Re-thinking the assessment and monitoring of large-scale coastal developments for improved marine megafauna outcomes

Thesis submitted by

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Statement of the Contribution of Others

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	Chapter 2	The concept was Groom's with content idea provided by Neil. Groom wrote the paper editorial support and advice about the structure from Neil and Marsh. Barton and Wulf also provided reviews.	Helene Marsh Kerry Neil Di Barton Peter Wulf
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"The good life is one inspired by love and guided by knowledge," Bertrand Russell.

Abstract

Pressures on Australia's coast are largely associated with land use and climate change (Clark and Johnston 2017). Coastal biodiversity status and trends are intimately linked to these pressures and require a varied approach for ecosystem adaptation and building resilience (Burrows et al. 2011; Babcock et al. 2019; Anthony et al. 2017). Additional pressures on coastal systems such as increases in sedimentation, nutrients and lighting (Fredston-Hermann et al. 2016) lessen the function and recovery potential of ecosystems and dependent species. All efforts to reduce pressures in the coastal environment are therefore necessary to lessen the severity of expected impacts from a changing climate.

Large-scale coastal developments have the potential to fundamentally change ecosystem structure and function in multiple ways. The process for assessing potential harm to biodiversity values from these large-scale developments is assessed within an Environmental Impact Assessment (EIA) framework. EIA is often perceived to be a flawed process, although evidence for this claim is typically confounded by multiple factors external to a development, operating at various temporal, spatial and ecological scales. Understanding the opportunities for intervention and conservation management and their limitations is critical to improving the process.

A professional doctorate must make a significant and original contribution to knowledge in the context of professional practice. My thesis aims to inform the professional practice of EIA in the coastal marine environment of the Northern Territory from the perspective of marine megafauna. The objectives of the research component of my doctorate were to:

1) investigate the capacity of EIA to adequately identify and manage risks to marine megafauna using a case study approach;
2) reduce the knowledge gaps in the Northern Territory (NT) for two Matters of National Environmental Significance (MNES) that trigger the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth), i.e. the flatback turtle and dugong, to facilitate a 'multiple lines of evidence' approach to evaluating impacts and improving management; and,
3) provide guidance to regulators and proponents in the NT on marine megafauna assessments.

My desktop evaluation of the EIA process as applied to developments at Port Melville (NT), and Gladstone and Abbot Point (Queensland), demonstrated considerable weaknesses in the identification and management of risks to marine megafauna (turtles, dugongs and coastal dolphins). Although the Cumulative Impact Assessment (CIA) process at Abbot Point demonstrated merit through elements of collaborative monitoring programs, strategic planning and independent assessments, areas of improvement remained. These weaknesses included data insufficiency, project and proponent constraints, and the relevance (and ineffectiveness) of the monitoring techniques. Where relevant, I suggested improvements to the process, including:

1) an independent technical review of the proponent's planned response to the requirements of the project's Terms of Reference of the Environmental Impact Statement (EIS) prior to the commencing of the studies;
2) strategic assessments to be made a priority where there are multiple developments over a common spatial area – the assessment should include cumulative impacts of concurrent, multiple developments in the same region;
3) minimum standards for baseline and impact assessment processes; and,
4) a review of the Commonwealth and State/Territory bilateral agreements to ensure effective and consistent carriage of assessment powers.

I demonstrated the value of applying biological research using long-term population data by analysing historical data collected:

1) on long-term trends (from 2002 to 2013) in abundance and survival for nesting flatback turtles in Kakadu National Park, Australia using mark-recapture techniques;
2) from a single broad-scale survey of the coastal waters of the NT in 2015 for dugongs; and,
3) from multi-year surveys (1984, 1994, 2007, 2014) of the coastal waters of the Gulf of Carpentaria for dugongs.

The results of my analyses and the associated modelling using environmental covariates facilitate an understanding of spatial and temporal trends in flatback turtles and dugong populations allowing for a risk-based approach in EIA, a necessary step to contextualise anthropogenic impacts and develop management strategies for sustainable coastal development. These analyses also improved understanding of the marine megafauna populations along the NT coast, enabling informed risk assessments and coastal planning. Although the size of the Field Island nesting flatback turtle population varied by almost a factor of two between years, there was a non-significant trend in abundance over 12 years of monitoring. Understanding long-term population trends of nesting marine turtles is fundamental for management and recovery of these at-risk species and EIAs ideally require a multi-year baseline.

Dugongs mostly occur within the 10 m depth contour in the NT. The most important habitat for dugongs and their calves is in the Pellew bioregion as surveys have demonstrated for more than 30 years. Although the dugong population in the NT waters of the Gulf of Carpentaria appears to be stable over the survey period, the standard errors for individual survey blocks were wide indicating that it will likely be impossible to detect change in dugong density at a local scale in the time-frame of development construction using these aerial survey data as a baseline.

The life histories of megafauna species, the difficulty in detecting trends in their abundance and the multiple confounding factors that influence their abundance at a local scale as demonstrated by the studies on the flatback turtle and dugong, make detecting a significant impact from a development impossible in a construction timeframe, unless the impact is direct and catastrophic. I therefore recommend that proponents be required to monitor surrogate indices of megafauna population health (such as changes in key habitat indicators) during the EIA process. I also suggest that proponents should not be required to engage in the futile practice of attempting to detect changes in abundance at a local scale attributable to a development *per se.* Rather, proponents should be required to underwrite scientifically rigorous studies of the distribution and abundance of the key relevant megafauna species at ecologically-relevant temporal and spatial scales, so that the factors contributing to long-term changes in these populations can be understood.

The marine fauna EIA guidelines that I developed for the NT Environmental Protection Authority (EPA) were drafted as part of the environmental legislation reform process occurring in the NT. The NT EPA have developed a framework of environmental values and marine fauna is one of several factors to have guidelines developed. The guidelines aim to provide clarity to regulators and proponents operating in the NT regarding the treatment of marine megafauna in an EIA. Findings from previous chapters have been incorporated to improve EIA process in a regionally relevant context. Although not prescriptive, the guidelines are of sufficient scope to guide the appropriate lines of enquiry expected of proponents in EIA these include legislative requirements, species ecology and distribution, management and mitigation measures and relevant online resources. These guidelines should lead to EIAs being conducted with greater rigour and consistency in the NT and should inform an ecosystem approach within an adaptive management framework to enable the EIA process to continually develop and improve as new knowledge is integrated.

This thesis thus contributes to the practice of EIA by addressing impediments in its policy, scientific and practice components. More broadly, an understanding of MNES within an EIA framework is made more accessible and the implications of a ‘policy and science disconnect’ is made apparent. Such change to improved EIA ultimately requires stronger leadership from government regulators for implementation into practice.

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Publications produced during my professional doctorate candidature

Peer-reviewed publications on which this thesis is based

Groom, R., Neil, K.M. & Marsh, H.D. 2018. Suggested Improvements to the Australian Environmental Impact Assessment Process to Benefit Marine Megafauna. *Environmental and Planning Law Journal* Volume: 35 Issue: 1, Pages: 46-59. (Chapter 2)

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Reports that contributed to this thesis

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Peer-reviewed publications external to this thesis

Dunshea, G.J., **Groom, R.A.** & Griffiths, A.D. *in review*. Observer performance and the effect of ambiguous taxon identification for fixed strip-width dugong aerial surveys. *Journal of Experimental Marine Biology and Ecology*

Shimada, T., Limpus, C., Hamann, M., Bell, I., Esteban, N., **Groom, R.,** & Hays, G. *in review.* Fidelity to foraging sites after long migrations. *Journal of Animal Ecology*

Waayers, D., Tucker, T., Whiting, S., **Groom, R.**, Vanderklift, M., Pillans, R., Rossendell, J., Pendoley, K., Hoenner, X., Thums, M., Dethmers, K., Limpus, CJ., Wirsing, A., Mcmahon, C., Strydom, A., Whittock, P., Howlett, K., Oades, D., Mcfarlane, G., Duke, T., Guinea, M., Whiting, A., Speirs, M., King, J., Hattingh, K., Heithaus, M., Mau, R. & Holley, D. 2019. Satellite tracking of marine turtles in south eastern Indian Ocean: a gap analysis of deployments spanning 1990-2016. *Indian Ocean Turtle Newsletter* No. 29

Palmer, C., Baird, R.W., Webster, D.L., Edwards, A.C., Patterson, R., Withers, A., Withers, E., **Groom, R.** & Woinarski, JCZ. 2017. A preliminary study of the movement patterns of false killer whales (*Pseudorca crassidens*) in coastal and pelagic waters of the Northern Territory, Australia. *Marine and Freshwater Research*, Volume: 68, Issue: 9, Pages: 1726-1733

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Groom, R. *Report for Western Basin Dredging and Disposal Project, Marine Megafauna Baseline and Impact Assessment*. 2009. Gladstone Ports Corporation. http://eisdocs.dsdip.qld.gov.au/Port%20of%20Gladstone%20Western%20Basin%20Dredging/EIS/appendix-r-marine-megafauna-assessment.pdf

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Groom, R. *Megafauna Assessment Report: Proposed Abbot Point Multi Cargo Facility Environmental Impact Statement.* 2009 Mackay: North Queensland Bulk Ports Corporation.

Postgraduate coursework completed as part of the requirements for my professional doctorate candidature[1]

Subject title	Grade	Affiliation
Indigenous Environmental Management	Distinction	JCU
Conflict Management and Transformation	Distinction	JCU
Qualitative Research in Social Science	Distinction	JCU
Environmental and Ecological Economics	Distinction	UQ
National and International Conservation Policy	Distinction	UQ
Research Topic - Coral Triangle Initiative and Coral Reefs, Fisheries and Food Security (CTI-CFF): *How do institutional differences between fisheries management agencies and marine conservation agencies influence policy development with respect to major regional initiatives?*	Distinction	UQ
Supervisor: John Tanzer (CTI Advisor, The Nature Conservancy)		
Sustainable Development in Practice	Distinction	UQ
Political Ecology	Credit	UQ

[1] I arranged with JCU to complete some of the coursework required for my professional doctorate through UQ because I was living in Brisbane at that time.

Chapter 1: General introduction

1.1 Introductory overview

The northern coast of Australia is subjected to the same pressures as most of Australia's coast; pressures that have been largely linked to land use and climate change (Clark and Johnston 2017). How these pressures manifest is complex and the consequences of a rapidly changing coastal environment are not fully understood. Regardless, essential ecological processes are in a poor state nationally due to multiple pressures on coastal ecosystems (Clark and Johnston 2017). Trends in the status of coastal biodiversity are intimately linked to these pressures and require a spatially customised approach for ecosystems to adapt and build resilience (Burrows et al. 2011; Babcock et al. 2019; Anthony et al. 2017). Additional pressures on coastal systems such as increased sedimentation, nutrients, lighting and noise (Fredston-Hermann et al. 2016) lessen their recovery potential. Thus, measures to effectively reduce such pressures are critical.

This thesis focusses on issues relevant to the management of the coastal environment and inshore waters of the Northern Territory (NT), the least populated and most sparsely distributed population in Australia. More than 85% of the NT's coast, or 'Sea Country' as it is generally referred to by indigenous Australians, is owned to the intertidal lands by Aboriginal people. The ownership is recognised under Commonwealth law and it is a resource rich area that provides habitat for many marine megafauna species that are listed as Matters of National Environmental Significance (MNES) under the *Environment Protection and Biodiversity Conservation Act (1999*) (henceforth EPBC Act) including marine reptiles, dugongs, dolphins, sharks and rays. Many of these species not only have high biodiversity value as listed threatened and/or listed migratory species but also have high cultural value to Indigenous Australians (Nietschmann and Nietschmann 1981, Bradley 1997, NAILSMA 2006).

Concurrently, the coastal interface supports important economic activity in the NT where ports and industrial processing facilities provide essential infrastructure for a multi-billion-dollar mining and manufacturing industry (22.7% of the NT economic output in 2018-19 (Department of Treasury and Finance, 2019). Development pressure on the coastal environment is expected to continue to keep pace with population growth and industry demand. New mines (including seabed mining) are proposed along the NT coast. These developments will necessitate the infrastructure required to facilitate production, processing and shipment. Such developments will occur alongside other coastal pressures, such as aquaculture facilities, commercial fishing and climate change. An effective Environmental Impact Assessment (EIA) process is essential to protect marine biodiversity values in the context of such rapid coastal change. However, multiple factors constrain the EIA process and limit the conservation outcomes. Conservation in this context refers to the protection, including the planned management of a natural resource to prevent exploitation, destruction, or neglect. In this chapter, I provide a rationale for my research, introduce its objectives and outline the structure of this thesis.

1.2 The context for environmental impact assessment in the coastal regions of northern Australia

The potential to manage biodiversity losses from large-scale developments is typically assessed within an EIA framework (Bigard et al. 2017). The effectiveness of this process at achieving minimal environmental harm is often considered to be flawed (Grech et al. 2013, Hawkins et al. 2017). In Australia, the EPBC Act is designed to protect species of conservation concern including marine megafauna, such as turtles, dugongs and coastal dolphins as MNES. Nonetheless, legal, biological and practice impediments limit the effective conservation of these species. These limitations are of concern along the coast of northern Australia.

The marine biodiversity values of the coastal waters of northern Australia are extensive and include rich species diversity, culturally significant places and some of the most important marine megafauna populations in Australia and indeed, globally (Butler et al. 2010). The Northern Territory is distinguished by extensive estuarine systems, large, intensely seasonal freshwater inflows from near-pristine river catchments (Murray et al 2006), and warm shallow seas (IMCRA 1998). Many marine species utilising this habitat are listed under the EPBC Act as threatened or migratory and are therefore regarded as MNES (Commonwealth of Australia 2013a). At present, there are nine defined categories of MNES, two of which are particularly important to the marine megafauna of this region that are considered in this thesis: listed threatened species and listed migratory species.

Dugongs have their population stronghold in the tropical and subtropical waters of Australia (Marsh et al. 2002, Marsh et al. 2011, Groom et al. 2017a). This area is also a significant foraging and nesting habitat for threatened sea turtle populations (Limpus 2007, Chatto and Baker 2008, Commonwealth of Australia 2017) and is critical habitat for three coastal dolphin species, two of which live only in coastal waters of northern Australia and southern New Guinea (Brown et al. 2016, Palmer et al. 2017). The heterogeneous environments within the coastal zone of this region are also of importance to multiple stakeholders and provide economic benefits, recreation and lifestyle for many coastal communities and enable the maintenance of customary practices for the region's Aboriginal communities (Clark and Johnston 2017).

The *EPBC Act* specifically provides that it does not conflict with the operation of either the *Native Title Act 1993* (Cth) or the *Aboriginal Land Rights (Northern Territory) Act 1976* (Cth). In the Northern Territory (NT), Aboriginal people own and manage 78% of the coastline through inalienable Aboriginal freehold granted under the *Aboriginal Land Rights (Northern Territory) Act 1976* (Cth) (Joint Standing Committee on Northern Australia 2018), with a further 12% subject to outstanding land claims, conferring a high degree of control over access and use. Importantly, the High Court of Australia determined in 2008 that permission from the Traditional Owners is required to access the waters overlying granted Aboriginal land, including the intertidal zone (known as the Blue Mud Bay decision (Brennan 2008). Aboriginal ownership and rights in the coast and intertidal zone of the Northern Territory provide an important context for the management of coastal resources. These rights guide, and influence management regimes proposed to ensure Traditional Owners' decisions and rights are recognised. With increasing pressures on the coastal and marine resources of this region, an improved approach to managing the marine environment has never been more important.

The pressure for development in tropical Australia has increased at an unprecedented rate in the last decade (Grech et al. 2013, Waltham and Sheaves 2015, Benham 2016) putting marine biodiversity values at risk. Large coastal developments have the potential to significantly impact marine megafauna through multiple pathways. There is a need to improve EIA and benefit the conservation outcomes of marine megafauna as multiple pressures continue to impact the coastal environment (Halpern et al. 2007, Oritz et al. 2018).

1.3 The Environmental Impact Assessment Process

The purposes of EIA are to identify and assess the potential significance of environmental effects associated with major development proposals and communicate this information to decision-makers, regulators and the public (Macintosh 2010, Morgan 2012, Tamis et al. 2016) through an Environmental Impact Statement (EIS). This process is necessary to ensure that appropriate mitigation measures are incorporated during the planning phases of projects, activities and operations (Marshall 2001). Biodiversity protection is a central objective of the EPBC Act and thus, assessment of biodiversity at the species, habitat, and ecological community level, including genetic diversity and the role of biodiversity in food web function is required (Commonwealth of Australia 2008).

If there is a potential for significant impacts on MNES, a proposal may require Commonwealth approval before it can begin. Whilst the *legislation* is silent as to the meaning of a *significant impact*, the government has developed Significant Impact Guidelines (Commonwealth of Australia, 2013a) (http://www.environment.gov.au/epbc/publications/nes-guidelines.html) to assist proponents in deciding if the action requires referral to the Minister for assessment and approval. The term *significant*, is crucial to determining whether Commonwealth assessment and approval is required. Under the Guidelines, factors to consider in determining significance include all direct, indirect and cumulative impacts, the frequency and duration of the action, the total impact attributed to the action over the geographic range over time, the certainty of impacts on the environment and the sensitivity of the receiving environment (Commonwealth of Australia 2013a).

Bilateral agreements between the Commonwealth and the states/territories relating to environmental assessment allow the Commonwealth Minister for the Environment to rely on specified EIA processes of the state/territory in assessing actions under the EPBC Act (https://www.environment.gov.au/epbc/one-stop-shop). The bilateral agreements aim to reduce duplication in EIA, ensure efficiency and effective process for environmental assessment, promote the conservation and sustainable use of natural resources and ensure high environmental protection and standards. These agreements apply to proposals that are 'controlled actions' requiring assessment under Part 8 of the EPBC Act and which are undergoing an EIS assessment process under the relevant state/territory agencies. Although the assessment powers fall within a bilateral agreement between the Commonwealth and states/territories, project approval remains the responsibility of the Commonwealth (McGrath 2014; https://www.environment.gov.au/nt-bliateral-agreement-assessment-2014).

1.4 Marine megafauna and the potential for significant impact

The Significant Impact Guidelines (2013a) have specific criteria for proponents to use when assessing the potential for a significant impact on MNES. The assessment criteria for listed migratory species and listed threatened species are different. For example, the listed threatened species assessment criteria require the proponent to assess the potential of their project to impact on: (1) the species' population, demographics and habitat use in order to determine if a long-term decrease in population size is likely, or (2) a reduced area of occupancy, or (3) population fragmentation, or if critical habitat is being adversely affected, or if the availability or quality of habitat is likely to lead to a population decline. Criteria for listed migratory species require proponents to assess the potential for their project to have a significant impact on: (1) habitat important to the species and determine if it will be destroyed or isolated, or (2) part of the lifecycle of a significant proportion of the population or, if the project could seriously disrupt part of the life cycle.

For both listed threatened and listed migratory species, the significant impact criteria are based on population and habitat use metrics that are rarely available for marine megafauna and take many years of study to obtain. The Significant Impact Guidelines offer advantages in terms of species-specific assessments; however, they do not ensure consistent assessments. The lack of a single standard protocol for: (a) determining what is meant by a significant impact, and (b) determining whether an impact is likely to be significant, means that the term "significant" can be interpreted in different ways (Lawrence 2007, Jones and Morrison-Saunders 2016). This subjectivity offers advantages in terms of decision-making because it can be applied to a wide range of potential impacts on biodiversity, however, it also substantially increases variation in practice (Lawrence 2007). Whether or not an activity is likely to have a significant impact, not only determines whether an activity is permitted to progress, this assessment also informs the degree of environmental controls, management, mitigation and offsets applied. Thus, an adequate process to determine the potential for a significant impact is of critical importance to the broader EIA process (Briggs and Hudson 2013, Ehrlich and Ross 2015).

The potential for determining whether a development will have a significant impact on marine megafauna in an EIA is undermined by the paucity of data in most marine ecosystems (Broderick 2015, Townsend et al. 2018) and specifically, the lack of robust ecological data on the megafauna species of conservation concern (Lewison et al. 2014, Martin et al. 2016, Sequeira et al. 2019). One of the challenges in determining the potential for a significant impact on marine megafauna is the degree of natural variability in their abundance, behaviour, and/or distribution. Abundance can vary substantially in space and time and may already be experiencing a trend (Taylor et al. 2007) that is undetectable by limited temporal studies (Gotelli et al. 2010).

Many migratory species have large home ranges, ranges that extend beyond the footprint of project assessments (Sheppard et al. 2006, Gredzens et al. 2014, Brooks and Pollock 2015, Shimada et al. 2016). Such species may use an area on an occasional basis and can be cryptic and hard to detect (McClellan et al. 2014, Peavey 2016). These features mean that determining their level of dependency on habitat within the project footprint as well as the prevalence or proportion of a population that may use the area (and be exposed to an impact) is very difficult or impossible in the timeframe of an EIA. During the relatively short period in which monitoring is carried out in EIA, it is often impossible to separate any impact from natural variability (Osenberg et al. 1994) as the monitoring results are not sufficiently contextualised, temporally or spatially. It can then be incorrectly assumed that if no impact is detectable, an impact did not occur (Maclean et al. 2009). Inadequate survey design, i.e., one with minimal survey effort, lowers the likelihood of detecting an impact and increases the likelihood of misinterpreting the risk of the development on the megafauna of conservation concern (Osenberg et al. 1994, Maclean et al. 2014). A study informed by a power analysis should increase the understanding of the potential of survey results to detect impact for a given survey effort (Antcliffe 1999). However, this tool is rarely deployed. In most cases the power analysis would demonstrate that the likelihood of detecting an impact will be low because of the inherent variability of detecting a species of marine megafauna at the local scale of a development.

When there is scientific uncertainty around determining the potential for a development to have a significant impact, the precautionary principle (refer to Glossary in Appendix 5) should be triggered (Gullett 2000). Use of the precautionary principle requires decision-makers to take a risk-based approach to decision-making. It provides a framework for governments to set preventative policies where existing science is incomplete or where no consensus exists regarding a particular threat. Section 391 of the EPBC Act prescribes the decisions in which the precautionary principle must be considered.

The precautionary principle has four central components: (1) taking preventive action in the face of uncertainty; (2) shifting the burden of proof to the proponents of an activity; (3) exploring a wide range of alternatives to possibly harmful actions; and (4) increasing public participation in decision-making (Kriebel et al. 2001). Precautionary measures are often applied to scenarios where marine megafauna are at risk and impacts need to be reduced to a perceived acceptable level. Examples implemented in EIA in response to marine megafauna are rare as the proponent's environmental reporting is often commercial in confidence. Many fisheries, however, have a degree of public reporting on their interactions with threatened species. For example, in the Pacific fishing fleets, high whale shark mortality was recorded from fishing activities (WCPFC 2010). This prompted management measures from the Western and Central Pacific Fisheries Commission (WCPFC) to ban the intentional setting of nets around whale sharks (WCPFC 2012). These management measures have been implemented as a precautionary approach because the WCPFC and Indian Ocean Tuna Commission (IOTC) consider whale sharks as vulnerable, ecologically important and emblematic (Capietto et al. 2014). Additionally, they admitted that accurate data on the interaction between purse seine operations and whale sharks are lacking. Preventative measures to protect the environment must be implemented even before scientific evidence of potential harm is observed. The value of the precautionary principle, therefore, lies in the timing of, rather than the need for, a remedy (Wang 2011). The versions of the Principle adopted in Australia, which reflect the 'Rio definition', permit precautionary measures but do not specify the nature or the extent of precaution to be applied. Decision-makers therefore apply precaution through risk management frameworks that take account of uncertainty. Efficient and effective implementation of precaution requires decision-makers to take account of the full range of relevant factors, including the magnitude, nature and severity of potential harm, as well as the economic, social, environmental, and health costs and benefits. However, in EIA, the actual risks and the relevance of the mitigation applied to marine megafauna remain unknown and there is no clear guidance from regulators on how best to apply the precautionary principle, limiting its conservation potential. While the precautionary principle is critical to decision-making on environmental matters, where there is rarely scientific certainty, the precautionary principle is not the only principle of ESD. If the principles of ESD are the guiding principles for the Act, they should be considered as a whole. Decision-makers are required to consider and act consistently with all the principles of ESD defined in the Act (refer to Chapter 5 and Appendix 5).

1.5 Significant Impact Guidelines - Population impacts

The life history of marine megafauna taxa makes them inherently vulnerable to impacts. They are long-lived, slow to reach maturity and have low recruitment (Musick 1999). Although degradation in the marine environment is not as extensive as the terrestrial environment, a relatively small number of marine species have undergone local, ecological, and commercial extinction (McCauley et al. 2015). Global assessments of human impact on marine ecosystems indicate that coastal habitats have been more affected than deep-water or pelagic ecosystems (Halpern et al. 2008), presumably because coastal habitats are more accessible. The populations of marine fauna closest to human settlements and trade networks are often reduced prior to a development occurring (Cinner et al. 2013, McCauley et al. 2013).

The Commonwealth's Significant Impact Guidelines (2013) include a criterion for proponents about population-level impact assessment. Understanding the genetic structure of populations including levels of gene flow among populations of the same species, is important for conservation status assessments and the effective management of a species (Flanagan et al. 2017). When determining the potential for a significant impact to occur on threatened and migratory species in EIA, the biological populations potentially impacted (or 'sub-population') should be identified (Chabanne et al. 2017). Assessing the potential for a significant impact requires information about population structure, so that decision-makers can evaluate the biological significance of potential impacts. For example, will the development affect the viability of a distinct population? However, the scale of an EIA rarely reflects the relevant ecological scale of marine megafauna, such as the movement between habitats for feeding and life stages. Knowledge of species ecology and responses to impacts is also incomplete.

For threatened species, such as marine turtles, the Significant Impact Guidelines (2013) consider an ‘important population’ to be “a population that is necessary for a species’ long-term survival and recovery”. Except for the leatherback turtle, Australia’s turtle populations are genetically defined into 22 nesting stocks (Commonwealth of Australia 2017). Their threatened and migratory listing suggests turtles should trigger the assessment process frequently, which they do; the loggerhead turtle triggers the EPBC Act more than any other listed migratory species and indeed, five of the top 10 migratory species triggering this Act are marine turtles; the dugong ranks 28th in this context. (Jason Ferris, Commonwealth Environment Department, personal communication to Helene Marsh 2019). However, marine turtle species are too often considered at the taxon level (marine turtle), rather than the level of species or genetic stock, which means there is an inherent risk of underestimating the impacts of a development at the appropriate level in an EIA.

Our knowledge of the genetic stocks of marine turtles potentially allows for the detection of a significant impact at the population-level, if a development is near a nesting beach where the abundance of the nesting stock can be measured. However, if the coastal development is likely to impact a turtle foraging habitat, mixed genetic stocks and age classes are likely to be present. Turtles are known to have high site fidelity to foraging areas (Shimada et al. 2016, Pearson et al. 2019) and so the EIA should be based on the foraging population using by mark-recapture at the site, rather than the genetic stock. The Significant Impact Guidelines are not clear on whether this approach is acceptable for determining a significant impact. In addition, turtles have variable migration pathways between their nesting and foraging sites (Waayers et al. 2019). These pathways are beyond the scale of a project’s footprint. Thus, the potential impacts of a development on these populations are unlikely to be detected unless mortality is catastrophic, an impact which may be unavoidable if the project has already been approved.

1.6 Spatial and temporal constraints

Assessment and monitoring of marine ecosystems in an impact assessment framework has traditionally focussed on physical and chemical parameters and increasingly includes associated observations on environmental condition (Smith and Smith 1991, Dafforn et al. 2016), stopping short of ecosystem-scale assessment. The ecological data informing an EIA are often collected at the scale of the development footprint (and sometimes the area of influence) (João 2007, Coston-Guarini et al. 2017) and rarely includes data of an ecologically relevant scale to migratory marine species that may be impacted by the development (Bigard et al. 2017).

During an EIA, time is limited to conduct environmental studies. This constraint means that the efforts to capture species and habitat data may not be representative of actual use patterns of the species of conservation concern. Thus, the environmental drivers that determine these patterns over several years remain unknown (Hewitt et al. 2007). The information collected from one wet/dry season cycle is unlikely to provide proponents with the information necessary to determine the potential for an impact on a marine megafauna population for many reasons: (1) these species have long generational times, (2) can be highly mobile – often beyond the development footprint, (3) may use multiple habitats at different life stages (Turner Tomaszewicz et al. 2017), and (4) their responses to environmental change are often lagged (Limpus and Nicholls 1988, Marsh et al. 2011, Meager and Limpus 2014, Fuentes et al. 2016b). In addition, they are often difficult to detect, and their detection probability varies spatially and temporally. Despite these inherent limitations, evaluating whether a potential development is likely to have an impact on a population of a MNES remains important. The metric used by the Commonwealth is the proportion of a population (for threatened species) as explained above. As population-level impacts also depend on population size, species with small populations are especially vulnerable. The assessment of effects on a population requires detailed demographic modelling and knowledge of demographic parameters. Such approaches are rarely conducted as part of an individual EIA that is trying to satisfy requirements across all potentially affected environmental receptors in a limited space and time.

Integrating multiple lines of environmental data to determine potential impacts on marine megafauna is necessary given the high variability in both marine megafauna populations and the marine environment (Suter and Cormier 2011, Marsh et al. 2015, Sequeira et al. 2018). In addition, many impacts that may not be affecting the environment in a significant way individually, can lead to serious adverse effects when considered as part of incremental changes caused by multiple developments and/or environmental pressures (Anthony et al. 2013). A key challenge is to address the ambiguity around the time period for which the reference or baseline conditions should be assessed. The concept of a baseline against which to compare predictions of the cumulative effects of proposed actions and reasonable alternatives is critical to the Cumulative Impact Assessment (CIA) process (Maclean et al. 2014). However, changes in the marine environment are dynamic and setting the baseline as the period immediately prior to a development will not capture the cumulative impacts of a series of sequential developments. This situation is further complicated by the necessity of understanding impact risk and ecosystem resilience immediately following the time of impact. Further, the uncertainties inherent in individual project-level assessments are multiplied when multiple projects are considered, often leading to a large degree of uncertainty and over-simplified cumulative impact outputs (Maclean et al. 2014). Regardless of whether impacts are predicted or monitored, the likelihood as well as the magnitude of the impact should be considered to account for uncertainty given that the responses of marine megafauna are largely not understood and often undetectable due to the low power of the monitoring.

1.7 The challenge of achieving a consistent approach

A fundamental challenge associated with predicting the significance of impacts is the inconsistency in data collection and assessment approaches. These inconsistencies arise in part from the absence of clear guidance from regulators regarding how the legislation and guidelines should be interpreted and implemented. Guidelines reduce ambiguity that would otherwise lead to an inadequate information base for an EIA. While providing guidance in EIA is progressive, without effective implementation and advice on the appropriate references against which to assess impacts, there will be no effective change. A greater emphasis on understanding impacts is necessary, particularly cumulative impacts, which should be more detectable with an ecosystem approach (Mueller and Geist 2016, Turra et al. 2017).

Clearly, the current process of EIA is failing the marine megafauna that it is designed to protect as MNES. Given the pace of development along the coastline of northern Australia, research is required to improve practice in this area. My research was designed to address that gap.

1.8 Thesis objectives

This thesis aims to contribute to the professional practice of EIA through improved policy and robust science in the coastal marine environment to facilitate improved conservation outcomes for marine megafauna by addressing the following objectives:

1) Investigate the capacity of EIA to adequately identify and manage risks to marine megafauna;
2) Address knowledge gaps and acknowledge limitations of marine megafauna in an EIA framework to facilitate a multiple lines of evidence approach to determine impacts and improve management;
3) Provide guidance to regulators and proponents on leading practice marine megafauna assessments for consistency in industry practice based on scientific rigour.

Objective 1: Investigate the capacity of EIA to adequately identify and manage risks to marine megafauna *(See especially Chapter 2)*

EIA is a regulated decision-making tool used to manage impacts to the environment as a result of potential project impacts (Wathern 1988, Schuijers 2017). In Australia, the primary environmental legislation is the EPBC Act, which regards listed migratory and listed threatened species as MNES. Thus, marine megafauna including turtles, dugongs, and coastal dolphins, all species with sensitive life history traits that make their populations susceptible to impacts, are MNES. The treatment of MNES in EIA requires special consideration to adequately determine impacts and subsequently implement effective mitigation. Coastal EIAs are evaluated for their adequacy in managing impacts to marine megafauna. Deficiencies in the current process are identified and recommendations provided to improve outcomes for marine megafauna within EIA.

Objective 2: Address knowledge gaps and acknowledge limitations of marine megafauna in an EIA framework to facilitate a multiple lines of evidence approach to determine impacts and improve management *(See especially Chapters 3 and 4)*

The species-environment relationship of marine megafauna is complex. Understanding this relationship and predicting impacts within the spatial and temporal scales imposed by an EIA is generally not possible. Multiple factors confound the abundance and distribution of marine megafauna which require long-term and broad-scale datasets as a reference in EIA. Abundance and distribution studies of MNES are used to demonstrate the significance of robust data in an EIA context.

Objective 3: Provide guidance to regulators and proponents on leading practice marine megafauna assessments for consistency in industry practice based on scientific rigour *(See especially Chapter 5)*

The terms of reference in an EIA are prescribed for proponents by regulators. Improvements to EIA outcomes include providing greater support to proponents through managing data delivery requirements. As part of a recent environmental legislation reform, the NT Government has enabled multiple improvements in EIA. The provision of EIA guidelines on environmental values is one such improvement. Marine fauna is considered as a factor within the NT EPA’s environmental values framework amongst many others. Within this framework, all factors will have guidelines to support the proponent’s decision-making and data quality in EIA. Marine fauna guidelines have been developed for the NT EPA for application in EIA. These are intended to provide consistency and rigour to the EIA process and ultimately lead to better outcomes for marine fauna.

1.9 Thesis outline

This thesis is presented as a series of chapters that have been written in a format that facilitates publication in peer review journals and can be used by the government to guide policy and practice. Figure 1.1 illustrates the structure of the thesis.

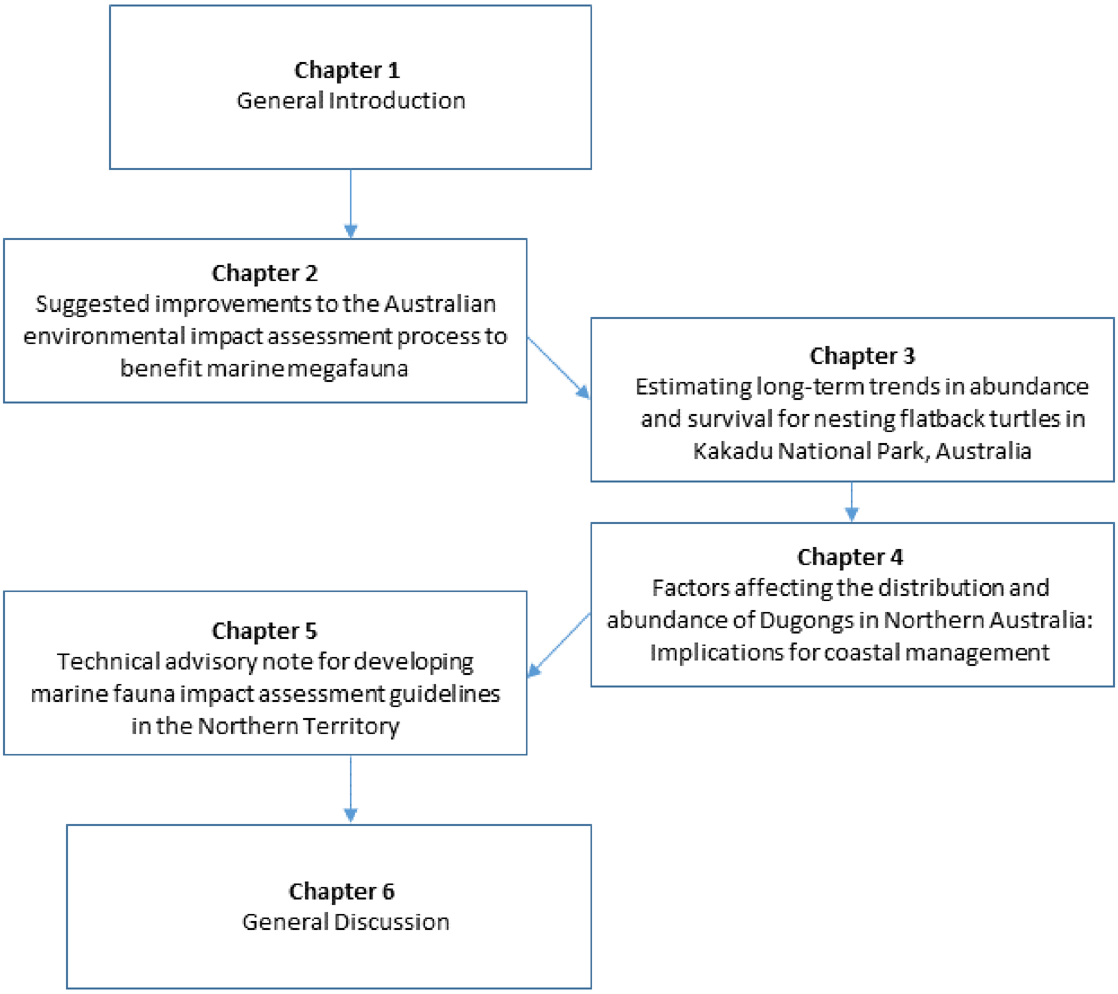


Figure 1.1: An illustration of the chapters of this thesis.

Chapter 1 (this chapter): introduces EIA and the factors limiting our understanding of impacts to marine megafauna and their conservation management within the EIA process.

Chapter 2: addresses Objective 1 by using three recent coastal development assessments in tropical Australia as case studies as a basis for reviewing the current Commonwealth impact assessment process and its ability to effectively manage risk for listed marine megafauna (turtles, dugongs and coastal dolphins). This chapter is based on a publication in *Environmental and Planning Law Journal* (Groom et al. 2018).

Chapter 3: addresses Objective 2 by illustrating the importance of robust long-term datasets to understand interannual variations in recruitment and long-term population trends for the Field Island, Kakadu National Park flatback turtle nesting population. This chapter, which demonstrates the need for multiyear data to provide robust baselines for megafauna in an EIA, is based on a publication in *Endangered Species Research* (Groom et al. 2017b).

Chapter 4: addresses Objective 2 by analysing historical dugong aerial survey data collected at two spatial scales: broad-scale coastal Northern Territory (NT) waters and multi-year aerial survey data from the Gulf of Carpentaria (NT) to determine the association between spatial, temporal and environmental covariates in influencing the distribution and abundance of dugongs. This chapter identifies the most important dugong habitats in the Northern Territory and provides empirical evidence of the challenge of detecting an impact for a local scale development. A version of this chapter will be submitted for publication in a peer-reviewed journal.

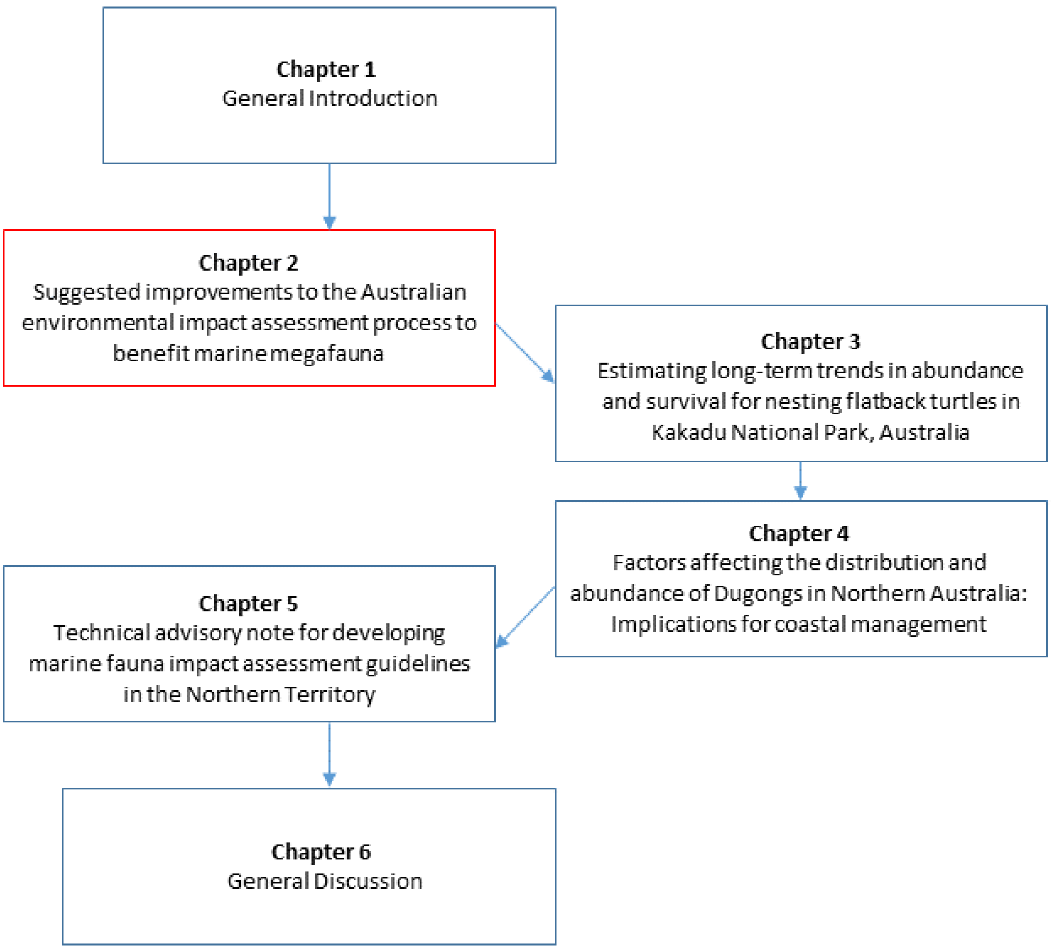
Chapter 5: addresses Objective 3 by providing a policy background and technical guidelines structure to support the Northern Territory government in assessing marine fauna values within an environmental impact assessment framework. Parts of this chapter will become a public document and be used to develop the NT Environmental Protection Agency's policy framework.

Chapter 6: shows how my research has achieved its objectives, outlines opportunities for implementing changes in the EIA process to improve the conservation outcomes for marine megafauna and suggests avenues for future research.

Chapter 2: Suggested improvements to the Australian environmental impact assessment process to benefit marine megafauna[2]

2.1 Overview

In this chapter, I review environmental policy, legislation and Environmental Impact Assessment (EIA) case studies in northern Australia to identify gaps in governance, EIA process and ecological constraints to conducting a robust EIA on marine megafauna. I compare EIA approaches for coastal developments and identify the relevant policy/legislation gaps that require change to benefit marine megafauna in the Northern Territory. Outputs of the assessment are recommendations to improve EIA in Australia more broadly and are applied to the Northern Territory in later chapters.



[2] A version of this chapter has been published as Groom, R. A., K. M. Neil, and H. D. Marsh. 2018. Suggested Improvements to the Australian Environmental Impact Assessment Process to Benefit Marine Megafauna. *Environmental and Planning Law Journal* **35**:46-59

2.2 Environmental Impact Assessment in Australia

The EIA and approval system is a multi-faceted process to assess environmental effects and deliver environmental management outcomes. Potential consequences of a project are identified at a stage where regulatory decision-making can influence the project outcome (Wathern 1988, Schuijers 2017). In Australia, the primary environmental legislation is the EPBC Act (refer to Chapter 1). The Act is founded in the principles of Ecological Sustainable Development and incorporates the precautionary principle and the principles of intergenerational equity (Hawke 2009). The EPBC Act provides the legal framework for protection and management of nationally and internationally important flora, fauna, ecological communities and heritage places (Department of the Environment and Energy 2016b). Under the Act, the conservation status of a species determines its treatment within the impact assessment process. Statutory criteria for assessment are described by the EPBC Regulations 2000 and are summarised in Table 2.1.

Table 2.1: Determination of a significant impact on EPBC listed species.

