastal subspecies endemic to the ETP; *S. l. orientalis*, an offshore subspecies endemic to the ETP; and *S. l. roseiventris*, the dwarf spinner dolphin of Southeast Asia (Perrin, Dolar and Robineau, 1999). Having been listed as "insufficiently known" and afforded "priority status" in the Action Plan for Australian Cetaceans 25 years ago (Bannister, Kemper and Warneke, 1996), and again a decade later (Ross, 2006), there have been no dedicated research or monitoring efforts on Australian *Stenella* spp. Opportunistic sightings data and samples have been gathered during field efforts targeting the other tropical inshore dolphins, which suggest there may be two or more subspecies in Australian waters, including *S. l. longirostris* and *S. l. roseiventris* (Allen et al., 2012; Woinarski, Burbidge and Harrison, 2014; Palmer, 2015). More recently, Leslie and Morin (2018) used nuclear DNA in a phylo-geographical assessment, suggesting that population-level division among *S. l. roseiventris* shows the northern Australian animals as being very different from those in Indonesia.

Figure 14: A suspected dwarf spinner dolphin in tropical inshore waters.

2.4.2 Australian distribution

Spinner dolphin distribution, or indeed which subspecies occur in which Australian regions, is largely unknown. Spinner dolphins caught in the Taiwanese gill net fishery off Australia's north in the early 1980s were recorded only as *S. longirostris* (Harwood and Hembree, 1987). Dwarf spinner dolphins have been reported in tropical inshore waters of, for example, the Gulf of Carpentaria, Kimberley region, North West Cape (where the nominate species is also seen), and as far south as Rottnest Island in WA (Allen et al., 2012; Woinarski, Burbidge and Harrison, 2014; Palmer, 2015; Fig. 15).

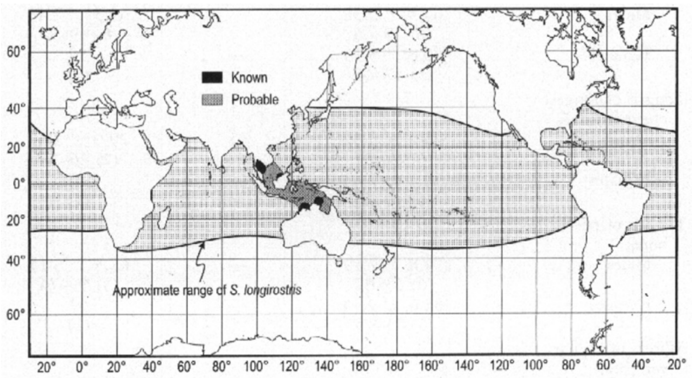

Figure 15: Indicative spinner and dwarf spinner dolphin distribution (from Perrin et al., 1999).*

*The distribution shown is loosely indicative of spinner (hatched) and dwarf spinner dolphin (grey “probable”, black “known”) distribution (Perrin, Dolar and Robineau, 1999). Note, however, that dwarf spinner dolphins appear much more broadly distributed around Australia’s coast than the demarcations shown here, including considerably further south in WA, as well as sightings and samples collected from the southern Great Barrier Reef’s Capricorn-Bunker Group, Qld. The small morph sampled in the shallow waters around the Capricorn-Bunker Group differ in colouration from those in the NT and WA (Cagnazzi, Allen et al., unpub. data; Fig. 16).

2.4.3 Abundance, trends and behaviour

No national or local population estimates are available for any spinner dolphin subspecies that occur in Australian waters. No trend data exist and, similarly, there is no published data on habitat use, nor social/population structure, life history characteristics or diet. Each of these traits is likely to be dependent on the eco-type / subspecies under consideration, i.e., each appears adapted to very different niches (Perrin et al., 1989, 1999).

Sightings incidental to other research and anecdotal reports suggest the different spinner dolphin ecotypes are both morphologically and behavioural divergent, the nominate species being larger and typically surface active (Fig. 16*i*), while the small morphs found in WA, NT and at the southern end of the GBR are less so, not performing the characteristic spinning leaps or being as prone to bow-riding (Fig. 16*ii* and *iii*).

Figure 16: Phenotypic differences between (*i*) nominate and (*ii*) dwarf spinners of GBR and (*iii*) WA, respectively.

Table 1: Published mark-recapture abundance and density estimates of humpback, snubfin and bottlenose dolphins in Qld, NT and WA study sites.

