Providing a knowledge base for implementing the National Partnership Approach to marine turtle and dugong management in the Gulf of Carpentaria by integrating Traditional Knowledge and Western Science

Dugong Beach, Groote Eylandt

Alana Grech*, Helene Marsh, and Mark Hamann

School of Earth and Environmental Sciences, James Cook University, Douglas, Townsville, 4811

All correspondence to: Alana Grech. Tel: 61-747-815561; Fax: 61-747-814020; E-mail: alana.grech@jcu.edu.au

JAMES COOK UNIVERSITY AUSTRALIA

Australian Government

Department of the Environment, Water, Heritage and the Arts

EXECUTIVE SUMMARY

Aerial surveys for turtles and dugongs conducted since the mid 1980s using standardised methodology have provided long-term information on the distribution and abundance of turtles and dugongs in the Gulf of Carpentaria. We used information collected from five aerial surveys spanning 16 years in conjunction with geostatistical techniques, including universal kriging, to develop spatial models of turtle and dugong distribution and relative density in the Gulf of Carpentaria. We categorised areas as of low, medium, medium-high or high ecological value for dugongs based upon the relative densities integrated across surveys. Our approach assumes that dugong density is a robust index of a region's value for dugongs. The model accounts for temporal changes in the use of various regions by dugongs including movements resulting from events such as seagrass dieback by integrating information across surveys.

The models of turtle and dugong distribution and relative abundance are indicators of the relative importance of sites as feeding grounds to large green and flatback turtles and dugongs. We identified two shallow water locations (or 'hot spots') where important feeding grounds for large green and flatback turtles and dugongs overlap. These 'hot spots' included the region north of Bentinck Island in Queensland, and the region north-west of the Sir Edward Pellew Group in the Northern Territory. We quantified the importance of the Gulf of Carpentaria as dugong habitat in the context of the entire east coast of Queensland and Gulf of Carpentaria. The model indicates that the Gulf of Carpentaria comprises 6 % of the total high ecological value dugong habitats and 29 % of the total medium-high value habitats on the north-eastern coast of Australia (ie. Nhulunbuy to Moreton Bay).

With assistance from the Anindilyakwa Land Council and the Northern Territory Department of Natural Resources, Environment and the Arts, information on turtle and dugong distribution and relative density was shared with the Anindilyakwa Land Council via a Global Positioning System (GPS) and geographical information system (GIS) training and community mapping workshop held from 20th – 25th October 2008. At the workshop, 11 participants (including 6 Indigenous rangers and 5 members of the Anindilyakwa Land Council Land Management group) were trained in: (1) fundamental GPS operation; and (2) using the overlay functions of GIS to combine their traditional ecological knowledge with information collected by western scientists and private and government organisations.

The workshop resulted in a GIS-based decision support system created by the Anindilyakwa Land Council Land Management group that included the spatial information they had collected prior to, and during the workshop; and information collected by James Cook University (including the models of turtle and dugong distribution and relative abundance) and Groote Eylandt Mining Company Pty. The GPS and GIS training provided the Land Management group with the capacity to develop their own GIS-based decision support system and maintain it into the future.

In consultation with the Land Management group of the Anindilyakwa Land Council, we conducted a spatial assessment of risk to dugongs from vessel strike associated with boats that navigate the Warwick Shipping Channel and Alyangula port limits. The results indicate that approx. 50% of dugong habitats of high ecological value within the Anindilyakwa Aboriginal people's sea country are at risk from vessel strike associated with boats that navigate the Warwick Shipping Channel and Alyangula port limits. We have supplied this information to the Land Management group of the Anindilyakwa Land Council to inform the design of future dugong management plans that are locally based; and to assist them in their negotiations with GEMCO.

This project has provided a knowledge base for implanting the National Partnership Approach to marine turtle and dugong management in the Gulf of Carpentaria by increasing the capacity of the Anindilyakwa Aboriginal people of Groote Eylandt make decisions about the management of natural resources by integrating their Indigenous Knowledge with information collected by western scientists.

INTRODUCTION

The importance of northern Australia to the conservation of the world's marine turtles and mammals is increasingly important as other areas of high biodiversity become degraded. Much of northern Australia is under Indigenous tenure and hunting of turtles and dugong is a Native Title right. Thus, empowering Indigenous Australians, including communities in the Gulf of Carpentaria, to work with government to make informed decisions about how to manage their sea country is of local, national and international significance and accords with government policy, in particular 'Sustainable Harvest of Marine Turtles and Dugongs in Australia –A National Partnership Approach'.