<table>
<tr><th colspan="2">Defining a significant impact on listed species</th></tr>
<tr><td colspan="2">• An impact which is important, notable or of consequence, having regard to its context and intensity.
• Significance depends on sensitivity, value and quality of the environment which is impacted. Intensity, duration, magnitude and geographic extent of the impact/s.
• To be 'likely' to occur, there should be a real or not remote chance or possibility.
• Lack of scientific certainty about potential impacts of an action will not itself justify a decision that the action is not likely to have a significant impact on the environment.</td></tr>
<tr><th>Listed Critically Endangered / Endangered / Vulnerable Species</th><th>Listed Migratory Species</th></tr>
<tr><td>•Lead to a long-term decrease in the size of a population/population of a species (vulnerable)
•Reduce the area of occupancy of the species/important population (vulnerable)
•Fragment an existing population into two or more populations
•Adversely affect habitat critical to the survival of a species
•Disrupt the breeding cycle of a population
•Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
•Introduce disease that may cause the species to decline, or
•Interfere with the recovery of the species.</td><td>•Substantially modify (including by fragmenting, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species, or
•Seriously disrupt the life cycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.
Note: Migratory species assessments are also defined by any guidance material – migratory bird criteria, i.e. draft referral guideline for 14 birds listed as migratory species under the EPBC Act.</td></tr>
<tr><td colspan="2">● Result in invasive species that are harmful to a critically endangered / endangered / vulnerable / migratory species becoming established in the species' habitat / an area of important habitat</td></tr>
</table>

Source: Matters of National Environmental Significance, Significant impact guidelines 1.1 (2013)

2.3 The high likelihood of marine megafauna triggering an assessment under the EPBC Act

Marine turtles, dugongs and cetaceans (inshore dolphins) among other large marine animals are a group of species that are collectively known as marine megafauna. They can be problematic in the assessment process given their wide-ranging behaviours, low detection probability, inherent vulnerability to population-level impacts and reliance on the coastal environment for their habitat needs. These species are Matters of National Environmental Significance (MNES); which the potential to impact upon is an immediate trigger under the Commonwealth assessment process (Commonwealth of Australia 2013a). Impacts from a proposed action could occur either directly to the species or indirectly to their habitats. These species and their habitats are captured by seven of nine MNES categories of protected under the EPBC Act, all of which are:

- World Heritage properties
- Wetlands of international importance (listed under the Ramsar Convention)
- Listed threatened species and ecological communities
- Listed migratory species (protected under the Convention on Migratory Species (Bonn), CAMBA, JAMBA, ROKAMBA)
- Commonwealth marine areas
- Commonwealth Land
- The Great Barrier Reef Marine Park (GBRMP)

Prior to the Commonwealth impact assessment process, States and Territories have a preliminary process to determine if a project warrants consideration under the EPBC Act or can be considered as State/Territory level assessment only. This process provides the option for the proponent of a proposed project to initiate self-assessment of the project through submission of an Initial Advice Statement (IAS) (in Queensland (QLD)), Environmental Scoping Document (Western Australia (WA)) or a Notice of Intent (NOI) (Northern Territory) to the relevant State or Territory Government agency (see Figure 2.1). This document provides a description of the proposed 'action' and outlines its potential effects on the environment. For marine related projects in WA, the proponent is also required to respond to marine-specific Environmental Assessment Guidelines. The level of detail provided in these submissions is central to informing the next step in the assessment pathway, including whether an EPBC Act referral is required in addition to State/Territory level assessment.

In the NT, the NT EPA is responsible for administering the EIA process under the *Environmental Assessment Act 1982* (NT). The Environment Division of the Department of Environment and Natural

Resources (DENR) provides the NT EPA with support and services to fulfil its role. The NT EPA does not have a decision-making role regarding assessments. Northern Territory agencies such as DENR are a key part of the EIA process and provide technical specialist responses with the NT EPA having legislative requirements to consult at certain steps of the assessment process. Comments made by NT government agencies are considered by the NT EPA at key decision steps (NOI decision, Draft Terms of Reference, EIS Supplement, Assessment Report) throughout the EIA process (Figure 2.1). The result of the EIA process is an Assessment Report, which is provided to the Environment Minister who provides it to the Minister/Authority responsible for approving/consenting to the proposal. When considering whether to approve or consent to the proposal, the Minister/Authority would then be required to consider the EIS and the NT EPA's Assessment Report.

The Commonwealth has developed Significant Impact Guidelines (2013, see Chapter 1) as a tool for determining whether a project is likely to have a significant impact on a MNES. The guidelines provide a 'self-assessment' process for proponents and aim to assist in determining whether a referral should be submitted for the project. 'Significant impact' is not defined within the Act. The Guidelines suggest that a 'significant impact' is "an impact which is important, notable, or of consequence, having regard to its context or intensity" (Commonwealth of Australia 2013a). The impact is to be considered within the context of the environment's "sensitivity, value, and quality which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts (Commonwealth of Australia 2013a)". Therefore, if available information indicates the presence of marine megafauna or habitat of importance in the development area and there is a real or 'not remote' possibility of a significant impact, the proposal will trigger the EPBC assessment process. If there are considerable knowledge gaps or scientific uncertainty about the impacts of the action and potential impacts are serious or irreversible, the precautionary principle is applied, and the referral process may also be triggered.

In the absence of objective scientific data on the species, impacts on species, or the receiving environment; the assessment process is inherently subjective, increasing the likelihood that a proponent should refer their development activity to the Commonwealth to gain clarity around potential impacts to MNES. Proponents are encouraged by the Commonwealth to engage in the referral process to achieve better and often negotiated environmental outcomes to reduce risk of environmental harm (Commonwealth of Australia 2013a, 2016a). Subjective norms, values and political interest may ultimately influence assessment decisions, particularly when they are controversial or of high economic value (Mostert 1996). The risks to proponents of failing to refer may have legal implications or impacts to a proponent's perceived corporate social responsibility.

In Australia, all species defined as coastal marine megafauna are listed threatened species (all marine turtles), listed migratory species (marine turtles, dugongs and coastal cetaceans) or both (all marine turtles). Multiple triggers for a referral under the Act can occur; for example, the flatback turtle (*Natator depressus*) is listed as vulnerable and migratory under the Act, has important nesting and foraging populations along the coast of Queensland, within the Great Barrier Reef World Heritage Area (GBRWHA), the National Heritage List and the Great Barrier Reef Marine Park (GBRMP) (Limpus 2007), (Environment 2016). Thus, five MNES would be triggered if the activity under assessment was a large-scale port expansion in Gladstone Harbour (Figure 2.1), with activities potentially impacting important flatback foraging and nesting areas or the species directly (entrainment from dredging or vessel strike), World Heritage properties and the GBRMP (indirectly). As the development is adjacent to the GBRMP there would still be potential for significant populations of flatback turtles and their habitat (values of the GBRWHA) to be significantly impacted, albeit indirectly.

Step 1a – Development Application, Environmental Scoping Document (WA), Initial Advice Statement (QLD) or Notice of Intent (NT)

Proponent self-refers the proposal for consideration by the relevant Department/Authority

Each Department/Authority considers the risks of the proposal to environmental values and provides a response to the Authority i.e. NT EPA

Step 1b – Referral (EPBC Act)

Proponent self-refers the proposal for consideration by the Australian Department of Agriculture, Water and the Environment (DAWE)

DAWE considers the risks of the proposal to Matters of National Environmental Significance (MNES)

Step 2 – Decision that further assessment is required

State/Territory decides that the proposal has the potential for a significant effect/impact (NT, WA) or is a State Significant Project under the *State Development and Public Works Organisation Act* (QLD)

State/Territory decide that a Public Environment Report (PER)/Environmental Impact Statement (EIS) is required

DAWE decides that assessment is required

State/Territory decide that the proposal can be assessed under the Bilateral Agreement

Step 3 – Draft Terms of Reference (ToR) / Guidelines

Existing generic ToR/Guidelines are adapted for the proposal outlining the required information

Bilateral agreements outline the scope of the assessment for MNES, cumulative impacts and consultation requirements (Schedule 4 of the EPBC Regulations)

Public and agency consultation is undertaken by the State/Territory

Step 4 – Public Environment Report/Environmental Impact Statement

EIS includes relevant technical documents to address the requirements of the ToR/Guidelines

Department/ authorities review the PER/EIS in consultation with other agencies, the public and DAWE

Assessment considers impacts to State/Territory environmental values

Step 5 – Supplementary PER and EIS

State/Territory Departments/Authorities provide comment on EIS/PER and request a Supplement to be prepared where knowledge gaps exist

Proponent submits Supplement which is reviewed by Department/Authorities and determine if further information is necessary

Step 6 - Co-ordinator General's Report/EPA Assessment Report

Provides recommendations for the responsible agency whether to proceed or refuse

If approval is recommended, what conditions may be attached by the responsible agency

Provides a separate section assessing MNES and recommendations for the Commonwealth Environment Minister

Step 7a – Australian Government Decision

The Minister for the Environment considers the State/Territory Report and consults on their 'proposed decision' with the proponent, responsible Ministers and members of the public (optional)

After considering the responses on the proposed decision, the Minister decides whether to approve/refuse the proposal and what conditions are attached

Any approval needs to consistent with Australia's obligations under international conventions/treaties and not be inconsistent with Recovery Plans or Threat Abatement Plans

Step 7b – State/Territory Consent/Approval

Considering the recommendations from the Coordinator General/EPA's Assessment Report, the responsible Minister decides whether to approve the action under the relevant legislation

Proponents are still required to obtain other relevant approvals from local authorities and State/Territory

Figure 2.1: Generalised Australian environmental impact assessment process

In other regions where the GBRMP and GBRWHA are not applicable, determining the significance of marine megafauna populations within the area of impact can be the main basis for the Minister's decision. In such cases, building a defensible body of evidence of the potential for, and relative significance of, marine megafauna impacts is inherently challenging. Based on information provided by the proponent and other information acquired during the assessment process, the Environment Minister is required to determine if a significant impact on a MNES is likely because of the development action. A balanced decision should incorporate an understanding of species ecology, population abundance, habitat use and movement ecology in the context of the development action.

As with many other species groups, fundamental data on marine megafauna are generally lacking (Taylor and Gerrodette 1993, Crouse 1999, Parra et al. 2006, Woinarski et al. 2014); thus, a robust and defensible assessment of impacts to marine megafauna is difficult or impossible to achieve (Parsons 2016). This lack of knowledge often necessitates application of the precautionary principle and erring on the conservative (Gullett 1998), an EIA should likely be undertaken.

2.4 The low likelihood of determining a 'significant impact' on marine megafauna

To determine if a development is likely to significantly impact marine megafauna, several matters require consideration. The ecology and life history parameters of marine megafauna are inherently difficult to study. These species are difficult to observe on survey from the air, underwater, on-ground or by vessel, due to their limited time at the water's surface, seasonal behaviours and often challenging environmental conditions (Marsh et al. 2011, Laycock et al. 2013). Low levels of detection of these species in areas likely to be affected by a development may provide a misleading reference point, suggesting low occupancy and abundance in habitats of importance. Surveys undertaken for an impact assessment are rarely able to quantify seasonality, population abundance, scales of habitat use, demographics, migration and natural variability over a relevant timeframe (Bejder et al. 2012). Their inherent limitations generally do not enable comprehensive assessment.

The assessment is potentially compromised further by unqualified practitioners designing and executing surveys that will not effectively sample the species or may not respond to the question of impact on the species or habitats in question. The interpretation of this data has the potential to be flawed when not contextualised. In the absence of pre-existing, robust studies, this information may be all that is available for the assessment. As such, a decision based on evidence, albeit limited, will have a low likelihood of proving that a development will have a significant impact. Robust reference points are necessary to monitor and determine impacts over time and space that may be attributable to the development (Bejder et al. 2012). However, it is generally not practicable to design surveys with the power to detect change in elusive and small marine megafauna populations in the time permitted and at the spatial scale of a project specific impact assessment program.

Marine megafauna typically have utilisation distributions greater than the footprint of a development. Although some species may exhibit relatively high site fidelity within a development area, they may migrate outside the impacted area for feeding or breeding (Sheppard et al. 2006, Lascelles et al. 2014, Shimada et al. 2016). These supplementary habitats may unknowingly be impacted and influence the presence/detection of the target species in the impacted area. Because the appropriate scale at which to include potential impacts to marine megafauna has not been established, impacts may be wrongly attributed to the development or be happening independent of the study. Alternatively, the development may contribute impacts to a region already degraded environmentally with significant impacts to marine megafauna. Thus, in such situations, the impacts associated with the development should be considered as additional or cumulative impacts on an already compromised environment (Schuijers 2017).

The high likelihood of marine megafauna triggering an EPBC assessment, yet low likelihood of being able to determine if a significant impact is triggered by a development is problematic. This mismatch not only impedes the conservation of marine megafauna and their habitats, but also reduces the integrity of the assessment process. Thus, industry faces uncertainty when marine megafauna are part of a development assessment. Project costs may potentially increase through design changes to reduce impacts or through programs to acquire more data, which are unlikely to inform potential impacts on the species in the timeframe available. These uncertainties reduce the public trust in the assessment process, which should be objective and well-informed. The resulting public conflict about the merits of the development versus its impact on marine megafauna may influence the Minister's decision while diminishing the objectivity of the assessment.

2.4.1 More than just EIA

In response to concerns over the operation and adequacy of the EPBC Act, an independent review was undertaken in 2008 by Dr Allan Hawke (Hawke 2009). The Hawke Review was generally positive about the overall operation of the EPBC Act but suggested areas for reform including the greater use of strategic assessments, a recommendation that was subsequently implemented by the Commonwealth (Marsden 2013a).

A strategic assessment provides an opportunity to review, and potentially approve, a series of proposals or developments (actions) over a regional spatial scale and extended timeframe (Department of the Environment and Energy 2016a). Strategic assessments are designed to be a collaborative process delivering mutually beneficial outcomes. Such assessments enable potential impacts to migratory species to be considered at a spatial scale more relevant to the species' distribution than the project footprint *per se.* This approach increases the potential to understand cumulative and multiple project risks at ecologically relevant scales (Marsden 2013 a,b). Other benefits include avoidance of duplication of technical investigations by multiple development proponents and improved governance over decided environmental controls. The precautionary principle is also factored into strategic assessment and approval processes prior to the planning and commencement of developments. While this approach aims to streamline the assessment and approval process, strategic assessments may potentially allow developments to take place with less scrutiny.

Post Hawke review, negotiations led to a streamlined approval process via development and adoption of bilateral assessment pathways. The main aim of this process is to have a 'one-stop-shop' approach for environmental assessments and approval, whereby State/Territory regulatory systems are accredited under Commonwealth environmental law to create a single environmental assessment and approval process (McGrath 2014, Hawke 2015). This policy and process is partly affected via a staged approach of bilateral agreements between the Commonwealth and State/Territory jurisdictions. Bilateral agreements apply to proposals that are 'controlled actions' requiring assessment under the EPBC Act and which will also undergo EIA in accord with the relevant State/Territory Acts (Department of the Environment and Energy 2016b). The State/Territory's EIA process is accredited by the Commonwealth (Department of the Environment and Energy 2016b). The Commonwealth retains its separate approval powers (McGrath 2014).

In areas of multiple existing or proposed operations, understanding the combined effects of activities on the environment is vital to delivering well-planned, managed and sustainable development. While such understanding could be achieved under a strategic assessment, at the level of a project specific bilateral or Commonwealth Environmental Impact Assessment (EIA) the process is addressed via a cumulative impact assessment (CIA). CIAs should consider actual and potential impacts of several activities that may interact over time and/or space (Franks et al. 2010).

The realities of complex scientific assessments are that there is rarely an ideal set of data or time-series to complete the assessment. As such, the process must be designed and managed in an adaptive manner to accommodate the unique circumstances that will apply (Kaveney et al. 2015). Currently the methodology for conducting CIAs is not described or standardised in the NT, a situation that puts assessments at risk of being poorly planned with a subjective determination of impacts. The Great

Barrier Reef Marine Park Authority (GBRMPA) has progressed the approach for conducting a CIA and developed a guiding policy for regulators and developers (GBRMPA 2015). These guidelines account for the complexity of these assessments and are not prescriptive as there is no one method of CIA that applies across all types of developments.

Strategic assessments (Part 10 of the EPBC Act) provide an opportunity for cumulative impacts to be better accounted for and managed across scales (temporal and spatial) of relevance. Strategic assessments are landscape scale assessments and unlike project-by-project assessments, which look at individual actions (such as construction and operation of a pipeline or wind farm), they can consider a much broader set of actions. For example, regional-scale development plans and policies that will be developed over many years or infrastructure plans and policies (Commonwealth of Australia 2013b). There is currently one strategic assessment underway in the NT which regards the offshore petroleum activities in the coastal waters of the NT. At a broad level, the process occurs in two steps:

1. assessment and endorsement of a 'policy, plan or program' and,
2. approval of actions (or classes of actions) that are associated with the policy, plan or program.

It is this second step that potentially allows development to proceed across a large area without further need for an EPBC Act approval of individual developments (project-by-project assessments) (Commonwealth of Australia 2013b). Strategic assessments are undertaken by the organisation responsible for implementing the Program (for example, state or territory government, local council, industry group or organisation) in partnership with the Australian Government. They are designed to be a collaborative process that delivers positive outcomes for both parties.

2.5 Environmental assessment of marine megafauna in Australia: the reality

The process of identifying and reforming legislation is critical to improving the EIA system in Australia to benefit sustainable development and conservation outcomes. In support of such reform, three case studies of recent EIAs in northern Australia are presented highlighting their issues in determining potential impacts on marine megafauna. The Gladstone Port gas developments occurred just prior to the 2009 statutory Hawke review of the EPBC Act (Hawke 2009). This is an independent review of its operation (refer to Section 522A of the Act) and the extent to which its objects have been achieved, to be undertaken at least once every 10 years. The review cited the importance of implementing strategic assessments and suggested a greater application should occur. Gladstone proved a good case study to demonstrate the need for such an approach where multiple proponents were operating across adjacent spatial footprints at similar temporal scales. Lessons learnt from Gladstone were then applied to the CIA for the Abbot Point Development. The Gladstone Port development generated an acute awareness around improving the management of cumulative impacts, de-risking projects to improve public perception and maximising data sharing opportunities. This highlighted the strengths of incorporating a strategic assessment approach and other measures for a potentially sustainable development. The CIA, however, also had challenges.

The revised Commonwealth-State/Territory bilateral assessment agreements (2014) provided an opportunity for regulatory reform but also posed challenges. The arrangement intended that the relevant EPBC requirements in relation to MNES would continue to be met. Although the reform delegated Commonwealth assessment powers to the States and Territories, the final decision (approval) on the assessment is still made by the Commonwealth Minister, a condition designed to maintain standards across Australia and reduce the potential for standard slippage. Our third case study (Port Melville, Northern Territory) considers these risks. Our review of these case studies identifies potential options for improvement, which are then discussed. Figure 2.2 shows the location of developments discussed in the case studies.

2.5.1 Case Study: Gladstone Port Gas Developments, Queensland

Increased population growth and global demand for liquefied natural gas (LNG) resources has seen a significant expansion of extraction and export facilities in Australia. The Port of Gladstone, on the central Queensland coast, is the primary corridor through which LNG is exported from Queensland and is Queensland’s largest commodity port. Simultaneously, Gladstone’s marine environment is recognised as having high biodiversity values and is within the Great Barrier Reef World Heritage Area (GBRWHA). Local habitats, including seagrass, rocky reefs and mangroves, support commercial and recreational fisheries and local populations of inshore dolphins, dugongs and turtles.

The years 2010 – 2013 saw approval of four LNG developments inclusive of processing facilities and port infrastructure, within a linear distance of 8 km on Curtis Island at the mouth of the Port. As all the LNG developments came online at a similar time, the Commonwealth EIA approval pathways and terms of reference (ToR) for each study were similar. However, each EIA interpreted the ToRs differently.

Approaches ranged from desktop reviews to full baseline field investigations, resulting in consideration of different biodiversity values and conclusions of impact. This ultimately led to different levels of management and mitigation being applied to parallel developments to protect the identified values (Table 2.2).

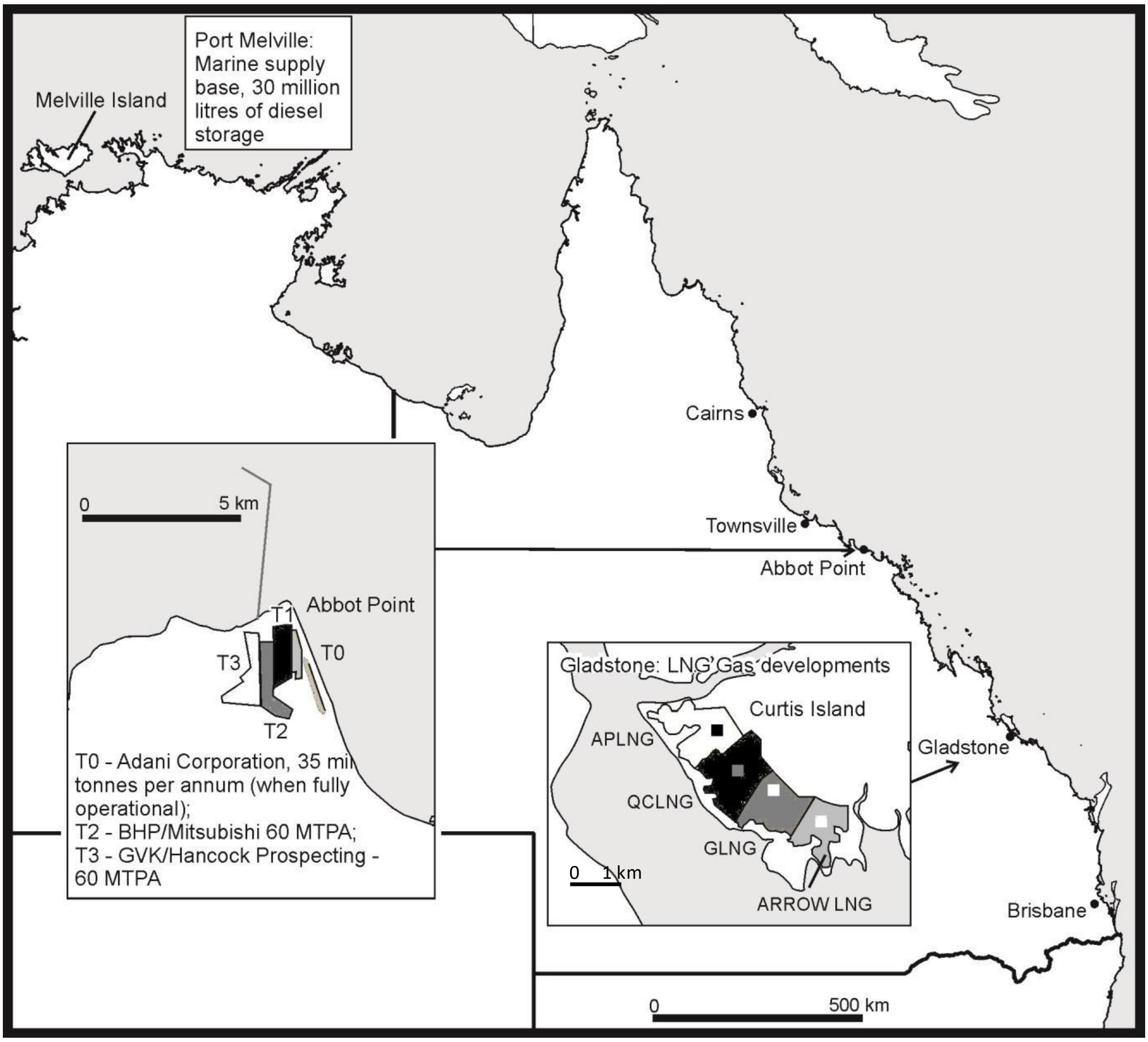


Figure 2.2: Location of development sites in Gladstone (QLD), Abbot Point (QLD) and Melville Island (NT). Gas companies are identified in the inset; APLNG (Australia Pacific LNG), QCLNG (Queensland Curtis LNG), Gladstone LNG (GLNG) and Arrow LNG

Concurrent with the LNG developments, the Western Basin Dredging and Disposal Project (WBDDP), a major dredging operation, was also being assessed via the Commonwealth EIA process. This project was intended to facilitate shipping movements of LNG tankers to all proposed processing plants through the removal of 22 M^3 of marine sediment. While all dredging to support the LNG developments was ostensibly to be captured within that EIA to consider potential cumulative risks, the EIA only considered the dredging related to the channel development. Each of the four gas proponents also required localised dredging around their port infrastructure to support marine offloading facilities and create berth pockets. As such, the WBDDP EIA was unable to truly assess all potential cumulative dredging risks as details regarding the offloading facility requirements were not available.

The Gladstone Ports Corporation attempted to facilitate information sharing between the five parallel assessments. However, their capacity to do so was affected by the inability to access commercially sensitive information across parallel developments working in competition to reach the commercial market. As an example, one LNG proponent commissioned a study by the Queensland Government seagrass research group to examine light attenuation thresholds of seagrasses. This information was not made available to inform the cumulative risks of dredging until late in the projects' lifecycle and assessment (QGCL 2010). This information coupled with other studies including shipping, underwater noise, hydrogeology modelling and aerial surveys were of critical importance to accurately assess potential risks to marine megafauna from cumulative pressures of proposed projects.

This parallel approach significantly limited the ability to accurately predict all potential risk scenarios in a timely manner. Dispersed investment, limited cooperation, and repetitive investigation of the same issues by proponents created a missed opportunity to build upon knowledge across projects.

The temporal and spatial scale of these projects would have benefited from a strategic assessment or an over-arching CIA. Whereby specialist technical review could have been applied prior to undertaking the independent EIAs, complementary and/or collaborative studies could have been designed to inform with greater accuracy the impacts to species and habitats within the Harbour. Despite the studies generally capturing likely impacts under their parallel EIS, the collective investigative power of all five proponents working in collaboration could have resulted in improved design and conduct of rigorous scientific surveys with the statistical power to determine change over time. This approach would subsequently have improved the ability to model potential cumulative or synergistic impacts for prescription of more relevant management and mitigation measures.

Following the commencement of dredging and construction work for some of the gas plants, one of the most damaging extreme weather events in Queensland’s history occurred over the 2010-11 summer. A strong La Niña phase precipitated tropical cyclone Yasi which resulted in widespread and severe flooding along the eastern Australian seaboard (Meager and Limpus 2014). The number of dead dugongs and turtles reported along the Queensland coast in the first seven months after this event exceeds any previous full year of records since the reporting program began in 1996 (Meager and Limpus 2012, Commonwealth of Australia 2016b, Meager 2012, McCook 2015). Episodic floods and cyclones, leading to declines in seagrass, have long been suspected to be key drivers of dugong mortality (Preen and Marsh 1995). Gladstone was a key marine megafauna mortality hotspot during this period (Department of Environment and Science 2016). The environmental data collected by the proponents during their EIAs was not able to quarantine them against accusations of significantly impacting the marine megafauna as a result of cumulative impacts to water quality and loss of seagrass from dredging and construction (Burdon 2014, Landos 2014).

A suggested approach to avoid similar challenges arising in future would be to require minimum standards of technical studies to be undertaken by proponents responding to ToR in the context of known cumulative effects and for the technical studies to be peer-reviewed pre-and post-implementation. This approach would work to ensure the most relevant data are used to determine potential impacts and develop appropriate mitigation measures (Fuentes et al. 2015). Data are sometimes but not always released publicly and can (and should) be made a requirement within the ToR or condition of approval. The public availability of data would encourage transparency and integrity by proponents and allow for better synthesis of datasets over many years.

Table 2.2: Baseline marine data summary from two Gladstone LNG proponents and their respective EIA application.

LNG Proponent 1 QCLNG	**LNG Proponent 2 APLNG**
Baseline Data Collection	
● Desktop review (Port Curtis Integrated Monitoring Program, grey and published literature)	● Desktop review (Port Curtis Integrated Monitoring Program, grey and published literature)
● Sedimentation and total suspended solids dispersion and light attenuation modelling ● Underwater noise model ● Maritime harbour movements within Port Curtis	● Sub-tidal visual assessments by video survey ● Inter-tidal visual assessments
Study Results/Mitigation	
● 0.03% direct (2 ha) and up to 4-7% (430 ha) indirect seagrass loss within Port Curtis as a result of this project. Predicted loss of seagrass including WBDDP 20.20 ha. ● No significant impacts to marine megafauna. Observation protocols developed for vessel operators. ● No significant impacts to benthic primary producer habitat, manageable through the Dredge Management Plan. ● ~ 70,000 – 80,000 vessel movements per annum with a 12% increase from this project during peak construction. ● Lighting impacts not quantified. ● Underwater noise impacts manageable through monitoring. ● Cumulative impacts not quantified	● 3% of Port Curtis seagrass removed (12.04 ha) as a result of the project. ● Some identified impacts: Fragmentation of mangroves, wetland areas, and intertidal areas. Underwater noise from drilling/dredging ● Potential impacts to marine megafauna – managed through Dredge Management Plan and a Marine Mammals and Turtle Management Plan. ● "Low-Medium" vessel strike risk to marine megafauna determined. Speed limits to be considered and designate routes with mitigation measures to be identified. ● Lighting impacts to turtles determined as "Medium" ● Monitoring of the area prior, during and after construction for marine megafauna ● Underwater noise determined as a "Severe" risk – mitigation measures identified ● Cumulative impacts from dredging/water quality to be managed through WBDDP. Referred to as potentially high cumulative impacts if not managed.

2.5.2 Case Study: Abbot Point, Queensland

Not long after the LNG developments and dredging commenced in Gladstone, Abbot Point (Queensland's second largest coal port) was proposed for expansion to facilitate an increased throughput of coal (Figure 2.2). Abbot Point supports a naturally deep-water port; it is also within the GBRWHA. The expansion comprised three proponents intending to undertake separate processes to construct coal terminal and off-loading facilities. The responsible port authority was in parallel considering what dredging may be needed to support development approval. The processes at Abbot Point were similar to Gladstone with multiple proponents seeking to undertake parallel port developments facilitated by dredging works. Observing the challenges experienced at Gladstone, proponents and the government were, however, aware of potential risks of completing the assessments in isolation and in parallel. A decision was made to complete a voluntary CIA across all projects.

Investment in this process was intended to foster greater certainty around potential environmental impacts to better inform approval and improve public and regulatory understanding of the development. The Abbot Point CIA was an industry-led process, unprecedented at the time of its inception.

The CIA required proponents to pool datasets under contractual sharing arrangements. The assessment process was managed under a working group arrangement comprising representatives of all proponents who provided guidance to environmental consultants with oversight from an independent expert review panel. The CIA comprised 16 technical studies including: shipping, fishing, noise, dredging, marine and terrestrial biodiversity and visual amenity. All technical reports were subject to State and Commonwealth review as well as independent peer review. All technical documents were made publicly available by the proponents, a process that is challenging for competing companies as it conflicts with commercial advantage.

The decision to undertake a CIA came after all proponents had already progressed their individual parallel EIA investigations. As such, the technical studies completed under the CIA process were largely a desktop exercise drawing from available datasets some of which were limited or dated. For instance, the marine megafauna assessment compiled in 2012 referenced data from a 6-month boat-based study (~2 days/month) completed in 2008-09. Detailed population ecology studies of these species designed to inform potential impacts across all developments were not undertaken. Validation of data relevance through additional field studies was not completed and thus the regional importance for migratory species was not well understood. The spatial and temporal constraints of numerous studies reduced their validity in the CIA and subsequently the conclusions drawn regarding potential impacts and management options were limited. This situation highlights that even if a CIA is considered, the spatial and temporal scale at which marine megafauna population assessments can be conducted is inconsistent with the types of studies relevant to EIA and CIA.

Despite its flaws, the CIA undertaken was an improvement on the Gladstone EIA process. It was commended by regulators, billed as best practice and undertaken within an impartial framework with proponents working towards a common goal of port expansion to support export by multiple parties (GBRMPA 2013). The collective investment in data sharing, analysis and use of independent technical expert review provided transparency and regulatory confidence and reduced uncertainty regarding marine megafauna impacts despite residual knowledge gaps (GBRMPA 2013).

The CIA concluded that the marine environment and hence, marine megafauna species, were not likely to be significantly impacted by the activities at Abbot Point given the proposed array of port-wide management strategies. These strategies were to be implemented via an adaptive management framework intended to be applicable to all future development. This Joint Environmental Management Framework included minimum operating standards set to provide an overall 'net environmental benefit' in the face of cumulative impact potential.

This process addressed some of the weaknesses (limited data sharing, parallel impact assessments and studies without independent review) evident from Gladstone. However, the Joint Environmental Management Framework remains a framework without prescriptive approval conditions for proponents; the projects will effectively be staggered in their approval and investment. The variable timing in project approval and mitigation has the potential to again result in management inconsistencies, inefficient monitoring and use of resources. Without integrated monitoring by the proponents the detection of impacts and their ability to appropriately respond is reduced.

2.5.3 Case Study: Port Melville, Tiwi Islands, Northern Territory

The remote Tiwi Islands have some of the highest biodiversity values in the Northern Territory (NT) (Kalippa et al. 2004, NRETAS et al. 2009). The coast is inhabited by important populations of dugongs, coastal dolphins (Parks and Wildlife Service 2003, Palmer 2014, Groom et al. 2015) and likely the most significant rookery of the endangered olive ridley turtle in the Asia-Pacific region (Chatto and Baker 2008, Limpus 2008). The region is relatively intact, not well-studied and is under pressure to develop industry to support local Aboriginal communities. Efforts to develop a local forestry industry have not been successful to date but renewed interest in the region's economic potential resulted in the construction of a marine supply base on Melville Island within the Tiwi group. The recently built development (2015) referred to as Port Melville, demonstrates that despite bilateral agreements being in effect important legislative weaknesses remain in the Territory and Commonwealth EIA process that affect MNES.

As required by the NT EIA process, the Port Melville proponent provided a description of their proposed action as a Notice of Intent under the *Environmental Assessment Act* to the NT Environment Protection Authority (NT EPA) (Figure 2.1). This process is intended to enable the NT Government to identify a relevant approval pathway and provide advice regarding minimum study requirements. However, the NT Government requested supplementary information following review of the NOI in 2013 to better inform their decision on the applicable assessment process. Prior to a decision being reached about the required approval, the proponent commenced site development. A revised NOI was submitted in 2014 which described completed works and proposed significant additional development that deviated markedly from the original NOI project scope (Environmental Services EcOz 2014). Again, the details of the proposed development were not considered sufficient for the NT EPA to determine an assessment pathway, however, they acknowledged in a letter to the proponent (May, 2014) that a Public Environment Report or EIS level of assessment would not be required despite outstanding concerns regarding potential to impact MNES (http://epbcnotices.environment.gov.au/). The unanswered requests for information relating to how the project may affect MNES should have been sufficient for the EPA to refer the proponent to the Commonwealth (see s69 of the EPBC Act) for assessment. However, the development seemingly went unchecked for consistency with the initial proposal or the continuation of previous land use. Existing deficiencies in the NT *Environmental Assessment Act* likely contributed to the outcome given the following confounding issues:

- NT environment assessment does not require a Responsible Minister for a proposed project – none was identified as being responsible for this proposed development (Oaten 2015, Morris 2016). The NT EPA issues its Assessment report and the recommendations are not put on any formal NT approvals

- The Port Melville development did not require any permit or approval under the *Planning Act 1999* (NT). The land on which the port is situated is “unzoned land” and therefore not subject to land use controls.

- Despite the development providing port facilities, the project was not defined as a “port” rather it was described as private infrastructure as multi-use, multi-purpose, fee for service commercial operation (Oaten 2015).

- Except for the Port of Darwin, regulated by the *Darwin Port Corporation Act* (NT) and the *Marine Act* (NT), no other ports in the NT are regulated by NT law (Morris 2016).

Given the potential impacts to MNES associated with this type of development, an assessment under the EPBC Act (referral) was requested by the Commonwealth in May 2015 (http://epbcnotices.environment.gov.au/). The Commonwealth's request for a referral was inconsistent with the NT EPA's advice; it outlined concerns regarding the "operational aspects of the project, such as biosecurity, fuel management and vessel movement that may impact listed marine species including marine megafauna and/or their habitat" (Referral – Appendix C, 2015 p.1). The request occurred after significant development at the project site. The NT EPA's advice pre-dated the Commonwealth's request resulting from the triggering of concerns about potential impacts to MNES. Consequently, in June 2015, over a year after development had commenced, an EPBC referral was submitted by the proponent outlining the proposed action and requesting a decision on suitability for development to proceed (EPBC referral 2015/7510). The referral received 393 submissions during the public consultation period, the majority of which regarded concerns for MNES (http://epbcnotices.environment.gov.au/).

The proponent identified MNES predicted or known to occur in the project footprint and for the extent of the Apsley Strait, between Melville and Bathurst Islands. The referral suggests there is a good understanding of the MNES in the region as a result of ad-hoc historical studies. It also highlighted the difficulty of being able to survey for megafauna and assumed their presence without including survey effort (adopting a precautionary approach). No detail on the ecology of listed threatened or listed migratory marine species or recent survey effort was provided, yet the proponent concluded that no significant impact is likely. A lighting study (received by the Commonwealth in August 2015) on the potential impact to nesting turtles ~16 km from the port was undertaken though not made publicly available. Shipping impacts, degraded water quality, altered lighting regimes and oil spills are potential risks to marine megafauna as a result of the project. No detailed risk analysis was presented and no information on benthic habitats, migratory shore birds or hydrology in the Apsley Strait, that could be applied to assess risk to marine megafauna from shipping and spills, was provided. In our opinion there were considerable scientific deficiencies in the data and arguments presented to support the conclusions reached by the referral.

The Commonwealth Environment Minister determined the project to be "not a controlled action" provided it was undertaken in the manner outlined in his decision (see Commonwealth's Statement of Reasons (December 2015) (Department of the Environment, Water, Heritage and the Arts, 2010). The Commonwealth's decision incorporated all information provided by the proponent, public submissions and regulatory agencies. The decision was later rejected as invalid under the EPBC Act. A review under the Administrative decisions (judicial review) Act, found a procedural error under the Act. Originally, a particular manner decision was made however, an actual action committed by the proponent was required and referred to the Minister for further deliberation (October 2016). After being referred to the Minister for further deliberation (October 2016) a delegate determined that the project was not-a-controlled action and could proceed without further assessment and approval (in December 2016).

In this case, weaknesses in the NT environmental legislation highlight the limited capacity of the NT to assume bilateral assessment powers. A 30 million litre diesel fuel farm and marine supply base is now almost complete on Melville Island without having any controlling provisions applied under the EPBC Act to manage its potential impacts to marine megafauna.

2.6 Discussion

While there is merit in the current EIA process, there are considerable weaknesses which inhibit effective identification and management of impacts to marine megafauna. The case studies identified multiple deficiencies in the EIA process which have potential to lead to impacts on marine megafauna. These deficiencies can be remedied through changes to the EIA process as outlined below.

Common to the three case studies was the insufficient environmental data available to describe the values of the proposed development areas. These deficient datasets flow through the EIA process to form the basis of risk assessments, mitigation measures, management plans and informing environmental offset programs. Building a robust knowledge base for the marine environment with surrogate indices to infer marine megafauna health and impacts should be required given the limitations of directly surveying marine megafauna (Bayliss 1986, Dulvy et al. 2003, Mellin et al. 2011). Longitudinal datasets on ecosystem health that capture seasonality at a spatial extent relevant to marine megafauna and the development area are essential for establishing robust reference points for which impacts can be measured against (Bejder et al. 2012). Without a comprehensive understanding of the regional environment, EIA studies may be misleading as coastal development areas in Northern Australia are vulnerable to the confounding effects of extreme weather as observed in the Gladstone Port case (Meager and Limpus 2012, Meager and Limpus 2014). The risks associated with an inadequate environmental baseline are demonstrated in the Port Melville case where it affected the initial assessment pathway decision and the resultant inaccurate reporting of MNES values subsequently facilitated poorly informed operational conditions from the Commonwealth. As Schuijers (2017) states, understanding the science is fundamental to the EIA system for all those participating in the process.

The EIA system is most vulnerable when the science is not clear; and more so when the science is not clear, and that fact is not acknowledged (Schuijers 2017).

To ensure technical studies capture data at spatial and temporal scales of relevance to inform project risks, I recommend proponent's planned response to addressing the requirements of EIS Terms of Reference include an independent technical peer review prior to investment in the studies. Such a review would provide an opportunity to achieve value in assessments and may identify whether the intended technical investment has enough rigour to avoid wasted investigation. Where multiple development interests and proponents are within regional proximity, I recommend that the government foster engagement in strategic assessment and CIA processes and seek to apply site-specific CIA guidelines in collaboration with regulators (Franks et al. 2010, Grech et al. 2013). These requirements should also include information sharing amongst proponents to reduce duplication of technical studies, facilitate transparency and improve assessment quality, content and quantification of cumulative impacts to the common region (Grech et al. 2013).

To provide surety to proponents about minimum technical expectations for studies, I recommend that the Commonwealth sets minimum benchmarks for baseline and impact assessment processes and trigger values for impact monitoring programs (Grech et al. 2013). These benchmarks may be presented in the form of referral guidelines, like the guidelines (Factor guidelines and technical guidance) developed by the WA Environmental Protection Authority (EPA). The WA Factor guidelines and technical guidance specifically outline the EPA's expectations for marine environment impact assessments (Environmental Protection Authority 2016). Guidelines that provide expectations around study design, public availability of data, environmental objectives and trigger values for habitats and species would improve the understanding of when potential unavoidable impacts are likely. It will also provide investment surety for proponents to support project delivery.

Biologically important areas (BIAs) are a new data construct designed to assist decision-making under the EPBC Act. BIAs have been identified using expert scientific knowledge about species' distribution, abundance and behaviour in a region (Department of the Environment and Energy 2016a). The presence of the observed behaviour is assumed to indicate that the habitat required for the behaviour is also present (Ferguson et al. 2015). Including BIAs as a MNES trigger in the assessment process would allow for a more detailed and consistent assessment of areas significant to marine megafauna with consistent application. As a MNES, BIAs would be a spatially defined trigger with quantified conservation value thus removing the subjectivity inherent in the present process of identifying areas of important habitat to marine megafauna.

To confirm that there is an adequate trigger and need for projects to be referred and assessed under the EPBC Act in a timely manner, I recommend that a review of all Commonwealth and State/Territory bilateral agreements be conducted to ensure effective and consistent carriage of assessment powers. Where State/Territory legislation and capacity is deficient, the bilateral agreement should be amended to reduce assessment powers e.g. remove assessment of ports (except for Port of Darwin) from the NT (Morris 2016).

Collectively, these recommendations support the informed assessment process of developments to reduce impacts to marine megafauna. Much has been written about optimisation of technical surveys to improve data application in an impact assessment framework (Jefferson et al. 2009, Bejder et al. 2012) however, fundamental process changes intended to benefit marine megafauna warrant further investigation. As environmental knowledge bases develop over time, these measures can be improved further, reducing the reliance on precautionary measures and providing greater certainty to industry and conservation outcomes.

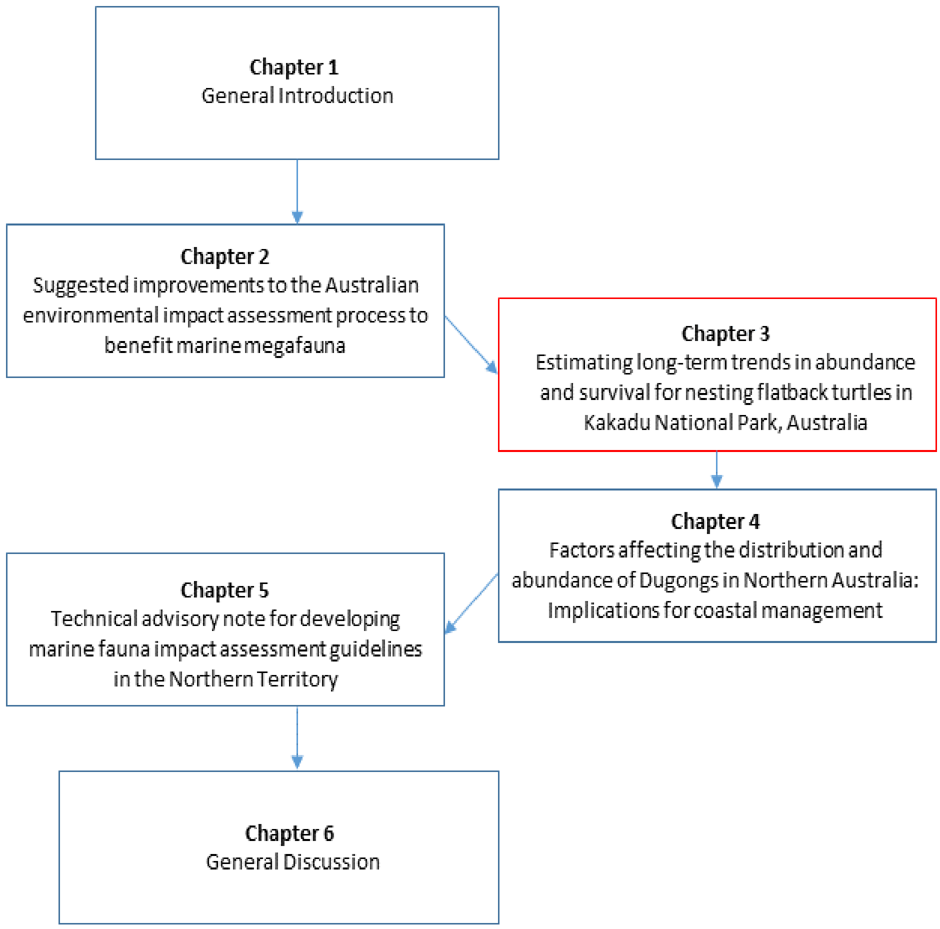
2.7 Chapter summary

- This study identified shortfalls in the bilateral governance between the NT and Commonwealth which has since been improved as part of an environmental reform process.
- There is a spatial disconnect between scales of ecological relevance to marine megafauna and project scales which result in futile efforts to understand impacts.
- Incorporating an independent technical review into EIA of MNES allows for improved rigour and impact predictions to be validated where possible.
- Surrogate indices should be utilised to infer megafauna health given the limitations of direct sampling marine megafauna in an EIA timeframe.
- Strategic assessments require greater application by regulators as they are an important approach to regional development where multiple developments are likely to proceed or exist. The scales of strategic assessments are ecologically more relevant to marine megafauna and therefore improve the EIA outcomes for marine megafauna. Strategic assessments in the NT will soon be an option following completion of the environmental reform process. At present, the NT can only engage in the Commonwealth's Strategic Assessment process.

Chapter 3: Estimating long-term trends in abundance and survival for nesting flatback turtles in Kakadu National Park, Australia[3]

3.1 Overview

In this chapter, I use an ecological modelling approach to investigate population demographics and the influence of temporal and environmental covariates on the nesting flatback population from Kakadu National Park, a World Heritage site in the NT. All turtles are listed as threatened and migratory species under the EPBC Act and frequently trigger the Act in EIA. Understanding population trends in response to environmental change is critical for effective management.