Species	Study site (approx. area)	Abundance estimates	Approx. density (km^{-2})[!]	Source
Humpback	Moreton Bay Qld (1,315 km^2)	119-163	0.09-0.12	(Corkeron et al., 1997)
	Great Sandy Straits Qld (1,000 km^2)	148*	0.15	(Cagnazzi et al., 2011)
	Curtis Coast Qld (510 km^2)	45-84	0.09-0.16	(Parra and Cagnazzi, 2016)
	Capricorn Coast Qld (980 km^2)	104-115	0.11-0.12	(Parra and Cagnazzi, 2016)
	Cleveland Bay Qld (310 km^2)	34-54	0.11-0.17	(Parra et al., 2006)
	Port Essington NT (325 km^2)	48-207	0.15-0.64	(Palmer et al., 2014)
	Darwin region NT (1,086 km^2)[#]	86-99	0.07-0.09	(Brooks et al., 2017)
	Cygnet Bay WA (130 km^2)	15-20	0.12-0.15	(Brown et al., 2016)
	North West Cape WA (130 km^2)	129	1.0	(Hunt et al., 2017)
Snubfin	Keppel Bay Qld (980 km^2)	71-80	0.07-0.08	(Cagnazzi et al., 2013)
	Cleveland Bay Qld (310 km^2)	64-76	0.21-0.25	(Parra et al., 2006)
	Port Essington NT (325 km^2)	136-222	0.42-0.68	(Palmer et al., 2014)
	Darwin region NT (1,086 km^2)[#]	19-70	0.02-0.05	(Brooks et al., 2017)
	Cygnet Bay WA (130 km^2)	48-54	0.37-0.42	(Brown et al., 2016)
	Roebuck Bay WA (100 km^2)	133	1.33	(Brown et al., 2016)
Bottlenose	Moreton Bay Qld (1,300 km^2)	554*	0.43	(Ansmann et al., 2013)
	Port Essington NT (325 km^2)	34-75	0.10-0.23	(Palmer et al., 2014)
	Darwin region NT (1,086 km^2)[#]	27	0.02-0.03	(Brooks et al., 2017)
	Cygnet Bay WA (130 km^2)	35-60	0.27-0.46	(Brown et al., 2016)
	Beagle Bay WA (130 km^2)	157	1.21	(Brown et al., 2016)
	Onslow and Thevenard Is WA (128 km^2)	79	0.59 and 0.83	(Raudino et al., 2018)
	North West Cape WA (130 km^2)	311-370	2.4-2.8	(Haughey et al., 2020)
	Shark Bay western gulf WA (226 km^2)	115-208	0.51-0.92	(Nicholson et al., 2012)
	Shark Bay WA (14,906 km^2)^	2,064 and 2,888	0.14-0.19	(Preen et al., 1997)
	Pilbara Trawl Fishery WA (25,580 km^2)^	2,274	0.09	(Allen et al., 2017)

[!] Differences in approx. densities between sites may reflect real differences or those in study design, including area, methodology or duration of sampling effort. * These figures represent abundance estimates combining two defined subpopulations, with north and south clusters in respective sites. [#] The Darwin region includes three adjacent sites: Darwin Harbour (471 km^2), Bynoe Harbour (461 km^2) and Shoal Bay (154 km^2). ^ These estimates over larger areas, the second of the congeneric *T. truncatus*, are provided for comparative purposes and were obtained from aerial surveys not corrected for availability bias. They are, thus, likely to be underestimates. Lastly, note that the % of **mature individuals** in a population is: **50%** of total population size in humpback dolphins; **unknown** for snubfin dolphins; and **60%** in bottlenose dolphins (Taylor et al., 2007).

3. THREATS

Although details of the specific life history characteristics of many dolphin species, including some of the tropical inshore dolphins, remain largely unknown, the basic biological information available from closely related species is sufficient to qualify them as: long-lived (multiple decades), late to reach sexual maturity (approx. a decade), with low reproductive rates (single offspring produced at a time, with inter-birth intervals of several years) and relative population stability (e.g., Lewison et al., 2004; Taylor et al., 2007; Karniski et al., 2018). These characteristics are advantageous in allowing populations to cope with seasonal or annual environmental and demographic stochasticity, but they render inshore dolphins particularly vulnerable to threatening processes and unnatural mortality.

The level of anthropogenic activity varies considerably across the northern Australian coastline occupied by tropical inshore dolphins, with some populations in remote areas rarely encountering human activity, but others exposed to a broad suite of potential stressors in variously industrialised areas. Beasley, Allen and Parra (2012) circulated a questionnaire to Australian researchers, seeking expert opinion on the threats faced by tropical inshore dolphins. Modified and updated, these broadly (and non-mutually exclusively) include:

1. Habitat loss and degradation through coastal development.
2. Disturbance from increasing shipping and boating activity.
3. The proliferation of underwater noise from anthropogenic sources.
4. Wildlife tourism targeting tropical inshore dolphins.
5. Depletion of food resources through commercial and recreational fishing.
6. Catchment run-off (including contaminants).
7. Bycatch in a variety of fishing gear, such as gillnets, trawl nets and purse-seines, as well as incidental capture in shark nets set for bather protection.
8. Climate change, including both gradual ocean warming and acidification, as well as more frequent and intense extreme weather events.

The latter three are at least loosely equivalent to the anthropogenic threats ranked as the greatest to marine ecosystems by Halpern et al. (2007): point-source organic pollution, demersal destructive fishing, and increasing sea temperature (Fig. 17).

Figure 17: The major threats of (*i*) contaminants/run-off and (*ii*) fisheries bycatch.

3.1 Habitat loss and degradation through coastal development

Coastal habitat loss and degradation has occurred, and continues to occur, in various parts of northern Australia through the development of residential areas, industrial ports and recreational marinas, aquaculture and associated activities. These activities include the reclamation of tidal flats and estuarine habitats, dredging, seismic surveys, drilling, blasting, pile-driving, boating, various forms of resource extraction, and tourism activity. Many of these activities are likely to result in localised, and in some cases regional, changes in the composition, structure and function of coastal and estuarine habitats. These activities increase the potential for a wide range of direct and indirect impacts including: the removal of foundation-forming habitats (such as seagrass meadows and mangrove forests that support juvenile fish assemblages), physical disturbance of other substrates, increased sedimentation, increased commercial and recreational vessel traffic, increasing underwater noise and the introduction of chemical pollutants, as well as viral and bacterial pathogens.