Decision support systems (DSS) are computerised systems that can assist in making decisions between alternatives based on estimates of the values of those alternatives. Geographical information system (GIS)-based DSS have the benefit of being able to incorporate many different kinds of data spatially to support the estimation, evaluation and comparison of alternatives. A GIS-based DSS is a visual representation of information, and can provide a simple and clear way of creating, communicating and analyzing data in a manner accessible to audiences of different cultural backgrounds. Thus, GIS-based DSS have great capacity to incorporate communities in their development.

Community developed solutions to problems that concern them tend to be reasonable, realistic and sustainable (Craig et al. 2002). A community's decision making process can be enhanced by GIS-based DSS as such systems provide information to help develop appropriate responses, and support the creation of map products and analysis. As a result of differential access to data and technology, remote communities often lack the advantages of GIS-based DSS to assist them in managing their natural resources.

In partnership with governments, remote Indigenous communities in the Gulf of Carpentaria are challenged with making a variety of decisions about the management of marine species, especially marine turtles and dugongs. Because of the primacy of Traditional Ecological Knowledge to Indigenous peoples and the primacy of Western Scientific Knowledge to governments, management of Indigenous sea country including turtle and dugong harvesting must be based on both knowledge systems. The capacity of these knowledge systems to better inform such decision making is enhanced if both types of information are presented in compatible formats. Unfortunately, in many areas Indigenous knowledge is being lost at an alarming rate and communities require technical support to assist them in maintaining and actively conserving this information. GIS-based DSS are able to bridge the gap between Indigenous Knowledge and Western Scientific Knowledge by collating a variety of information into a common format. An additional benefit of GIS-based DSS is their ability to store information and so support, maintain and conserve Indigenous Knowledge.

The objective of this project was to empower communities in the Gulf of Carpentaria to work with government in accordance with the National Partnership Approach and make decisions about management of marine turtles and dugongs by increasing their capacity to integrate their Indigenous Knowledge with information collected by western scientists. We conducted a project with the Anindilyakwa Land Council and Aboriginal people of Groote Eylandt that had the following aims:

(1) Produce an in -water spatial model of western scientific knowledge of marine turtle distribution and relative density in the Gulf of Carpentaria from data generated by an aerial survey conducted in 2007; and an integrated spatial model of western scientific knowledge of dugong distribution and relative density in the Gulf of Carpentaria from data generated by a time series of five aerial surveys conducted between 1991-2007 inclusive;

(2) Coordinate and conduct a cultural heritage mapping program for the Anindilyakwa Aboriginal people of Groote Eylandt in the Gulf of Carpentaria to record Indigenous Knowledge in a format that can be integrated with information collected by western scientists, especially the spatial models produced in (1) above;

(3) Integrate this Indigenous Knowledge and Western Scientific Knowledge into a GIS-based DSS and provide outputs to Anindilyakwa Aboriginal people in a common format to assist them to work in

partnership with government to manage their sea country and retain sustainable populations of marine turtles and dugongs; and

(4) Use a spatial risk assessment approach to assist the Anindilyakwa Aboriginal people and government in evaluating the likely efficacy of the management plans with respect to marine turtle and dugong conservation.

METHODS AND RESULTS

(1) Spatial models of marine turtle and dugong distribution and relative density in the Gulf of Carpentaria.

Data from the November 2007 aerial survey were integrated with turtle and dugong sightings from aerial surveys conducted in December 1991, November-December 1994 (survey conducted by Keith Saalfeld, Northern Territory Department of Natural Resources, Environment and the Arts), December 1997, and November 2006 to form a common GIS database. Using the method of Grech and Marsh (2007), turtle and dugong distribution and relative density was calculated at a grid size of 2km * 2km (Appendix 1 and 2) for the inshore areas of the Gulf of Carpentaria.

Aerial surveys have been used to estimate absolute dugong abundance by correcting sightings for perception bias (animals that are available to but missed by observers) and availability bias (animals that are unavailable to observers because of water turbidity) *sensu* Marsh and Sinclair (1989) and Pollock *et al.* (2006). No such corrections area available for turtles. The corrections for perception biases were applied at the spatial scale of entire surveys (thousands of square kilometers), an inappropriate spatial scale for our research. As a result, the models of turtle and dugong distribution and density are based on relative rather than absolute total density. Nonetheless, the relative densities among regions should be approximately comparable.