[3] A version of this chapter has been published as Groom, R.A., Griffiths, A.D. & Chaloupka, M. 2017. Estimating long-term trends in abundance and survival for nesting flatback turtles in Kakadu National Park, Australia. *Endangered Species Research* Volume: 32, Pages: 203-211

3.2 Introduction

All marine turtle species are exposed to a range of threatening processes including fisheries bycatch, coastal development, pollution, hunting or egg collection, pathogens, and climate change (Mast et al. 2005, Wallace et al. 2011). Monitoring long-term trends of marine turtles is important to inform conservation status, evaluate management decisions and track responses to management action (Campbell and McKenzie 2004, Lovett et al. 2007). There are inherent issues with estimating abundance of marine turtles including wide-ranging migrations, long lifespans and delayed sexual maturity that inhibit direct monitoring of individuals throughout most life stages (Heppell et al. 2000, McClenachan et al. 2012, see Appendix 3 for a general biological overview).

The flatback turtle *Natator depressus* is the only turtle species endemic to Australia with foraging grounds generally distributed throughout the Australian continental shelf, into Indonesian and Papua New Guinean waters (Limpus 2007, Whittock et al. 2016). It has an extensive nesting distribution from the Pilbara region of Western Australia along the Northern Territory and Queensland coast to central Queensland (Bustard et al. 1975, Limpus et al. 1983, Parmenter & Limpus 1995, Limpus 2007). Five genetic stocks of flatback turtle have been identified (Pittard 2010), and there is evidence of restricted gene flow among some of the Arafura Sea stock (NT), the stock referred to herein, which may be more independent than genetic studies can currently determine (FitzSimmons and Limpus 2014). Long-term (> 10 years) nesting studies on flatbacks are limited to Queensland's east coast (Limpus et al. 1983, Limpus et al. 1984, Parmenter and Limpus 1995, Limpus et al. 2013). More recently, population monitoring of nesting flatback turtles has been established at multiple rookeries in Western Australia (Pendoley et al. 2014).

The species is currently listed as Data Deficient in the Northern Territory and under the IUCN (1996), and Vulnerable under Commonwealth, Western Australian and Queensland legislation. The Commonwealth and all states and territories except South Australia have signed a Memorandum of Understanding which requires the listing status of species and ecological communities listed as threatened by the Commonwealth to be harmonised (refer to: http://www.environment.gov.au/biodiversity/threatened/publications/mou-cam). Thus, it is expected that the flatback turtle will be listed as Vulnerable across all Australian jurisdictions in time.

There are numerous approaches to long-term monitoring of marine turtle nesting populations. The simplest approach is the use of nesting track counts and these must be assumed representative if they are to apply to population abundance (Whiting et al. 2008, Whiting et al. 2013). The most complex is multi-state open robust-design modelling using capture-mark–recapture data which has provided highly reliable nesting-female abundance estimates and estimated rates of recruitment, survival, and breeding (Kendall and Bjorkland 2001, Dutton et al. 2005, Rivalan et al. 2005, Troëng and Chaloupka 2007). It is often not possible to implement the robust design due to logistic and economic limitations (Musick and Limpus 1997, Whiting et al. 2008, Stokes et al. 2014). As a minimum requirement abundance studies should incorporate individual heterogeneity and seasonality (Gerrodette 1993, Whiting et al. 2013).

In this study, population dynamics of nesting female flatback turtles at Field Island in the Northern Territory are examined using capture-mark-recapture data collected over 12 years. The Field Island population belongs to the Arafura genetic stock, which extends from the Torres Strait region in far north Queensland, through the Gulf of Carpentaria to the Northern Territory-Western Australian border. Flatback turtle rookeries are not well-defined in this region as nesting occurs throughout. However, areas of higher nesting density have been identified by Chatto and Baker (2008) and Limpus (2007). Specifically, nesting behaviour is described, apparent survival and recapture probabilities is estimated as well as long-term trend in abundance of nesting females. Additionally, environmental factors that influence apparent survival and recapture were examined. The results of this study will be used to: (1) inform assessments of the conservation status of this species, (2) prioritise resources for future monitoring and (3) inform and improve the EIA process in the Northern Territory (Chapter 5).

3.3 Methods

3.3.1 Study area

Field Island is in the Van Diemen Gulf, Northern Territory, Australia; approximately 172 km (straight-line distance) from Darwin. The unoccupied island covers 4429 ha and is 3.2 km from the mainland within the jurisdiction of Kakadu National Park (KNP) World Heritage Area (Figure 3.1). The region experiences a monsoonal wet-dry climate with annual average rainfall of 1571 mm falling predominately between November and April (Jabiru Airport, Bureau of Meteorology). Nesting activity by flatback turtles is limited to a small section of beach on Field Island, approximately 300 m on the northeast coast. An inter-tidal platform bounds the nesting beach, which at low tide is exposed, obstructing the flatback turtle’s access to the nesting beach.

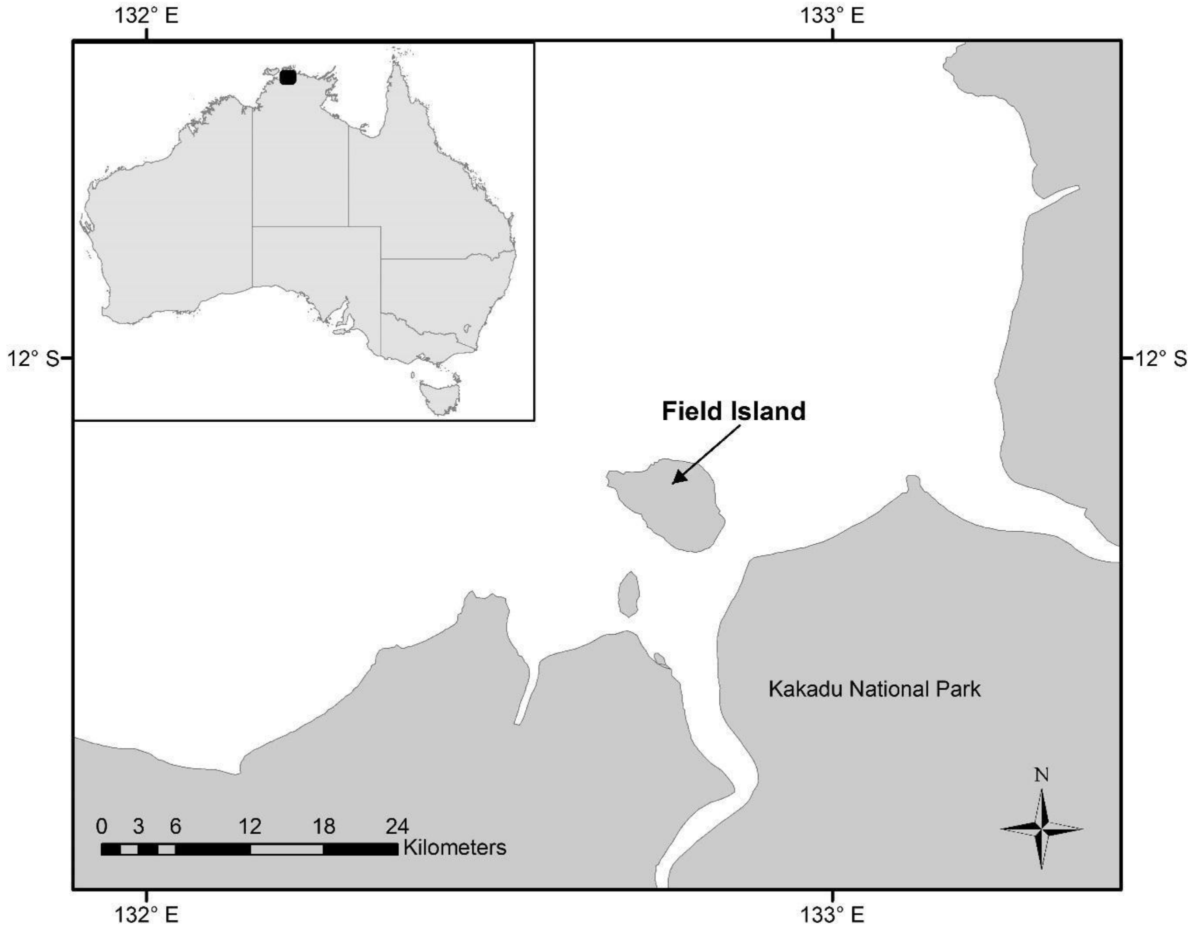


Figure 3.1: Location of Field Island, Kakadu National Park, Australia.

3.3.2 Sampling

Annual monitoring of nesting flatback turtles at Field Island commenced in 1994. Data from 2002 to 2013 were used, this period corresponded with more consistent survey protocols being implemented. Surveys occurred between late July and early September as previous surveys of nesting activity on Field Island indicated that while nesting can occur throughout most of the year, this period is when most of the nesting activity occurs (Schäuble et al. 2006). Survey timing captured a full tidal cycle and corresponded with evening spring high tides (i.e., largest tidal range) to allow access to the nesting beach. Annual sampling effort measured in field-days during the three-month sampling window varied from 12 to 20 days. Nightly beach patrols were conducted three hours either side of the high tide. Nesting turtles were measured along their curved carapace length (CCL, cm), from the anterior point at midline (nuchal scute) to the posterior tip at midline between the supracaudal scutes. All animals were individually marked with standard titanium flipper tags applied to both front right and left flippers (Limpus 1985, Limpus 1992) and a passive integrated transponder (PIT) tag implanted subcutaneously in the right shoulder. PIT tags were used to overcome problems caused by the high rates of flipper tag loss that flatback turtles typically experience (Parmenter 2003, Schäuble et al. 2006). Flatback turtles that had tag scars and no PIT tags comprised approximately 0.05% of the nesting animals. They were treated as new individuals as their capture history was unknown. Primary nesting turtles refer to turtles tagged for the first time and tagged turtles seen in following years are referred to as re-migrant turtles.

3.4 Data analysis

3.4.1 Survival and recapture probabilities

To estimate apparent survival and recapture rates, the Cormack-Jolly-Seber (CJS) model (Lebreton 1992) in Program MARK v8.0 (White and Burnham 1999) was used. Apparent survival (ϕ) is defined as the probability that a marked animal in the study population at occasion *i* survives until occasion *i* + 1 (i.e., between trapping occasions), while acknowledging that unobserved emigration from the trapping grid is possible (Pollock et al. 1990). Recapture (*p*) is defined as the probability that a marked animal in the study population at occasion *i* is captured during occasion *i*+1. Model assumptions include: (i) all animals having independent fates, (ii) every marked animal has an equal probability of recapture and survival, (iii) that no tags are lost, and (iv) that if temporary emigration is present, it is random (Pollock et al. 1990).

Nesting turtles exhibit two traits that potentially violate the assumption of equal probability of survival and recapture for the CJS model: transience and adult females skip breeding seasons (Chaloupka and Limpus 2001). Transients are individuals not resident in the sampling area but in transit across the area and are captured on one sampling occasion only. They do not have equal survival or recapture probability with resident individuals (Cormack 1993, Pradel et al. 1997). To test these assumptions a goodness of fit tests in Program U-CARE (Choquet et al. 2005) was applied with the full-time dependent model for survival and recapture probabilities. There was evidence of transience and trap-dependence in the capture-mark-recapture data for flatback turtles at Field Island (U-CARE Global TEST, transient statistic = 2.61, P = 0.008; trap-dependence statistic = 11.44, P > 0.001). The positive trap-dependence statistic indicates turtles exhibited “trap-shyness”, which supports the observed inter-nesting behaviour of female turtles (Chaloupka and Limpus 2002, Kendall 2004, Prince and Chaloupka 2012, Pfaller et al.

2013). To account for these violations, apparent survival of transients were estimated separately using a time-since-marking approach (Chaloupka and Limpus 2002). Trap-dependence for recapture probability was modelled using an individual covariate to indicate if a marked turtle had nested in the previous year (Choquet et al. 2009, Limpus et al. 2013) and random effects models to account for individual heterogeneity (Gimenez and Choquet 2010).

To examine variation in apparent survival and recapture probability an apriori candidate set of models following the approach described in Lebreton et al. (1992) was formulated. Body size was represented by mean CCL of an individual across all years, as an individual covariate to model its effect on apparent survival of nesting flatback turtles.

To examine variation in recapture probability, the effects of two environmental factors that have been shown to influence recapture of marine turtles: annual rainfall and inter-annual climatic variability were modelled. The probability of a female nesting in a given year is determined by nutrition (Bjorndal 1985), environmental/climatic factors and migration distance between foraging grounds and nesting beaches (Limpus and Nicholls 2000, Solow et al. 2002, Troëng and Chaloupka 2007). Remigration intervals for nesting marine turtles are also influenced by environmental conditions and climate cycles affecting foraging grounds (Carr and Carr 1970, Hays 2000, Limpus and Nicholls 2000, Solow et al. 2002). Environmental conditions that lead to poorer quality foraging habitats can potentially lower female fecundity and subsequently decrease recruitment (Kwan 1994, Hawkes et al. 2014). Annual rainfall for 12 months prior to the annual surveys from 11 weather stations on the Northern Territory coast (http://www.bom.gov.au/climate/dwo/IDCJDW0800.shtml) was used.

Australia's climate is driven in part by the El Niño-Southern Oscillation (ENSO) which varies the climate system on average every 4-7 years. Limpus and Nicholl (1988) observed a correlation between numbers of breeding green turtles and ENSO effects suggesting major fluctuations in ENSO may determine the proportion of females able to acquire fat reserves necessary for entering the vitellogenic phase of nesting preparation. Climatic variables likely to influence the nutritional pathway of green turtles were not identified by Limpus and Nicholl (1988) however, increases in net ocean primary productivity are pronounced in tropical regions where ENSO impacts on upwelling and nutrient availability are greatest (Behrenfeld et al. 2001). Similarly, large-scale inter-annual climatic variability has been shown to affect reproductive frequency of marine turtles i.e. green, leatherback and loggerhead turtles (Solow et al. 2002, Saba et al. 2007, Chaloupka et al. 2008). A one year average of the Multivariate El Niño Southern Oscillation Index (MEI) was used, which is calculated from sea-level pressure, zonal and meridional wind, sea surface temperature, surface air temperature, and total cloudiness fraction of the sky, all observed over the tropical Pacific (Wolter and Timlin 1993, Stenseth et al. 2003).

3.4.2 Nesting population abundance and trend

The Horvitz-Thompson type estimator (Chaloupka and Limpus 2001, Bjorndal et al. 2005) was used to estimate annual abundance of nesting flatback turtles at Field Island, in which:

$$N_i = (n_i/p_i) \tag{1}$$

where N_i is the number of turtles in the sampling population, n_i is the number of turtles captured in the ith year, and p_i is the recapture probability in the ith year. Recapture probabilities (p_i) were derived using variance-components analysis (Gould and Nichols 1998) in Program MARK v8.0 of the top-ranked CJS model described above to separate process and sampling error. Approximate 95% confidence intervals for N_i were then derived by first calculating the standard error of N_i as:

$$SE(N_i) = \{(n/p_i)^2[var(p_i)/(p_i)^2]\}^{0.5} \tag{2}$$

where var(p_i) is the variance of the recapture probability in the ith year. Then 95% confidence intervals of N_i were calculated as $N_i \pm 1.96 \times SE(N_i)$. Trends were evaluated in nesting flatback turtle abundance using variance-weighted linear regression models (Chaloupka and Limpus 2001) in Program R (R Core Team 2012). A first order moving average error was used to account for temporal correlation in abundance from one year to the next. The response variable was the log transformed Horvitz-Thompson estimator for each year and an independent parameter, Year was fitted using generalized least squares (GLS) by restricted maximum likelihood estimation (RMLE).

3.4.3 Model selection and goodness of fit

Model selection was based on Akaike's Information Criterion, corrected for small sample size: AIC_c (Burnham and Anderson 2002). The likelihood of each model, relative to others in the candidate set, was estimated with AIC_c weights (w) (Burnham and Anderson 2002) and models were ranked according to this measure. Finally, a goodness-of-fit test was performed on a partially-saturated model (no individual covariates), using the median $\hat{c}$ procedure available in Program MARK (Cooch and White 2007) to calculate a variance inflation factor $\hat{c}$. Tests were conducted using a partially-saturated global CJS model because goodness-of-fit tests are not available for models containing individual covariates.

3.5 Results

A total of 257 individual flatback turtles were recorded nesting on Field Island from 2002 to 2013. Of these, 160 (62%) were re-captured at least once (Figure 3.2) and primary nesting season turtles represented almost 38% of all tagged turtles at Field Island. For the 12-year monitoring period, the highest number of attempted nesting events by an individual turtle was seven. Approximately 7% of all turtles were observed to nest in consecutive years. During the annual surveys there was an average of 3.68 (SE ± 0.28) nesting turtles per night (over n = 220 nights). The CCL of the nesting animals ranged from 72 to 96.50 cm with an average of 86.30 cm (SE ± 0.26).

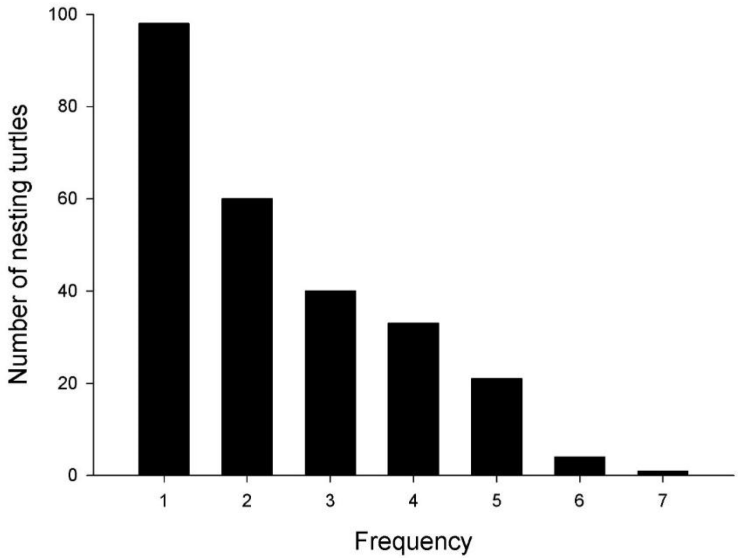


Figure 3.2: Frequency of individual nesting flatback turtle encounters at Field Island, Kakadu National Park, from 2002 to 2013.

3.5.1 Apparent survival and recapture probabilities

Apparent survival of nesting flatback turtles at Field Island was related to body size with the top-ranked model containing the parameter curved carapace length (CCL) (Table 3.1). Inspection of the beta coefficients showed a significant positive relationship between CCL and apparent survival for nesting animals (β = 0.51, 95% CI 0.16 to 0.87). For an average-sized (86.30 cm) nesting female at Field Island the annual apparent survival probability was 0.97 (95% CI 0.94 to 0.98). Recapture probability was influenced by inter-annual climatic variation with models containing MEI and rainfall in the previous 12 months ranked first and second within the candidate set (Table 3.1). Inspection of the beta coefficients showed a significant positive relationship with MEI (β = 0.25, 95% CI 0.07 to 0.42) and a significant negative relationship with total rainfall over the previous 12 months (β = -0.17, 95% CI -0.30 to -0.04) (Figure 3.3). The mean probability of recapture was 0.38 (SE ± 0.02) for nesting animals that had not nested in the previous year.

3.5.2 Nesting population abundance and trend

The estimated abundance of nesting flatback turtles at Field Island varied over time and ranged from 97 (95% CI 87 to 106) in 2007 to 183 (95% CI 165 to 200) in 2010 (Figure 3.4). There was no significant trend detected from 2003 to 2013 for Field Island nesting flatback turtles (year slope estimate = -0.02 ± 0.03, t = -0 79, P = 0.45).

Table 3.1: Summary of CJS model-selection results for nesting flatback turtles, Field Island, Kakadu National Park, Australia. K is the number of parameters. AIC_c is Akaike's Information Criterion, corrected for small sample size. ΔAIC_c shows the difference between the model AIC_c and the lowest AIC_c out of the set of models. AIC_c weights (w_i) are the relative likelihood of model i (normalised to sum to 1). The bigger the delta the smaller the weight and the less plausible model i. Model likelihood is level of support compared to the top ranked model. See Methods for description of model parameters.

Model name	K	AIC_c	ΔAIC_c	w_i	Model likelihood
Phi (M2 ./CCL) P(TD + MEI)	6	1664.11	0.00	0.56	1.00
Phi (M2 ./CCL) P(TD + Rain)	6	1665.06	0.95	0.35	0.62
Phi (M2 ./CCL) P(TD)	5	1669.66	5.55	0.03	0.06
Phi (M2 ./CCL) P(TD + time)	15	1670.16	6.04	0.03	0.05
Phi (M2 ./.) P(TD + Rain)	5	1670.24	6.13	0.03	0.05
Phi (M2 ./.) P(TD)	4	1674.81	10.69	0.00	0.00
Phi (M2 ./.) P(TD + time)	14	1674.83	10.72	0.00	0.00
Phi (M2 ./.) P(time)	12	1848.16	184.04	0.00	0.00
Phi (M2 ./CCL) P(time)	14	1849.92	185.81	0.00	0.00

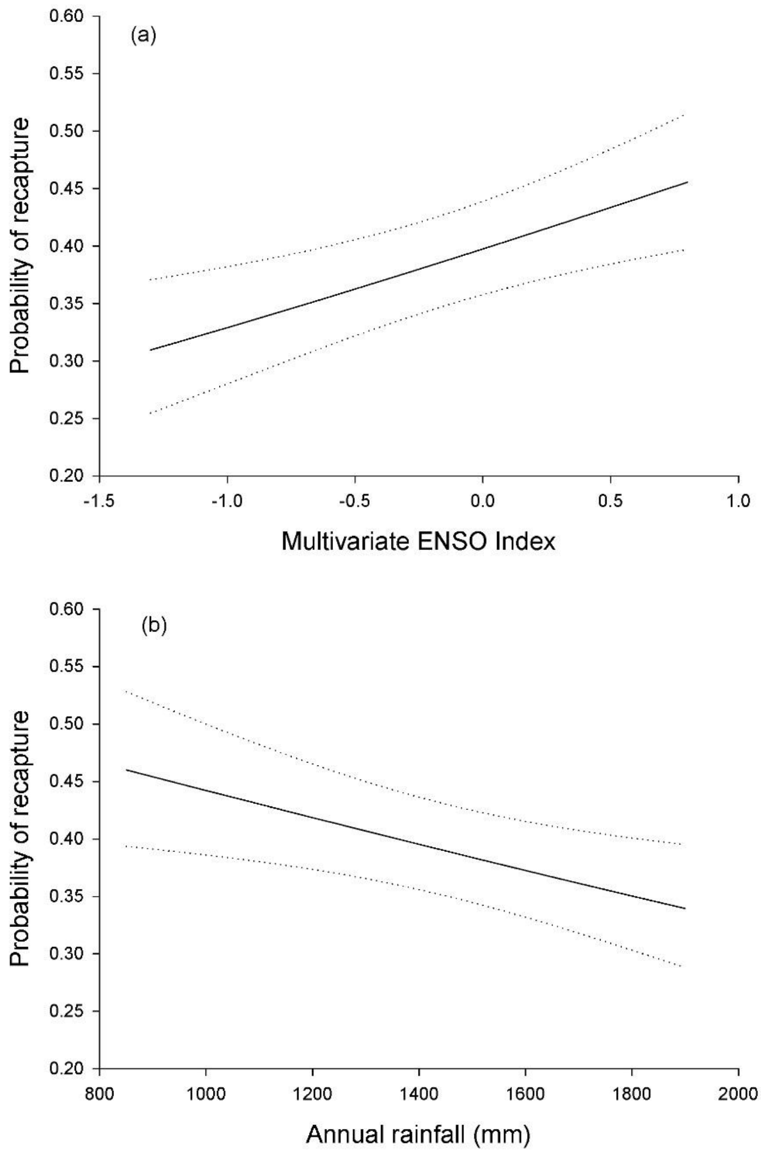


Figure 3.3: Predicted relationship between recapture probability of nesting flatback turtles at Field Island (a) Multivariate ENSO Index and (b) annual rainfall, based on the two top ranked CJS models. Dashed lines represent 95% confidence intervals.

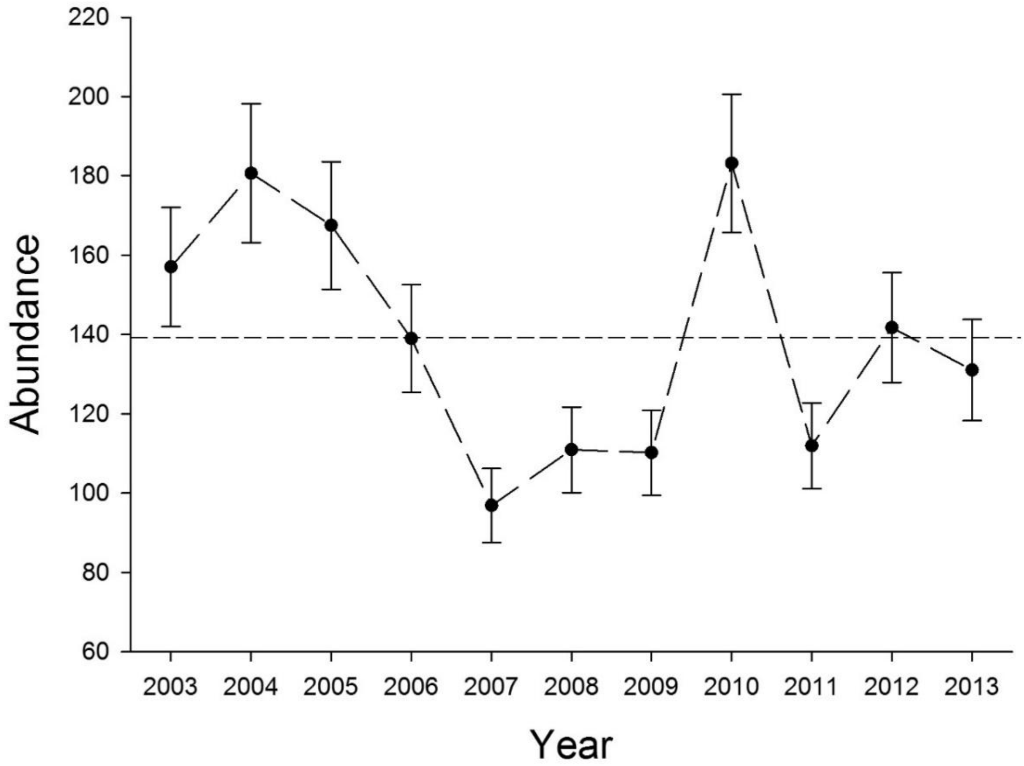


Figure 3.4: Annual estimates of abundance (Ni) for nesting flatback turtles at Field Island, Kakadu National Park, Australia. Error bars represent 95% CIs and dashed line mean abundance.

3.6 Discussion

The results from this study show that the Field Island flatback turtle nesting population is relatively small and stable. Apparent survival was high and increased with increasing body size. Moreover, flatback turtle nesting behaviour appears to respond to environmental cues with inter-annual climatic variability influencing the recapture probability.

The recapture probability of nesting Field Island flatback turtles was influenced by inter-annual climatic variability, represented by MEI and annual rainfall in our models. Positive MEI values were correlated with higher recapture probability, suggesting that productivity at flatback foraging grounds changes in response to El Niño/La Niña events. In northern Australia this equates to lower rainfall, higher temperatures and fewer tropical cyclones (Kuleshov et al. 2008). Most climatic effects on flatback turtles, as mid-level trophic feeders (diet primarily comprised of soft-bodied invertebrates), will be indirect as these effects function through changes in ocean productivity (Doney et al. 2012, Sydeman et al. 2015). Further research is required to understand the relationship between inter-annual climatic variability and flatback turtle nesting and foraging behaviour, particularly considering anticipated effects from climate change. Telemetry tagging studies on Arafura flatback turtles are limited and do not indicate areas of preferential foraging to date but highlight the extensive use of the waters around northern Australian and neighbouring jurisdictions.

Annual apparent survival probability for the Field Island flatback was high (0.97) and comparable with the stable east and west coast flatback sub-populations which have an average of 0.94 (95% CI 0.91 to 0.95) (Limpus et al. 2013) and Barrow Island (Western Australia) with a predicted annual survival of 0.92 (Chevron-Australia 2015). An exception to this is the Peak Island sub-population on the east coast which has a survival probability of 0.84 and is suspected to be declining with no cause attributed to date (Limpus et al. 2013). The high apparent survival of the Field Island flatback turtles suggests that the nesting population is not being impacted by threatening processes that affect adult survival such as ghost nets.

The results suggest the Field Island flatback nesting population is smaller when compared with other Australian rookeries. Annual abundance estimates ranged from 97 (95% CI 84 to 110) to 168 (95% CI 134 to 202). Although not directly comparable, nesting populations determined across a whole season at other rookeries are much larger. Barrow Island = 1986 (95% CI: 1807 to 2164), Mundabullangana = 1849 (95% CI: 1413 to 2286) (Chaloupka et al. 2012) and Peak Island = 642 (95% CI not available) (Limpus et al. 2013). Another metric for comparison is the mean nightly nesters. For Field Island the average number of nesting turtles per night was 3.68 (SE ± 0.28) and ranged from 0-21 nesters per night. This is relatively low when compared with Cape Domett with an average of 73.70 nesting turtles per night (SD = 74.80) ranging from 7-290 per night (Whiting et al. 2008) and Crab Island, Queensland with a nightly nester range of 6-235 flatbacks (Limpus et al. 1983, Limpus 1993). Other nesting rookeries in the Northern Territory from the Arafura flatback turtle subpopulation include West Island, Bare Sand Island and Greenhill Island and all have similar mean nesting per night estimates to Field Island, with less than 10 turtles nesting each night over a nesting season, extending at least nine months of the year (Limpus et al. 1983, Hope and Smit 1998, Whiting and Guinea 2006, Limpus 2007). However, northern Australian flatback nesting beaches are known to have protracted nesting seasons compared to southern beaches which limits in their comparison (Whiting et al. 2013).

The apparently stable population at Field Island is likely subject to various threats but these are generally unquantified in the Northern Territory. Turtle populations in Australia are vulnerable to a range of impacts such as coastal infrastructure and development, climate-related impacts, ingestion of and entanglement in marine debris, animal predation, indigenous use and habitat degradation are also likely to affect the Arafura flatback turtle subpopulation to varying degrees (Commonwealth of Australia 2017). Low-level mortality from ghost nets is recorded within the range of the Arafura flatback subpopulation (Mackarous and Griffiths 2016); however, the relative significance of this mortality to other threats is unknown. The Northern Prawn Fishery (NPF) operates across the region that overlaps with habitat of the Arafura flatback turtle subpopulation. It was considered to be one of the greatest sources of flatback turtle mortality prior to the introduction of Turtle Exclusion Devices (TEDs) in 2000 (Brewer et al. 2006). Riskas et al. (2016) report that flatback turtle interactions (not mortality per se) remain high with 91.67% of flatback turtle interactions recorded in the NPF but little mortality recorded (NPF species interaction reports). Pelagic gillnets in the Northern Territory were also recorded to interact with flatback turtles, likely in greater numbers than indicated due to a lack of identification in this fishery (Riskas et al. 2016). The impacts of coastal development are less certain though an increasing amount of lighting near nesting beaches is likely to have a direct impact on population recruitment as recognised by the Draft National Light Pollution Guidelines (2019) and as documented at some nesting beaches (but not Field Island) (Kamrowski et al. 2014, Sella and Fuentes 2019). Unexpected impacts to hatchling recruitment have recently been observed in Western Australia as a result of coastal infrastructure where predation on hatchlings was 7x higher near a jetty structure compared to an unmodified section of the coast (Wilson et al. 2019). Although no jetty structures yet exist on Field Island, such structures are located near some other flatback turtle nesting areas in the Northern Territory. Impacts to the Field Island flatback population are considered relatively low at present during the nesting period. There is occasional egg harvest by Traditional Owners and anecdotal predation by crocodiles. Rising sea-levels and increasing temperatures are likely to affect the population as the nesting beach is a narrow, short strip. However, none of these additional impacts has been quantified. Anthropogenic degradation of flatback foraging habitats is generally constrained to inshore coastal industry hubs and some offshore gas infrastructure in the NT but these are not quantified.

Marine turtle species occupy different habitat niches and so an assessment of impacts to one species such as the green turtle, which is considered to be largely a coastal seagrass specialist (Fuentes et al. 2006, Gredzens et al. 2014), will not necessarily reflect potential impacts to other turtle species. An assessment of impact risk to hawksbills and flatback turtles which are known to be more readily associated with coral, algae and sponge communities (Whiting 2000), or soft-sediment habitats with invertebrates (Zangerl et al. 1988), respectively, may have different variables in the assessment. Regardless, these results highlight the importance of long-term studies of marine turtles and improve our understanding of the poorly known flatback turtle Arafura Sea genetic stock. Within the context of perceived threatening processes (e.g. ghost net entanglement, fisheries interactions, coastal development, predation), these results will contribute to the prioritisation of conservation and management actions for marine turtles in the Northern Territory as well as the flatback conservation status assessment at a national and international level (i.e. IUCN) where it is currently listed as Data Deficient.

3.6.1 Implications for Impact Assessment

This study indicates the importance of having multi-year baselines for EIA when the species of concern exhibits population fluctuations or fluctuations in in the index component of the population. Although the flatback population that nests at Field Island was apparently stable from 2003 to 2013, the number of nesting females fluctuated by almost a factor of two from 97 (95% CI 87 to 106) in 2007 to 183 (95% CI 165 to 200) in 2010 and that variation was explainable by changes in the El Niño/La Niña cycle, a phenomenon that has also been recorded in the green turtle (Limpus and Nicholls, 2000). It would be impractical to require a proponent to conduct 10 years of monitoring prior to a development. Clearly, monitoring long-term trends in megafauna populations is a responsibility for the government and without such data, 'snap shots' that can be acquired in the EIA data collection phase may misrepresent the broader population status, and given their migratory behaviour, their spatial use. However, recognising resource constraints in government, such research could be funded by industry as an offset as has been done in Western Australia. For example, the North West Shelf Flatback Turtle Conservation Program is one of two conservation programs delivered from the Gorgon Gas Project via the Variation Agreement (2009) of the *Barrow Island Act* (2003) https://www.dpaw.wa.gov.au/images/documents/plants-animals/threatened-species/nwsftcp_strategic_conservation_plan_print_.pdf. This idea is discussed further in Chapter 6. A more meaningful approach to EIA technical studies would regard the collection of environmental data directly associated with the health of marine megafauna populations (surrogate measures). This data can provide a reference for the ongoing monitoring of habitat integrity and allow for adaptive management in response to development pressure. This approach is outlined in the NT EPA guidelines for marine fauna (see Chapter 5) and discussed further in Chapter 6. Where the study site (proposed development area) is determined as being in a degraded state i.e. significant predation pressure or habitat loss, an opportunity for remediation should be considered.

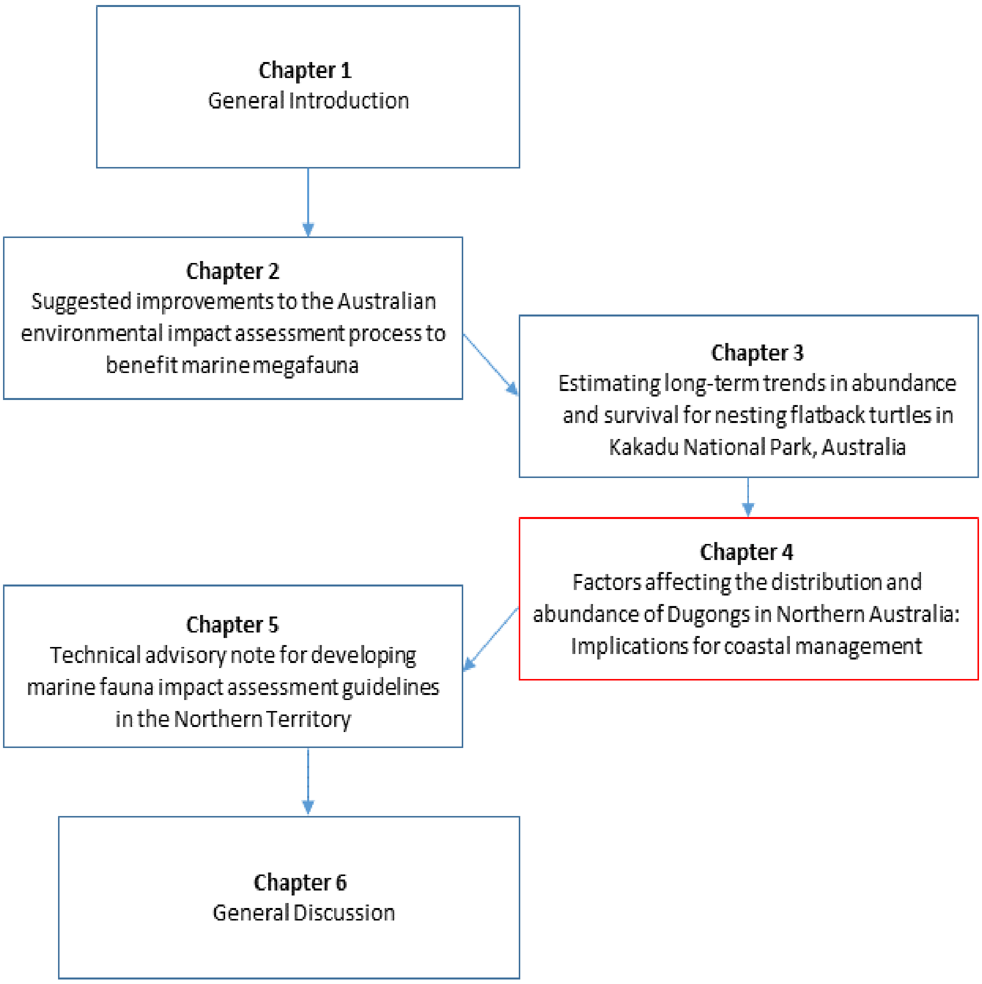
3.7 Chapter summary

- This study addresses an important knowledge gap for the Arafura flatback turtle population by identifying a stable but highly variable population trend. High nesting variability necessitates multiple years of data to determine species abundance trends. In EIA, this could be misinterpreted from limited sampling, increasing the risk of a perceived impact by proponents.
- Climate influences flatback turtle nesting behaviour with nesting recaptures decreasing with increased rainfall. Contextualising environmental effects on populations is important in EIA as changes could be otherwise misinterpreted as development impacts. This also highlights the need for long-term data needs required for EIA to be driven by the government rather than proponents.
- The Field Island flatback nesting turtle population is stable, however, given the vulnerability of turtles to multiple pressures such as climate change i.e. sea level rise and the difficulty in capturing other demographic data, caution should be applied when reviewing their population status.

Chapter 4: Factors affecting the distribution and abundance of dugongs in northern Australia: Implications for coastal management [4]

4.1 Overview

In this chapter, I investigate the associations between spatial, temporal and environmental covariates and the distribution and abundance of dugongs, aerial survey data collected at two temporal and spatial scales: (1) a single broad-scale survey of the coastal waters of the Northern Territory (NT) in 2015 (including the Gulf of Carpentaria), and (2) multi-year surveys (1984, 1987, 2007, 2014) of the coastal NT waters of the Gulf of Carpentaria were analysed.



[4] A version of this chapter will be submitted to Marine Mammal Science as: *Factors affecting the distribution and abundance of dugongs in Northern Australia*

4.2 Introduction

Although monitoring data are typically collected at the scale of a development site as part of an EIA process, there is increasing recognition that broad scale processes influence species distribution and abundance and that these processes need to be understood to interpret the impacts of a development (Bejder et al. 2012, Mannocci et al. 2017, Silber et al. 2017). Coastal marine megafauna such as the dugong are renowned for being a challenge to monitor because species detectability varies over space and time as a result of environmental conditions, especially water turbidity. Accounting for variability in detection is important as habitat types tend to be heterogeneous over both fine and coarse scale temporal and spatial scales (Hagihara et al. 2018).

The dugong is a species of conservation concern. It has high biodiversity value as the remaining member of the Family Dugongidae (Marsh et al. 2011) and has immense cultural value to many Indigenous communities along the north Australian coast as a cultural keystone species (Butler et al. 2012). The dugong is listed as Vulnerable by the IUCN at a global scale (Marsh and Sobtzick 2015) and is a matter of National Environmental Significance (MNES) in Australia under the EPBC Act, as a listed migratory species.

Dugongs feed within the coastal zone, predominantly on seagrass and algae (Marsh et al. 1982, Whiting 2002, Whiting 2008, Marsh et al. 2011). These factors constrain them to shallow areas with enough light to permit plant growth. These inshore areas are often subject to multiple direct and indirect pressures via broad and local scale environmental and anthropogenic impacts and management intervention is often required. The dugong triggers the EPBC Act more than any other mammal not listed as threatened (Jason Ferris personal communication to Helene Marsh, 2019).

In Australia, dugongs have been systematically monitored in many coastal regions since the early 1980s (Marsh and Sinclair 1989a, Marsh et al. 2002) with the aim of detecting trends over time and prioritising areas for protection (Marsh et al. 2005, Grech and Marsh 2007, Dobbs et al. 2008, Hodgson et al. 2008). Monitoring the response of dugongs to natural and anthropogenic impacts is challenging. Their cryptic behaviour, variable movements (Sheppard et al. 2006), long lifespan and low maximum rate of population increase (see Appendix 3 for additional biological information on dugongs) means that population change is typically detectable only when substantial (Marsh et al. 2011). In addition, the influence of habitat status on mortality and fecundity (Marsh and Kwan 2008, Marsh et al. 2011, Meager and Limpus 2014, Fuentes et al. 2016b) means that interpreting changes in population health within a broader environmental context is important when determining appropriate management responses to a specific development.

The aim of this analysis of the 2015 NT dugong aerial survey data was to determine whether the variation in dugong distribution and abundance (corrected for detection bias *sensu* Marsh and Sinclair 1989a) and the proportion of dugong groups with calves were associated with biophysical features of the NT coast such as IMCRA bioregion, bathymetry, tide or any additive combination of them. The objectives for the analysis of multiple surveys for dugongs in the Gulf of Carpentaria were to investigate temporal and spatial changes in their distribution and abundance, and to identify the covariates with the most influence on calf distribution and relative abundance over time. These analyses were both designed to provide a context for designing local-scale Environmental Impact Assessments for dugongs in the Northern Territory (NT).

4.3 Methods

4.3.1 Study Region

The NT coastline is extensive (10,953 km) and shallow (<70 m), with the eastern boundary defined at 139° E in the Gulf of Carpentaria in Queensland and the western border defined at 129° E in the Joseph Bonaparte Gulf. The region is dynamic and characterised by monsoonal seasonality in temperature, salinity, rainfall and wind regimes with the wet season occurring during December to April and the dry season outside of this period. Tidal type is variable with a micro tidal range (~2 m) in a restricted part of the western Gulf of Carpentaria, a macro tidal range in the Joseph Bonaparte Gulf and Darwin (tidal range: ~8 m) (Duke 2006) and a meso tidal range (2-4 m) in most of the Gulf of Carpentaria. The coastline generally has low wave energy enabling seagrass and mangrove communities to establish.

The Gulf of Carpentaria is a large (310,000 km^2), shallow water embayment shared by the NT, Queensland and Commonwealth jurisdictions, bounded by Arnhem Land to the west and Cape York Peninsula to the east. Sub-sea ridges separate its sea floor from Torres Strait and the Coral Sea to the east, the Wessel Islands (NT) and the Banda Basin of the Arafura Sea to the northwest. The seabed gradient of the Gulf of Carpentaria is low, and it has a maximum depth of 70 m. Seagrass beds grow along much of the coast (Poiner et al. 1987, Roelofs et al. 2005). The coastal waters of the Gulf of Carpentaria have the highest density of dugongs in the NT (Elliott et al. 1979, Marsh et al. 2008). The Gulf has therefore been a focus for intermittent standardised, aerial survey assessments of dugong populations in the NT since 1984.

4.3.2 Details of Aerial Surveys

I analysed data from NT dugong aerial surveys flown at two regional scales: the entire NT coast conducted in 2015 and the Gulf of Carpentaria (NT jurisdiction) in years 1984, 1994, 2007 and 2014. The total area surveyed in 2015 was approximately 93,145 km^2 (Figure 4.1) and the sampling intensity (the proportion of each block within transect strip-widths) ranged from 5 – 9 %. The survey, which I designed and led, aimed to record the distribution and abundance of dugongs across the coastal waters of the entire NT (Groom et al. 2017a).