There are sizeable tropical inshore dolphin populations in some heavily urbanised areas, Moreton Bay, Qld, for example (e.g., Chilvers et al., 2005). Nevertheless, the individual and cumulative effects of coastal zone development warrant consideration when assessing the long-term viability and conservation status of tropical inshore dolphin populations, which are susceptible to these impacts given their reliance on inshore and estuarine habitats, generally small population sizes, and the apparent lack of gene flow between populations (Corkeron et al., 1997; Parra, Corkeron and Marsh, 2004; Ross, 2006; Cagnazzi et al., 2013; Brown et al., 2014, 2016; Parra et al., 2018).

Numerous large-scale development projects progressed in the past in areas of known inshore dolphin populations without adequate baseline studies or environmental impact assessment prior to construction (Allen et al., 2012; Bejder et al., 2012). Examples include: multiple port and liquid natural gas (LNG) developments within Gladstone Harbour, Qld; dredging for the port of the McArthur River mine, western Gulf of Carpentaria, NT; and, extensive dredging and port development associated with the export of LNG and minerals across the Pilbara and Kimberley coasts, WA (Beasley, Allen and Parra, 2012). An intensive and rigorous sampling regime associated with the Ichthys LNG Project in Darwin Harbour, NT, revealed a decline in humpback dolphin numbers and a concomitant increase in adjacent bays (Brooks et al., 2017). Further data suggested this decline may have continued across humpback, snubfin and bottlenose dolphins (Griffiths et al., 2020). As part of an environmental offset-funded program of dolphin monitoring for the Wheatstone LNG Project near Onslow, WA, Raudino, Douglas and Waples (2018) documented a small population of bottlenose dolphins and too few humpback dolphins to model abundance. Unfortunately, the study was not of sufficient duration to capture before-development dolphin data, nor geographic extent to compare impacted vs unimpacted sites. Forthcoming findings from the broader marine fauna programme (Raudino and Waples, 2014) should reveal more. Each large-scale development that occurs without a sufficiently rigorous sampling regime represents a lost opportunity to gather baseline information on tropical inshore dolphins, as well as to quantify the impacts of coastal development. While not in northern Australia, several studies have documented temporary changes in abundance and behaviour (Weaver, 2021) and at least the temporary displacement of bottlenose dolphins from dredging activity and other construction projects (Buchanan et al., 2012; Pirotta et al., 2013).

3.2 Disturbance from increasing shipping and boating activity

Well-documented responses by inshore dolphins to approaches by vessels of varying size and capacity include changes in respiration rates, behavioural state, movements and habitat use (Allen, 2014). Increasing boating and shipping activity might thus result in at least short-term disturbance to critical activities, such as foraging, socialising and resting behaviour (Bejder et al., 2006a, 2006b). Disturbance from increasing vessel activity might be associated with coastal development, recreational fishing and tourism activities, for example. Increased vessel activity can result in the displacement of inshore dolphins from important habitats, or lead to more direct impacts such as boat-strike, which can have lasting effects even if not fatal (e.g., Greenfield et al., 2020). Whether or not disturbance from increasing shipping and boating activity leads to adverse impacts on vital rates, such as survival and reproductive success, of tropical inshore dolphin populations remains to be quantified (although see section 3.3 below).

3.3 Underwater noise

A broad suite of marine organisms across taxonomic groups are affected by underwater noise (Duarte et al., 2021; Gallagher et al., 2021). Using sound as a primary modality for navigation, hunting and communication obviously renders tropical inshore dolphins susceptible to disturbance from increasing underwater noise. Anthropogenic sources of sound introduced into the coastal environment can interfere with the ability to communicate over even relatively short distances and can mask other important natural sounds. The potential effects of elevated anthropogenic sources of noise (such as dredging, pile-driving, or blasting associated with development or harbour/port maintenance, underwater surveying, military sonar, shipping, recreational vessel motors and echo-sounders) on tropical inshore dolphins include: limiting their ability to detect natural sounds; disrupting normal behavioural patterns, including displacement from preferred areas; and physical trauma causing death or temporary or permanent physical damage to sensory systems. Humpback, snubfin and bottlenose dolphins display varying degrees of site fidelity and home range size, even within populations, but there are typically large proportions of residents in most populations studied to date, as well as marked individual and group preferences for particular habitats (Parra et al., 2006; Brown et al., 2016; Hunt et al., 2017; Connor et al., 2019; Haughey et al., 2020). Given this, as well as their typically complex social structures, with differentiated preferences and avoidances in associations (Parra et al., 2011; Connor and Krützen, 2015; Hunt et al., 2019), and foraging specialisations that are tied to particular habitats (e.g., Krützen et al., 2014), it is likely that these species do not possess the flexibility to move to other areas should their preferred habitats be exposed to high levels of anthropogenic noise. This increases the potential for underwater noise to become a chronic stressor as opposed to a short-term source of disturbance.

3.4 Wildlife tourism

Tropical inshore dolphins are exposed to commercial tourism operations in the form of food provisioning, incidental (not necessarily dedicated) swimming with dolphins and, most frequently, boat-based dolphin-watching operations (Allen, 2014; Bejder et al., 2006b).