There are three limitations to modelling the distribution of turtles and dugongs in the Gulf of Carpentaria from aerial survey data:

1. Aerial surveys are less effective for determining the in-water distribution of turtles then dugongs because of the difficulties in distinguishing between turtle species and detecting small individuals. Marsh and Saalfeld (1989) found that aerial surveys provide useful information on the in-water distribution of large green turtles (targeted by Indigenous hunters) in the shallow water areas used for hunting. It is particularly difficult to distinguish between green and flatback turtles as they look similar from above. In the Gulf of Carpentaria, aerial surveys may provide information on the distribution of large flatback turtles as well as green turtles. Our model is based on aerial survey data and is thus limited to modelling the distribution and relative density of large green and flatback turtles in their shallow water feeding grounds.
2. All aerial surveys are conducted in late spring or early summer when weather and sea states provide optimum survey conditions. Dugongs are unlikely to exhibit a seasonal component in their movements in the Gulf of Carpentaria, and so conducting multiple surveys in the same season should not confound our relative estimates of dugong distribution and relative density. In the Gulf of Carpentaria, turtle nesting season occurs between July and September. The model of turtle distribution and relative density is not biased towards turtles that are breeding and nesting, but it may be biased towards turtles that are migrating through the Gulf of Carpentaria as a result of the nesting season.
3. Aerial surveys are restricted to dugong habitats that occur in shallow waters of the Gulf of Carpentaria, and do not encompass the entire distributional range of turtles. Thus, our model of turtle distribution and relative density is limited to informing management of turtles when they are in shallow water areas.

The index of average relative turtle density in the surveyed Gulf of Carpentaria was estimated to be 0.288 turtles/km^2; relative density ranged from 0.0011 to 3.069 turtles/km^2. Average turtle relative density in the Northern Territory is higher than in Queensland (0.383 compared with 0.216 turtles/km^2). The highest relative density is also greater in the Northern Territory with a range of 0.0011 to 3.069 turtles/km^2 compared with the Queensland range of 0.0011 to 1.500 turtles/km^2. The areas of highest

relative turtle density (or 'hot spots') in Queensland are around the Wellesley Islands and in Albatross Bay (Appendix 1). 'Hot spots' along the Northern Territory coast are in the offshore waters: west of the Sir Edward Pellew Group; east of Numbulwar; and north-east of Groote Eylandt (Appendix 1).

The index of average relative dugong density in the surveyed Gulf of Carpentaria was estimated to be 0.060 dugongs/km^2; relative density ranged from 0.0011 to 1.10 dugongs/km^2. Average dugong relative density in Queensland is higher than the Northern Territory (0.070 compared with 0.053 dugongs/km^2). The highest relative density is also greater in Queensland with a range of 0.0011 to 1.010 dugongs/km^2 compared with the Northern Territory range of 0.0011 to 0.92 dugongs/km^2. The areas of highest relative dugong density (or 'hot spots') in Queensland are around the Wellesley Islands and in the coastal waters adjacent to Karumba (Appendix 2). 'Hot spots' along the Northern Territory coast are around the Sir Edward Pellew Group and in the waters adjacent to the mouth of the Limmen Bight River (Appendix 2).

The models of turtle and dugong distribution and relative abundance are an indicator of the relative importance of sites as feeding grounds to large green and flatback turtles and dugongs. We identified two shallow water locations (or 'hot spots') where important feeding grounds for large green and flatback turtles and dugongs overlap (Appendix 3). These 'hot spots' included the region north of Bentinck Island in Queensland, and the region north-west of the Sir Edward Pellew Group in the Northern Territory.

We used the same range of values of dugong density as Grech and Marsh (2007) to categorise dugong management units as low, medium, medium-high or high ecological value for dugongs in the Gulf of Carpentaria (Appendix 4). Our approach assumes that dugong density is a robust index of a region's conservation value for dugongs. This assumption is justified because: (1) density estimates are regarded as suitable surrogate measurements of habitat use; and (2) no critical habitats for dugongs have been identified other than the seagrass meadows where they spend most of their time. By using the time series of data collected over 16 years, the model accounts for temporal changes in the use of various regions by dugongs including movements resulting from events such as seagrass dieback. The resultant model of ecological value allowed us to quantify the importance of the Gulf of Carpentaria as dugong habitat in the context of the north-eastern coast of Australia (Appendix 5). We define the north-eastern coast of Australia as the shallow water regions of the Gulf of Carpentaria, south-east Queensland, Great Barrier Reef and Torres Strait. The model indicates that the Gulf of Carpentaria comprises 6 % of the total high ecological value dugong habitats and 29 % of the total medium-high value habitats on the north-eastern coast of Australia.

The models of turtle and dugong distribution and relative abundance in the Gulf of Carpentaria have been supplied in digital format to various organisations to inform the management of turtles and dugongs, including: Anindilyakwa Land Council; Northern Territory Department of Natural Resources, Environment and the Arts; Northern Planning Unit of the Department of Environment, Water, Heritage and the Arts; and the international marine mammal, sea turtle and seabird database OBIS-SEAMAP (Duke University). Due to the large spatial extent of the turtle and dugong models, they are able to inform large scale marine planning for both the inshore waters of the Northern Territory and the Northern Planning Region.

(2) Coordinate and conduct a cultural heritage mapping program for the Anindilyakwa Aboriginal people of Groote Eylandt in the Gulf of Carpentaria.