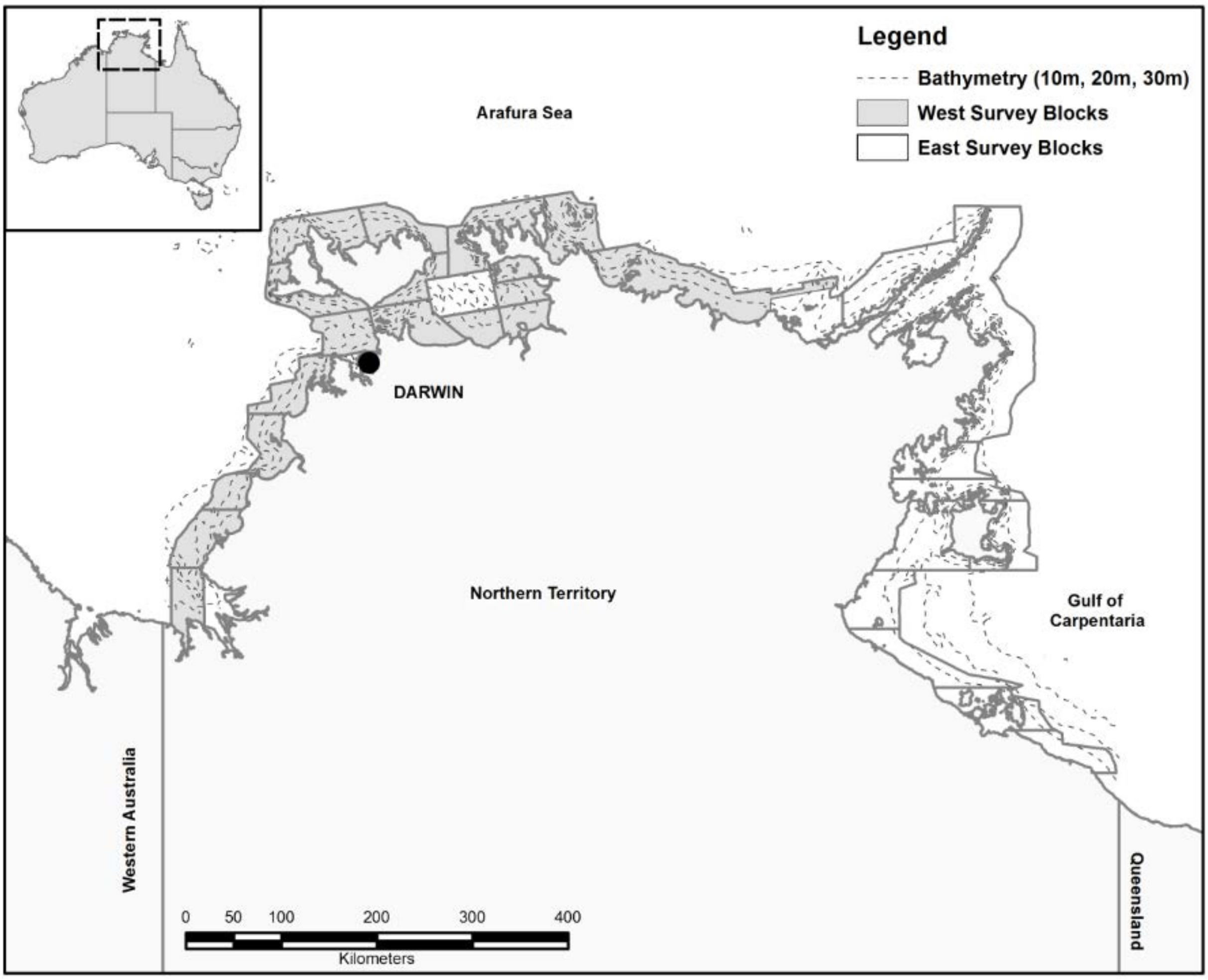


Figure 4.1: Map of the coastline of the Northern Territory, Australia (inset), showing the survey area of each survey aircraft (the east and west aircraft) in relation to bathymetry.

The dugong aerial surveys conducted in the Gulf of Carpentaria over multiple years (Figure 4.2) were designed and led by others (except for 2014, which I designed and led). These surveys were also designed to record the abundance and distribution of dugongs. The blocks surveyed in the Gulf of Carpentaria were truncated so that block sizes and transect lengths were consistent across years. Transects were systematically spaced 5 km apart, providing a mean sampling intensity of 8% and a total survey area of 13,534 km^2. The transect design was similar across surveys. The data from the 2015 survey were not included because of differences in the spacing of the transects.

The standardised dugong aerial surveys required trained observers to scan strip transects 200 m wide on the water surface on each side of the aircraft in passing mode. Each transect was demarcated using rods attached to pseudo wing struts (Marsh and Sinclair 1989a, b). Distance categories: low=50 m, medium=100 m, high=150 m, and very high 150-200 m, within the strip were marked by coloured bands on each pseudo wing strut. For each sighting, observers recorded the total number of dugongs seen, number at the surface of the water, position in the transect (e.g. low, medium). The number of dugong calves (animals less than 2/3 of the size of the adult dugong and swimming in proximity) was recorded for each dugong sighting.

All surveys were conducted at similar times of the year for temporal comparison and used the technique developed by Marsh and Sinclair (Marsh and Sinclair 1989a) with the following variations:

(1) surveys conducted in 1984 by Bayliss and Freeland (1989) and NT Parks and Wildlife (1994) used three observers (two port, one starboard in 1984 and one port, two starboard in 1994 in a Cessna aircraft), with the front starboard observer also acting as survey leader;

(2) 1984 and 1994 aerial surveys were conducted at lower altitudes (134 m, compared with 152 m in the later survey years).

Because dugong re-captures had not been identified in the available dataset making it impossible to correct for perception bias *sensu* Marsh and Sinclair (1989a), the 1984 data were included only in the analysis of the proportion of calves.

The difference in survey altitude changes the survey area (which was adjusted for). The difference between 137 m and 152 m altitude between years was deemed unproblematic with regard to the likelihood of the observers sighting dugongs on the basis of the experimental evaluation by Marsh and Sinclair (1989b). To account for differences in observer effort, the raw data from the three Gulf of Carpentaria surveys were reanalysed and corrected for availability (dugongs unavailable to observers because of turbid water) and perception (those that are potentially visible but not seen) bias using methods described in Marsh and Sinclair (1989a). The corrected counts of dugongs from the 2015 aerial survey data were also calculated using the methods outlined in Marsh and Sinclair (1989a) with availability and perception correction factors applied. There was no correction applied for water depth *sensu* Hagihara et al. (2018).

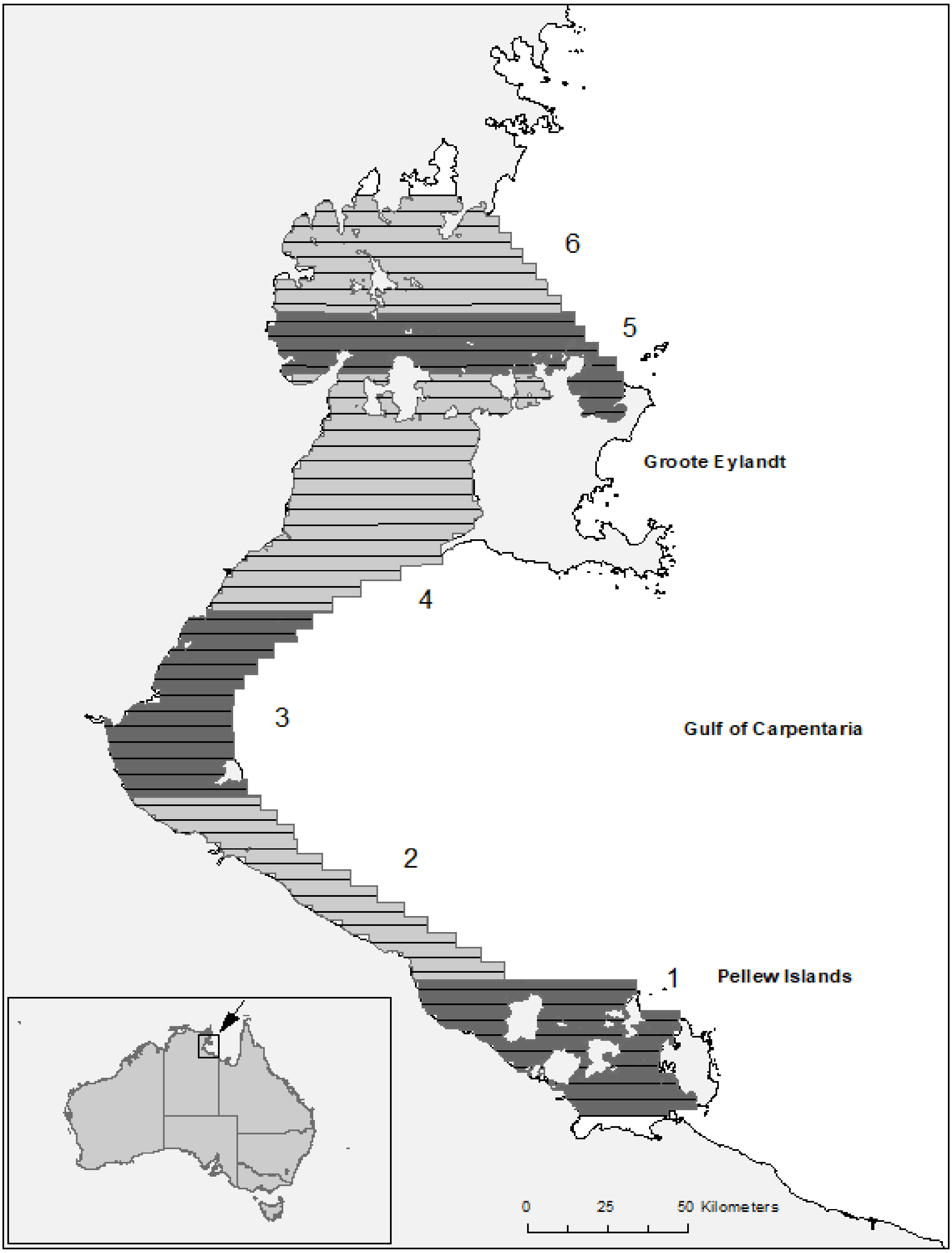


Figure 4.2: Map of the dugong aerial survey transects and blocks (differentiated by the grey shading and numbered) along the NT cost of the Gulf of Carpentaria truncated for comparison across years: 1984, 1994, 2007 and 2014.

4.3.3 Environmental covariates

A set of environmental covariates were compiled that were:

1) considered to have the potential to broadly influence distribution and abundance of dugongs and the proportion of calves across the study region;

2) available at the broad spatial scale of the study.

The environmental covariates (Table 4.1) included biophysical variables: bathymetry (lowest astronomical tide), tide type (meso or macro), Integrated Marine and Coastal Regionalisation of Australia (Interim Marine and Coastal Regionalisation for Australia 1998) (see Figure 4.3) and spatio-temporal variables (year, block).

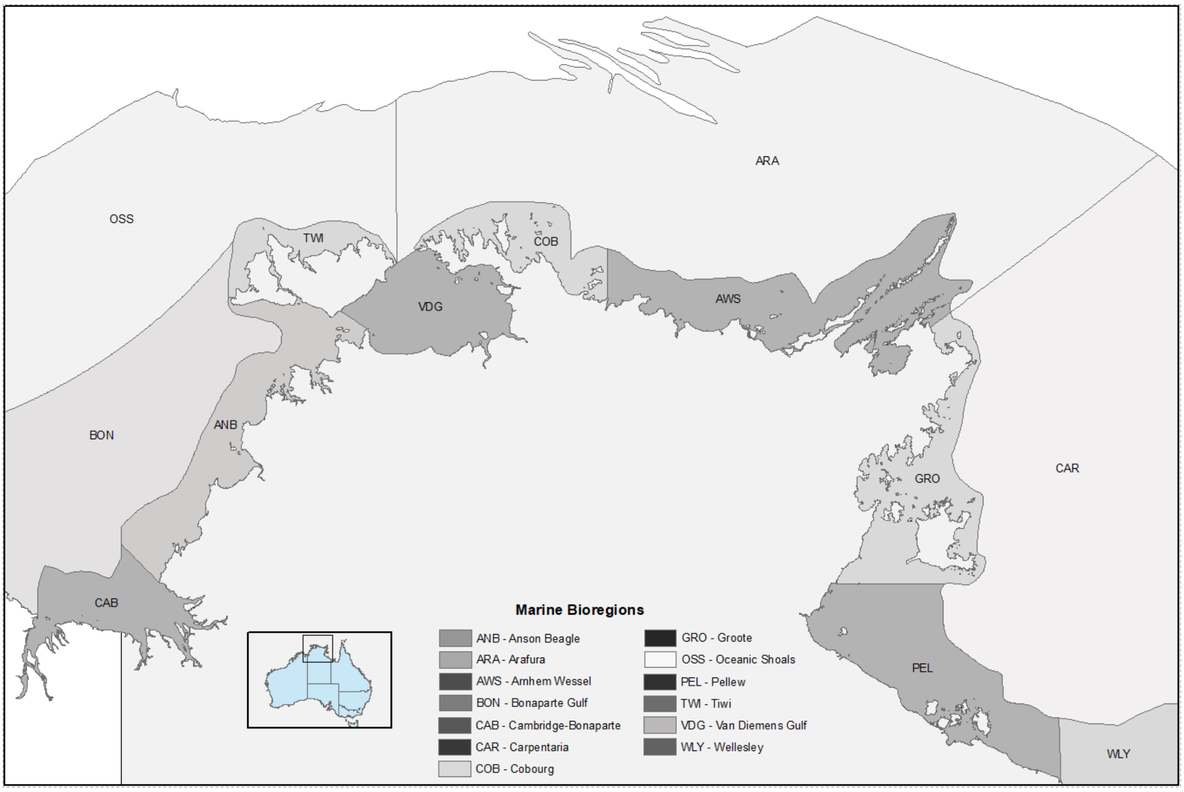


Figure 4.3: Integrated Marine and Coastal Regionalisation of Australia, meso-scale bioregions used in the analysis of the 2015 NT wide survey data.

Table 4.1: Covariates and hypotheses included in the analysis of dugong abundance and distribution data from IMCRA bioregion, bathymetry, tide or any additive combination of these 1984, 1994, 2007 and 2014 Gulf of Carpentaria aerial survey and the 2015 broad scale NT survey.

Name	Category/Data type	Application	Source/Rationale	Hypotheses: *1) Dugong relative abundance is:* **2)** *Proportion of dugong groups with calves is:*
Null				Not significantly different along the NT coast
Block – NT coastal	Categorical: Blocks 1-19 (2015)	Spatial	Demarcated by a combination of geographic features and apparent differences in dugong density.	Explained by block location
Block – Gulf of Carpentaria	Categorical: 1- 6 (1984 – 2014)			
IMCRA Region	Categorical: Pellew, Groote, Arnhem Wessel, Cobourg, Van Diemen's Gulf, Tiwi, Anson Beagle, Cambridge Bonaparte	Spatial - broad-scale habitat bioregions	Commonwealth: Combined sources, inshore regionalisation comprises biological and physical distribution data including: demersal fishes, marine plants, invertebrates, seafloor geomorphology, sediments and oceanographic data (https://www.environment.gov.au/system/files/resources/2660e2d2-7623-459d-bcab-1110265d2c86/files/imcra4.pdf).	Associated with the bioregion identified
Tidal Type (2015 survey)	Categorical: meso (<3-7m) macro (>7m) micro*	Spatial - potential predictor of available habitat	Defined by the range identified in Seafarer AusTides	Expected to be higher in areas where tidal range is moderate to allow seagrass adequate light and lower sedimentation rates without being over-exposed potentially leading to heat stress (Collier and Waycott 2014)
Bathymetry	Normalised data at the block level (0 – 1) – Proportion of block with <10 m depth	Spatial - predictor of seagrass presence given light availability requirements	GeoScience Australia – bathymetry datum is at lowest astronomical tide, categorised at the block level (LAT). Dugong sighting data was therefore not corrected for tide. The higher turbidity inherent along the NT coast which is favourable for seagrass growth	Expected to be higher in areas where there is a higher percentage of water <10m in a survey block as this is favourable for seagrass growth.
Year	Categorical: 1984, 1994, 2007, 2014	Temporal - changes in abundance and distribution	Categorical value only, other variables used to describe changes within and between years	Expected to be relatively stable across years

*Micro tide type was not used as it accounted for small regions only in northeast Arnhem (western Gulf of Carpentaria) that were surrounded by meso tide type. Although data more recent than the IMCRA data have been collected as part of the Northern Marine Parks planning process, these data were mostly collected from offshore waters and not consistently around the coastline of the NT.

4.3.4 Data analysis

The response variable was the number of dugongs per transect (density) corrected for availability and perception biases. Log transformed transect length (km) was used as an offset in all models so that the models were testing for changes in relative abundance (density) rather than population size *per se*.

The data were zero-inflated and over-dispersed, likely a reflection of the dugong's habitat use and behaviour (Hagihara et al. 2016, Sobtzick et al. 2017). Zero-inflated models require sightings on at least one but preferably several transects in each block. Recognising that the data are zero-inflated is important as using the wrong distribution will result in incorrect predictions at each site, although the average prediction across all sites will be consistent with that observed (Cameron and Trivedi 1998, Barry and Welsh 2002). Additionally, failure to recognise zero inflation will cause overly optimistic conclusions about the statistical significance of the explanatory variables (i.e. reduced standard errors of the coefficients). Under common model-building procedures such as stepwise selection, incorrect variables are more likely to be retained with zero-inflated data (Fitzmaurice 1997). Zero-inflated modelling considers the possibility that the drivers determining presence can be different to those that determine abundance (Ridout et al. 1998).

4.3.5 Data exploration

Broad-scale dugong survey, NT

Of the 19 survey blocks in the 2015 aerial survey, one contained no data and was removed from the analysis. Due to the excess of zeros for the dugong counts, zero-inflated and negative binomial count variance structures were deemed appropriate. The zero-mass component was considered to represent the probability that dugongs are absent on a transect, whereas the count component represented the predicted corrected count of dugongs when they are present on a transect. Given these two model components, model selection was performed by first reducing the count model, then the binomial model; the terms were then added back to each side sequentially. This process was then reversed where the binomial model was reduced, then the count model and terms added back sequentially to each (Bauman et al. 2015). Both processes resulted in the same final model. All analyses and graphics were produced in the statistical programming language R using the PSCL and MASS packages (R Core Team 2012).

Variation in dugong abundance (corrected counts) was compared across IMCRA, bathymetry and tidal bioregions. Dugong abundance was analysed using zero-inflated negative binomial structured generalised linear models (GLMs) for count data under a multiple working hypothesis framework (Anderson et al. 2000). This approach required the comparison of candidate models with different combinations of explanatory variables using information theoretic and classical model comparison and selecting the most parsimonious model. The response variable was dugong abundance (counts corrected for perception and availability bias) and explanatory variables were bioregion - Integrated Marine and Coastal Regionalisation (IMCRA) smaller scale or Region (pooled IMCRA bioregions), bathymetry (proportion of block with < 10 m depth) and tide (macro or meso range (micro was excluded as it only represented small regions within blocks surrounded by meso-tide type)).

Gulf of Carpentaria 1994-2014

I examined the response of dugongs to temporal and spatial covariates (year and block, respectively) in the Gulf of Carpentaria. Data from the 2015 broad scale aerial survey were not used in this analysis as the transects were greater distances apart. Exploratory data analysis suggested the data were over-dispersed (relative to a binomial distribution) and zeros were present in more than 30% of transects across all years combined. Zero-inflated negative binomial (ZINB) models were explored for their fit and temporal autocorrelation was checked in R using the autocorrelation function (acf) and the partial autocorrelation function (pacf) and was found to not significantly affect the data. Surveys in the Gulf were conducted at intervals of seven - 13 years. Although survey transects theoretically sample the same location; variability in tide state, seagrass presence at a fine-scale and the actual flight path mean that transects are not true replicates and so a mixed modelling approach was considered unnecessary. Individual transects were reviewed for the presence of dugongs and calves across the survey years. Less than 30 % of individual transects had repeated dugong presence across all survey years and there were no individual transects that had calves present across all survey years. Block and year were treated as fixed effects and a ZINB GLM for dugongs and a GLM for calves were applied to investigate temporal and spatial changes. The appropriate models were chosen by examining over-dispersion statistics and Akaike Information Criterion (AICc). The negative binomial distribution allows the variance to be larger than the mean and has been the main candidate to model distribution of corrected dugong counts previously (Marsh et al. 2008). Selected final models were validated by visual inspection of residual plots, normal QQ plots and residuals/leverage plots following Zuur (2010). The dugong density model was interpreted using a combination of plotting predicted values at relevant spatial and temporal resolution given the final model terms. The overall significance of terms in the final model was evaluated using likelihood ratio tests comparing nested models with and without the term.

Calf counts

Dugongs categorised as calves during aerial surveys are aged from neonates to about 18 months and are dependent on their mother (Marsh et al. 2011). The proportion of dependant calves observed during an aerial survey is thus a reflection of both: (1) births, a proxy indicator of population health in response to environmental conditions and (2) neonatal survivorship (i.e., potentially affected by extreme weather events (Fuentes et al. 2016b)).

The proportion of dugong groups with calves was investigated across two scales: (1) the entire NT coast (2015 data) and (2) the Gulf of Carpentaria, NT (1984, 1994, 2007 and 2014 data) using a GLM binomial logistic regression. For the 2015 dugong dataset, the proportion of dugong groups with calves was treated as the response variable and survey region as a categorical variable. I applied environmental covariates including region, IMCRA, bathymetry and tide, to investigate their association with the proportion of dugong groups with calves.

4.4 Results

4.4.1 Dugong distribution across the NT

The 18 survey blocks used in the analysis contained 379 transects. Of these, 69 transects had dugongs present (18.21%) resulting in a zero-inflated dataset (Figure 4.4). The spatial pattern of dugong distribution and abundance along the NT coast varied with bathymetry and IMCRA bioregion. Model 21 (Table 4.2) included the factors tide and bathymetry on the count side and IMCRA on the binomial side of the ZINB model. Tide type was positively associated with dugong distribution, though on closer inspection using a likelihood ratio test, the likelihood of the effect was only $P = 0.09$ and this factor was therefore removed from the model (Table 4.3). Model 22 had the next highest AICc and was the most parsimonious model score with bathymetry (count side) and IMCRA (binomial side). The final terms for this model are in Table 4.4 shows dugong abundance (observed and predicted) plotted against bathymetry and Figure 4.5 shows dugong presence (observed and predicted) against IMCRA bioregion.

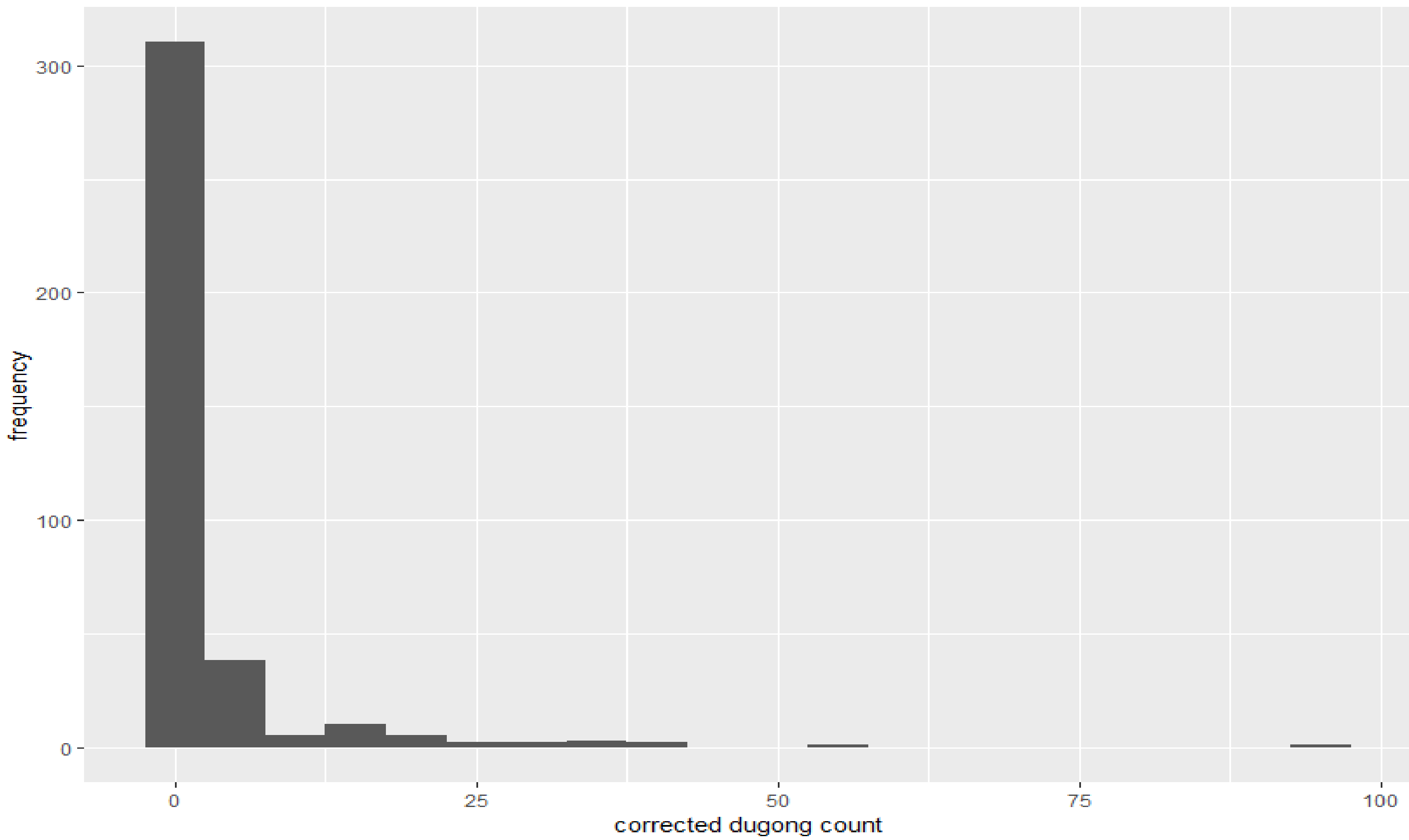


Figure 4.4: Dugong data (corrected counts) from the 2015 broad scale NT dugong aerial survey. No dugongs were sighted on > 81% of coastal transects indicating that the data were zero-inflated.

Table 4.2: Summary of zero-inflated model results that best explained dugong distribution and abundance across the NT, based on the 2015 survey. The best two models (M21 and M22) contained tide type and bathymetry or bathymetry only on the count side and IMCRA on the binomial side. Model Akaike's information criterion (AICc) values were compared to determine the best models.

Response variable – corrected dugong count; offset (Area_l) applied to all

Model #	**Count Model Formula**	**Binomial Model Formula**	**AICc**	**ΔAIC**	**LogL**	**Residual df**
M1	Region + Tide + Bathy	Region + Tide + Bathy	814.8	5.08	-393.924	13
M2	Region + Tide + Bathy	Tide + Bathy	842.3	32.49	-410.826	10
M3	Region + Tide + Bathy	Region + Bathy	813	3.19	-394.051	12
M4	Region + Tide + Bathy	Region +Tide	814.2	4.44	-394.677	12
M5	Region + Tide + Bathy	Region	812.2	2.39	-394.716	11
M6	Region + Tide + Bathy	Bathy	840.2	30.45	-410.864	9
M7	Region + Tide + Bathy	Tide	849.6	39.86	-415.565	9
M8	Region + Tide + Bathy	1	838.6	28.81	-411.095	8
M9	IMCRA	IMCRA	814.3	4.55	-389.31	17
M10	IMCRA	Tide + Bathy	842.5	32.72	-408.817	12
M11	IMCRA	Bathy	899	89.28	-438.162	11
M12	IMCRA	Tide	850	40.24	-413.644	11
M13	IMCRA	1	839	29.19	-409.18	10
M14	Tide + Bathy	Region + Tide + Bathy	810.8	1.01	-395.086	10
M15	Region + Bathy	Region + Tide + Bathy	813.2	3.44	-394.175	12
M16	Region +Tide	Region + Tide + Bathy	818.1	8.3	-396.604	12
M17	Region	Region + Tide + Bathy	816.2	6.43	-396.739	11
M18	Bathy	Region + Tide + Bathy	811.6	1.87	-396.571	9
M19	Tide	Region + Tide + Bathy	824.3	14.51	-402.893	9
M20	1	Region + Tide + Bathy	834.6	24.79	-409.082	8
M21	**Tide + Bathy**	**IMCRA**	**809.8**	**0**	**-392.456**	**12**
M22	**Bathy**	**IMCRA**	**810.5**	**0.73**	**-393.889**	**11**
M23	Tide	IMCRA	823.3	13.49	-400.268	11
M24	1	IMCRA	833.5	23.75	-406.457	10

Table 4.3: Likelihood ratio test comparing the best two models (M21 and M22) to determine whether tide type should be retained in the model

Likelihood ratio tests of similar top candidate models

Binomial Model Formula	**Model**	**Comparison**	**df**	**LogL**	**Δdf**	***X^2***	**P**
Tide + Bathymetry	1 (M21)		12	-392.46			
Bathymetry	2 (M22)	1V2	11	-393.89	-1	2.8666	0.09044

Table 4.4: The most parsimonious model (M22) explaining dugong distribution and abundance across the NT based on the results of the 2015 survey. The final model contained bathymetry on the count-side and IMCRA on the binomial side. Their values demonstrated that bathymetry is strongly associated with dugong abundance and that dugong absence is associated with available habitat type (IMCRA). The likelihood of dugongs being absent from the Arnhem-Wessel IMCRA is P = 0.002, more than seven times higher than the corresponding term from the Pellews IMCRA (P = 0.015).

Bathymetry - Count model coefficients (negbin with log link)

	Estimate	Std Error	Z value	Value Pr(>|z|)
(Intercept)	0.9280	0.1333	6.964	3.31e-12
Bathymetry	**1.1466**	**0.2464**	**4.652**	**3.28e-06**
Log(theta)	1.0331	0.2121	4.870	1.12e-06
IMCRA - Zero-inflation model coefficients (binomial with logit link)				
(Intercept)	0.2381	0.3967	0.600	0.54845
Arnhem – Wessel	**1.9278**	**0.6461**	**2.984**	**0.00285**
Cambridge- Bonaparte	-0.3451	0.6979	-0.494	0.62097
Cobourg	0.6656	0.5720	1.164	0.24459
Groote	-0.7764	0.5866	-1.3323	0.18569
Pellew	**-1.2426**	**0.5115**	**-2.429**	**0.01513**
Tiwi	-0.6285	0.5641	-1.114	0.26521
Van Diemens Gulf	0.3055	0.5278	0.579	0.56267

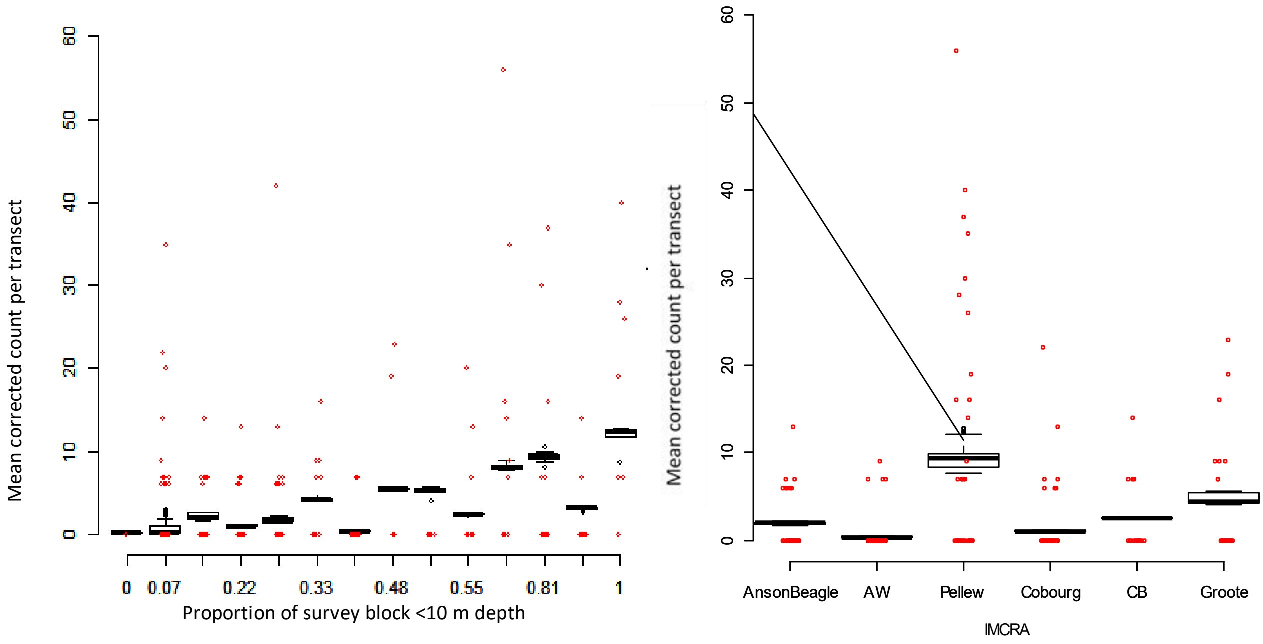


Figure 4.5: Model 22 Bathymetry | IMCRA plotted with the actual mean corrected count of dugongs per transect (in red) and the corresponding predicted values as box plots (median as horizontal solid line). The panel on the left shows the count-side of the model with the corrected count of dugongs across the NT positively associated with the proportion of a survey block that is <10 m depth. The panel on the right shows the binomial-side of the model with dugong presence associated with a particular IMCRA across the NT. The likelihood of dugong presence is greatest in the Pellew IMCRA. To improve the readability of this plot, one extreme value of ~ 100 (corrected dugong count) was removed, the value was located on the x axis at 1 and was in the Pellew IMCRA. IMCRA regions are illustrated in Figure 4.3 and include: Anson Beagle, Arnhem Wessel (AW), Pellew, Cobourg, Cambridge Bonaparte (CB) and Groote.

4.4.2 Dugong distribution and temporal pattern of abundance in the Gulf of Carpentaria

No dugongs were detected on a third (33.3%) of transects sampled in the Gulf of Carpentaria.

The most parsimonious model explaining dugong distribution and abundance in the Gulf of Carpentaria contained Block + Year on the count-side and Block on the binomial side of the zero-inflated model (M16, Table 4.5). Investigation of the final model terms (Table 4.6) for the count-side shows that temporal change in dugong abundance was observed in the Gulf of Carpentaria with the 2007 survey recording more dugongs (P = 0.024) than the 1994 or 2014 surveys. With all years combined, Block 1 had the highest dugong abundance. The binomial-side of the model shows that dugong presence is associated with block. Block 1 (Pellew Islands) was more likely than the other blocks to have dugongs present (P=0.001) whereas dugongs were most likely to be absent from Block 4 (west of Groote Eylandt) (P = 0.006). Figure 4.6 shows the final model plotted.

Table 4.5: Model selection table of zero-inflated models investigating the relationship between dugong distribution and abundance in the Gulf of Carpentaria, NT. Temporal-spatial variables included year and block and their interaction. Akaike's information criterion (AICc) values were compared to determine the most parsimonious model with the model containing Block + Year on the count-side and Block on the binomial-side (M16) having the lowest AICc value. Final model terms are shown here, and the final model is plotted in Figure 4.6.

Response variable – corrected dugong count; offset (Area_l)

	Count Model Formula	Binomial Model Formula	AICc	ΔAIC	LogL	Residual df
M1	Block * Year + Offset	Block * Year + Offset	1227	34.83	-567.207	37
M2	Block * Year	Block * Year + Offset	1226	33.84	-566.712	37
M3	Block + Year + Offset	Block * Year + Offset	1222.8	30.57	-579.692	27
M4	Block + Offset	Block * Year + Offset	1228.4	36.21	-585.221	25
M5	Year + offset	Block * Year + Offset	1254.2	61.97	-602.039	22
M6	Block	Block * Year + Offset	1227.5	35.33	-584.781	25
M7	Year	Block * Year + Offset	1245.3	53.11	-597.61	22
M8	Offset	Block * Year + Offset	1256.5	64.32	-605.764	20
M9	Block + Year	Block * Year + Offset	1221.5	29.26	-579.036	27
M10	Block + Year	Block * Year + Offset	1221.5	29.26	-579.036	27
M11	Block + Year	Block * Year	1215	22.82	-575.82	27
M12	Block + Year	Block + Year + Offset	1202.9	10.7	-582.663	17
M13	Block + Year	Block + Year	1196.4	4.23	-579.428	17
M14	Block + Year	Year + Offset	1200.1	7.88	-587.159	12
M15	Block + Year	Block + Offset	1198.7	6.47	-582.953	15
M16	**Block + Year**	**Block**	**1192.2**	**0**	**-579.716**	**15**
M17	Block + Year	Year	1194.2	2	-584.217	12
M18	Block + Year	Offset	1196.1	3.9	-587.435	10
M19	Block * Year	Block * Year + Offset	1227	34.83	-567.207	37
M20	Block * Year	Block * Year	1221	28.82	-564.204	37
M21	Block * Year	Block + Year + Offset	1205.1	12.86	-570.84	27
M22	Block * Year	Block + Year	1199	6.82	-567.82	27
M23	Block * Year	Block + Offset	1200.2	8.04	-571.134	25
M24	Block * Year	Year + Offset	1201.1	8.86	-575.487	22
M25	Block * Year	Block	1194.2	1.99	-568.111	25
M26	Block * Year	Year	1195.5	3.26	-572.684	22
M27	Block * Year	Offset	1196.5	4.32	-575.762	20

M28	Block * Year + Offset	Block + Year	1199	6.82	-567.82	27
M29	Block * Year	Block + Year	1197.6	5.38	-567.097	27
M30	Block + Year + Offset	Block + Year	1198.3	6.09	-580.36	17
M31	Block + Offset	Block + Year	1196.4	4.23	-579.428	17
M32	Year + Offset	Block + Year	1204.9	12.7	-586.067	15
M33	Block	Block + Year	1231.1	38.86	-602.647	12
M34	Year	Block + Year	1203.2	11.02	-585.228	15
M35	Offset	Block + Year	1221.9	29.68	-598.059	12

Table 4.6: Final ZINB model terms for the most parsimonious model for dugong distribution and abundance in the Gulf of Carpentaria, M16: Block + Year (count-side) and Block (binomial-side). The table shows that for the model's count-side, dugong abundance in the Gulf of Carpentaria, NT was highest in the 2007 survey and with survey years combined, Block 1 (Sir Edward Pellew Islands) has the highest number of dugongs. The binomial part of the model shows association between block and dugong absence when survey years are combined. Dugong absence is highest in Block 4 (west of Groote Eylandt and north of Limmen Bight and lowest in Block 1.

	Estimate	Std Error	Z value	Value Pr(>|z|)
Block + Year - Count model coefficients (negbin with log link)				
(Intercept) Block 1	3.4136	0.1515		**<-0.002**
Block 2	-0.3791	0.1760		**0.0312**
Block 3	-0.8726	0.1800		**1.24e-06**
Block 4	-0.8965	0.1809		**7.19e-07**
Block 5	-0.9644	0.2064		**2.97e-06**
Block 6	-0.4300	0.2001		**0.0317**
Year 2007	0.3068	0.1354		**0.0235**
Year 2014	-0.1672	0.1389		0.2289
Log(theta)	1.1364	0.1480	7.677	1.63e-14
Block - Zero-inflation model coefficients (binomial with logit link)				
(Intercept) Block 1	-1.7528	0.5434	-3.226	**0.00126**
Block 2	0.9267	0.6535	1.418	0.15621
Block 3	1.0398	0.6509	1.597	0.11016
Block 4	1.6937	0.6209	2.728	**0.00638**
Block 5	0.8037	0.7349	1.094	0.27409
Block 6	1.0540	0.6958	1.515	0.12982

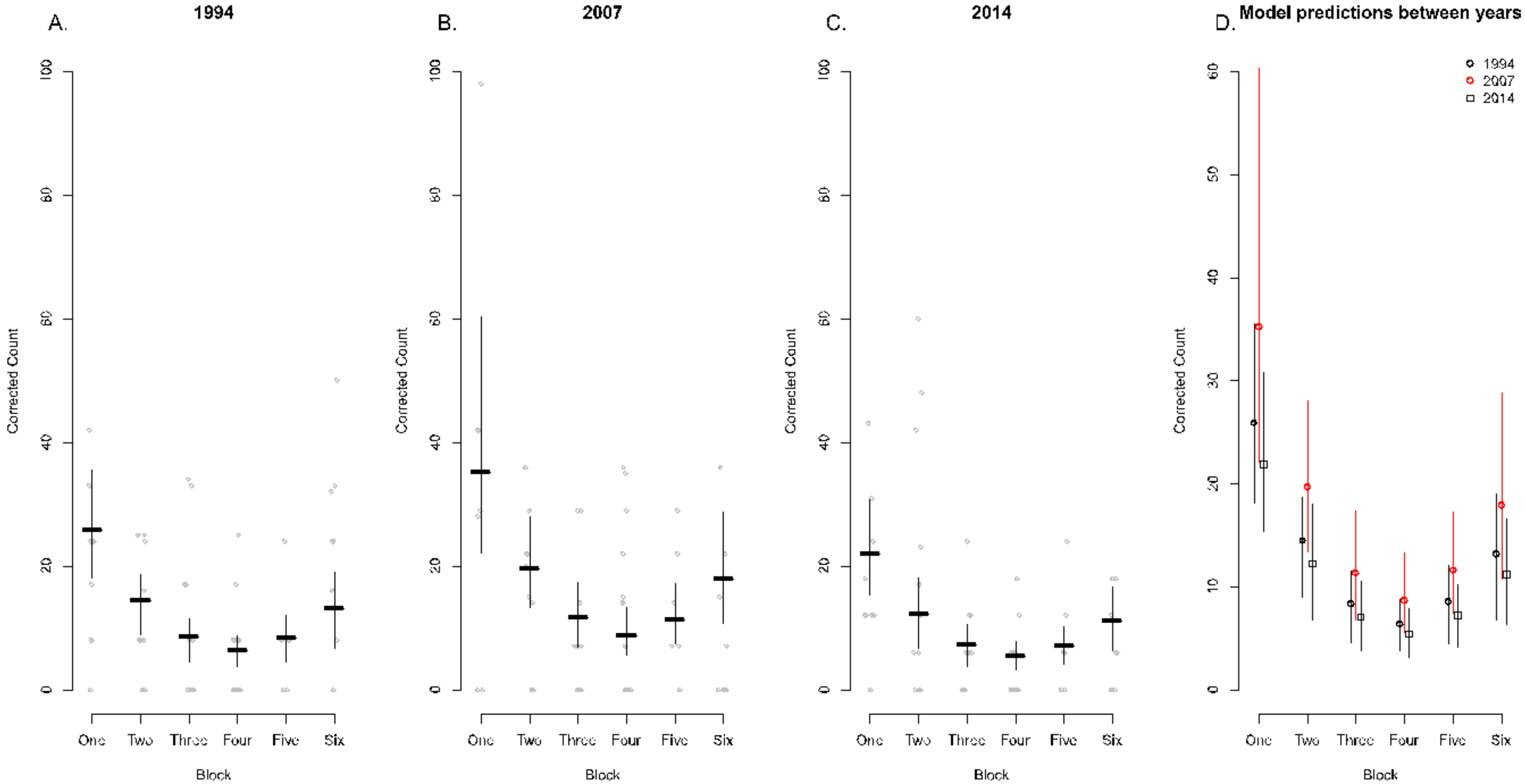


Figure 4.6: Model predictions of corrected dugong counts (y-axis) per survey block (x-axis) from the three survey periods from 1994, 2007 and 2014 (panels A. – C.). Grey points are raw data (corrected counts per transect), horizontal line is the model prediction; whiskers are bootstrapped 95% (percentile) confidence intervals. Panel D shows the comparison between years, points are model predictions, whiskers are bootstrapped 95% (percentile) confidence intervals. Note the difference in y-axis scale between panels A. – C. and panel D

Calf proportions across the NT and within the Gulf of Carpentaria

For the 2015 aerial survey, most dugong groups with calves were observed in the Gulf of Carpentaria region (Figure 4.7) (P = 0.077 s.e. 0.78)).

The model containing bathymetry (proportion of a survey block <10 m depth) and tide type (meso/macro) was the most parsimonious of the models considered (M10, Table 4.8). On further inspection with the likelihood ratio test, the probability of bathymetry being positively associated with the proportion of dugong groups with calves was much higher than tide type (Table 4.8).

The proportion of dugong groups with calves across the NT was positively associated with bathymetry as measured by the proportion of a block that was <10 m deep (Figure 4.8). The average proportion of dugong groups with calves across the NT was similar to the average proportion observed in the Gulf of Carpentaria over multiple years, 0.160 and 0.164 respectively.

The percentage of dugong groups with calves in the Gulf of Carpentaria ranged from 13% to 20.6 % over the approximate 30-year period of the surveys but did not change significantly across years. With survey years combined, 71% of calves (and 53% dugongs in total) were found in Blocks 1 (Sir Edward Pellew Islands) and 2 (southern Limmen Bight). The greatest influence on the proportion of dugong groups with calves and their distribution was the spatial covariate, Block, shown in Model 10 (Table 4.7).

The proportion of dugong groups with calves in the Gulf of Carpentaria (Figure 4.9) showing the distribution of samples with years combined across the blocks demonstrates that Blocks 1 (Sir Edward Pellew Islands) and 2 (southern Limmen Bight) are consistently important areas for calves.