Humpback and bottlenose dolphins are the focus of boat-based dolphin watching tours and also hand-feeding at two shore-based operations in SE Qld (Orams, 1997; Neil and Holmes, 2008; Barber, 2016; Fig. 18). In WA: the mixed species assemblage of snubfin, bottlenose and humpback dolphins are at times subject to dolphin watching at Cygnet Bay Pearl Farm (Fig. 18); the snubfin dolphins of Roebuck Bay are targeted by a seasonal dolphin-watching program; incidental dolphin watching takes place in the Dampier Archipelago, where humpback and bottlenose dolphins are observed; various tour operators that usually engage in swimming with whale sharks, manta rays and humpback whales will incidentally watch and occasionally swim with humpback, bottlenose and/or spinner dolphins around the North West Cape and Coral Bay; and bottlenose dolphins are involved in a hand-feeding program (Fig. 18), as well as subject to dolphin watching tourism in Shark Bay.

Figure 18: Tropical inshore dolphins and wildlife tourism; examples of hand feeding and boat-based watching.

Much has been made of the short-term effects of wildlife tourism on the behaviour and movements of inshore dolphins in the last 10-15 years, and how best to manage this, in places, still-growing industry (Allen et al., 2007; Bejder et al., 2006b). Indeed, such investigations are ongoing around Australia and New Zealand (e.g., Fumagalli et al., 2021; Puszka et al., 2021). While importance certainly lies in carefully managing the animal welfare issues that arise from provisioning wild animals, as well as addressing the potential impacts of all intensive dolphin-based wildlife tourism, it should be noted that few studies have been able to draw causative links between exposure to tourism and long-term negative impacts on dolphin vital rates, such as reproductive success or survivorship. Indeed, the most recent study in Shark Bay showed that the calves of hand-fed dolphins had lower mortality than their non-provisioned counterparts (Mann et al., 2021), implying a benefit to provisioning, while the broader community suffered the effects of a heatwave. It will be important for researchers to include the key drivers of fluctuations in dolphin abundance and movements (i.e., prey abundance/distribution, predator prevalence, environmental conditions) into future modelling efforts.

3.5 Depletion of food resources

Tropical inshore dolphins rely upon shallow coastal and estuarine waters for their dietary requirements of reef-, seagrass- and estuary-associated prey species. This will mean they are likely to be impacted by any marked decline in prey species due to human activities, such as habitat modification and destruction and/or recreational and commercial fisheries (DeMaster et al., 2001). Dolphins prey upon species that are both targeted by fisheries and that constitute bycatch in fisheries, hence their tendency (at least humpback and bottlenose dolphins) to forage on discards around, for example, trawling operations (e.g., Chilvers and Corkeron, 2001).

As well as competing for resources, degrading habitat, and increasing the potential for entanglement in fishing gear (as dolphins are motivated to forage in the vicinity), trawling activities can influence the behaviour, social structure and habitat use of dolphins (Chilvers and Corkeron, 2001; Ansmann et al., 2012b; Jaiteh et al., 2013; Allen et al., 2017). Tropical inshore dolphins are at risk of the depletion of food resources throughout their northern Australian ranges. Although this potential threat may be less apparent or perceived as less immediate than, for example, bycatch in fisheries, it has been realised elsewhere (Bearzi, 2007; Piroddi et al., 2011) and should, thus, not be ignored.

3.6 Catchment run-off (including contaminants)

Concerns over contamination of the marine environment and its effects on marine mammals came to the fore in the late 20th Century, with stark predictions of how these threats would be exacerbated by the increasing human population and growing economies, particularly through escalating industrial and agricultural activities along coastlines (Bannister, Kemper and Warneke, 1996; Anderson, 2001). Pollutants, including heavy metals, pesticides, herbicides, nutrients and sediments, enter estuarine and coastal waters at various points along Australia's northern coastline, and they do so from many sources (for example, industrial and sewage discharges, catchment runoff and groundwater infiltration). Meager and Limpus (2014) used a 17-year dataset to demonstrate a clear relationship between environmental forcing (namely, freshwater discharge and low air temperature) and tropical inshore dolphin (and dugong) mortality along ~2000 km of the Qld coast. Similarly, Cagnazzi et al. (2020b) detected declines in the number of humpback dolphins in the Fitzroy River over time and following major flooding events. Cagnazzi et al. (2020a) also found concentrations of PCBs, DDTs and HCB increased over time in humpback/snubfin dolphins biopsy sampled in the Fitzroy River and Port Curtis regions. A large proportion of the sampled population accumulated organochlorine contaminants above thresholds for which immunosuppression and reproductive anomalies are known to occur (Cagnazzi et al., 2020a).

Bottlenose dolphin carcasses exhibiting gross skin lesions have washed ashore around numerous urban centres in Qld, Victoria and WA over the last 10-15 years, some of which have carried concentrations of pollutants (including DDE and PCBs) that exceeded published thresholds for effects on immune function, as well as levels of the banned pesticide dieldrin among the highest reported globally (Holyoake et al., 2010). Most recently, Duignan et al. (2020) defined “freshwater skin disease” in inshore dolphins based on similar mortality events in Victoria and WA that occurred following abrupt salinity declines due to rainfall in the respective catchments (Fig. 19). Similar such events would be likely to go undetected along many of the more remote stretches of the northern Australian coastline.

Figure 19: A case of "freshwater skin disease" after heavy catchment runoff (Duignan et al., 2020).