In order for the Anindilyakwa Aboriginal people of Groote Eylandt to work with government in accordance with the National Partnership Approach, and make decisions about the management of natural resources, they require the capacity to integrate their Indigenous Knowledge with information collected by western scientists. With the assistance of the Anindilyakwa Land Council and Northern Territory Department of Natural Resources, Environment and the Arts we conducted a five-day GPS and GIS training and community mapping workshop in October 2008 with Sea Rangers (n=3), women rangers (n=3), and members of the Land Management group of the Anindilyakwa Land Council (n=5).

The availability of rangers and community members was compromised during the workshop as the Anindilyakwa community was in 'sorry time'. PI Alana Grech did not go conduct the workshops at the four Aboriginal communities on Groote Eylandt as there were restrictions on people entering the

communities who were not community members. Instead, PI Alana Grech conducted the workshop in the offices of the Anindilyakwa Land Council in the town of Angurugu.

Intellectual property and access to information (data sharing) protocols needed to be established to facilitate authorisation of data to be transferred or shown within the Anindilyakwa Land Council and to external agencies. At the beginning of the workshop, concerns regarding safe storage of information, intellectual property and data sharing were discussed in an open forum. During the open forum, workshop attendees were asked to discuss: (1) datasets collected by the Anindilyakwa Land Council; (2) who should have access to these datasets (eg. community/ Anindilyakwa Land Council / Northern Territory Department of Natural Resources, Environment and the Arts /Department of Environment, Water, Heritage and the Arts etc.); and (3) how can those who access the dataset use it (eg. can it be used for research, fisheries management etc).

PI Alana Grech produced a GIS and GPS training manual for participants prior to the commencement of the workshops. All participants were provided with a hard copy version of the training manual; and the Anindilyakwa Land Council was provided with hard copy and digital versions. PI Alana Grech supplied GPS units, GIS software, laptops, and spatial data layers to workshop participants in the context of a comprehensive introduction to all aspects of GIS and GPS, as well as hands-on experience using GIS and GPS to assist in natural resource decision making.

At the beginning of the training workshop, PI Alana Grech and Anindilyakwa Land Council Land Management Coordinator Gavin Enever discussed in detail the turtle and dugong management issues faced by the Anindilyakwa Land Council contend. This discussion resulted in the development of course material and a training schedule that was relevant to the management needs of the Anindilyakwa Land Council.

Each day of the five-day workshop had two components: GPS training was conducted during the morning, followed by GIS and community mapping training in the afternoon. GPS training consisted of an introduction to the GPS unit Garmin eTrex and field exercises. Training was conducted using the Garmin eTrex as it is the preferred GPS unit of the Anindilyakwa Land Council. During field exercises, participants were encouraged to record (with GPS units) information they consider relevant to the management of natural resources in their community, including sites of marine turtle and dugong presence, community infrastructure (roads, boat ramps), weeds, and areas of habitat destruction. In the afternoon, workshop participants imported their GPS data into the GIS program ArcGIS® 9.2 (ESRI, 2004). GIS training was conducted in ArcGIS® 9.2 as it is the preferred GIS program of the Anindilyakwa Land Council.

GIS and community mapping training consisted of exercises as described in the training manual (Appendix 5). Digital and hard copy versions of the turtle and dugong models produced in Objective 1 were supplied as examples of Western Scientific Knowledge. Participants used the GPS data that they collected in the morning during the afternoon's GIS training. Hard-copy maps were provided to participants to assist in the recording of spatial information. Participants were trained in: (1) transferring data from a GPS unit to GIS; (2) recording their spatial information Knowledge in a digital format using ArcGIS® 9.2; (3) overlaying their spatial information Knowledge with spatial information collected by other organizations including James Cook University and the Groote Eylandt Mining Company Pty Ltd (GEMCO); (4) using the various geoprocessing tools available in GIS (eg. buffer, intersect, clip, union) to inform their decision making; and (5) effective organisation of digital and hard copy information.

The GPS and GIS training and community mapping workshop that we conducted had two major outcomes: (1) it increased the capacity for rangers and members of the Land Management group of the Anindilyakwa Land Council to collect spatial information; and (2) it increased the capacity of workshop participants to interpret and apply the spatial information collected by western scientists, including the spatial models produced in (1) above.

(3) Integrate this Indigenous Knowledge and Western Scientific Knowledge into a GIS-based DSS and provide outputs to Anindilyakwa Aboriginal people.

During the GPS and GIS and community mapping workshop, 11 members of the Anindilyakwa Land Council were trained in: (1) recording their spatial information Knowledge in a digital format using GIS; (2) overlaying their spatial information Knowledge with spatial information collected by Western Scientists; and (3) using the various geoprocessing tools available in GIS to inform decisions made on retaining sustainable populations of marine turtles and dugongs. Digital and hard copy versions of the turtle and dugong models produced in Objective 1 and spatial information collected by the GEMCO were supplied as examples of Western Scientific Knowledge.