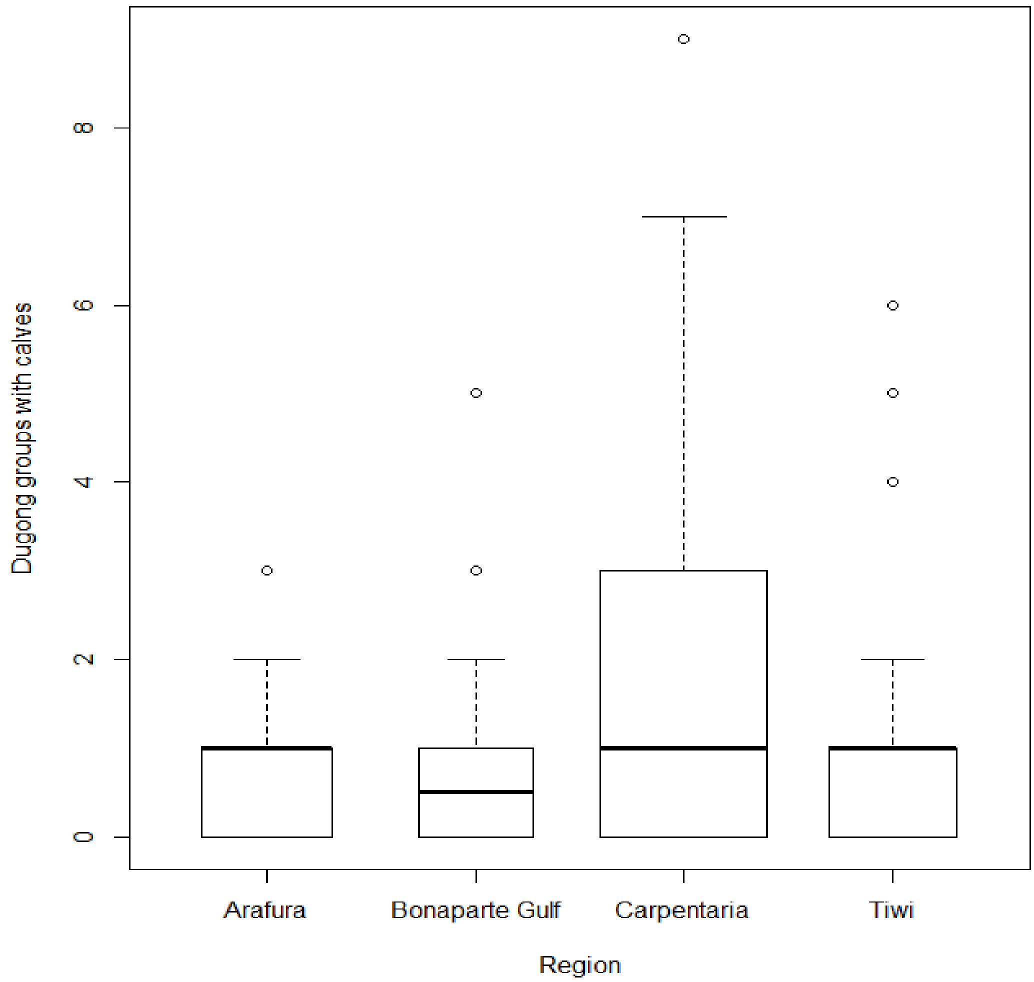


Figure 4.7: Dugong groups with calves observed on transect in various coastal regions of the NT with the Carpentaria IMCRA region identified as having the highest number of calves present in the 2015 survey. Solid horizontal lines represent the median value.

Table 4.7: Model selection table investigating association of covariates: region, tide type, bathymetry and IMCRA Bioregion with the proportion of dugong groups with calves across the NT. Bathymetry and tide (Models 10 and 12) were positively associated with the distribution and proportion of dugong groups with calves. The most parsimonious model was selected based on the lowest AICc value.

Response variable – proportion of dugong groups with calves

Model #	**GLM formula**	**AICc**	**ΔAIC**	**LogL**	**Weight**	**df**
M1	1	99	13.66	-48.481	0.001	1
M2	Region + Tide + Bathymetry	92.3	6.97	-39.489	0.015	6
M3	Region + Tide	93.4	8.01	-41.208	0.009	5
M4	Region + Bathymetry	90.6	5.21	-39.811	0.037	5
M5	Region	91.1	5.74	-41.24	0.028	4
M6	IMCRA + Tide + Bathymetry	94.8	9.45	-36.881	0.004	9
M7	IMCRA + Tide	94.4	9.04	-38.002	0.005	8
M8	IMCRA + Bathymetry	94.8	9.45	-36.881	0.004	9
M9	IMCRA	94.4	9.04	-38.002	0.005	8
M10	**Tide+ Bathymetry**	**85.9**	**0.54**	**-39.765**	**0.383**	**3**
M11	Tide	94.4	8.99	-45.085	0.006	2
M12	**Bathymetry**	**85.4**	**0**	**-40.589**	**0.501**	**2**

Table 4.8: Likelihood ratio test comparing the two top models with the greatest influence on the proportion of dugong groups with calves in the NT. Although the tide type was positively associated with the proportion of dugong groups with calves, the probability was only P=0.199. Tide was therefore dropped from the model leaving the final model as Bathymetry.

Likelihood ratio tests of similar top candidate models

Binomial Model Formula	**Model**	**Comparison**	**Df**	**LogL**	**Δdf**	***X^2***	***P***
Bathymetry	1 (M12)		2	-40.589			
Bathymetry + Tide	2 (M10)	2V1	3	-39.765	1	1.6478	0.1993

Table 4.9: Final GLM model term showing bathymetry (representing proportion of a block < 10 m in depth) as the most significant factor (P = <0.0001) associated with the proportion of dugong groups with calves across the NT.

Significance of Terms in Final Model

Binomial model term dropped	**ΔLogL**	**Δdf**	***X^2***	**P**
Bathymetry	7.892	-1	15.784	<0.0001
Final Model Coefficients				
Model Term	Estimate	Estimate S.E.	z value	P
(Intercept)	-3.2996	0.5655	-5.835	<0.0001
Bathymetry	2.7389	0.7516	3.644	**0.000268**

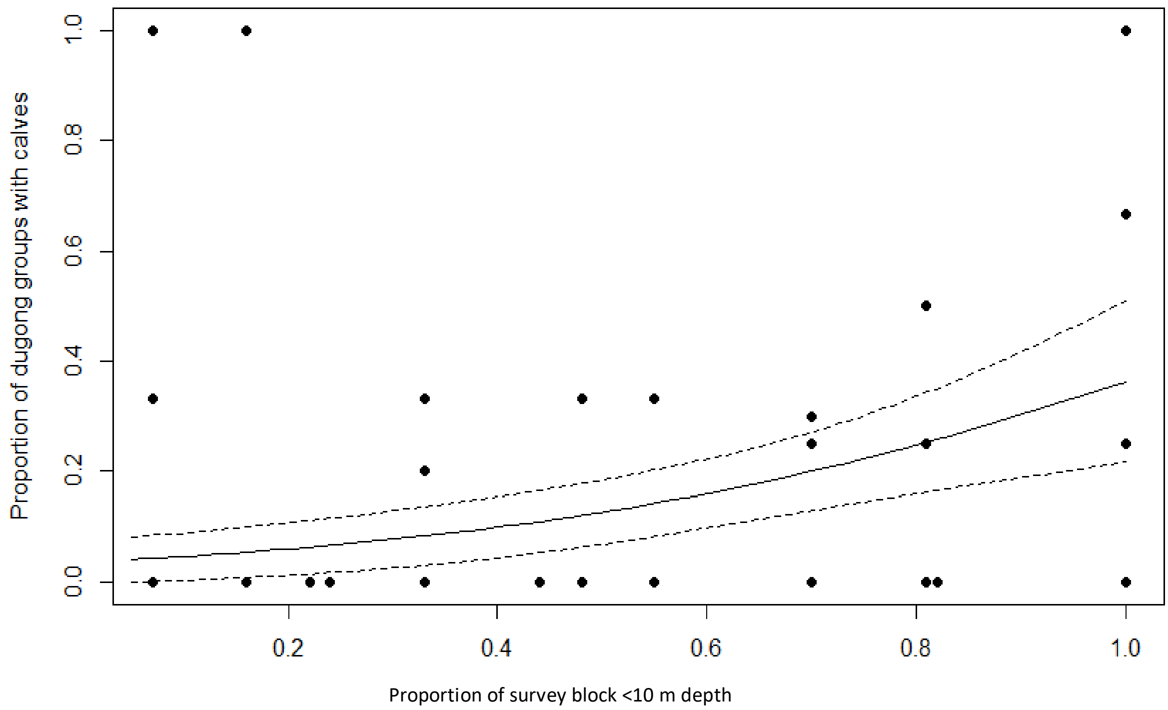


Figure 4.8: Predicted values for the proportion of dugong groups with calves (y axis) per block plotted against the proportion of a block < 10 m depth (bathymetry; x axis). The plot shows a positive relationship with the proportion of dugong groups with calves increasing as a greater proportion of the survey block approaches < 10 m depth. The mean of the predictions is represented by the solid line and the dotted lines represent the 95% confidence interval of predicted values.

Table 4.10: Model selection table investigating the effects of year, block and bathymetry on the proportion of dugong groups with calves in the Gulf of Carpentaria. The most parsimonious model was selected by the lowest AICc value. The model containing the covariate block, was associated with the proportion and distribution of dugong groups with calves. The final model terms are shown in Table 4.11.

Response variable – proportion of dugong groups with calves

Model #	**GLM formula**	**AICc**	**ΔAIC**	**LogL**	**Weight**	**df**
M1	Year * Block + Bathymetry	268.3	8.43	-119.927	0.004	13
M2	Year + Block + Bathymetry	262.3	2.47	-122.687	0.081	8
M3	Year * Bathymetry	264.2	4.38	-127.98	0.031	4
M4	Year * Block	266.2	6.34	-120.061	0.012	12
M5	Block * Bathymetry	261.7	1.84	-123.479	0.111	7
M6	Year + Block	260.4	0.57	-122.845	0.209	7
M7	Year + Bathymetry	262.7	2.9	-128.293	0.065	3
M8	Block + Bathymetry	261.7	1.84	-123.479	0.111	7
M9	Year	276.9	17.06	-136.409	0	2
M10	**Block**	**259.8**	**0**	**-123.65**	**0.279**	**6**
M11	Bathymetry	262	2.13	-128.942	0.096	2
M12	1	275.6	15.8	-136.802	0	1

Table 4.11: Final model terms for the most parsimonious model (with block as a factor) explaining the proportion of dugong groups with calves in the Gulf of Carpentaria. Blocks 1 (Sir Edward Pellew Islands) and 2 (southern Limmen Bight) were highly significant factors in the model. Block 5 (southern half of Blue Mud Bay, extending east to the top of Groote Eylandt) has fewer calves (P=0.0709) compared with the other blocks.

GLM = y ~ Block, binomial

	Estimate	Std Error	Z value	Value Pr(>|z|)
(Intercept) Block 1	1.8181	0.2156	8.432	**<2e-16 *** **
Block 2	1.0137	0.2984	3.397	0.000682
Block 3	-0.3605	0.4817	-0.748	0.454273
Block 4	0.3140	0.4108	0.764	0.444597
Block 5	-1.3600	0.7531	-1.806	0.070962
Block 6	-0.3414	0.4821	-0.708	0.478813

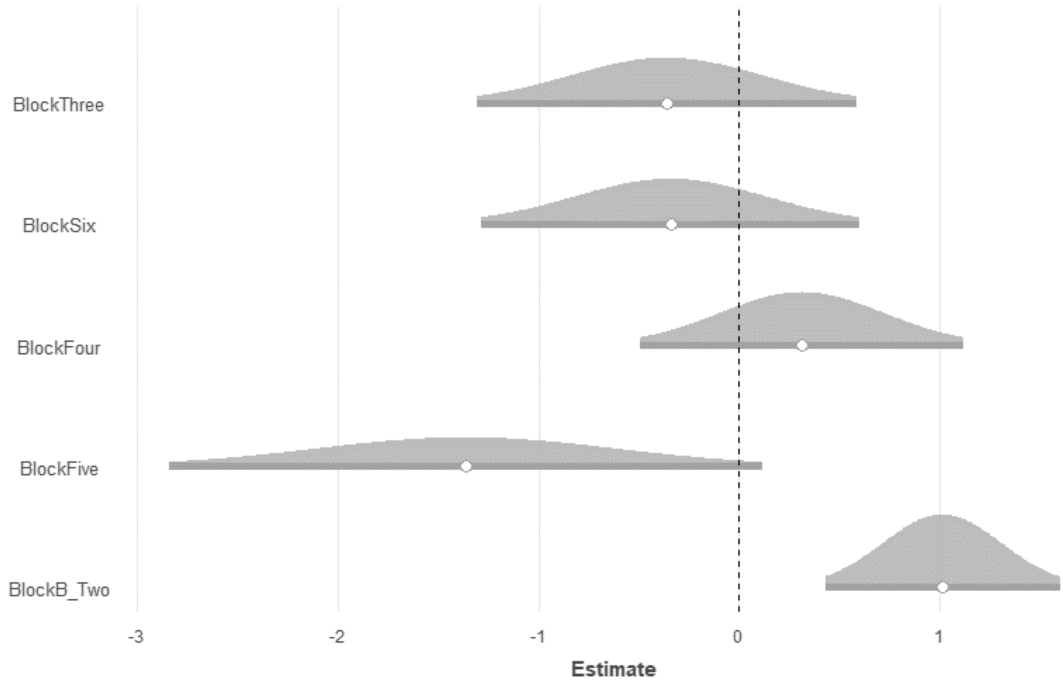


Figure 4.9: Predicted proportion of dugong groups with calves for combined survey years in the Gulf of Carpentaria with their distribution plotted at the block level. The horizontal line is the 95% confidence interval and the vertical dotted line is a scale bar providing a reference for uncertainty and magnitude of effect. The wide distribution in Block 5 suggests a greater level of uncertainty compared with Block 1 for which the confidence interval is relatively narrow. Block locations are in Figure 4.2.

4.5 Discussion

4.5.1 Dugong distribution and abundance across the NT

Across the NT, both dugongs and the proportion of dugong groups with calves were recorded in greater abundance in shallow areas (mostly < 10m). Light availability is one of the major drivers of seagrass growth and distribution worldwide (Dennison 1987, Duarte 1991, Ralph et al. 2007). Because much of the NT coast is shallow and naturally turbid as a result of fine sediment resuspension and coastal runoff (Wolanski and Ridd 1990, Andutta et al. 2019), the opportunities for seagrass viability are limited (Chartrand et al. 2012). The conditions that allow for seagrass growth are not homogenous along the NT coast, a situation that is broadly reflected in the distribution of dugongs and their calves in the shallow coastal environments, particularly in the Gulf of Carpentaria.

The Pellews habitat, as defined by the Integrated Marine and Coastal Regionalisation of Australia (IMCRA) is positively associated with dugong presence while the Arnhem-Wessel IMCRA is negatively associated. This analysis indicated that the Pellews IMCRA is the most important region in the NT for dugongs and their calves. This bioregion is defined as a “coastline of alluvial plains, composed of clays and muds in varying proportions. On these shores, mangroves can be regarded as continuous, extending up to 1 km inshore in parts. Coral reefs are entirely absent. Tidal range increases to a maximum of 3 m” (IMCRA 1998). The low profile of this coastal plain has enabled an expansive seagrass habitat to grow in a relatively sheltered environment (Poiner et al. 1987). The shallow depth distribution of seagrass communities in the Pellews region suggests that dugongs spend little energy diving between the surface and the sea floor when feeding, facilitating efficient energy use (Marsh et al. 2011). The optimal habitat identified in this study has characteristics that are geographically similar to other areas of high value habitat to dugongs (Grech and Marsh 2007). If dugongs are to be conserved in the NT, this region is clearly worth protecting from anthropogenic influences.

In the Gulf of Carpentaria, aerial surveys over multiple years have shown that some survey blocks are consistently important dugong habitats. Block was a factor associated with dugong abundance and the proportion of dugong groups with calves. The high abundance of dugongs in Blocks 1 and 2 (refer to Figure 4.2) in the Sir Edward Pellews region and Limmen Bight regions demonstrates that these areas are “hotspots” for dugongs that could be differentiated further with a finer spatial scale analysis (Sheppard et al. 2006, Grech and Marsh 2007). To improve the evidence base for the conservation management outcomes for dugongs across the NT, the underlying biological and physical processes that form these important areas should be better understood at the appropriate scales so they can be protected (Grech et al. 2011b).

Despite the coarse scale of the analyses, significant change in dugong abundance was observed across years but the aerial surveys suggest that the dugong population in the Gulf of Carpentaria is stable. Consistent themes emerged regarding the association of environmental and spatial covariates with dugong abundance and distribution. Understanding spatial and temporal trends in dugong populations is critical for contextualising anthropogenic impacts and developing sustainable conservation management strategies. Coastal regime shifts in the face of a changing climate are currently a serious concern and appear to be occurring in the Gulf of Carpentaria, see (Duke et al. 2017, Wolanski et al. 2017).

The spatial mismatch between the data available on dugongs and current knowledge of seagrass habitat across the NT limits the assessment of risks to both dugongs and their habitats. Dugongs expand their diet opportunistically in times of nutrient shortages, when seagrass beds are seriously depleted (Marsh and Kwan 2008, Marsh et al. 2011, Sobtzick et al. 2012). Such shortages may occur because of the natural or human-induced loss of seagrass or be due to seasonal or tidal restrictions on access. The loss of more than 1000 km^2 in Hervey Bay in southern QLD in 1992 following two floods and a cyclone, demonstrated that when their food supply fails, individual dugongs variously exhibit one of two functional responses. Dugongs may emigrate from the affected area or remain consuming any remaining seagrass and low-quality food such as algae and postpone breeding or potentially die of starvation (Spain and Heinsohn 1974, Meager and Limpus 2014). The dugongs that stayed in Hervey Bay delayed breeding and/or suffered high calf mortality. Calves observed on aerial survey declined from 22% in 1988 to 2.2% in 1993 and 1.5% in 1994 (Preen and Marsh 1995, Marsh and Corkeron 1997), suggesting that the impacts of habitat loss on fecundity/calf survivorship may last several years (see also Marsh and Kwan 2008).Mortality was recorded in the dugongs that left Hervey Bay (presumably in search of food) (Preen and Marsh 1995). The percentage of calves in Hervey Bay then increased concomitant with the seagrass recovery. In addition to stable population abundance estimates for the Gulf of Carpentaria, stable calf counts reinforce that the dugongs in the Gulf of Carpentaria are a relatively healthy and robust population (Marsh et al. 2011, Fuentes et al. 2016b).

4.5.2 Protecting dugong hotspots

The Gulf of Carpentaria is a hotspot for marine megafauna diversity (Groom et al. 2017a) and the recently developed network of Commonwealth and Territory (Limmen) marine parks will likely afford some protection to multiple species assemblages, functional ecosystems, and exceptional habitat features. Wherever marine spatial planning initiatives proceed in the coastal regions of Northern Australia, dugongs (and other marine megafauna) require special consideration given their movement and feeding ecology (Grech et al. 2011b, refer to Appendix 3) and status as MNES. In the NT coastal Indigenous Protected Areas (IPAs), protection for a large proportion of habitat for some species. Although this protection is not supported with legislation, IPAs can be powerful tools as they engage multiple stakeholders with an interest in the estate. Sustainable solutions are sought to benefit multiple users as required under the IUCN for protected areas (categories 5 and 6). Community-based measures such as restrictions on traditional use are also considered to be more effectively implemented as part of the IPA plan of management as they can be more flexible and accessible to community members.

IPAs have the potential to deliver cost-effective environmental, cultural, social, health and wellbeing and economic benefits to Indigenous communities (Smyth 2015). As well as protecting biodiversity, IPAs can deliver cost-effective environmental, cultural, social, health and wellbeing and economic benefits to Indigenous communities (Smyth 2015). While the IPA concept is still evolving, IPAs can provide surety in placement of (government-managed) protected areas that may improve reserve performance and accommodate habitat features such as seagrass beds that support species such as dugongs. Incorporating some high-density dugong areas in the large-scale marine planning initiatives in the Gulf of Carpentaria should increase the resilience of dugong populations in the region to multiple threatening processes.

The dugong is a culturally significant animal for the Indigenous peoples of the NT (Bradley 1997). The dugong's range is broadly coincident with the distribution of seagrass in the tropical and subtropical Indo-West Pacific (Marsh et al. 2011). The coastal zone and in particular the intertidal zone are areas of high value habitat for dugongs and Aboriginal Traditional Owners in the NT are legally recognised as having exclusive ownership of much of this region (Brennan 2008). Tides restrict dugong foraging in intertidal seagrass meadows daily (Anderson and Birtles 1978, Nietschmann and Nietschmann 1981, Sheppard et al. 2009). In areas where the intertidal area is large such as the NT, the area of intertidal seagrass meadows to which dugongs have limited access is considerable. The high use of intertidal habitat by dugongs (and other significant marine fauna) creates a strong bargaining position for coastal Aboriginal people in the NT to negotiate joint management with the NT fishing industry (Brennan 2008) and other industry that intersects with the coastal zone (refer to *Northern Territory v Arnhem Land Aboriginal Land Trust* (High Court of Australia, Jackson SC, 4 December 2007). The effective conservation management of dugongs in the NT must be inclusive of Aboriginal people's management aspirations. Critical to the effective management of dugongs is the sharing of new knowledge with Aboriginal people, allowing for informed decisions on sustainable use at a community level. Such measures have been successfully developed elsewhere (Grayson 2011, Fuentes and Marsh 2012, Grech et al. 2014) and should be incorporated into coastal management planning, such as IPAs where appropriate and sought by communities.

Information on dugong habitat use is important for identifying areas of conservation significance and, increasingly the diverse value of coastal habitats (Macreadie et al. 2019). The dugong's dependence on seagrass communities has been used to infer hotspots for biodiversity and to inform conservation area prioritisation (Grech and Marsh 2007, Grech and Marsh 2008, Hays et al. 2018). In the absence of recent, broad scale seagrass distribution mapping, dugong presence and bathymetry along the NT coast are likely reasonable correlates of seagrass presence (Hays et al. 2018). With the exception of some historical seagrass surveys in the Gulf (Poiner et al. 1987, Roelofs et al. 2005), knowledge of the distribution of seagrass across the NT is generally poor with no time-series data available outside of Darwin Harbour. Proxy studies for dugong population health such as water quality, feeding trail presence, calf count and seagrass monitoring can contribute to the evidence base that may forecast dugong population increases or declines.

Conservation planning should combine climate scenarios, the current information on dugong distribution in the NT plus the location of threats. This information could be used by the NT government to proactively engage with coastal communities to improve protection outcomes for dugongs and their core habitats. Spatiotemporal information on some anthropogenic activities can be sensitive and difficult to access, such as resource use (i.e. fisheries). Regardless, spatial overlap analyses are valuable tools for evaluating risk and planned or realised management measures (Grech et al. 2011a). Quantitative data on the nature and frequency of dugong interactions with anthropogenic activities is needed (i.e. bycatch, indigenous catch, boat strikes, entanglement in marine debris) to inform this process. Data sharing should be a two-way communication whereby industry can access the analyses outputs to improve environmental performance and improve dugong conservation outcomes. Managers of Sea Country should also have access to such information and be made aware of the existing pressures in the context of their Sea Country planning and management.

Although the maintenance of ecosystem health and function is directed by marine policies, issues of scale need to be investigated to identify species-environment relationships. For example, dugong distribution patterns are likely determined by daily cycles (i.e. diurnal tides) (Sheppard et al. 2009), seasonal events (i.e. monsoon), and climatic cycles (i.e. SOI) (Meager and Limpus 2014, Fuentes et al. 2016b) and episodic events i.e. cyclones (Preen and Marsh 1995). Fuentes et al. (2016b) found a significant negative relationship between the proportion of calves and the SOI, each lagged by two years in the Northern Great Barrier Region (Grayson et al. 2008). It is likely that similar relationships exist for some other regions, including the NT. The relationship between dugong fecundity and the responses of coastal seagrasses to perturbations in water turbidity, sediment deposition and resuspension, are linked to some extreme rainfall events (Preen and Marsh 1995, Larcombe and J. Woolfe 1999, Longstaff and Dennison 1999, Waycott et al. 2009). The dugongs of tropical Australia are clearly prone to episodic low fecundity and in extreme instances high natural mortality (Preen and Marsh 1995, Marsh and Kwan 2008, Marsh et al. 2011, Meager and Limpus 2014) as a result of seagrass dieback some of which are caused by extreme weather events. The intensity of such events is expected to increase with climate change (Foden et al. 2019). With many other pressures affecting dugong populations, the cumulative impact should be explored using multiple lines of enquiry to determine risk to dugongs more accurately.

4.5.3 Environmental Impact Assessment of dugongs in the NT

There are two fundamental messages from this study regarding Environmental Impact Assessment (EIA) and the effect on dugongs in the NT. The first is the importance of the Pellews bioregion, which my analyses confirm as the most important dugong area in the NT. This fact needs to be considered in the approval of further developments in the area that have the potential to directly or indirectly affect dugongs in the Pellews region.

Although only limited research has been conducted on dugong movements in the Gulf of Carpentaria (Udywer et al. 2019), data from tagged dugongs further supports the finding that the habitat around the Pellews region (Yanyuwa IPA) is of high value. The nine tagged dugongs spent many months feeding only within the Yanyuwa IPA, in waters mostly < 3 m deep. (Udywer et al. 2019). In theory, dugong feeding behaviour is considered to follow an optimal foraging strategy, whereby feeding site selection is based on maximum energy gained with minimal energy expended (Aragones et al., 2006; Preen, 1995; Sheppard et al., 2007). This relatively small scale of habitat use can be a risky strategy when living in a region frequently subjected to cyclones. The episodic nature of environmental disturbances such as cyclones in the Gulf of Carpentaria can mean that damage to large areas of seagrass habitat is unavoidable (Preen 1995, Vanderclift et al. 2016). Similarly, coastal industry i.e. dredging, can cause smothering or directly remove important habitat (Erftemeijer and Lewis, R. 2006). In response to such changes, dugongs are likely to move where seagrass habitats persist (Preen & Marsh 1995; Marsh & Kwan 2008, Marsh et al. 2011), and in the case of the Gulf of Carpentaria, this may mean into Queensland and/or Commonwealth waters.

Movements have been recorded across the NT and Queensland Gulf of Carpentaria border by dugong (Sheppard et al. 2006) and marine turtles (Ian Bell, Queensland Department of Environment and Science, personal communication to Rachel Groom 2020). Ensuring that habitats of significance are given the highest level of protection is vital. To achieve this in the Gulf of Carpentaria requires consideration by multiple jurisdictions so not to confound conservation efforts. The Gulf of Carpentaria is of significance to multiple stakeholders such as Indigenous peoples, recreational users, the mining industry and commercial fisheries. Bauxite, manganese, lead and zinc mines and commercial fisheries have operated for decades along the Queensland and Territory coasts without co-management arrangements. Additional projects are proposed for the NT Gulf of Carpentaria (no new projects identified for Queensland as of March 2020) which include an iron ore mine and dam on the Roper River, a manganese mine on Winchelsea Island (off Groote Eylandt) and an aquaculture facility off Groote Eylandt). The multiple existing and proposed projects for the Gulf region lends itself to a strategic impact assessment approach. Despite the Gulf of Carpentaria having a low political powerbase as a result of relatively small, isolated communities (ABS, 2016); the economic value of coastal industries and the environments they dependent on warrant more attention. A strategic assessment would allow cumulative impacts to be appropriately accounted for, particularly in the context of a rapidly changing climate at a relevant regional scale.

In 2015/2016 a significant mangrove dieback event was recorded in the Gulf of Carpentaria (7,400 ha) across the NT and Queensland coasts (Duke et al. 2017). The dieback was attributed to a water balance deficit compounded by record low spring tide levels due and an El Nino sea level drop (Duke et al. 2017). Mangroves have a critical role in the local ecosystem as a nursery for aquatic life, capturing and filtering sediment and stabilising coastal environments. These values have conservatively been estimated at AU$1.7 billion per annum (Lovelock et al. 2015). This event is unlikely to be isolated given that multiple climate drivers will continue to pressure the ecosystems within the Gulf of Carpentaria, and consequently the economic viability of dependent industries, and the environmental sustainability of resources on which coastal communities depend. Impacts from climate drivers i.e. elevated sea surface temperatures, rising sea levels and more intense cyclones on the seagrass habitat and the dugong population are predicted in years to come. Understanding the magnitude and quantified impact on habitats and species in the context of other threatening processes i.e. commercial fishing, Traditional hunting will be vital to informing an adaptive management response.

The Marine Fauna guidelines (Chapter 5) developed for the NT EPA provide the proponent and regulator with tools to conduct an improved impact assessment on dugongs in the NT. These guidelines or similar advice would be beneficial across jurisdictions where listed migratory and listed threatened species are known to occur for a consistent management approach. In addition to the consideration of spatial and temporal constraints, such assessments in coastal NT should engage with Traditional Owner groups with a cultural connection with species and habitats potentially impacted, this has not been conducted well to date. Future assessments should also clearly consider the multiple cumulative impacts operating in the coastal zone (including e-flows and catchment management) and interpret these in scales of relevance to dugongs. The effect of seagrass dieback on dugong populations is known, e.g. movements, mortality of adults and reduced proportion of calves (Marsh et al. 2011, Meager and Limpus 2014, Fuentes et al. 2016b) and requires better management application in practice. By taking a whole of ecosystem approach to impact assessment and mitigation as described in Chapter 5, environmental values connected to dugong population health will be better monitored and managed. This approach is particularly pertinent in the context of an increasingly variable climate where there is a risk to the health and function of this important dugong habitat that needs to be explored and considered in the EIA process.

The second message concerns the statistical difficulty of detecting a significant impact on a marine megafauna population. Despite relatively consistent differences over time in dugong density at the block level in the Gulf of Carpentaria, the power to detect change in the size of a dugong population using aerial surveys such as those described here is limited. The coefficients of variation in dugong aerial surveys are high, even with an optimised survey design and prospective Bayesian power analysis of longitudinal data from the Great Barrier Reef region indicates that these problems are very difficult to overcome even with more intense and more frequent sampling (Marsh et al. 2018). This result highlights the limitation of aerial surveys designed to monitor dugongs at regional scales as a monitoring tool for detecting the local scale impacts of developments. Detecting local-scale impacts in a construction timeframe is near impossible. An aerial monitoring program (i.e. drones) over high-density dugong environments for impact detection is more likely to detect change and may prove feasible. However, such locations are exceptional and under these circumstances, I consider that it would be more useful for a proponent to fund research and proxy studies that inform management of long-term impacts on the site, a topic addressed further in Chapter 6. Such proxy studies could include techniques to mitigate potential impacts on coastal seagrass habitats or restore such habitats (Rezek et al. 2019). The Great Barrier Reef Marine Park Authority's Reef 2050 Integrated Monitoring and Reporting Program report (2018) outlines multiple diagnostic approaches that aim to improve the interpretation of dugong population estimates. These approaches have evolved from decades of surveys that recognise the challenge in detecting population change due to multiple confounding factors. Greater scrutiny and improved EIA of developments in or adjacent to areas providing important habitat for marine megafauna populations is necessary. I developed guidelines for the NT government to address this problem (see Chapter 5).

4.6 Chapter summary

- This study investigates an important conservation problem for a listed migratory species, the dugong. I used broad-scale surveys to study the distribution and relative abundance of the dugong in the NT.
- Although the time series of aerial surveys suggests that dugong abundance is stable in the NT, there remains a high likelihood of a slow decline being undetected given the statistical challenges in determining long-term trends.
- My modelling produced ecologically plausible outputs but does not account for environmental perturbations such as climate change or cyclonic events; and was constrained by the bounds of the study area (not including the Queensland side of the Gulf of Carpentaria).
- EIA is a spatially and temporally constrained process that requires studies of broader and long-term scales to provide an adequate ecological context for risk-based decisions. This study demonstrates the value of broad-scale scale assessments as a fundamental means for informing management approaches to dugong conservation. This topic is discussed further in Chapter 6.

Chapter 5: Technical advisory note for developing marine fauna impact assessment guidelines in the Northern Territory

5.1 Overview

This chapter was developed for the NT government as a guiding document for the NT EPA EIA process. The document thus accords with the objectives of a professional doctoral which is to inform practice.

Stages of EIA vary in their relevance to the user; therefore, this document should be navigated in a pragmatic way. To support this, the reference guide provided in Table 5.1 outlines document sections of most relevance to each user group. For a detailed understanding of the impact assessment process as it relates to marine fauna in the Northern Territory, reference to all sections in this document is advised.[5]

The guidelines *inter alia* aim to inform multiple users of the NT environmental impact assessment (EIA) framework with respect to marine fauna. Marine megafauna are a focus for the guidelines as they are MNES and vulnerable to impacts given their life history parameters and ecology. Many marine megafauna species are protected through conservation listings under Territory or Commonwealth legislation. They are used in this chapter to demonstrate assessment and mitigation that may be required in an EIA.

[5] I developed this material in my professional capacity as an officer of the Northern Territory Government as is appropriate for a Professional Doctorate. Hence, the scope is necessarily broader than marine megafauna per se.

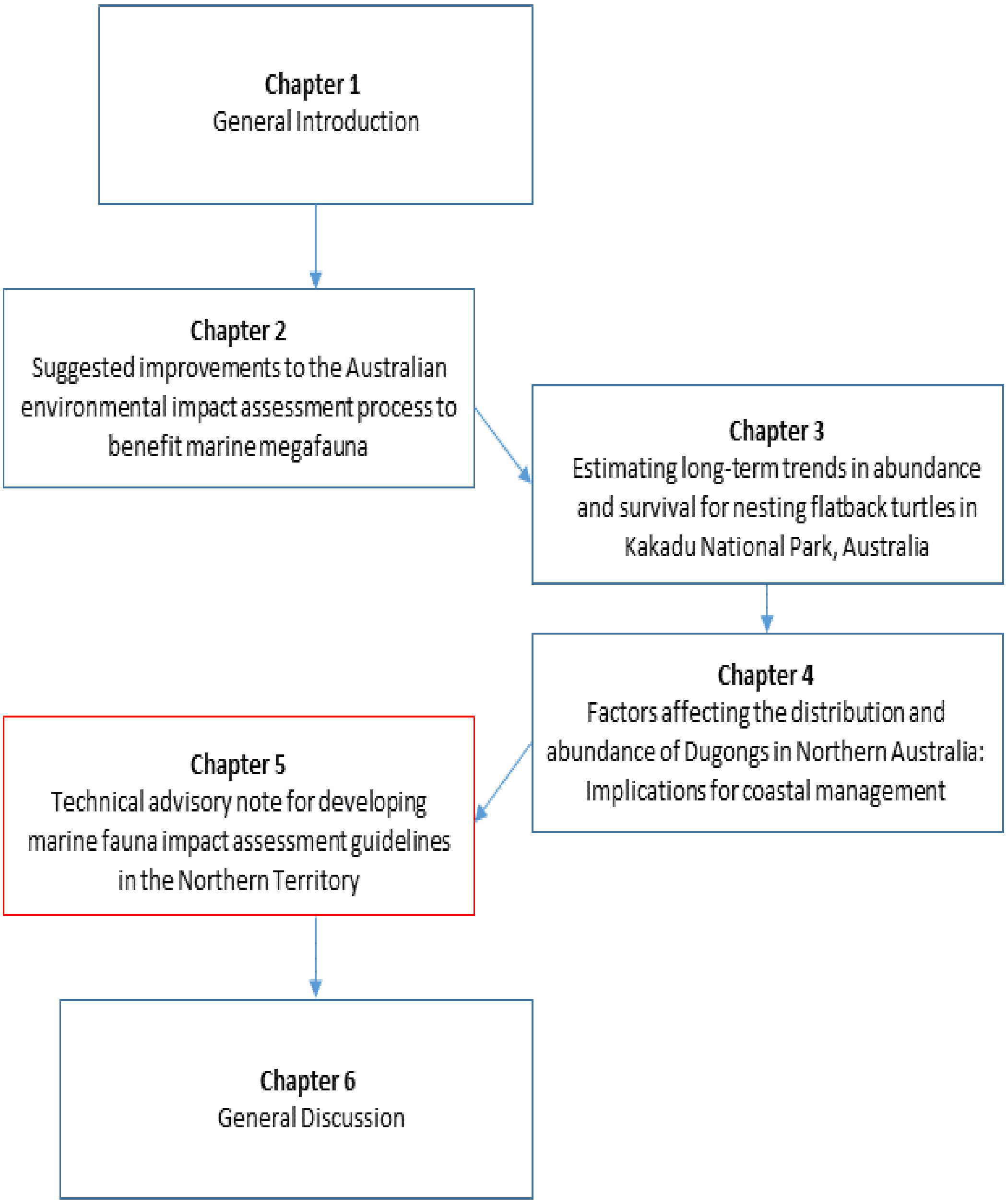

Chapter 1
General Introduction
Chapter 2
Suggested improvements to the Australian environmental impact assessment process to benefit marine megafauna
Chapter 3
Estimating long-term trends in abundance and survival for nesting flatback turtles in Kakadu National Park, Australia
Chapter 4
Factors affecting the distribution and abundance of Dugongs in Northern Australia: Implications for coastal management
Chapter 5
Technical advisory note for developing marine fauna impact assessment guidelines in the Northern Territory
Chapter 6
General Discussion

Table 5.1: Reference guide to document sections for end user relevance

Section	User
Introduction	All end users
Legislative requirements	Regulatory agencies
Marine fauna in the NT	Proponents and environmental practitioners
Marine fauna impact assessment	All end users
Assessing impacts on marine fauna	All end users
Management and mitigation measures	All end users
Implementing best practice impact mitigation	All end users
Referring the activity to the NT EPA	Proponents and environmental practitioners
Appendices (at back of thesis): **1. EIA document checklist** **2. Mitigation and monitoring examples** **3. NT marine fauna overview** **4. Online resources**	All users

5.2 Introduction

The Northern Territory (NT) coast provides habitat for marine fauna species of biological, ecological, cultural, social and economic value. The species (and some habitats) are protected by multiple legislative and regulatory instruments that operate at Territory and Commonwealth levels of governance. How these legislative instruments apply is detailed in **Section 3** of this guideline.

Protection of marine fauna values is considered as part of the Northern Territory environmental impact assessment (EIA) process regarding the *Environmental Assessment Act 1982* (EA Act) and principles of Ecologically Sustainable Development (ESD). The Commonwealth's EPBC Act also considers these principles and within an EIA context, identifies marine fauna values under listings referred to as Matters of National Environmental Significance (MNES).

Central to the meaning of ESD is using, conserving and improving natural resources so that ecological processes on which life depends can continue. The NT Environmental Protection Authority's (EPA) framework of **Environmental Factors and Objectives (Table 5.2)** is designed to encompass the object of ESD and include a mechanism for matters of 'Territory significance' and 'desired environmental outcomes'. These key pieces of legislation must be adhered to for adequate EIA in the Territory regarding marine fauna.

To integrate the principles of ESD whereby conservation of and continuation of ecological processes can be maintained, the NT EPA has identified 13 environmental factors categorised under five themes: Land, Water, Sea, Air and People and Communities. Environmental factors are those parts of the environment that may be impacted by an aspect of a proposal. This approach in identifying environmental factors and objectives to better assess and reduce risk has also been implemented by the Western Australian (WA) EPA. For both jurisdictions (NT and WA), this EIA approach has not required legislative amendment, rather, a new application of the environment assessment law implemented by through discretion of the EPA chair.

Of relevance to the Marine Fauna Guidelines is the '**Sea'** Environmental Theme which includes the Factors and Environmental Objectives outlined in Table 5.2.

To support achieving the environmental objective of Marine Fauna, Marine Fauna Guidelines have been developed. These provide guidance to regulators, proponents, environmental practitioners, stakeholders and the community on the Marine Fauna Factor and Objective, including identification of marine fauna values and potential impacts. These guidelines also provide an outline of the information required for preparing a notification report or statement to enable the NT EPA to decide whether a proposal requires environmental impact assessment under the EA Act. In this regard, the guidelines support, and complement, requirements for an EIS in addition to the draft Terms of Reference provided by the NT EPA. These guidelines also reflect requirements identified for the EPBC bilateral assessment process.

Table 5.2: Factors and Environmental Objectives used in the 'Sea' environmental theme.

Factor	Environmental Objective
Marine Fauna	Maintain the biological diversity and ecological integrity of marine fauna
Benthic Communities and Habitats	Maintain the biological diversity and ecological integrity of benthic communities and habitats
Coastal Processes	Maintain the geophysical and hydrological processes that shape coastal morphology so that the environmental values of the coast are supported
Marine Environmental Quality	Maintain the quality and productivity of water, sediment and biota so that environmental values are supported

The inherent connectivity of Marine Fauna and other 'Sea' Factors necessitates a whole-of-system approach when considering each assessment. These guidelines should, therefore, be read in conjunction with other guidelines relevant to the assessment of activities in the marine environment.

In addition to considering potential impacts on marine fauna, the NT EPA also considers the social and economic impact of the project when making the final decision. Matters such as the cultural significance of marine fauna to Indigenous communities and their potential impacts from the action would also be considered at this point.

If you are uncertain about whether your proposed action requires consideration under the NT EA Act, or if the level of information sufficient for the NT EPA to consider the submission, you should liaise with the NT EPA in the first instance or for more technical details, with DENR. Once a referral has been received, the NT EPA will provide a report to the Minister and the Minister will decide whether assessment under the NT EA Act is required. Each action is examined on a case-by-case basis.

5.2.1 Objectives

These Marine Fauna Guidelines provide regulators, proponents who have an action proposed to occur in the marine and coastal environment and other stakeholders with information and technical guidance on:

- The legislative and regulatory context of EIA as it relates to marine fauna
- Environmental values and significance of marine fauna
- Information requirements often required by the NT EPA in respect of marine fauna
- Activities and pressures that can impact on marine fauna
- Recommended mitigation and management to minimise risk of harm to marine fauna

With this information, the end-user is guided to identify risks to marine fauna and work with regulators to reduce the potential for significant impacts to important marine fauna populations and habitats. NT coastal waters is a belt of water 3-nautical miles seaward of the territorial sea baseline (at lowest astronomical tide). Jurisdiction over the water column and the subjacent seabed is vested in the Territory as if the area formed part of Territory. Aboriginal traditional ownership is recognised over inter-tidal waters in the NT.

5.3 Legislative Requirements

EIA involves assessment and review of multiple matters and a range of Northern Territory and Commonwealth legislation. Frequently applied legislation relating to potential impacts in the marine environment are listed below. The list is indicative of matters that may require assessment though is not exhaustive. As specific needs of each assessment are determined on a project by project basis, proponents and assessors should carefully review projects to determine legislated requirements relevant to projects. How different legislation has informed these guidelines and has relevance to EIA is discussed in sections following to support understanding of what may be relevant to each project.

The issuing of an assessment report by the NT EPA does not infer approval under any other Territory or Commonwealth Acts. Where impacts are likely to occur on vulnerable marine fauna or listed threatened species and their habitats, approval would only be granted via the Minister responsible for administering the *Territory Parks and Wildlife Conservation Act 1976* (TPWC Act) or EPBC Act. Similarly, waste discharge, dredging and other activity-specific approval would only be granted from the appropriate decision-maker signing-off.

The Northern Territory is a party to a Memorandum of Understanding between the Commonwealth and the States and Territories (South Australia has not yet signed) aimed at harmonising the listing of threatened species (and ecological communities) referred to as the common assessment method (CAM) (http://www.environment.gov.au/biodiversity/threatened/publications/mou-cam). The CAM seeks to align listings under the EPBC Act with those of the states and territories. This reform has the potential to affect assessment outcomes based on species listings in the NT (except for species which are not listed by the Commonwealth). The process has not been extended to migratory species that are not listed as threatened and currently only the EPBC Act specifies protection for listed migratory species as MNES. Some EPBC Act listed migratory species are not listed under the TPWC Act i.e. coastal dolphins. An EIA for a project likely to significantly impact NT coastal dolphins will also likely require assessment under the EA Act and the EPBC Act (bilateral agreement). When conducting an EIA, a proponent should check both the EPBC and EA listings to ensure the all the appropriate species listings are applied. It is possible and legitimate for coastal dolphins or dugongs to be listed as threatened in the NT but not by the Commonwealth. However, if they are listed by the Commonwealth, the NT listing must be consistent with the Commonwealth listing under the CAM.

Field surveys and assessments should, therefore, be designed to meet the NT and Commonwealth EIA requirements as appropriate, see:

- https://ntepa.nt.gov.au/environmental-assessments/env-assessment-guidelines
- http://www.environment.gov.au/epbc/publications/significant-impact-guidelines-12-actions-or-impacting-upon-commonwealth-land-and-actions

5.3.1 Northern Territory legislation

The legislation listed has been used in developing these Guidelines:

- *Environmental Assessment Act 1982*
- *Aboriginal Land Act 1978*
- *Planning Act 1999*
- *Water Act 1992*
- *Biological Control Act 2011*
- *Territory Parks and Wildlife Conservation Act 1977*
- *Marine Pollution Act 1999*
- *Waste Management and Pollution Control Act 1998*

5.3.2 Commonwealth legislation

Some proposed actions may additionally require assessment under Commonwealth legislation. In the marine environment, Acts that may directly or indirectly apply to marine fauna and their habitats include:

- *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)*
- *Aboriginal Land Rights (Northern Territory) Act 1976*
- *Native Title Act 1993*
- *Environment Protection (Sea Dumping) Act 1981* (refer to International context)

Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act provides protection for nine MNES and two protected matters. The Australian Environment Minister determines whether an action could have a significant impact on a matter protected under the EPBC Act and whether the action requires assessment and approval. The protected matters include:

- World Heritage properties
- National Heritage Places
- Ramsar wetlands of international importance
- Nationally threatened animal and plant species and ecological communities
- Migratory species
- A water resource, in relation to coal seam gas development and large coal mining development
- Commonwealth Marine Areas
- Commonwealth actions
- The environment on Commonwealth land
- Great Barrier Reef Marine Park
- Nuclear actions (including uranium mines)

Proponents are referred to the Commonwealth's website for comprehensive information on EPBC Act requirements: http://www.environment.gov.au/epbc

Specific information on matters of national environmental significance can be found at: http://www.environment.gov.au/epbc/protect/index.html

Aboriginal Land Rights Act 1976 (Cth)

Many coastal Aboriginal peoples maintain strong cultural links with the coastal environment (also referred to as Sea Country) including marine fauna values. When an action is proposed within Sea Country, consideration of cultural values and how the action may impact these should be evaluated. The *Aboriginal Land Rights (Northern Territory) Act 1976* (Cth) has enabled Aboriginal people to gain inalienable freehold title to almost 90 per cent of the NT coastline (see reference to the Blue Mud Bay case below). Under this Act, decisions over the use of Aboriginal land must have the consent of the traditional owners as a group and ratified by the Land Council (where relevant). Any project proposed on Aboriginal Land requires the engagement of Traditional Owners and should ensure that the nature and the purpose of the project is understood. Additionally, any Aboriginal community or group that may be affected by the proposed action must be consulted and allowed an adequate opportunity to express its view to the relevant Land Council. Aboriginal land in the Northern Land Council area is held as inalienable Aboriginal freehold – the strongest form of title in Australia.