3.7 Bycatch in fishing gear and shark nets

Bycatch in fisheries is widely recognised as one of the most pressing threats to the persistence of many marine megafauna populations globally (e.g., Read et al., 2006; Lewison et al., 2014), tropical inshore dolphins included. Entanglement in fishing gear contributed markedly to the extinction of the baiji, or Yangtze River dolphin (*Lipotes vexillifer*), for example (Turvey et al., 2007). Fishing's direct (bycatch) and indirect (habitat modification and prey depletion) impacts have also been linked to declines in common dolphins (*Delphinus delphis*) in the Mediterranean Sea (Bearzi et al., 2008; Piroddi et al., 2011); humpback dolphins in the eastern Taiwan Strait (Slooten et al., 2013); the near-extinct vaquita (*Phocoena sinus*) in the Sea of Cortez (Jaramillo-Legorreta et al., 2019); as well as the endemic sea lions (*Neophoca cinerea* and *Phocarctos hookeri*) of New Zealand and Australia (Robertson and Chilvers, 2011; Hamer et al., 2013).

Most direct anthropogenic mortality of Australia's tropical inshore dolphins is likely to have been caused by (*i*) entanglement in shark nets and drum lines that have been set to create the perception of swimmer protection as part of the Queensland Shark Control Programme (QSCP), and (*ii*) bycatch in commercial and recreational gillnets across northern Australia (Corkeron et al., 1997; Parra et al., 2004; Beasley et al., 2012; Parra and Cagnazzi, 2016). Dolphins are occasionally caught on baited drum lines set as part of the QSCP, hundreds of dolphins were caught in the QSCP nets between the late 1960s and early 2000s, and thousands were caught in Taiwanese gillnets set of northern Australia in the early 1980s alone (Harwood and Hembree, 1987; Gribble et al., 1998; Beasley et al., 2012). Although only domestic fisheries remain operating in Australia's coastal areas, gillnetting is likely to remain a threat throughout the extent of occurrence of tropical inshore dolphins, especially when set around rivers, creeks and estuaries (Beasley et al., 2012; Parra and Cagnazzi, 2016). There is also limited independent observer coverage of gillnet fisheries, some bycatch mitigation methods have proven ineffective, and the absence of records of bycatch suggest under-reporting is likely, as it is in other fisheries (Soto et al., 2013; Allen et al., 2014; Bouchet et al., 2021).

Humpback and bottlenose dolphins are widely known to follow trawlers and feed on discards throughout their range, occasionally being caught in coastal trawl fisheries (e.g., Exmouth Gulf and Shark Bay prawn trawl fisheries; Fig. 20). These incidents are routinely referred to as "rare" and of "negligible impact" by fisheries management agencies (e.g., Gaughan, Molony and Santoro, 2019; Gaughan and Santoro, 2020) but, again, independent observer coverage is low and the death of even a few individuals per year can have detrimental effects on the viability of local populations of K-selected species (e.g., Williams and Lusseau, 2006; Wade et al., 2012; Lewison et al., 2014).

Figure 20: Dolphins foraging around (i) aquaculture facilities, (ii) demersal trawlers and (iii) trawler bycatch.

3.8 Climate change and extreme weather events

Human-induced climate change, ocean warming in particular, continues to have profound effects on marine systems, impacting abundance and distribution across taxa from the poles to equatorial regions, and fisheries and ecosystem services in turn (Cheung et al., 2009, 2012; Amesbury et al., 2017; Hastings et al., 2020). There is already evidence of poleward shifts in a number of mobile species in attempts to stay within the thresholds of particular water temperature ranges or, in the case of predators like dolphins, in pursuit of prey attempting to do so (e.g., Salvadeo et al., 2010). Unfortunately, this type of response may not be possible for some coastal dolphin populations that are tied to, or indeed bound by, particular habitats, geographical barriers to movement or even social systems upon which their reproduction and survival depend. It is also of concern that there is a propensity for large-bodied animals to be disproportionately impacted by climate change and the emerging mass extinction in our oceans (McCain and King, 2014; Payne et al., 2016). Climate change is thus a pervasive threat to tropical inshore dolphins and their habitat, and although northern Australian inshore waters are recognised as being some of the least impacted by human activities on a global scale (Halpern et al., 2008), they are nonetheless classified as a global hotspot for extinction risk in marine mammals (Davidson et al., 2012).

Some of the weather patterns associated with climate change are increasingly likely to have negative impacts on tropical inshore dolphins, via such things as higher rainfall and run off from storms and floods. This will mean greater exposure to freshwater and the contaminants it brings (as per section 3.6 above), as well as indirect impacts on the productivity of the ecosystems upon which these animals depend (Meager and Limpus, 2014; Cagnazzi et al., 2020a; Duignan et al., 2020). Extreme weather events, such as marine heatwaves, are becoming longer and more frequent (Oliver et al., 2018), and one such event resulted in massive losses of the foundation-forming seagrass meadows of the World Heritage listed Shark Bay Marine Protected Area, WA (Arias-Ortiz et al., 2018; Strydom et al., 2020). This, in turn, lead to mass mortalities of invertebrate and fish communities, cascading negative effects on the abundance of a suite of megafauna (Nowicki et al., 2019), and long-term declines in the survival and reproduction of dolphins (Wild et al., 2019). Fluctuations in vital rates associated with climate anomalies have thus now been detected in both great whales (Cartwright et al., 2019) and tropical inshore dolphins (Fig. 21).