By the end of the workshop, the Anindilyakwa Land Council Land Management group had created their own GIS-based DSS that included spatial information that they had collected prior to and during the workshop; and information collected by James Cook University and GEMCO. The GPS and GIS training that was provided to the Anindilyakwa Land Council during the five-day workshop also gave the Land Management group the capacity to maintain their GIS-based DSS into the future. PI Alana Grech and Anindilyakwa Land Council Land Management Coordinator Gavin Enever have maintained regular phone and email contact since the October 2008 workshop, and PI Alana Grech has continued to provide technical support in the development and application of the GIS-based decision support system that informs the management of the Anindilyakwa sea country and marine turtles and dugongs.

(4) Use a spatial risk assessment approach to assist the Anindilyakwa Aboriginal people and government in evaluating the likely efficacy of the management plans with respect to marine turtle and dugong conservation.

The Anindilyakwa Land Council has not yet developed a management plan for marine species within their sea country. During the workshop that integrated Indigenous Knowledge with Western Scientific Knowledge, members of the Land Management group identified a potential conflict with marine species and boats that navigate the Warwick Shipping Channel and Alyangula port limits (Appendix 6). In consultation with the Land Management group, we conducted a spatial assessment of risk to dugongs from vessel strike associated with boats that navigate these areas. The primary users of the Warwick Shipping Channel and Alyangula port are ships transporting freight from the Groote Eylandt Mining Company Pty Ltd (GEMCO).

On advice from the Anindilyakwa Land Council, we assumed the spatial extent of the Anindilyakwa Aboriginal people's sea country was 3nm from the coast of Groote Eylandt and its neighbouring islands. We also assumed that boats navigating the Warwick Shipping Channel travel within 0.5nm from the designated channel line.

Using GIS, we overlayed the model of dugong distribution and relative density from (1) with spatial information on the Warwick Shipping Channel and Alyangula port limits. We then quantified: (1) the total area of dugong habitat of varying ecological value within the Aboriginal people's sea country; (2) the total area of dugong habitat within the Warwick Shipping Channel and Alyangula port limits; and (3) the proportion of dugong habitat within the Anindilyakwa Aboriginal people's sea country that is also within the Warwick Shipping Channel and Alyangula port limits (Table 1).

Ecological Value	Anindilyakwa Aboriginal people's sea country total area (km^2)	Warwick Shipping Channel and Alyangula port limits total area (km^2)	Proportion (%)
High	16	8	50
Medium High	308	28	9
Medium	1584	48	3
Low	2040	40	2

Table 1: Results from a spatial assessment of risk to dugongs from vessel strike within the Warwick Shipping Channel and Alyangula port limits.

The results indicate that dugongs within approx. 50% of high ecological value dugong areas are at risk from vessel strike associated with boats that navigate the Warwick Shipping Channel and Alyangula port limits. We have supplied this information to the Land Management group of the Anindilyakwa Land Council to inform the design of future management plans for dugongs in the region; and to assist them in their negotiations with GEMCO.

DISCUSSION

Our objective was to empower the Anindilyakwa Aboriginal people to work with government in accordance with the National Partnership Approach and make decisions about management of marine turtles and dugongs. An appropriate way of assisting the Anindilyakwa Aboriginal people to work with government to manage marine turtles and dugongs is to increase their capacity to integrate their Indigenous Knowledge with information collected by western scientists.

By conducting GPS and GIS training and community mapping workshop with the Anindilyakwa Land Council, the capacity has increased for the Anindilyakwa Aboriginal people to use their own Indigenous Knowledge with spatial information collected by western scientists. It was appropriate to provide such training as it allowed the Anindilyakwa Land Council Land Management group to create their own GIS-based DSS and gave them the capacity to maintain their GIS-based DSS in the future.

Digital and hard-copy versions of the spatial models of turtle and dugong distribution and relative density were provided to the Anindilyakwa Land Council and Land Management group to inform turtle and dugong management within their sea country. It was appropriate to deliver the model of dugong distribution and relative density to the Anindilyakwa Land Council through a workshop as it provided an opportunity for Anindilyakwa Land Council staff to have their concerns addressed directly and learn how to use the model in conjunction with their own Traditional Ecological Knowledge via a GIS-based DSS. Results from the 2007 turtle and dugong aerial survey conducted by Helene Marsh and her Group were also discussed with Anindilyakwa Land Council staff.