Blue Mud Bay Decision

The *Blue Mud Bay case* held that pursuant to the *Aboriginal Land Rights (Northern Territory) Act 1976* (Cth), land in the intertidal zone (the area between high and low water marks including river mouths and estuaries) in the NT could be claimed and recognised as Aboriginal land. Under the statutory land rights system in the NT (which is distinct from Native Title) Aboriginal land takes the form of inalienable fee simple, which the High Court has confirmed is the practical equivalent of full ownership.

Native Title Act 1993 (Cth)

Most land and coastal sea in the Territory is either Aboriginal freehold, leasehold, or other tenures that exist concurrently with underlying Native Title. Under the *Native Title Act 1993* (Cth) there is a provision for Aboriginal and Torres Strait Islander people to:

- 'Share' the land with other people or parties with an interest in the land

- Provide a right to hunt, conduct ceremony and have a say over what development can occur on the land
- Any proposed action on land or sea with native title should allow for continued cultural use by recognised traditional owners

5.4 Territory and Commonwealth bioregional instruments

5.4.1 Agreements and commitments

The NT government is committed to national policy agreements and specifically commitments to establish a National Representative System of Marine Protected Areas (NRSMPA). The agreements and commitments include:

- Intergovernmental Agreement on the Environment (1992)
- National Strategy for Ecologically Sustainable Development (1992)
- National Strategy for the Conservation of Australia's Biological Diversity (1996)
- Strategic Plan of Action for Establishing the NRSMPAs

5.4.2 Marine protected areas and other managed marine areas in the NT

There are multiple mechanisms in the NT used to spatially manage the marine environment; these are listed in Table 5.3.

Table 5.3: Marine protected areas and other managed marine areas in the NT

MPAs and marine managed areas	**Legislation**	**Primary management goal**
National parks, reserves	*Territory Parks and Wildlife Conservation Act 1977* *Crown Lands Act 1992* *Cobourg Peninsula Aboriginal Land, Sanctuary and Marine Park Act 1981*	Establishment and management of parks and reserves and sustainable utilisation of wildlife. Example: Cobourg Marine Park, Limmen Bight Marine Park
Fisheries closures (e.g. species protection)	*NT Fisheries Act 1988*	Conserve, enhance, protect, utilise and manage aquatic resources and habitats
Aquatic Life Reserves	*NT Fisheries Act 1988*	Conserve, enhance, protect, utilise and manage aquatic resources and habitats
Indigenous Protected Areas (IPAs)	None; Agreement between Traditional Owners and Australian Government	IPAs are governed by the continuing responsibilities of Aboriginal peoples to care for and protect lands and waters for present and future generations
Sacred sites	*NT Aboriginal Sacred Sites Act 1989*	Protection of cultural values, customary practices and interests
Sea closure	*NT Aboriginal Land Act 1978*	Protection of cultural values, customary practices and interests
Heritage place/object	*NT Heritage Act 2011*	Protection of historic and cultural heritage

5.4.3 National parks and reserves

National parks, coastal reserves and other terrestrial conservation reserves afford some level of protection over marine, estuarine and coastal habitats in the NT as declared under the EPBC Act (Kakadu National Park) or NT TPWC Act. These include:

- Kakadu National Park (Commonwealth)
- Coastal reserves (Channel Island, Shoal Bay and Casuarina),
- Coastal national parks (Mary river and Charles Darwin) and
- Conservation area (Tree Point) declared under the TPWC Act.
- Marine parks (Garig Gunak Barlu (Cobourg), Limmen Bight)

5.4.4 Other spatial marine management

There is also a range of spatial marine management mechanisms that contribute to marine conservation such as:

- Sacred sites (declared under the *NT Sacred Sites Act 1989*)
- Sea closures (declared under the *NT Aboriginal Land Act 1992*)
- Fisheries closures (declared under the *NT Fisheries Act 1988*), see Table 5.3.

The *NT Sacred Sites Act 1989* provides Aboriginal traditional owners and managers, through the support of Aboriginal Land Councils, the opportunity to protect both cultural and biological values of seascapes, sacred sites and dreaming tracks associated with marine features (i.e. reefs and islands), and by extension, associated marine life.

5.4.5 Indigenous Protected Areas (IPAs)

An Indigenous Protected Area (IPA) is an area of Indigenous-owned land or sea where traditional Indigenous owners have entered into an agreement with the Australian Government. The primary objective is to promote biodiversity and cultural resource conservation permitting customary sustainable resource use and sharing of benefits. IPAs are established and managed independently of government legislation, consistent with the IUCN protected area definition, which refers to protected area management by 'legal or other effective means'. Although they are not government protected areas, IPAs are supported through partnerships with state and territory agencies, natural resource management bodies, business enterprises and research institutions. Their strength of management is achieved through mutually agreed outcomes with multiple stakeholders. This has the effect of moderating outcomes to meet multiple objectives whilst continuing to deliver to the aspirations of the Traditional Owners. IPAs are however, not protected by legislation. IPAs make up over a third of Australia's National Reserve System (Godden and Cowell 2016). The following coastal IPAs have been declared in the Northern Territory:

- Anindilyakwa IPA
- Dhimurru IPA
- Djelk IPA
- Laynhapuy IPA

- Marri-Jabin, stage one of the Thamarrurr IPA
- Marthakal IPA
- Yanyuwa IPA

5.4.6 Commonwealth marine parks

Australia has a network of marine parks across representative areas of coastline in Commonwealth waters (3-200 nautical miles from the coast). The network of marine protected areas was designed to protect representative examples of the region's ecosystems and biodiversity in accordance with the goals and principles for the establishment of the National Representative System of Marine Protected Areas in Commonwealth waters (ANZECC, 1998). The marine parks are supported by bioregional plans that aim to improve the way decisions are made under the EPBC Act, particularly in relation to marine biodiversity protection and the sustainable use of marine resources by industry (Department of the Environment and Energy 2019). The North Marine region covers Commonwealth waters and seabed of the Arafura and Timor seas and Gulf of Carpentaria from Cape York Peninsula to the NT–Western Australia border. There are five Commonwealth marine parks abutting NT coastal waters and therefore have the potential to be referred under the EPBC Act if an action is likely to have a significant impact on a MNES. The marine parks in the Northern Marine Region include:

- Limmen (with habitat protection zone)
- Wessel (with habitat protection zone)
- Arnhem (special purpose zone)
- Arafura (multiple use zone)
- Joseph Bonaparte Gulf (multiple use zone and special purpose zone)

Natural values of the Northern Marine Region represent examples of the region's marine environments including ecosystems, species and habitats including biologically important areas, for a range of protected species and biologically important areas where aggregations of individuals of a protected species breed, forage or rest during migration (Department of the Environment and Energy 2019).

5.5 International context

The EPBC Act incorporates Australia's international commitments and obligations from the:

- Convention on Biological Diversity
- Convention on Migratory Species
- World Heritage Convention
- Convention on International Trade in Endangered Species of Wild Fauna and Flora
- International Whaling Commission

Additionally, some matters which may impact on marine fauna such as disposal of marine dredging spoil and marine debris are also subject to requirements under the International Convention for the Prevention of Pollution from Ships (MARPOL), to which Australia is a signatory. This convention regards the disposal of substances in international waters and is enacted in Commonwealth waters via the *Environment Protection (Sea Dumping) Act 1981* and accompanying regulations. Proponents must be aware of their obligations regarding the disposal of substances in the marine environment.

5.6 Marine Fauna in the Northern Territory

5.6.1 Overview

The NT coastal and marine environment contains values of national and international significance (Harrison et al. 2009). These values include a diverse marine fauna, extensive coastal and benthic habitats and complex processes that drive these systems. The coastal waters are extensive and encompass seas and major estuaries. The Gulf of Carpentaria covers much of the east coast and is characterised by shallow waters with fringing reefs and seagrass meadows (Poiner et al. 1987, Roelofs et al. 2005). The Arafura Sea covers the north coast and lies over the Sahul Shelf that connected Australia and New Guinea in the last glacial period (Chivas et al. 2001). The Timor Sea covers the west coast and is adjacent to three substantial inlets on the Northern Territory coast: Joseph Bonaparte Gulf, Beagle Gulf and the Van Diemen Gulf. This dynamic coast represents one of the world's most intact marine and coastal environments.

In general, there is a relatively good understanding of the distribution of marine vertebrate fauna within Northern Territory waters but there is a limited understanding of their long-term population trends or drivers of environmental processes. Less is known of the Territory's invertebrate marine fauna and lesser still on the distribution of benthic habitats. The size and remoteness of much of the Territory, combined with a high level of biological diversity and limited knowledge, is a key challenge for assessing environmental impacts to marine fauna in the Northern Territory.

Marine fauna rely on a range of habitats, ecological conditions, physical and bio-chemical properties of the marine and coastal environment during various stages of their life cycles (Gillanders et al. 2011, Kenchington and Hutchings 2018). Many fish and invertebrate species rely on habitats such as seagrass meadows for protection and food resources for juveniles (Henderson et al. 2017). Other species migrate to specific areas to spawn, relying on hydrodynamic conditions and physical properties such as water temperature as signals to prompt aggregation and breeding (Payne et al. 2018). Undertaking development activities within areas that are important for key life cycle stages of fauna and/or during seasonal conditions that overlap with life cycle presence has the potential to significantly impact these species. As a result, avoiding these locations and times is important.

Some marine fauna are recognised as having a high community and cultural value. They are iconic and may also be viewed as environmental health indicators, i.e. mud crabs, turtles, dugong, barramundi and dolphins as they are easily recognisable by most people as responding to changes in the environment. Given their higher public profile, these species may elicit greater assessment requirements and mitigation to alleviate public concern.

Appendix 3 provides an overview of marine fauna found in the Northern Territory marine environment.

5.6.2 Threatened marine fauna

All species of marine fauna are important, forming part of the broader marine and coastal ecosystem, however, some species populations have declined to levels where they are now listed threatened under Territory and Commonwealth legislation (Miller et al. 2018). These species tend to be those that have greater exposure risk or vulnerability to anthropogenic impacts.

Several biological and ecological traits of some marine fauna increase their vulnerability to impacts. Many marine mammals, reptiles and some sharks and rays are long-lived and slow breeding (Lotze et al. 2011). Their preference for coastal habitats places them under the influence of coastal development and activities, which can directly or indirectly impact individuals or sub-populations (Wade 1998, Carneiro 2011, Cagnazzi et al. 2013). Ecological traits that contribute to species vulnerability include:

- Being long-lived and maturing late
- Low fecundity and a low potential rate of population increase
- Adult survival must be high for populations to be maintained

- Preference for shallow coastal water habitats
- High site fidelity and/or philopatry

Generally, the potential for marine fauna to interact with threatening processes such as commercial fishing, light pollution and habitat modification/loss is higher in coastal environments. This may have a compounding effect on existing pressures such as climate related impacts (Booth et al. 2011, Grech et al. 2011a, Kamrowski et al. 2014).

Climate change in coastal environments is occurring at a rapid rate, i.e. 2.6 mm annual sea level rise in Darwin Harbour (McInnes et al. 2015). The scale, rate and nature of the projected change, and the interactions between climate change and other threatening processes, have the potential to overwhelm the capacity of current ecosystems to recover or adapt (Groffman et al. 2006a, Crain et al. 2008, McCauley et al. 2015). When evaluating potential impacts from a proposed development, consideration should always be given to existing pressures and how they are likely to interact and affect the local habitats and subpopulations.

Listed threatened and/or listed migratory marine fauna likely to be found on the proposed development site can be determined from the DENR fauna database and threatened species fact sheets (https://nt.gov.au/environment/animals/threatened-animals), scientific literature and the Commonwealth's protected matters search tool (https://www.environment.gov.au/epbc/protected-matters-search-tool) and Species Profiles and Threats Database (SPRAT).

5.7 Requirements of Marine Fauna Impact Assessment

5.7.1 Marine Fauna EIA Objectives

The objectives of a marine fauna impact assessment require the proponent to present to a regulator, through various lines of evidence:

- Marine fauna values occurring at or adjacent to the site of the proposed activity that may potentially be impacted
- Important populations, or important habitats for listed threatened marine and listed migratory fauna (as listed under the TPWCA and/or EPBC Act) found on or adjacent to the site of the proposed activity
- The local and regional status of marine fauna, include all listed threatened and listed migratory marine fauna

- The conservation significance of a development's impacts on marine fauna including listed threatened and migratory fauna, important sites at local and regional levels.

This information will be required for the NT EPA to determine if the marine fauna objectives of the EIA have been met and the likelihood of a significant impact occurring. Requirements of the EPBC Act and DENR should also be met. The marine fauna objectives reflect guidelines and requirements that are often referred to in species recovery plans, approval documents, mitigation and monitoring.

5.7.2 Ecosystem approach

The functional capacity and resilience of an ecosystem depends on a dynamic relationship within species, among species and between species and their abiotic environment, as well as the physical and chemical interactions within the environment, as stated in the Convention for Biological Diversity Guidelines (2004). It is of fundamental importance that ecosystems are managed within the limits of their functional resilience. Due to their life history traits, marine megafauna species (refer to Appendix 3), are vulnerable to population-level impacts and are generally difficult to monitor. An ecosystem approach considers the connectivity of the environment using multiple surrogate measures to indicate potential population health. For example, environmental health can infer the health status of the dependent species e.g. long-term loss of seagrass may suggest that dugongs may have moved elsewhere, (refer to Table 6.1 for examples of surrogate monitoring for marine megafauna).

Ecosystems are inherently dynamic and change, including species composition and population abundance. They are beset by a complex of uncertainties and management should adapt with such changes (refer to NT EPA Adaptive Management Guidelines). Traditional disturbance regimes may be important for ecosystem structure and functioning and may need to be maintained or restored. To adequately understand the ecosystem functionality, assessment should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.

Proponents should also take account of the environmental conditions that limit natural productivity, ecosystem structure, functioning and diversity when considering environmental management objectives of relevance to a project. The approach should be bound by spatial and temporal scales that are appropriate to the marine fauna EIA objectives and recognise the varying temporal scales and lag-effects that characterise ecosystem processes. The ecosystem approach is a conceptual framework that should underpin the marine fauna assessment.

5.7.3 Information requirements

Desktop assessment

A thorough desktop assessment by proponents will include a review of published scientific knowledge, government documents, grey literature and a review/analysis of appropriate datasets that are relevant to the region affected by the proposed activity. Datasets should include those made available to the public and those in Commonwealth and Territory reports and databases maintained by (but not limited to):

- NT Department of Environment and Natural Resources (DENR)
- Aboriginal Area Protection Authority (AAPA)
- Register of National Heritage Places
- Commonwealth Heritage list
- NT Department of Primary Industries and Resources (DPIR)
- Commonwealth Science and Industrial Research Organisation (CSIRO)
- Australian Fisheries Management Authority (AFMA)
- Australian Marine Mammal Centre (AMMC)
- Department of Environment and Energy (DoEE)
- Geoscience Australia
- Integrated Marine Observing System (IMOS)

In most cases, a written request for data may be required and a discussion with specialists to ensure the most recent data is captured and interpreted correctly. Data may also be requested from Aboriginal ranger groups or Aboriginal Land Councils where available and should be managed in an agreed manner.

Datasets should cover as many years as possible and include several sampling periods throughout the year (assuming biologically relevant) and use peer-reviewed methods. Include where possible genetic boundaries between populations if known.

As all threatened or migratory sub-populations are considered ‘important populations’; any activity that could potentially affect these populations may have a significant impact on the species. Most populations are data deficient and so the precautionary principle should be applied.

If listed marine fauna occurs at the proposed activity site, the proponent may be required to provide information or studies within the following broad topics:

- Description of the listed marine fauna likely to be impacted by the proposal, including identification of habitat and ecological windows for affected species
- Assessment of the values and significance of the marine fauna likely to be impacted at a relevant local, regional and Territory scale
- Identification of the threats and pressures on listed marine fauna from the proposal
- Quantification of the likely direct and indirect impacts to listed marine fauna in terms of the extent, duration and severity, in order to predict the consequent impacts on the ecological integrity of the broader ecosystem
- Modelling of lighting near nesting beaches, underwater noise, contaminated sediments, hydrodynamics and sediment transport are often requested for an EIA to determine likely impacts including delineating areas of potential physical and behavioural impacts (where applicable)
- Consideration of cumulative impacts from other existing and approved developments and local industry (including fisheries) or environmental degradation in order to determine whether the proposed action, in combination with other developments, will significantly impact listed marine fauna or the ecological integrity in the relevant area
- All analysis should be conducted to a standard that is consistent with recognised published guidance where available and reviewed by an independent technical specialist
- Where robust data acquisition or direct observations of listed marine fauna values is spatially and temporally limited for the project, surrogate studies should be used to identify environmental trends of relevance
- Demonstration of how impacts to listed marine fauna and their habitats (i.e. seagrass) have been avoided, managed and/or mitigated

Proponents should be mindful that the assessments should reflect the limitations and assumptions of the information used, as well as understanding the original scope for which the data were collected.

After following these steps, knowledge gaps in the available information should be apparent. If the knowledge gaps are extensive, or there are additional/new key pieces of information required to assess the project’s impact significance, targeted studies are recommended.

Alternatively, where site knowledge of species presence is lacking, instead of field studies, a proponent may choose to assume that listed marine fauna occurs and concentrate on describing appropriate mitigation strategies prior to submitting a referral (or Notice of Intent (NOI). This may only be agreeable to regulators if there is a low likelihood of a significant impact occurring on protected species or their critical habitats. Should the latter scenario be likely, data regarding species and/or habitat use would be expected to inform risk and design of mitigation strategies.

Spatial tools for informing species and habitat distribution

a. Northern Territory spatial tools

The Department of Environment and Natural Resources (DENR) maintains a database (Atlas of Living Australia) and mapping tool with marine fauna records from across the Northern Territory. The data include spatial layers of habitats and records with dates of species sightings and conservation status. Information can be accessed via the DENR website (https://denr.nt.gov.au/) and additionally through the NR Maps NT mapping function (http://nrmaps.nt.gov.au/nrmaps.html). Detailed data for specific sites can be acquired by contacting datarequests.denr@nt.gov.au.

Marine fauna information may also be extracted through the NT Government environment site (https://nt.gov.au/environment/environment-data-maps/environment-data. These data are useful in establishing the likely level of knowledge of the fauna of a site, and in making a preliminary assessment of the threatened and/or migratory species likely to occur (or not) within an area. A less reliable understanding of threatened and/or migratory fauna possibly occurring in an area can be obtained using the Commonwealth's online search tool for Protected Matters. This tool uses predictive modelling rather than presence/absence records.

b. Commonwealth spatial tools

Many species of marine fauna are coastal specialists and important habitat is likely to occur in most coastal waters. A spatial assessment of species distributions, habitats and potential ranges is the first step in determining the likelihood of an impact. The Commonwealth Government has developed a spatial tool for species from state and territory jurisdictions in a database that allows for general queries into the relative importance of regions to a species level. A hierarchy of habitat classes is available and can assist proponents and the NT EPA in assessing the significance of a proposed project's impact for species with Recovery Plans and some other groups of species considered vulnerable in the NT, including:

- Marine turtles
- River sharks
- Dugong
- Coastal dolphins

A hierarchy of habitat classes is based on the importance of the habitat type or geographic location. The hierarchy of habitat classes is outlined below:

Habitat Critical to the Survival of listed threatened marine fauna: is defined as any area within their **extent of occurrence** where local populations are known to exist. The number of such areas is expected to increase with further research and population studies. As information on population locations is poorly understood at present, the precautionary principle applies. Thus, the presence of most listed threatened marine fauna in an area is an appropriate proxy for this criterion. Refer to relevant species Recovery Plans to see Habitat Critical to the Survival.

Biologically Important Areas (BIAs): BIAs have been identified using expert scientific knowledge about species' distribution, abundance and behaviour in the region. BIAs are based on the following:

a. behaviour (feeding, nesting, inter-nesting, migration) occurs in the area;
b. certainty of occurrence (only areas of 'known' or 'likely' occurrence are considered);
c. the level to which species use the BIA;
d. The season(s) during which species use the BIA; and
e. source(s) of the information upon which the BIA is based. The BIA maps are a dynamic tool which allow for up-to-date information to be stored and referenced in a geospatial environment.

In order to identify whether a project is likely to impact on Biologically Important Areas (BIAs) or Habitat Critical to the Survival of marine fauna populations, proponents are expected to use more than one of the following sources of information to make their assessment:

- Relevant peer-reviewed literature which highlight important or critical areas and threatening processes
- Relevant experts with knowledge about values present and where the action is occurring
- Relevant NT and Commonwealth Government authorities, non-government organisations, or researchers with access to current data and knowledge

Proponents should take a precautionary approach if they are unsure about whether the impacts of a proposed action may affect BIAs or Habitat Critical to the Survival of marine fauna. Further details can be found at:

http://www.environment.gov.au/marine/marine-species/bias#BIA_Species_tables

Knowledge from Aboriginal peoples

Incorporating knowledge from Aboriginal peoples is encouraged prior to conducting ecological surveys (Weiss et al. 2012). In most coastal regions, Aboriginal communities will have traditional knowledge of areas where marine fauna inhabit. Many Aboriginal ranger groups have spatial data for their relevant jurisdiction on species and may also have records stored in databases. The use of information from Aboriginal peoples should be managed in a transparent and fair manner, with the intellectual property of those providing it protected where appropriate.

Independent technical review

The application of independent specialist knowledge is a critical component to developing a credible assessment. Engaging recognised specialists and people with experience in the local environment is necessary to provide the most contemporary and relevant information. As part of the rigorous EIA process, an independent specialist should be engaged to review technical studies on and relating to marine fauna to assess, survey adequacy and appropriate interpretation of results.

5.7.4 Targeted surveys

Targeted surveys should aim to fill relevant knowledge gaps regarding species presence/absence, ecological function and spatial and temporal patterns of habitat use and/or behaviour in the region of the proposed action. Many marine fauna species are naturally cryptic, rare or patchy and require specialist survey methods to provide confidence in data records.

Surveys should:

- Be designed and conducted by a suitably qualified person(s) with demonstrated skill and experience in marine fauna surveys
- Ensure survey coverage is representative of the impact site, adjacent areas and all available habitat to marine fauna within the area
- Maximise the probability of detecting the target species through adequate survey design and effort
- Account for detectability, uncertainty and error
- Account for seasonal variability and prevailing weather conditions by conducting studies at different times of the year unless advised otherwise

- Account for repeatability, replication and survey effort
- Be consistent with published techniques

Alternative methods may be required for assessment of species abundance versus presence. Sampling should occur at suitable times of the year and be of an appropriate intensity to obtain estimates of population abundance where the species occur, when required. The adequacy of sampling needs to demonstrate data robustness.

If the action occurs in an area that is data deficient, pre-referral surveys are advised; particularly in areas identified as BIAs, even if populations have not yet been identified. The proponent may also assume presence of important species and habitats and detail strategies to mitigate impacts accordingly. However, as noted earlier, if there is the potential for a significant impact to occur, targeted surveys will be required to assist the decision-making process (more and better-quality information allows for greater confidence in decisions). Information about surveys conducted (or justification why surveys were not conducted) must be provided with a referral or EIS, when submitted.

Additional authorisations and permits will be required for entry into some areas such as parks and reserves, Aboriginal-owned land, controlled waters and Indigenous Protected Areas (IPAs). Activities involving wildlife may also require relevant permits from an Animal Ethics Committee and the appropriate TPWC Act permits to interfere with wildlife for scientific purposes or from other relevant agencies (refer to NT Fisheries Act, EPBC Act).

Assessment of sites of conservation significance

Assessment of the conservation significance of fauna should be based on the observed number of threatened / migratory species present, the regional significance of these observational records, and the population size of the threatened marine megafauna. These data can only be interpreted in relation to known threatened/migratory species distributions/abundances in the locality or region. In many cases, there will be limited information other than that observed at the site. Interpretation must use existing information from the site including supplementing with similar habitats outside the development area in order to develop a suitable comparative basis for the assessment of conservation significance. The precautionary principle will need to be used in interpreting the conservation significance of findings. The conservation significance of aggregations or of sites for marine megafauna can only be assessed based on:

- ecology of marine fauna species involved (to be accessed from the scientific literature)
- pattern of occurrence, abundance and importance of those habitat features to the species in the marine ecosystem

5.8 Assessing Impacts on Marine Fauna

The Environmental Objective for the Marine Fauna Factor involves the protection of marine fauna so that biological diversity and ecological integrity are maintained.

In determining whether a proposed action is likely to have a significant effect on the environment and consequently whether a proposed action that is referred to the NT EPA should be assessed, some of the matters to which the EPA may have regard to include:

- values, sensitivity and quality of the environment which is likely to be impacted
- extent (intensity, duration, magnitude and geographic footprint) of the likely impacts
- consequence of the likely impacts (or change)
- resilience of the environment to cope with the impacts or change
- cumulative impact with other actions
- level of confidence in the prediction of impacts and the success of proposed mitigation
- objects of the EA Act, NT EPA policies, guidelines, and procedures, or other NT environmental acts
- public concern about the likely effect of the proposed action on the environment

Actions that are likely to have a significant effect on NT marine megafauna, even if the proposed action is outside Territory waters, must be referred to the NT EPA before commencing. The object of the *Environment Assessment Act 1982* is to ensure, to the greatest extent practicable, that each matter capable of having a significant effect on the environment, is fully examined and taken into account.

Although not specifically defined in the EA Act, a 'significant effect' is considered in the usual sense of the definition and in the context of ESD when applied to EIA. Five principles of ESD are applied when assessing an action for its potential to have a significant impact:

- Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations (the 'integration principle').
- If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation (the 'precautionary principle').

- The principle of intergenerational equity – that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations (the ‘intergenerational principle’). d) The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making (the ‘biodiversity principle’).
- Improved valuation, pricing and incentive mechanisms i.e. polluter pays, should be promoted (the ‘valuation principle’).

In completing the assessment, proponents should consider how these principles relate to the proposed action and if there is the potential for a significant impact.

For the purposes of EIA, significant impacts to marine megafauna can include:

- mortality or harm of individuals such that there are declines in the population or the range of species
- reductions in populations of species of local and regional importance
- impacts to species or groups of species that fulfil critical ecological functions within the ecosystem
- loss or impact to critical marine megafauna habitat, including habitats such as nesting beaches, nursery areas, specific foraging or breeding areas, and fish spawning aggregation areas
- reduction in species diversity in an area, which may be due to factors such as migration or range contraction resulting from a decline in the quality of the local environment
- introduction and/or spread of invasive marine species or diseases

It is the role of the proponent to provide evidence on the significance of the marine megafauna populations that may be affected by the proposed development. The assessor, or regulator will determine the significance of a population when considering the risks and impacts.

5.8.1 Direct and indirect impacts

There is a range of direct and indirect impacts to the marine environment that can occur through development. Direct impacts on marine fauna occur through direct interaction with an activity (i.e. entrainment in a dredger, vessel strike or entanglement in a net) *or* direct removal of habitat (e.g. seagrass beds) through dredging, construction on or reclamation of the seabed. These impacts can be severe but are often localised and relatively easy to monitor and measure. As such they are amenable to adaptive management actions to avoid and minimise those impacts.

Most indirect effects on marine megafauna result from changing characteristics in the marine and coastal environment and are often produced away from the activity or as a result of a complex impact pathway. Changes can occur as a result of altered chemical and physical properties such as temperature, pH, sedimentation, hydrodynamic processes, and light availability in the water column. Indirect impacts might be temporary, long-term or permanent in nature and occur at different project stages. Such actions may include, but are not limited to:

- increasing levels of marine debris
- facilitating an increase in privately-owned water vessel activity
- fragmenting a marine fauna population
- degrading water quality or habitat values
- chemical run-off or organic waste into coastal systems
- disrupting the breeding cycle of an important population
- facilitating the introduction or establishment of invasive species (such as pigs, dogs or marine invertebrates)
- facilitating the introduction of disease leading to species decline
- interfering with species recovery (refer to Commonwealth recovery plans for marine turtles, threatened whale species, threatened shark species and marine birds)

Underwater noise such as seismic activity is an example of an impact that can be direct and indirect, depending on the marine species and distance from the source (Williams et al. 2015, Carroll et al. 2017, Tibbetts 2018). It can cause direct mortality in some animals (zooplankton and small fish) from sound pressure waves or indirectly impact some species by inducing avoidance, disrupting communication behaviours and reducing prey availability.

One of the most significant indirect impacts is the removal or degradation of habitat (Díaz et al. 2019). A loss of habitat reduces the food resources which will reduce the survival and reproduction within a population. Depending on the species of marine fauna, the impacts will have different consequences and these need to be understood.

Figure 5.2 shows a cause and effect diagram of impact pathways for marine fauna. Drivers identified include overarching causes that can drive environmental change (State of the Environment Committee 2011, Commonwealth of Australia, 2018). Activities, referred to as Pressures, are the change mechanisms that result from Drivers (GBRMPA 2017). One activity is often linked with multiple pressures and one pressure may be linked to multiple activities. For example, indirect pressures affect marine fauna health by causing changes in the status of the seagrass communities. Direct pressures that can cause marine fauna mortality are also stated. As a result of pressures, the ‘state of the environment’ is affected, meaning the physical, chemical and biological conditions of the environment have changed. The extent, duration and intensity of impacts will be specific for each action and each should be addressed in an EIA for review by the NT EPA.

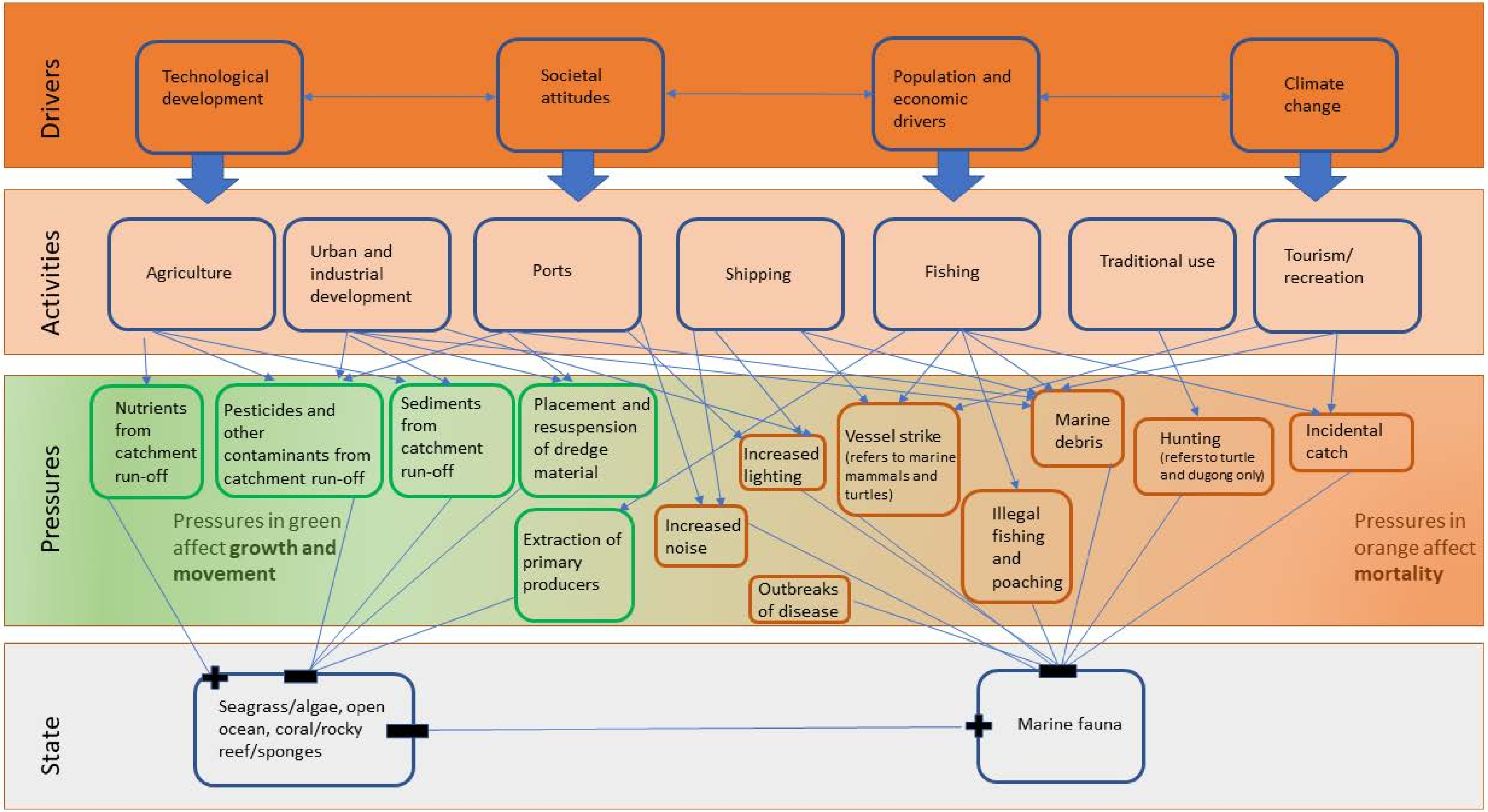


Figure 5.1: Impact pathways for marine fauna showing the relationships among drivers, activities and pressures (adapted from Marsh et al. 2018)

5.8.2 Cumulative impacts

In addition to direct and indirect impacts, cumulative impacts occur as a result of the combined impacts from other activities causing related and often amplified impacts (Crain et al. 2008, Coles et al. 2015). They may arise from the compounding effect of activities co-occurring from a single proposed action or from interactions with other development activities and pressures (Groom et al. 2018). In the NT, potential cumulative interactions include, but are not limited to commercial fishing, climate-related impacts, oil spills, pollution and contaminated run-off and coastal development.

The environmental consequences of climate change such as increased severity of storms and wave energy, elevated sea surface and land-based temperatures, and ocean acidification are predicted to significantly impact marine fauna populations and their habitats (Hoegh-Guldberg and Bruno 2010, Sydeman et al. 2015). Some species will adapt through shifts in diet and extending habitat ranges; particularly when existing at the upper limits of their range however, reduced resilience at the population level is expected as a result of cumulative pressures. The NT EPA will assess all proposed actions in the context of existing impacts. Any impacts resulting from an action are likely to exacerbate changes to biological diversity and ecological integrity.

To adequately consider cumulative impact risk potential, the NT EPA will assess all proposed actions in the context of existing impacts and their potential to be confounded by the proposed action or provide a cumulative pressure onto a system. Any impacts resulting from an action likely to exacerbate changes to biological diversity and ecological integrity must therefore be described to support adequate assessment by the NT EPA.

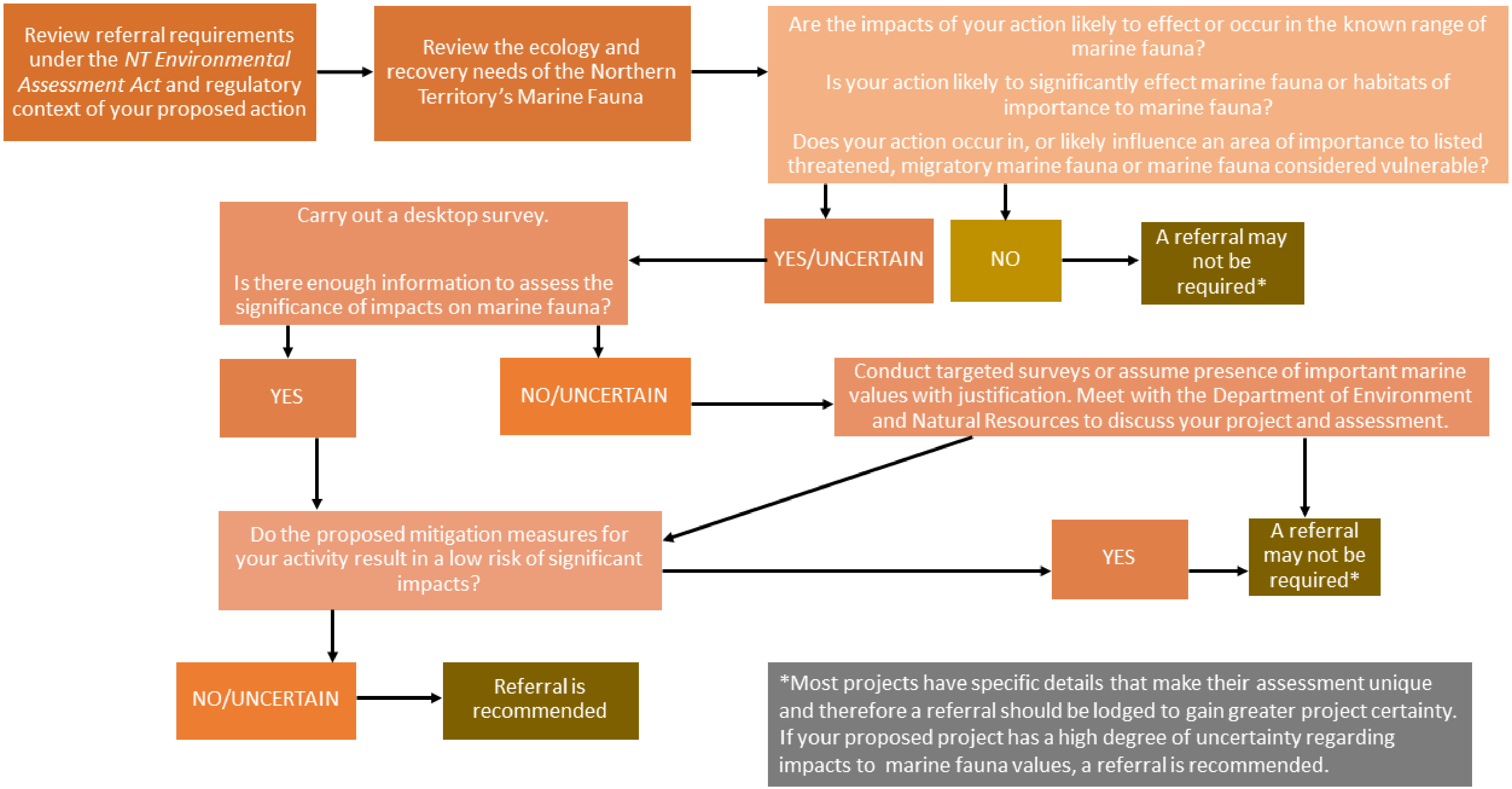


Figure 5.2: Referral decision-making flowchart

5.9 Management and Mitigation Measures

5.9.1 Environmental thresholds

Ecological thresholds have been defined as the breaking points of ecosystems, whereby once passed, the ecosystem may no longer be able to return to its state by means of its inherent resilience (Hughes et al. 2010, Serrao-Neumann et al. 2016). Crossing an ecological threshold often leads to rapid change of ecosystem health. Ecological thresholds represent a non-linearity of the responses in ecological or biological systems to pressures caused by human activities or natural processes.

At a threshold there is an abrupt change in ecosystem quality, property or phenomenon. Thus, small changes in an environmental driver can produce large responses in the ecosystem (Groffman et al. 2006b). These kinds of dramatic shifts have been documented for many systems, from rapid eutrophication of coastal waters to structural changes in fish communities. Some of the mechanisms underlying regime shifts are reasonably well known. For instance, the loss of plant communities on the seafloor can be attributed to increasing nutrient concentrations that stimulate the growth of phytoplankton and epiphytic algae, and their expansion in turn shades seagrasses and macro algae (Krause-Jensen et al. 2008).

Thresholds can be detected at different spatial, temporal or functional scales. Analyses of thresholds should recognise the possibility of interacting ecological thresholds at different scales. Threshold levels (or "tipping points") are quantitative critical values which, if crossed, could generate serious or socially unacceptable environmental change and/or irreversible consequences (Serrao-Neumann et al. 2016). Thus, baseline information on the marine environment likely to be impacted by a proposed action is important to understand natural variability as well as for determining conservative threshold values.

5.9.2 Adaptive management

An ecosystem approach utilises adaptive management in order to anticipate and respond to changes. This is a structured, iterative process of robust decision-making applied to reduce uncertainty over time through system monitoring (Vugteveen et al. 2015). In doing so, decision-making concurrently meets one or more management objectives and collects information required to improve management. Adaptive management is a tool used to effect change and learn about a system (Fuentes et al. 2016a, Serrao-Neumann et al. 2016, Van den Brink et al. 2016). It can be challenging to find a balance between gaining system knowledge for improved management and defining the best short-term outcome based on current knowledge. This should be met with caution as making a decision may exclude some effective management.

5.10 Implementing Best Practice Impact Mitigation

When designing the proposed action, avoiding impacts on listed marine megafauna should be the primary aim. Alternatives should be considered wherever possible to avoid significant impacts and any residual impact should be subject to mitigation strategies and potentially environmental offsets as per NT and/or Commonwealth policies.

Effective mitigation measures will reduce the degree of impact from an action and when designed suitably, marine megafauna will be buffered from potential cumulative impact risks. It is often appropriate for impact mitigation and a monitoring program to be designed successively in a manner that allows for adaptive management. Management of cumulative net loss/impacts should be considered within the monitoring and mitigation program to provide the greatest benefit to marine megafauna and address ESD principles.

The tables in Appendix 1 outline the main pressures on marine megafauna and some suggested mitigation measures. They are not intended to be exhaustive or prescriptive but include the most prevalent impacts associated with marine projects, including:

- physical damage to habitats
- increased lighting
- increased sedimentation
- degraded water quality
- increased vessel activity
- increased underwater noise
- increased marine debris

As new environmental and species information becomes available, and as technology advances, improved mitigation measures will develop. Proponents should actively seek to include mitigation measures that are considered leading practice at the time of the proposed action. By including performance targets like those provided in Appendix 2, projects should be designed such that mitigation measures support impact management to an acceptable outcome. Appendix 2 provides examples of mitigation and monitoring that can reduce impacts.

5.11 Referring the activity to the NT EPA

It is the responsibility of the proponent proposing the action to decide whether the action should be referred. If it is supposed that the action is a high risk of having a significant impact on listed marine megafauna, the action should be referred to the NT EPA. If it is uncertain whether the proposed action will have a significant impact on listed marine megafauna, the proponent should also refer. Where a lack of data exists, proponents should adopt a precautionary approach and refer.

The tables in Appendix 1 contain examples of thresholds to marine fauna which indicate when a proposed action should be referred. These tables are a prompt and not considered to be exhaustive or prescriptive.

5.11.1 Survey information to accompany a Notice of Intent

If desktop or targeted field surveys identify the presence of one or more species of listed marine fauna, the following information should be provided in the Notice of Intent:

- details and maps of the survey area/s
- information about the existing environment
- maps detailing the extent of key habitat, also showing the extent of habitat that may be lost or degraded due to the proposed action
- explanation of the survey methods chosen and why (e.g.: desktop, aerial and boat survey etc.)
- survey results and discussion of results
- details on survey effort and timing
- discussion of detectability and statistical confidence in survey results

Where there is the potential for a significant impact to marine megafauna, the proponent should demonstrate where avoidance measures have been used, where impacts have been minimised to as low as reasonably possible and why site selection is justified in terms of risk to marine fauna values. Impacts to marine megafauna should be described in detail, and where required, mitigation measures implemented to reduce impacts.

For further information on the referral process you should consult the following guide 'Referring a Proposal to the NT EPA':

https://ntepa.nt.gov.au/__data/assets/pdf_file/0011/570872/guideline_referring_proposal_to_ntepa.pdf

Links to relevant websites and online resources are provided in Appendix 4.