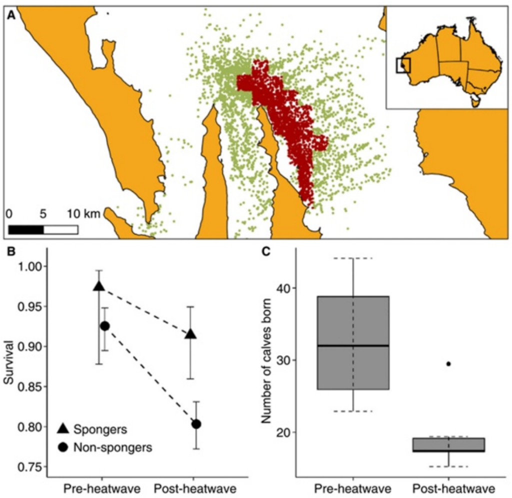

Figure 21: Dolphin vital rates, Shark Bay, before and after a marine heatwave (Wild et al., 2019).

4. CONSERVATION STATUS

4.1 Background

The Australian Government commissioned the *Current Status of Inshore Dolphins in Northern Australia* review, as well as the *Draft Coordinated Research Strategy to Collect Information Required to Assess the National Conservation Status of Australian Tropical Inshore Dolphins* (Beasley, Allen and Parra, 2012; Parra et al., 2012, respectively). These were considered the first steps toward developing a co-ordinated strategy to be utilised by inshore dolphin researchers nationwide, to ensure research outcomes could contribute to the development of more informed inshore dolphin management and policy initiatives. The attendees of subsequent technical workshops, including cetacean researchers, statisticians, government management agency representatives, indigenous representatives and other stakeholders, then agreed upon three high priority research objectives as follows:

1. Provide for access to and analysis of standardised national tropical dolphin data to assess distribution and underpin management and conservation,

2. Gather and use information over long-term timescales to determine trends, mitigate impacts from threats, and support adaptive management and conservation of tropical inshore dolphins, and,

3. Identify, map and assess threats to tropical inshore dolphins, understand related impacts, and mitigate risks (Department of the Environment, 2015).

A number of research projects were subsequently undertaken across northern Australia through, for example, the *Whale and Dolphin Protection Plan*; others previously funded through the *Australian Marine Mammal Centre* were completed, as were several monitoring efforts associated with large-scale port developments for the extraction and export of mineral and gas resources. These studies have vastly improved the state of knowledge on tropical inshore dolphins at a number of sites (e.g., Table 1) but, on a national scale, these priority objectives remain unfulfilled. Basic information on abundance, trends and demography are still not available for many northern Australian tropical inshore dolphin populations and, even at those study sites where rigorous sampling has taken place, low abundance or movements over scales larger than the study areas have precluded mark-recapture modelling of abundance and movements (e.g., Brown et al., 2016; Brooks et al., 2017). Broader data sharing and a nationwide assessment of genetic population connectivity are yet to occur. As a result, decision-makers and management agencies must still rely upon a combination of incomplete ‘current’ knowledge (that does not include a national estimate of abundance or trends thereof, or extent of movements), and existing legislative and management policies, limiting their ability to make informed population management decisions or listings.

This section outlines the current international and national listings for Australia’s tropical inshore dolphins; details the most apt criteria under which an upgraded listing might be achieved; summarises the cultural importance of inshore dolphins to Aboriginal Australians; and re-iterates previous recommendations on tropical inshore dolphin monitoring and research moving forward.

4.2 International and national listings

Australia's tropical inshore dolphins are all listed by international conservation bodies and under national legislation, action plans and reviews of status (Table 2). All cetacean populations are protected within the Australian Whale Sanctuary under the EPBC Act, including all Commonwealth waters from the 3nm State waters limits to the boundary of the Exclusive Economic Zone (out to 200nm), with corresponding protection and management in State waters (Woinarski, Burbidge and Harrison, 2014).

Table 2: International and national listings for each tropical inshore dolphin across conventions and action plans.

Listing body/ Action plan	Humpback dolphin	Snubfin dolphin	Bottlenose dolphin	Spinner dolphin
International:				
IUCN[!] Redlist	Vulnerable	Vulnerable	Near threatened	Least concern
CMS*	Appendix II	Appendix II	Appendix II	Appendix II
CITES[#]	Appendix I	Appendix I	Appendix II	Appendix II
National:				
EPBC Act 1999	Listed, Migratory	Listed, Migratory	Listed, Migratory	Listed, Migratory
Woinarski et al., 2014^1	Near threatened	Near threatened	Data deficient	Data deficient
Ross, 2006^2	Priority species	Priority species	No category assigned	Priority species
Bannister et al., 1996^3	Priority species	Priority species	Not yet recognised	Priority species

[!] IUCN = International Union for the Conservation of Nature. * CMS = Convention on Migratory Species of Wild Animals. [#] CITES = Convention on International Trade in Endangered Species. ^1 Action Plan for Australian Mammals (Woinarski, Burbidge and Harrison 2014). ^2 Review of Conservation Status of Australia's Smaller Whales and Dolphins (Ross, 2006). ^3 Action Plan for Australian Cetaceans (Bannister, Kemper and Warneke, 1996). ^ All listings under these 3 documents were based primarily upon the species being insufficiently known.

4.3 Criteria for listing under the EPBC Act

There are five regulated listing criteria under the EPBC Act, with a number of "matters considered" and "indicative thresholds", past which a taxon might be considered Vulnerable, Endangered or Critically Endangered. These criteria include 1. Reduction in numbers, 2. Precarious geographic distribution (with matters considered including extent of occurrence and area of occupancy), 3. Precarious geographic distribution (with matters considered including the estimated number of mature individuals), 4. Small population size, and 5. Probability of extinction in the wild. These five criteria are largely equivalent to the five (A-E) under which a taxon might be considered threatened on the IUCN Red List (Fig. 22).