The models of turtle and dugong distribution and relative abundance in the Gulf of Carpentaria have also been supplied in digital format to other organisations to inform the management of turtles and dugongs in the region, including: Northern Territory Department of Natural Resources, Environment and the Arts; Northern Planning Unit of the Department of Environment, Water, Heritage and the Arts; and the international marine mammal, sea turtle and seabird database OBIS-SEAMAP (Duke University). Due to the large spatial extent of the turtle and dugong models (see Appendix 5); they are able to inform large scale marine planning for both the inshore waters of the Northern Territory and the Northern Planning Region.

We found that presenting the results of the turtle and dugong aerial surveys as a continuous spatial model was an effective method of communicating the aerial survey results. Members of the Anindilyakwa Land Council found the maps of turtle and dugong distribution and relative density very easy to understand and many said that this Western Science information was congruent with their Indigenous Knowledge. The positive reactions to the maps of our continuous spatial model contrasted with their much less positive reactions to our previous presentations of the aerial survey results as maps showing turtle and dugong sightings as point data, a format preferred by some western environmental managers. In our experience, Indigenous people find the point data difficult to comprehend and to relate to their own knowledge.

PI Alana Grech and Anindilyakwa Land Council Land Management Coordinator Gavin Enever have maintained regular phone and email contact since the October 2008 workshop, and PI Alana Grech has continued to provide technical support in the development and application of the GIS-based decision support system that informs the management of the Anindilyakwa sea country and marine turtles and dugongs. Regular contact and future training workshops are necessary if the GIS-based decision support system is to be maintained by the Anindilyakwa Land Council. We recommend that capacity building in the use of GPS and GIS technology is continued as an integral part of the National Partnership Approach for managing the turtle and dugong harvest of Indigenous Australians.

This report provides a publically-available summary of the outcomes of our project on integrating Indigenous knowledge with information collected by western scientists in the Gulf of Carpentaria using Groote Eylandt Aboriginal communities as a case study. A publication written for a scientific journal will be produced from outcomes of this project after we have integrated its findings with the outcomes from other projects that we are currently conducting in other regions of the Northern Territory and Queensland. This publication will also be available to the public, and forwarded to the relevant government agencies to inform a National Partnership Approach to marine turtle and dugong management in the Gulf of Carpentaria.