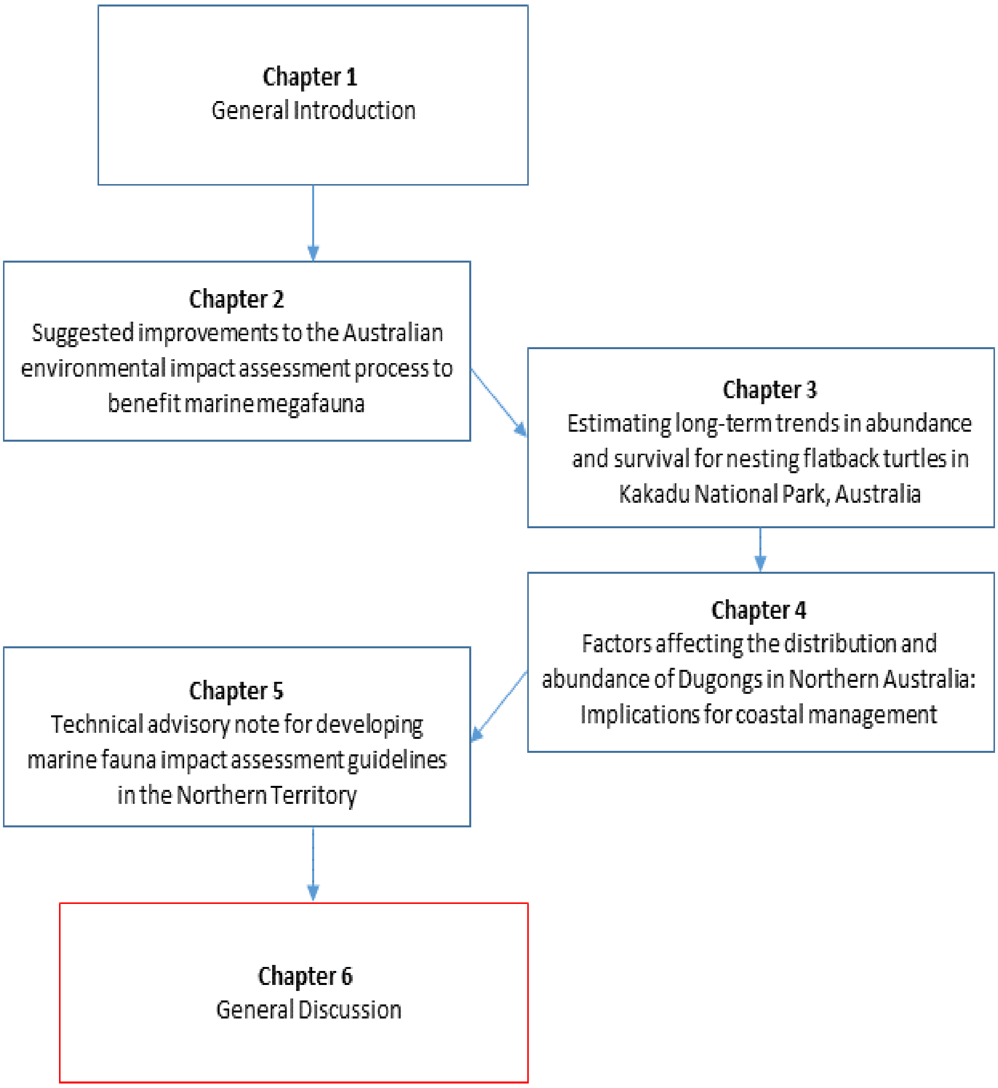
5.12 Chapter summary

- These Marine Fauna Guidelines were drafted as part of the NT environmental reform process and had to conform to the requirements of that process. As one of several factors listed within the NT EPA's environmental values framework for which such guidelines will be developed, this document provides proponents with a consistent and rigorous approach to conducting EIA where listed marine megafauna is potentially impacted.
- This document incorporates some of the relevant findings from previous chapters of this thesis including outlining the temporal and spatial limitations of assessing marine megafauna populations and using surrogate measures where appropriate to supplement knowledge gaps and improve the EIA.
- These guidelines are specific to the NT though they demonstrate the value in a reference document for proponents on values with complex management and ecology that could similarly be applied in other jurisdictions.
- Although not prescriptive, the guidelines are of sufficient scope to guide the appropriate lines of enquiry expected of proponents in EIA relating to listed marine megafauna.
- All appendices to the Guidelines are at the end of this thesis.

Chapter 6: General Discussion

6.1 Overview

In this chapter, I provide a summary of the outcomes of this thesis and their implications to the environmental impact assessment (EIA) and management of marine megafauna in northern Australia. I discuss how a combined shift in EIA policy and focused research are necessary for improving the assessment of impacts and providing better conversation outcomes for marine megafauna in an EIA context.



6.2 Contribution to practice

According to the Australian Qualifications Framework (https://www.aqf.edu.au/sites/aqf/files/aqf-2nd-edition-january-2013.pdf), a professional doctorate must make a significant and original contribution to knowledge in the context of professional practice. My thesis explored the professional practice of Environmental Impact Assessment (EIA) in Australia's coastal marine environment from the perspective of marine megafauna, a topic deemed appropriate for a professional doctorate in Tropical Environmental Management by JCU. My investigation identified shortcomings in EIA processes regarding marine megafauna and solutions that would improve project assessment, monitoring and mitigation to achieve better conservation outcomes.

The policy, biological and practice impediments that I identified illustrate the need for a new way of thinking about EIA for an adequate assessment to be achieved. The EIA system is most vulnerable when there is considerable uncertainty in the evidence base, especially when this deficiency is not acknowledged. My EIA case studies and chapters on long-term flatback turtle and dugong population abundance (Chapters 2-4) illustrate the multiple confounding factors hindering the ability to detect a significant impact on marine megafauna populations caused by a local scale development, unless the impact is catastrophic and/or direct and underpin my recommendation that a whole of system investigation is needed. Investment in research to contextualise the uncertainty around impacts to marine megafauna and better understand their ecological dependency on habitats is critical to EIA supporting conservation outcomes given the low likelihood of detecting a significant impact. Robust data and surrogate indices should be collected and integrated wherever possible to understand the ecology of marine megafauna and their response to environmental change.

Accordingly, I have contributed to EIA practice in the NT by addressing the impediments in the policy, biological and practice components of EIA through this thesis. My research included a desktop study of the scientific and governance literature in Chapter 2. The resulting research identifies regulatory deficiencies, some of which have since been remedied within the NT environmental legislative reform process. The contribution of this work is evidenced by the current use of this article as core reading material for a Charles Darwin University environmental law subject. More broadly, this article makes an understanding of Matters of National Environmental Significance (MNES) within an EIA framework more accessible and the implications of a policy and science disconnect more apparent.

My analysis of long-term population data for flatback turtles and dugongs and broad-scale data for dugongs illustrates the broad-scale temporal (flatbacks) and spatial (dugongs) variation in the distribution and abundance of these species in the NT. Findings illustrate the potential value to the EIA process of biological research at long temporal and large spatial scales. Such information is pertinent to the conduct of baseline surveys of marine megafauna and interpreting the findings within the limited temporal and spatial context of a development. These population analyses have contributed to better understanding marine megafauna populations along the NT coast, enabling more informed risk assessments and coastal planning.

Collectively, my research provides clarity to regulators and proponents regarding the treatment of marine megafauna in the EIA process in the NT. The guidelines I developed for the NT government include recommendations on minimum assessment requirements, the adoption of which will improve the rigour and consistency of EIAs in the NT; a small but important step in the right direction for improving conservation outcomes for marine megafauna. An ecosystem approach and an adaptive management framework will allow the NT EIA process to continually develop and improve. I discuss my findings in the context of each of the objectives of my research below.

Objective 1: Investigate the capacity of environmental impact assessment (EIA) to adequately identify and manage risks to marine megafauna

While Commonwealth and NT legislation incorporate the principles of Ecological Sustainable Development (ESD), the application of these principles in an EIA process is inevitably constrained. EIA is a governance tool used to account for and manage the impacts of development, a platform for conflict between the values of scientists, industry and government regulators (Brugnach and Ingram 2012, Cvitanovic et al. 2015). The EIA process is constrained by time, data and resources – all critical factors affecting informed decision-making. Identifying opportunities for process improvement is important given that large developments have the potential to exacerbate species decline through direct mortality, and habitat loss and degradation. The pressures that affect Australia's marine megafauna are generally known; however, the impact of these pressures is mostly not quantified (or published).

The effective function of the NT EIA process is dependent upon the availability of robust ecological knowledge at multiple scales to inform potential impacts to marine megafauna and their respective habitats. Projects being assessed by EIA in the NT examine potential impacts principally within the immediate footprint of the development without considering how the project may trigger an impact beyond this footprint or how drivers beyond the project may influence the biodiversity values being monitored within the footprint. Consequently, there is a high likelihood that the goal of achieving ecologically sustainable development will not be fully understood or met. Further, applying the precautionary principle by assuming species presence in the absence of knowledge, limits a true understanding of site-based direct and indirect risks of harm. An EIA should seek to identify what species are at genuine risk of impact, identify options to avoid impacts, and target the most appropriate management controls most appropriate to mitigate the risks. Some marine megafauna are listed as migratory without appropriate recovery advice being in place. Under the EPBC Act, Commonwealth agencies must have regard to conservation advices (threatened species) or wildlife conservation plans (listed migratory species). The bar is higher for recovery plans; the Minister must not act inconsistently with a recovery plan. Conservation advices must be prepared for all EPBC-listed threatened species; the Minister may choose to make a recovery plan (threatened species) or a wildlife conservation plan (migratory species) and not all listed migratory species have a wildlife conservation plan in place e.g. coastal dolphins and dugongs. When such plans or advices are not in place or outdated, the listed species, particularly listed migratory species, are at risk of being overlooked in EIA.

The non-negotiable factors constraining an EIA are time and the development's spatial footprint/area of influence. Appreciating that the time available to proponents within an EIA to monitor the surrounding environment is unlikely to change and will always be limited, more extensive datasets are needed to contextualise the critical information needs of an EIA. Longitudinal and broad-scale data can be evaluated alongside local-scale data from developments to provide a broader and relevant information base for risk assessment. Thus, investment in a strategic approach to data collection is required by governments to determine longer-term information needs for EIA and to insure against impacts to significant populations of marine megafauna.

The three case studies from tropical Australia that I considered in Chapter 2 illustrate the spectrum of variability in a proponent's commitment to rigour in EIA. At the lower end of the spectrum, a case from the NT represents a poorly conducted EIA, the other two examples from Queensland were included to provide a range of examples. One of these cases is at the other end of the spectrum, an early example of a cumulative impact assessment (CIA) in Australia. This voluntary CIA involved collaboration between several proponents at Abbot Point, within the Great Barrier Reef World Heritage Area and adjacent to the Great Barrier Reef Marine Park (GBRMP). The proponents had a shared investment in understanding the local marine environment and sought an independent technical review of their proposal to gain objectivity and engender greater confidence from regulators and the public. The CIA is a relatively sophisticated example of a strategic approach by proponents to manage the EIA process in a shared spatial development footprint. This approach was undoubtedly motivated, at least in part, by the high degree of regulatory and public scrutiny afforded to Abbot Point because it is within the GBRWHA (a MNES) with a dedicated management authority (GBRMPA) resourced to assess developments. This case study not only illustrates how the EIA process has matured over time in at least one jurisdiction, but also demonstrates the considerable variability in practice.

The capacity for proponents to manage a CIA or deliver a scientifically rigorous EIA is in part, attributable to them having a long operational history in industry, greater investment in environmental conduct and disclosure to shareholders (Grossman 2005, Lu and Abeysekera 2014). Some companies commit to the principles of ESD and support an improved EIA process to improve their image among investors. Such companies are unlikely to commit beyond what is required and will seek to maintain a competitive advantage. Therefore, stronger leadership from government regulators is required to establish minimum standards i.e. data pooling and cooperation. Co-operation between well-established proponents, who have the resources and long-term expertise to commit to rigorous scientific studies, will then be positioned to guide less experienced proponents.

In many cases (Chapter 2), the approval conditions do not require the data from the proponent's information/monitoring to be available publicly, despite regulators being within their rights to require this through approval conditions. The Western Australian government has made data availability a compulsory approval condition and, as part of the environmental reform process; the NT also intends to implement this requirement. The EPBC Act is currently being reviewed independently and given the change practice by some other jurisdictions, a similar recommendation may be made for the Commonwealth by the Review Panel.

Objective 2: Address knowledge gaps and acknowledge limitations of marine megafauna in an EIA framework to facilitate a multiple lines of evidence approach to determine impacts and improve management.

Species-environment relationships are complex and dynamic. Marine megafauna and the habitats they depend on, respond to multiple seasonal, climatic, circadian and anthropogenic drivers (Mazaris et al. 2009, Marsh et al. 2011). The capacity of direct monitoring of marine megafauna to assess the impact of development *per se* is constrained by time and multiple other factors external to the development. If species-environment relationships are not understood, the potential for erroneous impact prediction and therefore flawed impact management is high. For example, a proposed port site surveyed on only one occasion to identify marine environmental values will misrepresent the ecological value of a site if sampled in the months following a cyclone where habitat would be degraded, and multiple species may have been displaced or died. This altered state would be a poor baseline on which to base environmental assumptions as species dependent on this habitat such as green turtles and dugongs respond to significant environmental change in variable ways (Preen and Marsh 1995, Marsh and Kwan 2008, Hawkes et al. 2009, Meager and Limpus 2014, Fuentes et al. 2016b). The application of environmental lag effects is demonstrated in Chapters 3 and 4 where they were applied to the flatback turtle and dugong population data respectively. Interpreting lag effects on populations is only possible with long-term data on species, habitats and climate.

To improve marine megafauna conservation outcomes in an EIA context, research needs to meet the critical information gaps of marine resource managers and allow for knowledge transfer between stakeholders. Chapters 3 and 4 illustrate the value of using long-term and broad-scale data to contextualise the local environment of a development. This concept is also articulated in the marine fauna guidelines in Chapter 5 where an ecosystem approach to EIA is advised. An ecosystem approach to EIA necessitates in-depth knowledge of the functional marine environment. Without site-specific data on habitats, species presence and an understanding of habitat use and ecosystem drivers, risk to marine megafauna populations cannot be adequately defined and therefore management controls to megafauna populations or their critical habitats are also likely to be inadequate.

Findings from this research suggest that the NT regulator should alter the current strategies for requesting and assessing the knowledge of marine megafauna likely to be impacted by a project. The ambiguity in the legislation regarding the treatment of significant impacts to MNES is compounded by the challenging task of gathering robust information on these species. Given that project studies tend to focus on relatively small spatial footprints (far smaller than the habitat range of most marine megafauna), the capacity for proponent led projects to interpret impacts on marine megafauna at an ecologically relevant scale is limited.

My findings, detailed in Chapters 2, 3 and 4, identify the importance of studies that build knowledge regarding fundamental ecosystem processes directly linked to the health of marine megafauna. Detailed understanding of the connectivity between marine megafauna population health and habitat condition is key for adequate risk mitigation. It is therefore relevant for proponents to direct resources into research on relevant proxy indicators of marine megafauna health. These would include benthic primary producer habitat (seagrass, coral, algae) health, prey species and water quality to gain insights into the relationships between habitat condition and marine megafauna population health. Importantly, this approach could identify when non-project related drivers are placing species or habitats under pressure masking any effect of the development. Without a site-specific context, generic controls are used. This approach does little to achieve the intent of EIA or ESD.

Areas of important habitat to marine megafauna are not homogenous across the seascape (Sequeira et al. 2018). Foraging specialisation or habitat fidelity are two functions that can compromise a species' ability to persist in altered habitats. Therefore, maintaining habitat integrity and quality is likely to be of greater conservation value than directly monitoring key species for changes in abundance. The design of programs that improve understanding of species and habitats (with rigorous science) rather than species directly, is advised. Variation in habitat use by species will in some cases require species-specific mitigation. For the dugong, as observed in the Gulf of Carpentaria, the value of protecting specific habitat areas can have a relatively significant effect on maintaining population health given the high value of local habitats as feeding and nursery areas. Shifting the emphasis of project studies away from understanding impacts on species, to a focus that improves our understanding of species-environment relationships has broader application. Such studies would largely contribute to understanding multiple scales of drivers and pressures across the marine ecosystems, informing EIA and project conditioning to mitigate risk. Effective mitigation would be enhanced by an accessible database. As recommended in Chapter 2 and discussed above, regulators requiring project data to be publicly available by (through ToR or project conditioning) should improve the assessment and management of project impacts.

Objective 3: Provide guidance to regulators and proponents on leading practice marine megafauna assessments for consistency in industry practice based on scientific rigour.

The quality of evidence underpinning decision-making in EIA is often questioned because inadequate or incomplete evidence inhibits policy formulation and the implementation of effective management. My review of EIAs in Chapter 2 highlighted numerous process flaws and subsequently provided recommendations for improvement. In some cases, these recommendations have been implemented i.e. included within the environmental law reform process in the NT. However, in most instances it is more likely that unless they form part of a policy framework within the regulatory agency responsible for EIA, implementation will not occur. Bridging the gap between science and industry practice is necessary to improve EIA, monitoring and mitigation. The application of rigorous study design, methodology, analysis, interpretation, and reporting remains variable between projects. In response to these deficiencies, I have proposed guidelines for the NT EPA (Chapter 5) to address issues arising from inconsistency in assessment approach. These guidelines also provide a common foundation for proponents to seek information regarding the EIA process in the NT.

The increasing demand for more rigorous EIAs is undermined by the lack of confidence in the proponent's data. Whilst the CIA proponents in the Abbot Point study underwrote external verification of their data, there are no generally accepted auditing standards for the reporting or review of EIAs and project data has not been required to be publicly available. The reformed environmental management framework in the NT requires the development of guidelines for 13 environmental factors nested within five environmental themes: Land, Water, Sea, Air and People and Communities and will require proponents to make their data publicly accessible. The marine fauna guidelines (Chapter 5) represent the first example and will be used as a tool by the NT EPA to communicate regulatory expectations and provide consistency for regulators, environmental practitioners and proponents.

These guidelines (Chapter 5) should reduce the uncertainty around how to conduct rigorous EIA studies for listed marine threatened or listed migratory marine species in the NT. The guidelines outline the recommended process with enough background information to allow industry to adopt and achieve consistency and rigor despite the variation in factors such as location, existing information, season and potential project impacts. As discussed above, EIA Terms of Reference and approval conditions more frequently require project data to be made public. Accessible environmental data from government and proponents alike is fundamental to improving decision-making on project risks, monitoring, mitigation and future data needs. Additionally, an independent expert review, the need for which was identified in Chapter 2 has been incorporated into these guidelines as a means of increasing the likelihood of rigorous assessment.

Nonetheless, the constrained spatial and temporal bounds of an EIA limit the application of new and robust data, thus, alternative means of collecting prescribed data on marine megafauna are necessary. Although not often used, the EPBC Act provides scope for the Commonwealth regulator to request studies that address strategic information needs of marine megafauna when a project approval is being conditioned. Even though the project has been approved by this stage, the conditions provide a strategic opportunity for information needs to be addressed; particularly in areas of f high conservation value for marine megafauna that are subject to ongoing impacts or multiple future developments. Part 9 of the EPBC Act describes how the Minister must decide on project approval and conditions. Section 134 outlines the types of conditions that the Minister may attach and consider, including any conditions that have been imposed, or are considered likely to be imposed, by a state or territory or under another law of the Commonwealth. Ministerial determination of project approval conditions provides an opportunity to improve the knowledge base for marine megafauna in an EIA. Implementing robust project conditions is an appropriate avenue for establishing improved conservation outcomes.

6.3 Directions for future research

My research has identified avenues for future research that support a process of continual improvement within the existing EIA framework and should be applicable in the NT and perhaps more generically. Examples of future research are outlined in Table 6.1 and are broadly categorised as: Species-specific, Applied and Proxy, and EIA and Management. This table only considers research of direct relevance to EIA and does not consider other impacts on marine megafauna e.g. predation, fisheries interactions or marine debris, however, these are also necessary to consider when assessing population and habitat impacts.

For consistency with bilateral assessment functions, the approach should be founded on a bilateral strategic vision of research priorities that inform the long-term conservation management goals of marine megafauna. Government agencies should recognise the limitations of marine megafauna assessments within EIA timeframes, underwrite research that allows for the broader interpretation of marine megafauna ecology, especially for ecological hot spots or high value habitats within a jurisdiction, which should be avoided if possible.

If such '"hotspots" cannot be avoided (e.g. mouth of the McArthur River in the Pellew region in the NT, Chapter 4), it would be valuable for governments to develop plans for the region so that regulators and proponents can identify the studies required to provide a context for EIA and consider how studies conducted in an association with an EIA can provide supplementary evidence. Figure 6.1 summarises the conceptual flow of this process and includes opportunities for targeted research to be funded through environmental offset agreements or project approval conditions. Examples of Government-led and proponent-led studies are in Table 6.1.

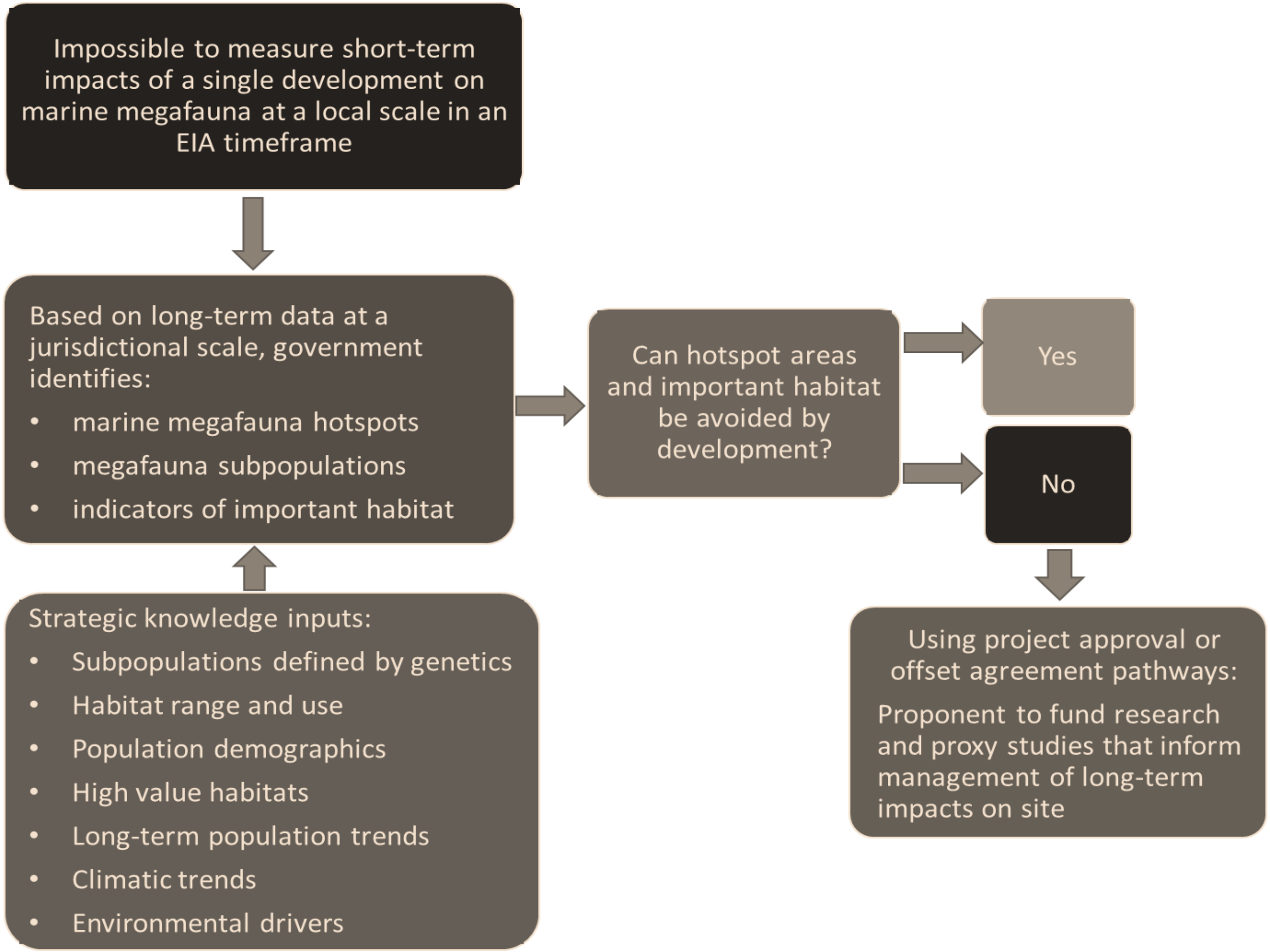


Figure 6.1: Pathway to improving marine megafauna conservation management outcomes through research applied to EIA

Table 6.1: Government-led and proponent-led approaches to improving EIA of marine megafauna

EIA of marine megafauna	Objective	Research activity
Habitat and surrogate environmental monitoring for marine megafauna	Conduct studies that indirectly relate to the health and function of marine megafauna. Studies should aim to capture evidence to support changes in presence, abundance, body condition, calf numbers, turtle hatching success and reproductive intervals of marine megafauna.	***Government-led – longitudinal, broader scale*** **Benthic habitat** ● Robust benthic habitat studies (seagrass/algae, reef) of known or potential importance to turtles, dugongs and prey species of coastal dolphins (where possible, determined by lavage, necropsy, direct observation or faecal studies). Sampling should include condition (epiphyte presence), photosynthetic active radiation (PAR), community composition and extent ● Baited remote underwater video (BRUV) to observe temporal changes in fish species and aggregations ● Collect eDNA to determine the presence of species undetermined in the local area but are elusive or difficult to survey **Water quality** ● Ongoing research into developing threshold values for site-specific environments i.e. sensitive receptors such as primary producer habitats and invertebrates in areas likely to be developed or already developed ● Implement long-term seagrass mapping and monitoring programs in important habitat areas for dugongs and turtles to provide a reference for environmental health in addition to the direct monitoring of populations. **Climate** ● Investigate drivers of nutrient availability and cycling ● Ongoing remote sensing to include detailed resolution of environmental drivers i.e. current, wind and sea surface temperature ● Investigate linkages between climatic variability and marine megafauna population dynamics **Acoustic** ● Passive acoustic loggers to determine baseline underwater noise levels across the jurisdiction and cetacean presence and relative habitat use over time **Fisheries** ● Engage with relevant Fisheries agency to incorporate inter-annual stock changes and by-catch data to infer impacts to prey species or direct mortality from fisheries interactions

		Proponent-led – shorter term, area influenced by project ● Pre-, during- and post construction: Acoustic, water quality, benthic habitat, lighting modelling and assessments (models should be validated) ● Real-time monitoring of environmental technical studies where available
Marine turtles	Quantify changes in turtle health and habitat use. Provide robust links to habitat condition and turtle health.	***Government-led – longitudinal, broader scale*** ● Mark-recapture and health studies on foraging turtle populations. Record metrics such as: body condition, gut composition (from stomach lavage), length/weight, blood profiles of relevance ● Collect DNA to determine the composition of the foraging population and monitor for changes over time ● Broad scale longitudinal aerial surveys for: abundance, distribution, and occupancy ● Develop spatial models from long-term aerial data to identify areas of important habitat and changes in use over time ● Long-term studies of index sites for nesting and foraging marine turtle species in the NT – should include all life stages where possible to develop an understanding of population demographics ● Maintain a Marine Wildlife Stranding Database ***Proponent-led – shorter term, area influenced by project*** ● Conduct aerial surveys of the foraging habitat and nesting beach closest to the development site and adjacent nesting areas over a period of at least 12 months before work commences to determine the relative importance and compare with broader scale assessments ● Hatchling emergence studies to determine potential lighting impacts
Marine mammals	Quantify changes in marine mammal health and habitat use. Provide multiple robust links to habitat condition and marine mammal health.	***Government-led – longitudinal, broader scale*** ● Broad scale genetic sampling of marine megafauna to determine subpopulations and potential abundance. ● Broad scale longitudinal aerial surveys for: abundance and distribution, occupancy and calf counts. ● Develop spatial models from long-term aerial data to identify areas of important habitat and changes in use over time ● Record body condition of marine mammals using drone-based photogrammetry ● Maintain a Marine Wildlife Stranding Database ***Proponent-led – shorter term, area influenced by project*** ● Record body condition of marine mammals using drone-based photogrammetry

		● Record injured or dead marine megafauna observed during the project timeframe in the Marine Wildlife Stranding Database, conduct detailed necropsies where possible.
EIA process	Identify opportunities to increase information sharing and data capture to improve EIA	***Government-led – longitudinal, broad scale*** ● A multi-user access portal managed by the regulator stores site-specific datasets e.g. seagrass mapping, water quality and hydrodynamic modelling. New knowledge and data are uploaded by regulators and proponents following consecutive developments to increase transparency, improve environmental system understanding, cumulative impacts and reduce overall project risk. ● Bayesian learning network approach applied to improve the information base for risk assessments whereby the data from previous environmental studies are incorporated into a probability network to inform risk assessments. ● Guidelines prescribing information requirements to proponents to ensure data consistency and the fundamental objectives of the program are met. ● Conduct vulnerability assessments on marine megafauna and their habitats across coastal NT to identify areas more vulnerable to development and subsequently improve conservation outcomes. ● Support Aboriginal ranger groups to increase their capacity to monitor and manage marine megafauna and habitats of high cultural and biodiversity value through an integrated ecosystem approach.

Another area of research would be to explore how IPAs could be used as a tool to manage the pressures of industry. Although such protection is not currently supported with legislation, IPAs have the potential to be a powerful tool as they engage multiple stakeholders with an interest in the estate.

Using IPAs to manage the pressures of industry in their jurisdiction would require the development of an appropriate legal framework that takes advantage of the fact that in the NT, coastal Traditional Owners have the potential to reduce some pressures on the coast because they have exclusive title to the intertidal area along some ~85% of the coast (Brennan 2008). The *Blue Mud Bay case* held that pursuant to the *Aboriginal Land Rights (Northern Territory) Act 1976* (Cth), land in the intertidal zone could be claimed and recognised as Aboriginal land. The implications of this ruling continue to be explored. Nonetheless, they are potentially substantial for not only for commercial and recreational fishers but also for industry. Since 2012, multiple agreements have been made between the NT Government, relevant Aboriginal land trusts and the Northern Land Council (NLC). These agreements have been applied over discrete areas (including the Borroloola /Sir Edward Pellew Islands) where there is a high level of non-Indigenous commercial and recreational fishing interests. Most of these agreements are for 20 years, but some are for shorter periods. Each of these agreements broadly includes:

- permission for recreational fishers and other recreational users to access these waters *without* individual permits or permit fees;
- permission for commercial fishers and other commercial uses to access these waters; and
- a variety of benefits to the communities.

Community benefits include funding to support local marine ranger programs, enhancement of Aboriginal Coastal Fishing Licences, investment into infrastructure, environmental studies, the establishment of governance bodies and support to develop local codes of conduct for visitors to the area.

These benefits provide insight into the various mechanisms and tools that relate to Sea Country in the NT and that could be used in negotiations with industry along with monetary payments. Indigenous marine ranger programs are taking on an increasing role, including in monitoring compliance with fisheries regulations. Three of the agreements include commitments for ‘funding as cash payments’ to recognise the level of recreational and commercial fishing (including Fishing Tour Operators) in the region.

IPAs have the potential to deliver cost-effective environmental, cultural, social, health and wellbeing and economic benefits to Indigenous communities (Smyth 2015). While the IPA concept is still evolving, IPAs can provide surety in placement of (government-managed) protected areas that may improve reserve performance and accommodate habitat features such as seagrass beds that support species such as dugongs. Research on how they could be used to regulate industrial development in a manner that is concordant with the values and aspirations of Traditional Owners would be valuable.

6.4 Chapter summary

- This research has made a significant contribution to the practice of EIA in the NT and identified avenues of improvement for marine megafauna conservation outcomes more broadly. Impediments to the conservation of marine megafauna were identified within the EIA framework.

- Robust data on species and their ecology were recognised as a critical component to EIA, allowing for better informed risk assessments and improved impact management.

- The key findings from the review of current practice, legal framework and species ecology provided a foundation for a marine fauna EIA guidelines document in the NT. The guidelines document will fit within the newly reformed environmental assessment framework within the NT EPA.

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Appendix 1 - refer to chapter 5

Checklist for EIA documents prior to submission: A guide for proponents, regulators and environmental practitioners

Marine Fauna EIA Checklist for proponents

Purpose

This checklist aims to provide environmental practitioners, proponents and regulators with a guide for submission to the NT Environmental Protection Authority (EPA) for referral (Notice of intent) or environmental impact assessment (EIA). The checklist applies across all phases of work supporting the initial project planning and environmental scoping process through to the final checking of documents pre-submission. This checklist may be refined on an ongoing basis; proponents should confirm they are using the most up-to-date version.

This checklist provides a minimum standard for the fundamental elements of EIA documentation before documents are submitted to the NT EPA. Meeting this minimum standard facilitates timely consideration of documents by the NT EPA.

The checklist has been set out in three parts:

- Part 1 addresses general elements of document quality
- Part 2 focusses on EIA requirements specific to marine megafauna and the habitats they rely on
- Part 3 sets out the requirements for certification of the checklist

To confirm that each element has been addressed a tick should be placed in the boxes provided. A copy of this checklist certified by an appropriate representative as complete and accurate should be lodged with EIA documentation and submitted to the NT EPA for review. Incomplete or inaccurate checklists will be returned for proponents to address outstanding matters before the NT EPA will commence its review of EIA documents.

The NT EPA's acceptance of a complete and accurate checklist only indicates that basic requirements of document quality and general comprehensiveness have been met. The NT EPA's acceptance of the checklist does not imply adequacy of technical work or appropriateness of 'policy' application / interpretation. These matters are reviewed in more detail during the EIA process.

Part 1 Quality of documents

	Tick if complete
A clear and concise title outlining basic information about the proposal and purpose of the document	
Date and document revision number	
Information identifying the document's author and publishing entity	
All issues identified in a scoping guideline or scoping document have been addressed and covered in the report	
Relevant Traditional Owners have been engaged and understand the nature and the purpose of the project proposal. All outcomes of any agreements or discussions regarding the project should be included.	
Complete and correct tables of contents, maps, tables and figures	
Appropriately scaled maps showing the proposal in a regional and local context	
Figures, plates, maps, technical drawings or similar including scale bar, legend, informative caption, labels identifying important or relevant locations/features referred to in the document text	
All survey site locations and derived data products (e.g. benthic habitat maps, marine megafauna maps) have been provided as maps and appropriate GIS-based electronic database forms	
All data from marine megafauna and habitat surveys have been provided in electronic database form (Access/Excel)	
Proposed infrastructure is shown on scaled maps and associated spatial data and are provided in an appropriate GIS-based electronic database form	
A list of references has been cross-checked to ensure that all references in the Reference list are cited in the text (and vice versa)	
All information based on 'expert' opinion/judgement are explicitly attributed, by name and qualification, to a person/s or organisation	
Where relevant, appendices are attached to the main EIA document that describe the details of technical work undertaken to underpin the content of the main document, and explicitly attributed by name to the author/s and (if applicable) their organisation	
Description(s) of the proposal are consistent throughout all documentation and allow potential environmental impacts to be assessed in local and regional contexts (where appropriate), including cumulative impacts of existing and approved developments	
Descriptions of the local and regional environmental features most likely to be directly or indirectly affected by the proposal. Identify relevant sections of the report here:	

Part 2 Marine fauna

	Tick if complete
The proposal has been reviewed in the context of the NT's Environmental factors and objectives: https://ntepa.nt.gov.au/__data/assets/pdf_file/0005/546791/guideline_environmental_factors_objectives.pdf	
The proposal has been fully evaluated for alternatives to avoid impacts to marine fauna values, reduce impacts where they are unavoidable. This should include site selection, construction and operational activities.	
posal's location and surrounding area has been investigated in relation to planning schemes, land and sea ownership, management plans and policies. Initial consultation with relevant land/sea owners, agencies and relevant stakeholders has taken place to raise awareness and identify any major issues early.	
op and spatial assessment of the proposal location and adjacent areas have been conducted using the most up to date information available. Agencies responsible for research and management of the Territory's marine fauna have been consulted with to ensure the most recent information is being used. Relevant websites have been used to inform the technical content, e.g. Atlas of Living Australia: https://www.ala.org.au/ NR Maps: http://nrmaps.nt.gov.au/nrmaps.html DENR: https://denr.nt.gov.au/ Commonwealth Environment Department: https://www.environment.gov.au/marine/marine-species/bias https://www.environment.gov.au/topics/marine/marine-bioregional-plans/conservation-values-atlas http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl	
Assessments and field surveys and were designed and conducted to meet the NT and Commonwealth requirements where available, refer to: https://ntepa.nt.gov.au/environmental-assessments/env-assessment-guidelines http://www.environment.gov.au/epbc/publications/significant-impact-guidelines-12-actions-or-impacting-upon-commonwealth-land-and-actions	
For proposals likely to impact benthic primary producer habitat of value to listed marine fauna, the EIA document describes how potential impacts have been addressed including: • details of the measures taken to address the impacts • scaled benthic habitat maps showing the current extent and distribution of benthic habitats and the areas of habitat predicted to be lost if the proposal proceeds • descriptions of technical work (e.g. benthic habitat surveys) carried out to inform the benthic habitat map (e.g. a technical appendix) • clearly set out calculations of cumulative loss of benthic habitat	
For proposals that involve any type of waste discharge or disposal in NT coastal waters or adjacent to, potential impacts are relevant guidance provided in the Australian and	

New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000 (and revised 2018 version online: https://www.waterquality.gov.au/anz-guidelines)	
For proposals that involve dredging activities, potential impacts have been addressed in the context of the Guidelines for Marine Dredging (https://ntepa.nt.gov.au/__data/assets/pdf_file/0007/287422/guideline_assessments_marine_dredging.pdf) to ensure that the predicted extent, severity and duration of impacts are presented in a clear and consistent manner.	
If numerical modelling has been carried out to inform the prediction of environmental impacts i.e. lighting, sedimentation, hydrodynamics etc., the report(s) associated with this modelling, including the key assumptions, is (are) provided as a technical appendix. Wherever possible, models should be validated for robust assessments and confidence in findings	
For proposals likely to impact on marine fauna, the EIA document describes how potential impacts have been addressed including: • determining the level of marine fauna survey required • describing the survey area and methodologies, including reference to timing, duration, survey effort, any survey limitations, and the nomenclature used • maps and text describing the survey area/plot sites, location of significant species, habitat mapping and predicted extent of impact on the habitat; • a comprehensive list of marine fauna species identified and assessment of threatened, priority or other significant fauna known or reasonably expected to occur in the area • evaluating the impact of the proposal on the species/communities, including reference to the extent of regional impacts and ecological connectivity; and • all survey data used in reporting is provided as electronic database in raw form, in addition to hardcopy reports	
For proposals with the potential to impact on a subpopulation of a marine threatened species, the EIA document includes: • early initial assessment for marine threatened fauna that have subpopulations, including advice from the NT Museum and the DENR. • maps and text describing the survey area, potential threatened species habitats and regional context and extent of predicted impact on the habitat. • describing the survey methodologies, including reference to timing, duration and survey effort used to sample each of the fauna groups sampled, and any survey limitations. • a survey report with assessment of threatened fauna found or reasonably expected to occur in the area, including any significant fauna, their known occurrence/habitats locally and their wider status if known, and an evaluation of the risk of the proposal to long-term survival of the species and community. • Data should be provided to the regulator in an agreed format.	
Impacts to marine fauna and habitats of importance have been evaluated for potential direct, indirect and cumulative impact to marine fauna.	
Where possible environmental thresholds to sensitive receptors have been identified, e.g. water quality, coral cover, habitat loss.	
Mitigation for impacts has been developed with technical specialists and is leading practice	
Monitoring plans are relevant to confirming mitigation measures are effective and provide for adaptive management.	

Part 3 – Certification of completeness and accuracy

Name
……………………………………………………………………………………………………
Position
……………………………………………………………………………………………………
Signature
……………………………………………………………………………………………………

Date:

Appendix 2 - refer to chapter 5

Example impact mitigation and monitoring

Lighting mitigation

Threat: Lighting
Many species of marine fauna have biological processes that are regulated by light. Impacts on marine fauna from increased lighting include altered settling patterns of filter feeders, marine sea bird fledglings injured and dying from falling after being attracted to bright lights, altered predation behaviour from multiple marine species, disoriented marine turtle hatchlings, resulting in a higher likelihood of mortality (often through predation), road strike, dehydration and disturbance to adult turtles in terms of locating nesting beaches and returning to the ocean. Lighting impacts to turtle nesting beaches have been observed up to 18 km away (Hodge et al. 2007).
Performance measure
● No seaward facing lights or light spill into the marine environment ● Complete darkness in the vicinity of habitat critical to the survival of marine turtles ● Complete shut-down of light sources during the nesting and hatching periods (including a buffer period) ● 100% turtle hatchling dispersal directed toward the ocean when hatchling ● Fledgling birds at near-by roosting sites are not able to see by project lighting
Recommended monitoring and mitigation
● Lighting to be modelled to determine directionality, intensity, sky glow and likely area of impact to be managed with mitigation measures applied accordingly ● Keep light spill off beaches and sea surface ● Allow a buffer zone between infrastructure and lighting in coastal environments ● Enclose infrastructure where feasible ● Use shielding, directional alignment, window tinting/covers and other techniques to reduce light spill ● Where lighting impacts are unavoidable, use dark, high silhouettes between the marine environment and artificial lighting ● Avoidance of white, green and blue light (e.g. mercury vapour, metal halide, halogen, LED and fluorescent light) or other coloured lights ● High pressure sodium (HPS) vapour lights used in unavoidable circumstances should be fitted with filters to exclude the transmission of short wavelengths (< 570 NM) ● Use reflective tape or personal lighting apparatus to reduce ambient light requirements ● Light glow reflected light off clouds and other aerosols above the beach (for example gas flares), should be avoided. This may include reduction using downward facing luminaries ● Strictly maintain vessel safety protocols and limit lighting of moored vessels to only what is necessary for occupational health and safety ● Light intensity minimisation to levels that are As Low as Reasonably Practicable (ALARP) in habitat critical to the survival of marine turtles ● Wavelengths of all artificial lights should be chosen based on avoiding effects on marine fauna, including the mix of wavelengths proposed (see Draft Commonwealth Lighting Guidelines 2019) ● For further lighting mitigation information refer to the Commonwealth Lighting Guidelines (2019)

Dredging mitigation

Threat: Dredging
Dredging has the potential to pose short and long-term impacts to some marine fauna. In the short term, the result of habitat removal will immediately impact some invertebrates and vertebrates and increased sedimentation may degrade adjacent habitat. Migrating, foraging, mating or nesting turtles may abandon normal behaviours that are critical to their survival, or turtles may be killed or injured by the process itself. In the long term, dredging may cause habitat degradation, change local hydrodynamics, facilitate increased human activity and dredged channels may provide artificial habitat for the turtles (exposing them to increased risk of injury). Key considerations include: size and duration of the dredging campaign and cumulative impacts in the local area.
Performance measure
• No dredging in waters identified as habitat critical to the survival of marine turtles • Where practicable, dredge screens (silt curtains) or other management devices will be used to reduce migration of the dredge plume into adjacent habitats of importance to benthic invertebrates, vertebrates and habitat critical for marine turtles • Low speed limits set for vessels associated with the dredge campaign (<10 knots) • A suitable number of trained Marine Fauna Observers (MFO) are on-board any water-borne vessel undertaking dredging and are operational whilst those activities are being carried out. MFO's to impose pre-established exclusion/shut-down zones
Recommended monitoring and mitigation
• The dredge plume is modelled to determine its predicted spatial extent in response to meteorological and oceanographic conditions and a plume management plan is established to minimise impacts on important habitat. Model outcomes should be compared with plume monitoring during operational phase. Where important habitats are impacted an adaptive management strategy should be triggered. • Suitably located turbidity/sedimentation/light loggers will run in real time during dredging activities, and rates of change will be monitored with the possible suspension of activities if rates exceed pre-specified thresholds. • Before dredging begins, monitoring of Exclusion Zones and surrounding areas (a minimum of 30 minutes prior) will be carried out. If the monitored zones have listed marine fauna present, the proposed operations will be postponed until such a time as the area is (and will remain) clear of animals. Dredge head should not be started until in contact with the benthos. • An adaptive management protocol is in place which mandates that all marine turtle mortalities are assessed for cause of death, and options for preventing recurrence discussed and (those which are feasible) implemented. The findings and outcome of such investigations is to be reported to relevant regulatory authorities. • During dredging activities, the following will be undertaken by a trained individual (or individuals) to identify any occurrence of marine turtle mortality or injury: o Inspection of accessible parts of hopper for any animal matter o Inspection of dredger overflow screens and drag heads o A report based on monitoring of dredge spoils for each load o Procedures will be identified for appropriate handling of marine megafauna remains, including requirements for identification by experts (preferably to stock level). If possible, an authorised individual should determine cause of death • During spoil disposal activities, the following will be undertaken;

o Employees undertaking spoil disposal activities will be trained in recognition and recording of marine turtle injury and mortality o Procedures will be identified for appropriate handling of marine turtle remains, including requirements for identification by experts. If possible, an authorised individual should determine the cause of death.

Vessel strike mitigation

Threat: Boat strike
Vessel strikes on marine fauna are a known cause of injury and mortality. Vessel strike occurs most frequently when vessels are traveling at high speed over shallow waters where they limit the opportunity for avoidance behaviour. Similarly, in shallow water, turtles, dolphins and dugongs cannot dive below the vessel and are more likely to be impacted.
Performance measure
• Implementation of speed restrictions of <10 knots for all project vessels travelling in habitat critical to the survival of marine fauna.
Recommended management and mitigation
• All mitigation and management actions should be developed with reference to those identified in the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia, 2017). • All vessels are to operate in accordance with requirements of relevant governing agencies (the Australian Maritime Safety Authority, Marine and National Park Authorities, Port Authorities or other Government Agencies). This includes boat speed restrictions, exclusion zones and areas to be avoided where applicable • Implement go slow zones in shallow areas within the proposed site of activity for all vessels associated with the activity • Report all stranded/injured/sick marine fauna to NT Government Marine WildWatch Program. • Adaptive management processes should be in place where vessel strike is identified as a problem through monitoring of stranded or injured marine fauna.