The research frameworks of 2013 and 2015 (Department of the Environment, 2013, 2015) aimed to guide the delivery of the information required for the future assessment of one or more of Australia's tropical inshore dolphins, particularly under Criterion 3(B) of the EPBC Act. While this information still eludes us, this criterion was deemed to be, and likely remains, the most suitable for assessing the status of these dolphins under the EPBC Act, requiring an estimate of the total number of mature individuals within the population, an indication of a continued decline and an assessment of the precariousness of their geographic distribution. A continued decline can be observed, inferred or projected in any of extent of occurrence; area of occupancy; area, extent and/or quality of habitat; number of locations or subpopulations; or number of mature individuals.

A. Population size reduction. Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4			
	Critically Endangered	**Endangered**	**Vulnerable**
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%

A1 Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased.

A2 Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction projected, inferred or suspected to be met in the future (up to a maximum of 100 years) *[(a) cannot be used for A3].*

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

based on any of the following:

- **(a)** direct observation *[except A3]*
- **(b)** an index of abundance appropriate to the taxon
- **(c)** a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality
- **(d)** actual or potential levels of exploitation
- **(e)** effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)			
	Critically Endangered	**Endangered**	**Vulnerable**
B1. Extent of occurrence (EOO)	< 100 km^2	< 5,000 km^2	< 20,000 km^2
B2. Area of occupancy (AOO)	< 10 km^2	< 500 km^2	< 2,000 km^2
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented **OR** Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline observed, estimated, inferred or projected in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** area, extent and/or quality of habitat; **(iv)** number of locations or subpopulations; **(v)** number of mature individuals			
(c) Extreme fluctuations in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** number of locations or subpopulations; **(iv)** number of mature individuals			

C. Small population size and decline			
	Critically Endangered	**Endangered**	**Vulnerable**
Number of mature individuals	< 250	< 2,500	< 10,000
AND at least one of C1 or C2			
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future):	25% in 3 years or 1 generation (whichever is longer)	20% in 5 years or 2 generations (whichever is longer)	10% in 10 years or 3 generations (whichever is longer)
C2. An observed, estimated, projected or inferred continuing decline AND at least 1 of the following 3 conditions:			
(a) **(i)** Number of mature individuals in each subpopulation	≤ 50	≤ 250	≤ 1,000
(a) **(ii)** % of mature individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals			

D. Very small or restricted population			
	Critically Endangered	**Endangered**	**Vulnerable**
D. Number of mature individuals	< 50	< 250	**D1.** < 1,000
D2. *Only applies to the VU category* Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time.	-	-	**D2.** typically: AOO < 20 km^2 or number of locations ≤ 5

E. Quantitative Analysis			
	Critically Endangered	**Endangered**	**Vulnerable**
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)	≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)	≥ 10% in 100 years

1 Use of this summary sheet requires full understanding of the *IUCN Red List Categories and Criteria* and *Guidelines for Using the IUCN Red List Categories and Criteria*. Please refer to both documents for explanations of terms and concepts used here.

Figure 22: Summary of criteria used to evaluate if a taxon belongs in an IUCN red list threatened category.

In order to be elevated in conservation status under Criterion 3B from listed only to Vulnerable, for example, the estimated total number of mature individuals (50-60% of total population size, depending on the species in question; Taylor et al. 2007; Table 1) must be considered “Limited” (<10,000 individuals), and the geographic distribution considered to be precarious for the species’ survival. Precariousness is judged on a case-by-case basis, having regard to the degree of threat operating on the species.

Using the evidence available at the time, Parra and Cagnazzi (2016) considered Australian humpback dolphins Vulnerable under IUCN criterion C2a(i) (Fig. 22), comparable to the EPBC Act's criterion 3B. This was because the total number of mature individuals was plausibly fewer than 10,000; there was an inferred continuing decline due to cumulative impacts; and each of the defined populations studied to date was estimated to contain fewer than 1,000 mature individuals (typically far fewer, Table 1; Parra and Cagnazzi, 2016).

4.4 Tropical inshore dolphin cultural importance

Australian Aboriginal people associate cetaceans with sacred sites, Dreaming tracks, language and clan names, and celebrate them in traditional and contemporary songs, stories, dance and art. There is, indeed, relatively recent evidence of mutually beneficial foraging relationships between Australian Aborigines and bottlenose dolphins from Moreton Bay, Qld, where they worked together to herd and capture migrating mullet (*Mugil* spp.), while elsewhere snubfin dolphins were reportedly hunted (Beasley, Allen and Parra, 2012; Allen, 2014, and references therein). Cetaceans are thereby deeply significant to the culture of many Aboriginal and Torres Strait Islander communities, and this is evident in the representations of, for example, whales carved into boab trees (Fig. 23), and dolphins found in rock paintings across northern Australia (Beasley, Allen and Parra, 2012; Allen, 2014).

Figure 23: Whale mother and calf carved into a boab tree in the remote Kimberley region, WA (with permission from D. Woolagoodja, senior custodian of the Dambimangari/Worwoorra People).