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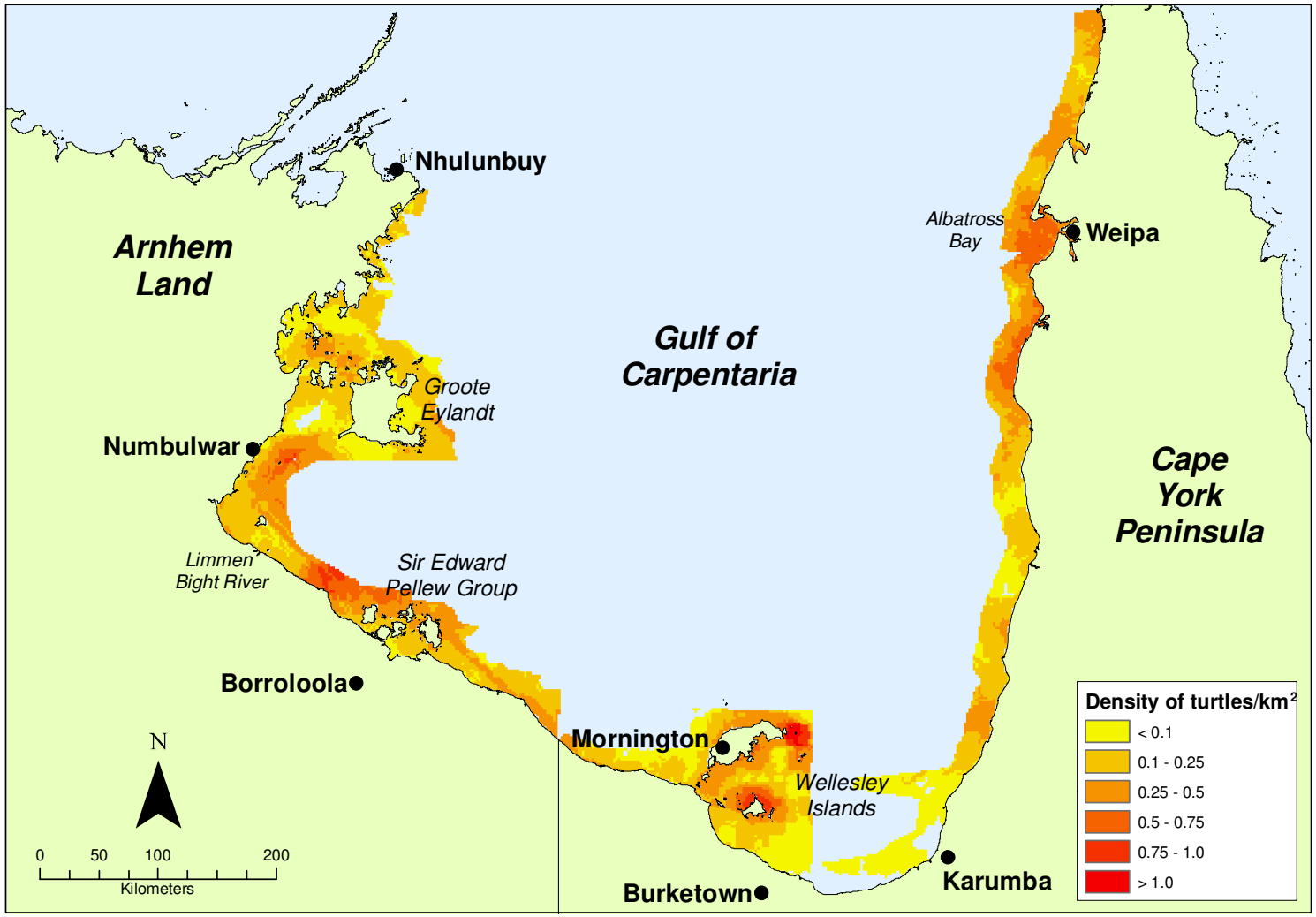
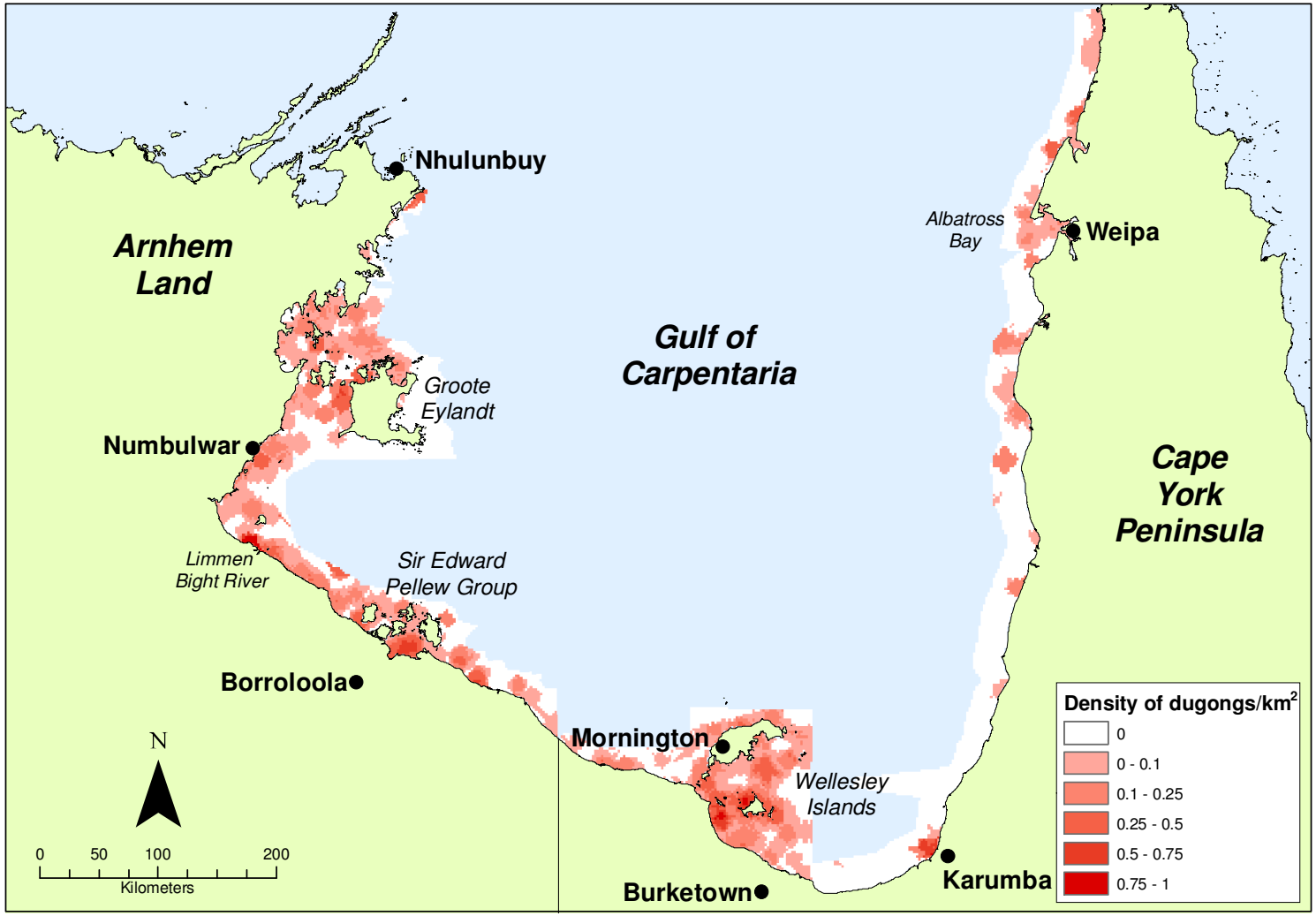
Marsh, H. and Saalfeld, W. (1989). Aerial surveys of sea turtles in the northern Great Barrier Reef Marine Park. Australian Wildlife Research 16: 239 – 249.