Noise mitigation

Threat: Underwater noise
Noise pollution can potentially affect critical biological functions of some marine fauna, including mating, nesting, migration, communication and foraging behaviours. It has the potential to cause mortality in the larval stages of fish and invertebrates and some small fish.
Performance measure
• Suitably sized exclusion zones between noise source and habitat critical to the survival (suitable distance depends on the type of noise, intensity and duration and modelled underwater noise outputs). • A suitable number of trained MFO are on-board any water-borne vessel undertaking noise-intensive activities, such as piling, seismic surveying or blasting and are operational whilst those activities are being carried out • Attenuation or silencing devices on all stationary or mobile plant or machinery nearby to sensitive locations
Recommended mitigation
• Sound intensity (especially at frequencies known to elicit responses) will be minimised to levels that are As Low as Reasonably Practicable (ALARP) in nearshore areas. • Engines, thrusters and stationery or mobile plant will not be left on standby or running mode unnecessarily • Noise attenuation or minimisation equipment installed on plant wherever feasible • All equipment and vessels will be operated and maintained in accordance with appropriate industry and equipment standards • Measures to reduce noise and vibration from any pumps will be enacted, for example pumps will have an acoustic blanket and motor enclosures • Use of exhaust gas silencer for diesel engines where possible • Emergency generators to include an acoustic enclosure and exhaust gas silencer • Piping within any permanent structures to have acoustic insulation, with vibration isolation between piping and pipe supports • A monitoring program implemented to assess noise and vibration levels and effects on marine fauna and identify areas where sound pollution can be reduced

Water quality mitigation

Threat: Water pollution
Water pollution and poor water quality are known to affect all life stages of marine fauna and may, in some cases, lead to mortality. Chronic exposure to toxic compounds at sub-lethal doses may reduce reproductive fitness and cause immunosuppression. Some toxicants can be transferred from mother to offspring and cause developmental abnormalities in calves/pups/hatchings often leading to reduced health and success or death.
Performance measure
• No runoff or discharge from the site. All wastewater captured and re-used or transferred off-site for re-use or disposal • All stored liquids on site to be contained and protected from damage • Waste management plan and/or spill management plans in place
Recommended management and mitigation
• Incorporate procedures for waste discharge that ensure the protection of the marine environment such as dilution of discharge (within an approved mixing zone) and an outfall monitoring program • Analyses of Persistent Organic Pollutants (POPs) and heavy metals conducted using methods described in van de Merwe et al. (2010), and analyses of Polybrominated diphenyl ethers (PBDEs) conducted via methods described in Hermanussen et al. (2008) • Analysis of Organochlorine Pesticides (OCPs) and Polychlorinated biphenyls (PCBs) according to most up to date methods available • Analysis of discharges known to be produced from oil and gas operations • If there is a possibility that marine fauna may be affected by any waste discharge, the proponent will enact a reporting and action strategy that will inform all stakeholders (local, state and federal Governments, Aboriginal groups etc.) and aim to reduce the impact on the environment • Clean-up strategies or pollution management plans for dealing with a water pollution event • Appropriate management of aerosol particles emitted from infrastructure.

Habitat degradation mitigation

Threat: Habitat degradation
Some marine fauna display high site fidelity to foraging, breeding and nesting habitat (i.e. turtles, migratory birds). Degradation of important habitat may cause a reduction in reproductive success or alterations in sex ratio (turtles), loss of optimal food source or other alteration of behaviours and in some cases leading to mortality.
Performance measure
• No Biologically Important Areas are to be directly or indirectly degraded by the action
Recommended mitigation and management
• Plan activities for times that avoid periods of increased marine fauna presence i.e., during mating, nesting or hatching/calving where known. • Major habitats in the vicinity of the action are monitored for changes in integrity or functionality. • Restriction of activities in areas of high value marine fauna habitat. Restriction or prohibition on vehicles, pets, fishing etc. may be appropriate in habitat critical to the survival of marine fauna. • Develop habitat health thresholds that can be monitored • Implement an action plan to prevent damaging activities when threshold values are reached

Marine debris mitigation

Marine debris threat
Marine debris is a known cause of mortality in marine fauna either due to ingestion or entanglement. Consuming marine debris may also lead to chronic exposure to toxic compounds that may compromise immunity and reproductive output.
Performance measure - update
• Commitment to zero emission of debris during project operation. This will likely require details around disposal of all equipment, staff training and incentives/penalties, monitoring and clean-up procedures • Procurement or packaging procedures which exclude the purchase of some items, such as plastic bags. Elimination of single-use plastic items on site • Provision of an approved waste management plan • Where appropriate, limits on recreational fishing in areas in and around habitat critical and biologically important areas
Recommended mitigation and management
• All mitigation and management actions should be undertaken in conjunction with those identified in the 'Threat Abatement Plan for the impacts of marine debris on the vertebrate wildlife of Australia's coasts and oceans', (Commonwealth of Australia 2018). • Permanent monitoring program set up to monitor surrounding beaches for strandings. Program will aim to rescue stranded animals, remove any debris from the ecosystem in a permanent manner, record details of stranding events, report the findings of the program to any relevant organisations (including relevant local, Territory or Commonwealth Agencies or Aboriginal Corporations and groups such as Tangaroa Blue, GhostNets Australia) and encourage public involvement and awareness (including development/support of stranding hotlines and stranding response programs).

Table 0-1 Referral guidance for proponents

High risk actions to marine fauna: referral required
Direct mortality ● Any mortality of other listed migratory or listed threatened megafauna. ● Any action likely to cause mortality of multiple individuals of a listed migratory or listed threatened megafauna on an annual basis. **Habitat** ● Any temporary, long-term or permanent destruction, modification, fragmentation or other degradation of habitat important to listed threatened, migratory or commercially valuable marine megafauna. ● Any long-term or permanent destruction, modification, fragmentation or degradation of a Biologically Important Area where surveys (desktop and/or targeted) have confirmed the presence of listed migratory or listed threatened megafauna ● Any action occurring in habitat critical to the survival of listed migratory or listed threatened megafauna. ● Any action occurring in a Biologically Important Area where baseline data (>2 years) is absent. ● Any action occurring in a Biologically Important Area where desktop or field surveys have confirmed the presence of threatened or migratory marine megafauna. ● Any action that may result in the introduction of or increases in the population of feral pig or feral dog in the region of nesting habitat critical to the survival or a biologically important area (nesting/roosting beach). ● Activities that modify, destroy, remove, isolate or otherwise degrade habitat critical to the survival of listed migratory or listed threatened fauna megafauna. ● Any action that may inhibit the dispersal of hatchlings from nesting habitat critical to the survival (i.e.: netting offshore of a nesting beach during the courting and/or breeding season). ● Any increase in chemical or nutrient-laden runoff into Habitat Critical to the Survival or a Biologically Important Area. ● Any increased accessibility for workers or the general public to Habitat Critical to The Survival or to a Biologically Important Area where surveys have confirmed important marine fauna presence. **Dredging and vessel traffic** ● Any activity that will result in light spill in the visible area around nesting/roosting habitat critical to the survival or a biologically important area (nesting/roosting beach). ● Any action involving dredging in habitat critical to the survival of marine fauna or in a Biologically Important Area where dredge spoil will amount to 10t or more. ● Activities that will increase vessel traffic by any amount for any period in habitat critical to the survival or increase vessel traffic by 25% or more in a Biologically Important Area for other listed migratory or listed threatened megafauna. ● Any increase in vessel traffic in habitat important for other listed migratory or listed threatened megafauna. **Seismic, blasting, underwater noise** ● Any seismic activity that is proposed within 80 km of nesting habitat critical to the survival of marine turtles or within 20 km of habitat critical to the survival of any other listed migratory or listed threatened megafauna.

- Seismic activity, blasting or pile driving that will result in higher than background levels of underwater noise at important habitat areas.
- Any action involving blasting or pile driving activities within 5 km of habitat critical to the survival of the marine fauna or within 1 km to a Biologically Important Area.
- Activities that will remove strand vegetation or modify the foreshore at nesting habitat critical to the survival of marine threatened species.

Medium-low risk actions to marine fauna: Referral advised

Habitat

- An action which may have a long-term impact on water quality in habitat critical to the survival of threatened marine fauna.
- An action that will modify, destroy, remove, isolate or otherwise degrade a Biologically Important Area.
- An action which may alter the sex ratios of hatchlings.
- An action that will increase marine debris in Biologically Important Areas or habitat with confirmed threatened marine fauna occurrence.
- An action which may include permanent removal, modification, fragmentation or degradation of areas within 10 km of habitat important to marine fauna.
- Any temporary fragmentation, modification or degradation of a Biologically Important Area where surveys (desktop and/or targeted) have confirmed the presence of listed threatened, migratory or vulnerable marine fauna.
- Any removal, modification or permanent fragmentation or degradation of habitat where surveys (desktop and/or targeted) have not confirmed the presence of listed threatened, migratory or vulnerable marine fauna.
- Any large scale, permanent removal, modification, fragmentation or degradation of habitat of listed threatened, migratory or vulnerable marine fauna.
- Any activity that will result in light spill in the vicinity of nesting habitat critical to the survival or more than 150 km offshore of nesting habitat critical to the survival of marine fauna.

Dredging and vessel traffic

- Any action involving dredging in a Biologically Important Area where dredge spoil will amount to < 10 t.
- Dredging in general biophysical habitat with confirmed threatened or migratory marine fauna where dredge spoil will amount to 100 t or more.
- Any action that will increase short-term vessel traffic in a biologically important area by < 25%.
- Any action that will increase the long-term (ongoing) vessel traffic in a biologically important area.

Seismic, blasting, underwater noise

- Any seismic activity proposed to occur within 120 km of habitat critical to the survival of threatened or migratory marine fauna or within 50 km of habitat critical to the survival of any other species, including commercially valuable species.
- Seismic actions within 20 km of a known migration route, or within 80 km of a known turtle migration route.
- Any action involving blasting or pile driving activities within 10 km of habitat critical to the survival of threatened or migratory marine fauna or within 5 km to a biologically important area.
- Activities (other than seismic) that will increase (short or long-term) underwater noise in habitat critical to the survival of threatened or migratory marine fauna.

Low risk: referral unlikely to be required
• An action not likely to cause mortality to one or more threatened or migratory species. • Any action that does not impact on any type of important marine fauna habitat. • An action not likely to impact or significantly change any threatened or migratory marine fauna habitat or migratory pathway. • An action not likely to impact marine fauna and has enough baseline data and supporting information with an ongoing monitoring program to detect impacts.

Appendix 3 - refer to chapter 5

Northern Territory marine fauna overview

Cetaceans

Recent large-scale aerial surveys and intensive boat-based surveys have resulted in improved understanding of the distribution, abundance and movement of the most common coastal dolphin species (Brooks and Pollock 2015, Palmer et al. 2017). However, knowledge of the less common species and non-resident species that occur in Territory waters remains limited. A total of 17 species of cetaceans occur in the Northern Territory. Of these, seven species are resident or occasional visitors. These species include the Australian snubfin dolphin (*Orcaella heinsohni*), Australian humpback dolphin (*Sousa sahulensis*), dwarf spinner (*Stenella longirostris roseiventris*), false killer whale (*Pseudorca crassidens),* killer whale (*Orcinus orca*), humpback whale *(Megaptera novaeangliae*) and Indo-Pacific bottlenose dolphin (*Tursiops aduncus*). Coastal dolphins (Australian humpback dolphin, Australian snubfin dolphin and the Indo-Pacific bottlenose) rely on the waters of the NT and adjacent coastal areas for breeding and foraging (Brown et al. 2014, Brooks et al. 2017, Palmer et al. 2017). A recent broad-scale helicopter survey found coastal dolphins were present along the extent of the NT coast (Palmer et al. 2017). Bottlenose dolphins were significantly more abundant in coastal areas than in estuaries and the Australian snubfin and Australian humpback dolphins were broadly distributed around the coast (Palmer et al. 2017). False killer whales also readily use NT coastal waters, with a recent study demonstrating individuals travelling up to 7,577 km in 104 days, with almost a third of their habitat use recorded within 10 km from the coast (Palmer et al. 2017). Humpback whales are the most common whale species recorded in the NT. They visit the NT coast annually in low numbers (<20 individuals) during calving migrations (July-October). The genetic stock remains undetermined due to limited sampling, but it is likely that the humpback whales represent the upper range limit of the Western Australian stock. The calving period is a time when adult and calf humpback whales are vulnerable given their use of coastal waters for resting. Other whale species occur infrequently in NT waters and some are only known through stranding records (Chatto and Warneke 2000).

The abovementioned cetacean species are listed as migratory under the EPBC Act and either Data Deficient or Least Concern under the TPWC Act (TPWC Act). The humpback whale is listed as Vulnerable under the EPBC Act and recent harmonisation of Commonwealth and NT species conservation listing suggests they will also soon be listed as Vulnerable under NT legislation.

Coastal dolphin species feed on a wide variety of fish associated with inshore habitats (Parra and Jedensjö 2014). Preliminary information suggests that humpback dolphins in Australian waters exist as a meta-population of small and genetically isolated population fragments (Brown et al. 2014). They are known to occur in small numbers ranging from 15 to about 200 individuals per study area (Brown et al. 2016, Parra and Cagnazzi 2016, Brooks et al. 2017). Similar attributes have been observed for the snubfin and bottlenose dolphins. Combined with the life history characteristics of dolphins, these features make coastal dolphins vulnerable to habitat degradation and fragmentation. Threats to these cetacean species in NT coastal waters are not well-documented however, interactions with fishing gear (Allen et al. 2016), chemical discharge (Cagnazzi et al. 2013), underwater noise (Weilgart 2007, Paiva et al. 2015), prey depletion, habitat loss, and coastal development are some of the threatening processes that may impact cetaceans though these are poorly quantified in Australia, particularly the NT (Palmer 2014, Mann and Karniski 2017).

Dugongs

Knowledge of the dugong population in the Northern Territory is relatively robust compared with other marine animals. Large-scale aerial surveys over the last 30 years, mostly in the Gulf of Carpentaria, have provided important information on the size and distribution of the population. Additionally, extensive research into the demography and ecology of the species in Queensland and Western Australia is applicable to the Territory population. The waters of the NT support significant populations of dugongs (Bayliss and Freeland 1989, Groom et al. 2017a). The most recent broad-scale dugong aerial survey for the NT estimated a population of 8,176 (± 958) (Groom et al. 2017a). The population is distributed across the entire coastal waters of the NT but the majority (almost 60%) occur in the Gulf of Carpentaria. Other high-density regions include the Tiwi Islands and Cobourg Peninsula. The dugong is listed as Near Threatened under the TPWC Act and as a migratory species under the EPBC Act.

Dugongs are strictly marine herbivores, feeding on seagrass habitats in the coastal zone usually in waters <10 m deep (Grech et al. 2011a). They have been observed to undertake movements at local scales as well as long distance (100s of km in a few days) (Sheppard et al. 2006). The population biology of dugongs makes them particularly vulnerable to mortality as adults (Marsh et al. 2011). Dugong demography is characterised by long lifespans (greater than 70 years), long gestation (12–14 months), single offspring, long intervals between births (more than 2.5 years), prolonged periods until sexual maturity (6–17 years) and high and temporally stable adult survival (Marsh et al. 1984). Adult survival is the most important determinant of population growth. The maximum rate of population increase under optimum conditions when natural mortality is low is approximately 5 % per year (Marsh et al. 2011). The maximum sustainable mortality rate of adult females killed by human activities is approximately 1 or 2 per cent (Marsh et al. 1997, Marsh et al. 2004), (Heinsohn et al. 2004), and lower when food supplies are low. Given their reliance on seagrass beds, dugong populations may be at risk from changes in the extent of seagrass meadows caused by anthropogenic sources (Grech et al. 2011a) or natural disturbances such as cyclones (Preen and Marsh 1995, Meager and Limpus 2014).

Marine birds

Shorebirds are a group of birds including sandpipers, plovers, stints, oystercatchers, godwits, curlews, knots and greenshanks found along sandy or rocky shorelines, mudflats and shallow waters. Some species are resident, and others are migratory and spend the non-breeding season in Australia. The Northern Territory is home to significant populations of marine and migratory bird species. The coast and seas provide important breeding and foraging habitat for a diverse range of breeding and non-breeding bird species. There are 33 species of shorebird recorded in the NT (Chatto 2003) of which 26 species are in such high abundance they likely to represent >1% of the total Australian population, which classifies them as significant under the EPBC Act. The current state of knowledge for the NT is based on extensive aerial and ground surveys conducted in the 1990s (Chatto 2003). While most of this information on shorebird and seabird distribution is still relevant, it is likely that changes have occurred with regard to population abundance as a result of habitat degradation and removal. Changes in the population status for many species are due to impacts in countries that they migrate to (Garnett et al. 2011).

The regions supporting the largest populations of shorebirds in the NT include Anson and Fog Bays on the west coast, Van Diemen Gulf east of Darwin, Castlereagh and Buckingham Bays, the Cadell Strait on the north coast, and the Limmen River and Port McArthur on the east coast (Chatto 2003). The NT coast and offshore islands contain significant breeding colonies of seabirds (Chatto 2001) which are mostly dominated by various Tern species but Gulls and Noddys are also present in large numbers. Almost 150 individual breeding colonies have been recorded, the largest being >60,000 individuals (Chatto 2001). The breeding colonies predominantly occur on the northern and eastern NT coasts with high densities from north east Arnhem Land to Groote Eylandt and the Sir Edward Pellew Islands (Chatto 2001).

All species of marine birds are dependent on the sea for foraging. Waterbird populations occur throughout the coast and offshore islands of the Northern Territory (Chatto 2006). Colonial waterbirds include species of egrets, herons, cormorants, ibises, and the Australian Pelican, Darter and Royal Spoonbill. This includes nationally and globally significant numbers of colonial nesting waterbirds, particularly Intermediate, Great, Little and Cattle Egrets. Mangrove forests are used by 14 of the 15 waterbird species for breeding sites (Chatto 2006). The most important areas for colonial waterbird breeding were the floodplains between the Moyle and Finniss Rivers and between the Adelaide River and Murgenella Creek. Several raptor species such as sea eagles, brahminy kites and ospreys have a diet that is partly supplemented by marine fauna such as fish, turtles and sea snakes. Consideration of potential impacts to these species and their prey items is necessary for any coastal development. There are numerous threats to migratory shorebirds and seabirds. The loss or degradation of breeding and foraging habitat is the most significant factor responsible for observed declines; however, regional climate change and possibly micro-plastics are possible future threats (Sutherland et al. 2012).

Marine reptiles

Marine turtles

All species of marine turtles have a complex lifecycle covering a large geographic range over multiple habitats and many decades (Commonwealth of Australia 2017).

Marine turtles are highly migratory during some life phases, but during others show high site fidelity to small geographic areas. The number of females nesting can fluctuate widely between years. For successful incubation, marine turtle eggs must be buried in ventilated, high humidity, sandy sites that are not subjected to flooding or erosion and have a temperature range that persists within 25-35^{o}C for the duration of incubation (Ackerman 1997, Howard et al. 2015).

Marine turtles have temperature dependent sex determination. This means that the temperature during egg incubation determines the sex of hatchlings, with higher temperatures producing predominantly females (Miller 1985). There are also upper and lower temperature thresholds for successful incubation. The time frame for incubation differs across species but is typically about two months.

In general, marine turtle growth is slow and varies among species, habitats, sex and maturity. Marine turtles require 20-50 years to reach sexual maturity (Avens and Snover 2013) and females will only reproduce when they are able to obtain and store sufficient fat to make the breeding migration and produce eggs. The time between female reproductive activity may vary from 1-8 years depending on species and food availability (Miller 1997).

The current state of knowledge of the Northern Territory's marine turtles is mainly confined to the distribution of nesting beaches. This is based on extensive aerial and ground surveys conducted in the 1990s (Chatto and Baker 2008), and while most of this information is still relevant, it is likely that there have been changes over time. Much less is known on the ecology and demography of marine turtles in the Northern Territory, although research from Australia and overseas is relevant to the populations occurring here. Six of the seven species of marine turtles inhabit the coastal waters of the NT. The region supports globally significant populations of green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and flatback (*Natator depressus*) turtles (Commonwealth of Australia 2017). There is also an internationally significant population of olive ridley (*Lepidochelys olivacea*) turtles. All species nest in the NT apart from the loggerhead turtle (*Caretta caretta*), including the only remaining recorded nesting for the leatherback turtle (*Dermochelys coriacea*) in Australia. All six species are listed as threatened and migratory under the EPBC Act. Under the TPWC Act, one is Critically Endangered, three are Vulnerable, one Near Threatened and one Data Deficient.

The coastal waters of the Territory provide foraging habitat for marine turtles from multiple populations from other national and international jurisdictions including Queensland, Western Australia, Timor Leste and Indonesia. Some turtles that nest on the Territory coast spend most of their time foraging in other jurisdictions whilst others forage exclusively within NT waters (Commonwealth of Australia 2017). The Gulf of Carpentaria, particularly the south-west region, is a significant foraging habitat for marine turtles (Commonwealth of Australia 2017). Based on aerial survey data, the highest turtle density in NT waters was recorded in the Limmen Bight region with a density of 18.7 turtles per km^2 (Unpublished data, Groom et al. 2017). There is a limited understanding of the long-term trends in abundance and nesting of marine turtles in the Northern Territory. The flatback turtle is the only species that has been monitored over a long period. The analysis of long-term nesting population abundance and trend was investigated on Field Island (Kakadu National Park) and the population was found to be relatively small with a few hundred nesting turtles and generally stable (Groom et al. 2017b). This may be indicative of other NT flatback turtle nesting sites, but further study is required. Other nesting data on flatback turtles in the NT have not been analysed to date and no other population abundance estimates on NT nesting stocks are available.

There are multiple pressures affecting marine turtles in the Northern Territory. These include but are not limited to: marine debris (Wilcox et al. 2018); interactions with commercial fisheries (Riskas et al. 2016); habitat (seagrass, reef, open water, nesting beaches) degradation and loss (Groom et al. 2018); unsustainable use; lighting near nesting beaches (Kamrowski et al. 2014); underwater noise; predation and climate change affecting sea-level rise; nesting temperatures (Jensen et al. 2018) and habitat quality (Butt et al. 2016, Commonwealth of Australia 2017). These pressures affect different turtle species at different stages of their lifecycle and vary depending upon their location. Accounting for existing threatening processes in a region is important when assessing potential project impacts to a population as there is likely to be a cumulative effect (Groom et al. 2018).

Saltwater crocodiles

Saltwater crocodile (*Crocodylus porosus*) populations in the Northern Territory have recovered strongly since their protection began more than 30 years ago (Webb et al. 2010). Standardised monitoring since 1975 provides longitudinal relative density indices (1975–2009) as a record of their post-protection recovery. The high reproductive capacity of *C. porosus* has contributed to its successful recovery. Large geographical variation in abundance exists across northern Australia with the NT having considerably higher densities than adjacent jurisdictions (Fukuda et al. 2007). The current estimate of crocodiles (excluding hatchlings) is estimated to be in the order of 80,000 –100,000 individuals (Y. Fukuda, NT Department of Environment and Natural Resources, unpublished data).

The saltwater crocodile is referred to as an opportunistic feeder and uses either an 'active hunting' or an 'ambush' strategy (Cooper-Preston and Jenkins 1993). Its primary food sources are crustaceans, insects, fish, amphibians and small mammals; larger crocodiles consume larger mammals. In areas of higher salinity (mangroves), crocodiles eat larger volumes of crab and a smaller volume of shrimp, fish and insects (Taylor 1979). In freshwater swamps and upper mangroves, individuals consumed more insects (Taylor 1979). The saltwater crocodile is highly adapted to saline environments, predominantly select freshwater habitats for nesting (Fukuda and Cuff 2013). Nest site selection seems to be influenced by multiple factors, including freshwater habitats being more available than saline habitats, physiological advantages of freshwater to nesting females and/or hatchlings, and the suitability of the ground layer vegetation for constructing mound-like nests. Vegetation communities may be used to assess the suitability of nesting habitat for management and conservation purposes (Fukuda and Cuff 2013). Threats to the saltwater crocodile include mortality due to fishing nets and the effects of habitat destruction (Taplin 1987). Habitat destruction also pressures saltwater crocodile populations. In Arnhem Land, Northern Territory, feral animals such as the buffalo (*Bubalus bubalis)* destroy nesting habitat in wetlands by increasing drainage and reducing vegetation (Webb et al. 1987).

Sea snakes

The NT coast and seas are an important area for sea snakes and is one of the richest areas for sea snakes along the Australian coastline. It has all the widely distributed Australian species of true sea snakes and two regional endemics: the mud snake species and marine file snake. More than 20 species are known to occur in the region and are all listed as Marine species under the EPBC Act (Guinea et al. 2004). Under Northern Territory legislation, some species of sea snake such as *Aipysurus laevis* and *Hydrophis elegans* are listed as Least Concern because they are believed to be widespread and abundant. Others such as *Enhydrina schistosa* and *Hydrophis czeblukovi*, are considered Data Deficient (Guinea et al. 2004). Mangrove and file snakes occupy the neritic zone and should also be considered when assessing development impacts in coastal areas. Sea snake life histories are characterised by relatively long-lived individuals, growing slowly after birth and taking several years to reach sexual maturity. Females produce smaller broods in their early breeding years and have long gestation periods with only one brood per year or every second year as resources allow (Guinea et al. 2004). The distribution of sea snakes is influenced by seasonal factors associated with either mating or breeding aggregations of gravid females. Such aggregations for *Aipysurus eydouxii* presumably occur in estuaries across northern Australia (Limpus 1975). Sightings of large aggregations of sea snakes were recorded around and to the south of the Wellesley Islands, to the north and west of Groote Eylandt (COMALCO 1993). Sea snakes utilise a variety of habitat types including shallow waters near land, around islands, coral reefs, somewhat sheltered waters, as well as near estuaries and mangrove swamps (Stidworthy 1974, Rasmussen 2001). They have also been reported swimming up rivers, 160 km from the sea (Rasmussen 2001). Pelagic species such as *Pelamis platurus*, are found in drift lines or slicks of floating debris brought together by surface currents (Dunson and Ehlert 1971). Sea snakes feed selectively on small fish, their eggs and eels (Guinea et al. 2004).

As specialist feeders, any increase in turbidity that impacts on either their prey or their ability to detect their prey would impact negatively on sea snake populations. Sea snakes are vulnerable to human-induced pressures because of their slow growth rates and low fecundity (Heatwole 1997). Impacts such as dredging or increased boat traffic have the potential to disrupt normal feeding activities. Additionally, the noise generated by increased boat traffic and associated machinery is a source of potential disruptive noise pollution capable of displacing sea snakes out from important habitat. Boat strikes are a common cause of sea snake mortality in areas where sea snakes and small boats share the same waterways (Guinea et al. 2004). The greatest source of mortality to sea snake populations in NT waters is commercial fishing. The annual trawler bycatch of sea snakes during 1984 to 1986 in the Gulf of Carpentaria was estimated at almost 120,000 sea snakes, of which, almost half of the individuals died (Wassenberg et al. 1994). Similar catch rates were recorded in the Gulf of Carpentaria in 1989 and 1990 (Ward 2000).

Fish

The NT has a diversity of fish fauna with 1474 fish species (195 families) occupying marine and freshwater habitats (Larson et al. 2013). The Gobiidae (gobies) family is the most speciose with 150 species inhabiting coral reefs and mangroves (Larson et al. 2013). The Territory's fish fauna is grouped within the Central Indo-Pacific region (Kulbicki et al. 2014) and most closely resembles that of north-western Western Australia (Larson et al. 2013). Most of these species are not unique to northern Australia, with approximately 14% endemic to tropical Australia, and only 2.1% of fish species endemic to the NT (Hoese et al. 2006).

Among the Northern Territory's fish fauna there are 57 species considered to be threatened under various listings (TPWC Act, EPBC Act). For some species, NT waters may be one of the few remaining geographical regions where viable populations remain in Australia (Pogonoski et al. 2002), however, the poor state of knowledge of the NT's fish populations and their true distribution hinders assessment (Larson et al. 2013). Besides being of economic importance, fishes are the major predator within the marine ecosystem. As such, they have a far-reaching role in balancing the trophic structure within the ecosystem and structuring habitats (Blaber 2000). The reverse is also true, in that, large changes in habitat characteristics or loss of habitat, can lead to changes in fish community structure, which is often irreversible. More recently, fish assemblages have been described for assessing the biological values within the economic development, fisheries or conservation context (e.g. Darwin Harbour, Nhulunbuy, Groote Eylandt, Bing Bong, Kakadu National Park, Arnhem Land and Gulf of Carpentaria). At least 460 bony fish and 56 cartilaginous species (e.g. sharks and rays) have been recorded as bycatch from trawl fishery in coastal areas of the NT. Although sampling seems to be extensive, many information gaps remain. Specifically, sampling in tandem with environmental and habitat characteristics to allow for a better understanding of environmental drivers for fish distribution and abundance (e.g. determining physiological tolerances) and habitat use by fishes in terms of their breeding, feeding and migration traits (Blaber 2000).

There are many fish species in the NT that have diadromous life cycles including those of commercial value (barramundi, mangrove jack, sea mullet) and those listed as threatened, such as sawfish. Consideration of habitat and movement requirements of these species is critical when conducting an impact assessment as significant impacts can easily occur at the population level if breeding migrations are prevented or reduced.

We have a poor understanding of the environmental drivers that determine fish fauna distribution, their life histories and habitat use, and connectivity of fish populations within and between subregions, such as Gulf of Carpentaria, Arafura and Timor Seas and Joseph Bonaparte Gulf. Much of the life history of fishes is unknown (Larson et al. 2013), except for a few commercial species, such as barramundi (Griffin 2007). There is a lack of understanding which habitats are important for spawning and which are important as juvenile refuge/feeding areas. It is important to note that juveniles and adults are often partitioned across different environmental niches and therefore assessments of impacts require assessments across multiple habitats that are important for the different life histories of fishes (Galaiduk et al. 2017). Further, there is insufficient information about the connectivity between regions and the movement of fish between regions and local scales (e.g. habitats). Understanding fish population connectivity plays a fundamental role in local and metapopulation dynamics, community dynamics and structure, genetic diversity, and the resilience of populations to human exploitation (Cowen et al. 2007, Berkström et al. 2013).

It is difficult to identify specific threats to many fish species because there is very little known about their ecology and biology. Natural variability (seasonal and long-term climate variability) and large weather events (cyclones and storms) all play a role in structuring marine and coastal environments (Booth et al. 2011). However, habitat degradation and loss as well as activities that change ecosystem processes that underpin the entire life cycle of fishes are likely threats that have the potential to change whole ecosystem functions. For example, activities that lead to a reduction in oxygen content in the water (e.g. dredging, habitat destruction) can change the escape behaviour of prey and swimming and feeding behaviour of predators. This has the potential to cause major changes in the relative pathways of different energy pathways in estuarine food webs.

Invertebrates

The state of knowledge of taxonomy, biological and ecological knowledge of marine invertebrates in the Northern Territory is generally poor. From a taxonomic perspective, the intertidal and shallow waters of the Darwin region are relatively better understood, while remaining coastal areas and deeper offshore invertebrate fauna are virtually unknown. A large percentage of identified species are endemic to Australia. Although it is recognised invertebrates are critical for maintaining healthy ecosystems, we have a poor understanding of the key drivers for invertebrate distribution, the habitats they depend on, and their specific roles within the coastal and marine ecosystems. Most of the existing data (taxonomic and distribution) resides with museums and has been collected through several surveys across several regions. The purpose of many of the surveys are around describing the biological values (e.g. Commonwealth Marine Parks, (Heap et al. 2010, Przesławski et al. 2011), Beagle Gulf (Smit et al. 2000), NW Arnhem Land (Russell and Smit 2007), Gulf of Carpentaria (Salini and Liron 1991, Harris et al. 2006). The number of species present in NT waters is largely unknown, however, a collation of existing taxonomic databases estimates that there are approximately 12,500 marine taxonomic units and there are about 3000 species in Darwin Harbour alone.

Among the Northern Territory's invertebrate fauna there are no species considered to be threatened / endangered under various listings (TPWC Act, EPBC Act). Marine invertebrates include all members of the animal kingdom, except vertebrates and include, for example, snails, clams, squid, polychaete worms, crabs, prawns, sea lice, sponges, jellyfish, corals and sea stars. They range from microscopic to several metres in size. They can be found in all environments and live in a wide range of habitats, including the open water (pelagic), on the seafloor (epifauna - reefal habitats, mangroves, intertidal and subtidal mud/sand flats and shelves) and within the sediments (infauna). Their importance cannot be underestimated. All exploited marine fauna depends on invertebrates either directly or indirectly and marine ecosystems would collapse without their services. Their ecological and biological importance can only be broadly described, with even the best studied species; their environmental envelope is poorly understood. In broad terms, they are the foundation of many ecosystem processes, including:

- recycling of nutrients, where they breakdown of organic matter and detritus (e.g. mangrove crabs consume 30-80% of mangrove litter);
- oxygenating and irrigation of sediments which allows most bacteria to breakdown organic matter and nutrients (Gray and Elliott 2009);
- stabilising ecosystems and carbon sink and allowing energy and nutrient transfer between trophic groups;
- regulating water quality (invertebrate filter feeders filtering water) and sediment quality (infauna processing organic matter to improve sediment quality);
- provide habitat and structure for other flora and fauna (e.g. a sponge can have over 100 invertebrate species living on/in it); and
- play a key role in the reproductive cycle of other marine fauna and flora (refuge, predation, herbivory and parasitism).

Some invertebrates (e.g. all corals and some sponges) form symbiotic relationships with photosynthetic organisms, such as blue-green algae, micro and macro algae. These invertebrates are entirely or mostly dependent on light for survival. As there is a lack of understanding about the key drivers for invertebrate distribution, the habitats they depend on, and their specific roles within the coastal and marine ecosystems, it is difficult to identify specific threats to invertebrates. However, degradation and loss of habitat and activities that change ecosystem processes are likely to impact on the ability of invertebrates to effectively contribute towards maintaining the ecosystems in its functional state.

Appendix 4 - refer to chapter 5

Online resources

A selection of online resources online that may assist when conducting a desktop assessment of marine fauna in the region of a proposed activity.

International and Regional	
SEATURTLE.ORG	http://www.seaturtle.org
The Indian Ocean South East Asia Marine Turtle Memorandum	http://www.ioseaturtles.org/
The International Sea Turtle Society	www.seaturtlesociety.org/
The State of the World's Sea Turtles (SWOT)	www.seaturtlestatus.org/
IUCN red list	https://www.iucnredlist.org/
Marine Mammals: National Ocean and Atmospheric Administration	https://www.fisheries.noaa.gov/national/international-affairs/international-marine-mammal-conservation
National	
Bioregional Plan (North)	https://www.environment.gov.au/topics/marine/marine-bioregional-plans/north
Action Plans (marine)	https://www.environment.gov.au/resource/conservation-overview-and-action-plan-australian-threatened-and-potentially-threatened https://www.environment.gov.au/resource/action-plan-australian-cetaceans
Indigenous Protected Areas	https://www.pmc.gov.au/sites/default/files/files/ia/IEB/ipa-national-map.pdf
Marine Turtle Recovery Plans	http://www.environment.gov.au/marine/publications/recovery-plan-marine-turtles-australia-2017

Sawfish and Rivers Sharks – Multi Species Recovery Plan	http://www.environment.gov.au/biodiversity/threatened/publications/recovery/sawfish-river-sharks-multispecies-recovery-plan
Whales	http://www.environment.gov.au/marine/marine-species/cetaceans/species-found-australian-waters https://www.environment.gov.au/marine/marine-species/cetaceans/industry https://www.environment.gov.au/resource/epbc-act-policy-statement-21-interaction-between-offshore-seismic-exploration-and-whales http://www.environment.gov.au/biodiversity/threatened/publications/recovery/blue-whale-conservation-management-plan
A Biological Review of Marine Turtles	http://www.derm.qld.gov.au/services_resources/item_list.php?series_id=200007
Marine Mammal Data Portal	https://data.marinemammals.gov.au/
Australian databases and maps	http://www.environment.gov.au/erin/
Conservation values atlas	http://www.environment.gov.au/coasts/marineplans/cva/index.html
Conservation advice for the NT	http://www.environment.gov.au/cgi-bin/sprat/public/conservationadvice.pl
Protected Matters Search Tool	http://www.environment.gov.au/epbc/pmst/index.html
Species Profile and Threats Database	http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl
Atlas of Living Australia	www.ala.org.au
Atlases and Databases	http://www.nrm.gov.au/resources/other-esources/atlases-databases.html
Threat Abatement Plans	https://www.environment.gov.au/biodiversity/threatened/threat-abatement-plans/approved
Fauna Collection Database of Australian Museums	http://www.ozcam.org/
IMOS	https://portal.aodn.org.au/

Open access to marine data	https://www.australia.gov.au/directories/australia/imos
Northern Territory	
Marine Fauna Stranding Report	2012-2014 http://www.territorystories.nt.gov.au/bitstream/10070/257001/1/NT%20Marine%20Megafauna%20Stranding%20Report%20May%202015.pdf 2014-2015 http://www.territorystories.nt.gov.au/jspui/bitstream/10070/262496/2/Final_NT%20Marine%20Megafauna%20Stranding%20Report%202016.pdf 2016 http://www.territorystories.nt.gov.au/jspui/bitstream/10070/278386/1/NT%20Marine%20Megafauna%20Stranding%20Report%202017%20Final.pdf 2017 http://www.territorystories.nt.gov.au/jspui/bitstream/10070/278386/1/NT%20Marine%20Megafauna%20Stranding%20Report%202017%20Final.pdf
Marine WildWatch (NT)	http://root.ala.org.au/bdrs-core/nt-dlrm/home.htm
Technical Reports	Dugongs: http://hdl.handle.net/10070/265115 Coastal dolphins: http://www.territorystories.nt.gov.au/jspui/handle/10070/259636 http://hdl.handle.net/10070/305351 Marine turtles: https://denr.nt.gov.au/land-resource-management/consultation-publications/flora-fauna-publications/flora-and-fauna-publications/2008 Shorebirds: https://dtc.nt.gov.au/__data/assets/pdf_file/0008/279917/2003_shorebirds_rpt76.pdf Waterbirds: https://dtc.nt.gov.au/__data/assets/pdf_file/0009/279918/2006_waterbirds_report76.pdf

	Fisheries reports – key species: https://dpir.nt.gov.au/fisheries/fisheries-strategies,-projects-and-research/fisheries-research
NT marine threatened species fact sheets	https://nt.gov.au/environment/animals/threatened-animals
Community Organisations	
AusTurtle Inc	http://www.austurtle.org.au/
Sea Turtle Foundation	http://www.seaturtlefoundation.org/
Australian Seabird Rescue	http://seabirdrescue.org/
Birdlife Australia	http://www.birdlife.org
Aboriginal Land Councils	
Aboriginal Land Councils	Northern Land Council: https://www.nlc.org.au/ Anindilyakwa Land Council: https://www.anindilyakwa.com.au/ Tiwi Land Council: http://www.tiwilandcouncil.com/

Appendix 5 - refer to chapter 5

Glossary

The source of term definitions is provided in parentheses, where (C) Commonwealth Environment Department, (NT) NT government are shown or as identified by citation.

Benthic communities: Biological communities that live in or on the seabed. These communities typically contain light-dependent taxa such as algae, seagrass, mangroves and corals, which obtain energy primarily from photosynthesis, and/ or animals such as molluscs, sponges, ascidians and worms, that obtain their energy by consuming other organisms or organic matter.

Biologically Important Areas (BIA) (C): Biologically important areas are a Commonwealth Government data construct designed to assist decision-making under the EPBC Act. BIA maps and descriptions are available online in the Conservation Values Atlas (http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf). The spatial layers are important for identifying habitat areas of protected species and where aggregations of individuals engage in biologically important behavior, such as breeding, foraging, resting or migration.

Critical habitat (C): The EPBC Act requires that habitat critical to the survival of listed threatened species is identified in the applicable Recovery Plan. These habitats are spatially defined areas that should be identified in an EIA where relevant.

Cumulative impact: Cumulative impacts are defined as the interaction of effects between one or more impacts and past, present, and reasonably foreseeable future pressures (GBRMPA 2018 Cumulative impact management policy). Cumulative impacts can result from individually minor but collectively significant actions taking place over space or time.

Desktop survey: A desktop survey is a limited-scope assessment that does not include details of a specific site visit to the area of the proposed activity. Due to its limited scope, the desktop report is often used as a cost-effective initial screen to determine the potential for environmental liability at the site, such as identifying important habitat or listed species, or contamination from a nearby site. Proponents should apply an appropriate distance buffer based on technical advice, investigations and current and future uses of the site.

Ecological integrity: The composition, structure, function and processes of ecosystems, and the natural variation of these elements.

Ecologically Sustainable Development (ESD) (NT &C): Under the NT EPA Act and EPBC Act, ecologically sustainable development (ESD) means using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life now and in the future can be increased. The NT EPA uses the core objectives and guiding principles contained in the *National Strategy* to provide further guidance and meaning on the fulfilment of its environmental impact assessment functions. Five principles of ESD are applied when assessing an action for its potential to have a significant impact:

- Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations (the 'integration principle').
- If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation (the 'precautionary principle').
- The principle of intergenerational equity – that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations (the 'intergenerational principle'). d) The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making (the 'biodiversity principle').
- Improved valuation, pricing and incentive mechanisms i.e. polluter pays, should be promoted (the 'valuation principle').

Ecosystem approach: An ecosystem approach is defined as *"The comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity."* (Secretariat of the Convention on Biological Diversity 2004)

Extent of occurrence: The total area where the presence of a member of a species is known or likely to occur.

Fecundity: The ability to produce an abundance of offspring or new growth; fertility.

Habitat: A description of habitat that utilises both biological (i.e. species assemblages) and physical (i.e. substrate or climatic) characteristics.

Indicator Species: Indicator species are animals, plants, or microorganisms used to monitor changes in the environment. For example, they can be used to detect the impact of pollution on an ecosystem, or how well a degraded environment is being managed or restored. Indicator species can also provide warning signals for upcoming changes or shifts to an ecosystem, such as climate change.

Besides being sensitive to change, indicator species need to be representative of the other organisms in the ecosystem, easily observable and able to be sampled, and they should react consistently to environmental changes. Indicator species are sometimes called proxy or surrogate species.

Life-history: The series of stages or changes an organism undergoes during its life

Marine fauna: When applying the Marine Fauna Guidelines during any stage of an EIA, from a referral or Notice of Intent (NOI) to and Environmental Impact Statement (EIS), marine fauna is defined as any animal inhabiting the marine environment which is reliant upon this environment for all or most of its life. It includes a diversity of species inhabiting Territory waters (3 nautical miles outward from the coast) ranging in size from microscopic zooplankton to the blue whale.

Marine fauna that inhabit the ocean for their entire life include dugongs, sharks, cetaceans (whales and dolphins), most sea snakes, most fish and most crustaceans. Some marine fauna such as turtles, crabs have life stages such as nesting, feeding or resting out of the ocean but remain within the coastal environment. Animals such as seabirds and shorebirds are also regarded as marine fauna as they rely on fish and other marine organisms for food and frequently nest and roost in the coastal environment. Although corals and sponges are also technically marine fauna, they have a key functional role in benthic communities and habitats and are therefore included in the **Benthic Communities and Habitats Factor.**

Any animal inhabiting the marine environment which is reliant upon this environment for all or most of its life.

Migratory (C): Migratory species are animals that migrate to Australia and its external territories or pass though, or over Australian waters during their annual migrations. Examples of migratory species are species of birds (e.g. albatrosses and petrels), mammals (e.g. whales) or some species of reptiles (marine turtles). Migratory species listed under international agreements to which Australia is a party are protected under the EPBC Act. The Migratory listing is an artefact of the International agreements and less reflective of annual migration behaviours observed in Australia as many species listed as Migratory remain in Australian waters e.g. coastal dolphins.

Precautionary principle (NT &C): Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In Australia, the precautionary principle is one of the guiding principles of ESD and it’s a key component of the EA Act and the EPBC Act. References to the principle have been incorporated into many laws and policies including fisheries legislation, rules governing the grant of development approvals, and other natural resource management policies. Refer to Ecologically Sustainable Development in the Glossary for further detail.

Primary producers: Organisms that produce complex organic compounds (such as carbohydrates, fats, and proteins) from simple substances present in its surroundings, generally using energy from light (photosynthesis) or inorganic chemical reactions (chemosynthesis). Phytoplankton is at the base of the marine food web. Its carbon fixation, the net primary productivity (NPP), sustains most living marine resources. In tropical regions natural fluctuations of NPP have large impacts on marine ecosystems including fisheries (Behrenfeld et al. 2002) and regulates the global climate (Murtugudde et al. 2002, Sabine et al. 2004). Primary producer communities include coral reefs, algal-dominated biogenic reefs, algal-dominated rocky reefs, seagrass meadows and mangrove forests. Algal mats and salt marshes growing on intertidal sand/mud flats are also classed as benthic primary producer communities.

Resilience: The ability of an environmental component to cope with change or exposure and remain in a desirable functioning state. It includes the ability to absorb impacts and continue functioning, and recover, reorganise or build capacity to learn and adapt in between events.

Significance (NT): In determining whether a proposed action is capable of having a significant effect on the environment the NT EPA may have regard to various matters, including the following:

1. Objects of the EA Act, EAAP or other NT environmental legislation
2. Values (e.g. effects to environmental factors and objectives), sensitivity and quality of the environment which is likely to be impacted
3. Extent (intensity, duration, magnitude, frequency and geographic footprint) of likely impacts
4. Consequence of likely impacts (or change)
5. Resilience of the environment to cope with the impacts or change
6. Cumulative impact with other actions
7. Connections and interactions between parts of the environment to inform a holistic view of impacts to the environment
8. Level of confidence in the prediction of impacts and the success of proposed mitigation 9. Public interest about the likely effect of the proposed action on the environment and public information that informs the NT EPA's assessment.

Significance (C): In an EIA context for the Commonwealth Government, refer to the Significant Impact Guidelines to provide overarching guidance on determining whether an action is likely to have a significant impact on a matter protected under national environment law.

Site fidelity: The tendency to return to a previously occupied location. Foraging site fidelity, for example, enables animals to increase their foraging efficiency by returning to locations where productivity was previously high. However, this strategy is only efficient if prey distribution is predictable at the spatial and temporal scales at which animals forage. Under predictable conditions, an animal should return to a location where it was previously successful and choose an alternative site if it was unsuccessful.

Vulnerability: In reference to species conservation vulnerability is where a species is susceptible to endangerment or population decline.