Twenty five years ago, Bannister et al. (1996) noted “*it is clearly of benefit to explore the historical and contemporary knowledge that Aboriginal and Torres Strait Islander peoples have of cetaceans, and to cooperatively use this experience to more effectively manage human impacts on these animals and their habitats*”. Indigenous communities are providers of environmental management in remote northern Australia, a region which not only supports globally significant populations of tropical marine wildlife of conservation concern but is also one of 13 regions identified as a global hotspot for marine mammal species extinction risk (Davidson et al., 2012).

These species reside in 'Sea Country', over which Indigenous communities have legal rights. It is, therefore, both legally mandated and logistically prudent for the national approach to conservation management of marine wildlife in tropical northern Australia to involve management agencies and research institutions working in partnership with Indigenous communities and Sea Ranger groups (e.g., Grech et al., 2014). Key roles fulfilled by Indigenous agencies and Sea Rangers include the management of heritage sites and marine wildlife, and surveillance of, for example, illegal fishing (Beasley, Allen and Parra, 2012; Grech et al., 2014). The conventional approach to tropical inshore dolphin research and monitoring is based on western science techniques, which are both logistically challenging and prohibitively expensive to implement across northern Australia, due to both scale and remoteness. Further, conventional approaches value western scientific knowledge over other knowledge systems and are, thus, inappropriate in the primarily Indigenous landscape of northern Australia. The approach that harnesses the growing capacity of Indigenous communities for marine wildlife monitoring using Indigenous Knowledge in conjunction with western science techniques is fortunately becoming more prevalent (e.g., Marsh et al., 2010; Grech et al., 2014; Brown et al., 2017; Bouchet et al., 2021).

4.5 Summary of research and conservation objectives and actions

Australia's inshore dolphins were considered in the *Action Plan for Australian Cetaceans* (Bannister, Kemper and Warneke, 1996) and, a decade later, in the *Review of Conservation Status of Australia's Smaller Whales and Dolphins* (Ross, 2006). Ross (2006) provided specific conservation objectives (based largely on those made in the *Action Plan for Australian Cetaceans*) for 3 of the 35 cetacean species listed in the review: the Australian snubfin, the (now) Australian humpback and spinner dolphins. Each of these species, as well as the Indo-Pacific bottlenose dolphin, were later given precautionary classifications (Near Threatened and Data Deficient, Table 2) in the *Action Plan for Australian Mammals* based largely on there still being insufficient information to adequately assess them (Woinarski, Burbidge and Harrison, 2014).

In order to address the knowledge gaps that still exist, it seems prudent for future research efforts to, at the design phase, revisit and attempt to adhere to the guidelines set out in, for example, *A Coordinated National Research Framework to Inform the Conservation and Management of Australia's Tropical Inshore Dolphins* (Parra et al., 2012; Department of the Environment, 2015). That is, programmes should be:

1. Well-designed and coordinated, with experts in the field of marine mammal survey design and biostatistics involved in project design.

2. Effectively implemented, appropriately funded, and with experienced personnel involved in fieldwork.

3. Analysed, as soon as is practicable following the completion of fieldwork sessions.

4. Reported on to all stakeholders and, preferably, published in peer-reviewed literature as a matter of priority.

The prioritised research objectives and actions for the conservation and management of Australia's tropical inshore dolphins were as follows (*emphases* added):

Enabling objective and action:

Objective 1 - Indigenous Engagement: *Foster effective and informed partnerships with Australia's Indigenous communities* to enable sustainable conservation management of tropical inshore dolphins.

Research objectives and actions (high priority):

Objective 2 - National Distribution Data: *Provide for access and analysis of standardised national tropical dolphin data* to assess distribution and underpin management and conservation.

Objective 3 - Long-term Monitoring: *Gather and use information over long-term timescales* to determine trends, mitigate impacts from threats, and support adaptive management and conservation of tropical inshore dolphins.

Objective 4 - Threat Risk Assessment: *Identify, map and assess threats* to tropical inshore dolphins, understand related impacts, and mitigate risks.

Research objectives and actions (medium priority):

Objective 5 - Dispersal and Movement: *Improve understanding (at national, regional and local scales) of dispersal, movement, and genetic connectivity* of tropical inshore dolphins to aid conservation and management at appropriate geographic scales.

Objective 6 – Mortality and Life History: *Foster collaborative and national approaches* to effectively gather mortality, life history and dietary information from stranded and by-caught specimens.

Objective 7 – Citizen Science: *Foster community participation in data collection* on tropical inshore dolphins and develop a continuous-improvement approach to methods and related programs.

In closing, while some gaps highlighted above remain and renewed efforts to better coordinate and tackle areas of uncertainty are warranted, a number of research and monitoring efforts have now produced abundance and density estimates for discrete tropical inshore dolphin populations across northern Australia (Table 1). Bouchet et al*.* (2021) recently integrated multiple data sources to estimate the extent of occurrence and area of occupancy of snubfin dolphins in the Kimberley region, suggesting a Vulnerable classification under IUCN criteria B2 at a regional scale. Meanwhile, Udyawer et al*.* (2021) have used distribution models to estimate areas of medium and high quality suitable habitat for snubfin and humpback dolphins. Combining these approaches across the northern Australian ranges of tropical inshore dolphins' ranges will likely prove informative.

A key challenge that remains for assigning an apt conservation status for each species is the estimation of the number of animals in areas that have not been surveyed. Scenario modelling/sensitivity analysis around the likely population sizes (and, therefore, the number of mature individuals) based on existing knowledge, including assumptions about numbers in unsurveyed areas, should be given due consideration. Conclusions drawn should of course be robust to a range of scenarios and the exercise should be explicit around uncertainties.

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