Marsh, H. and Sinclair, D.F. (1989). Correcting for visibility bias in strip transect aerial surveys of aquatic fauna. Journal of Wildlife Management. 53(4): 1017-1024.

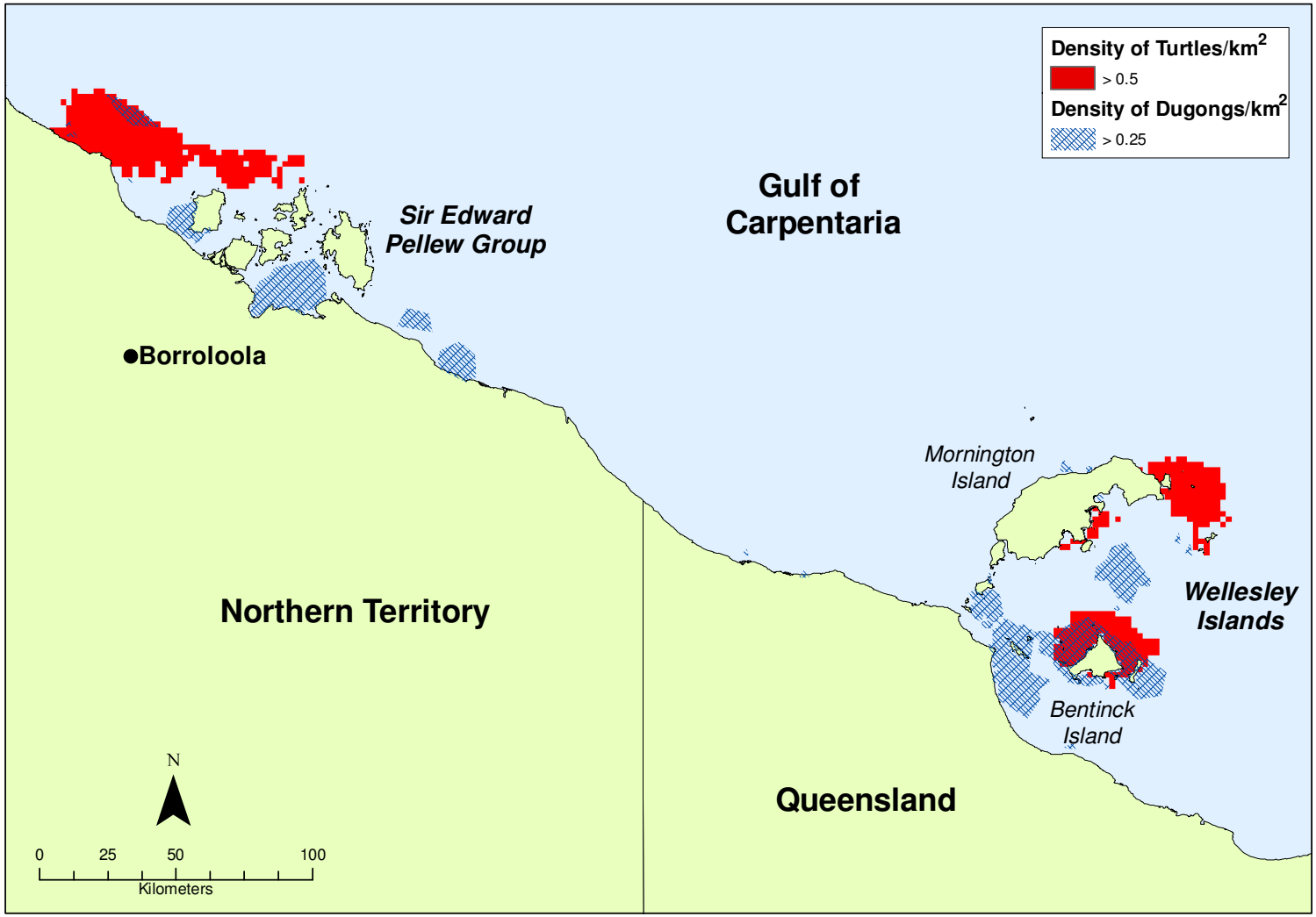
Appendix 1: Model of turtle distribution and relative density in the Gulf of Carpentaria based on the turtle sightings from aerial surveys conducted between 1991 and 2007.



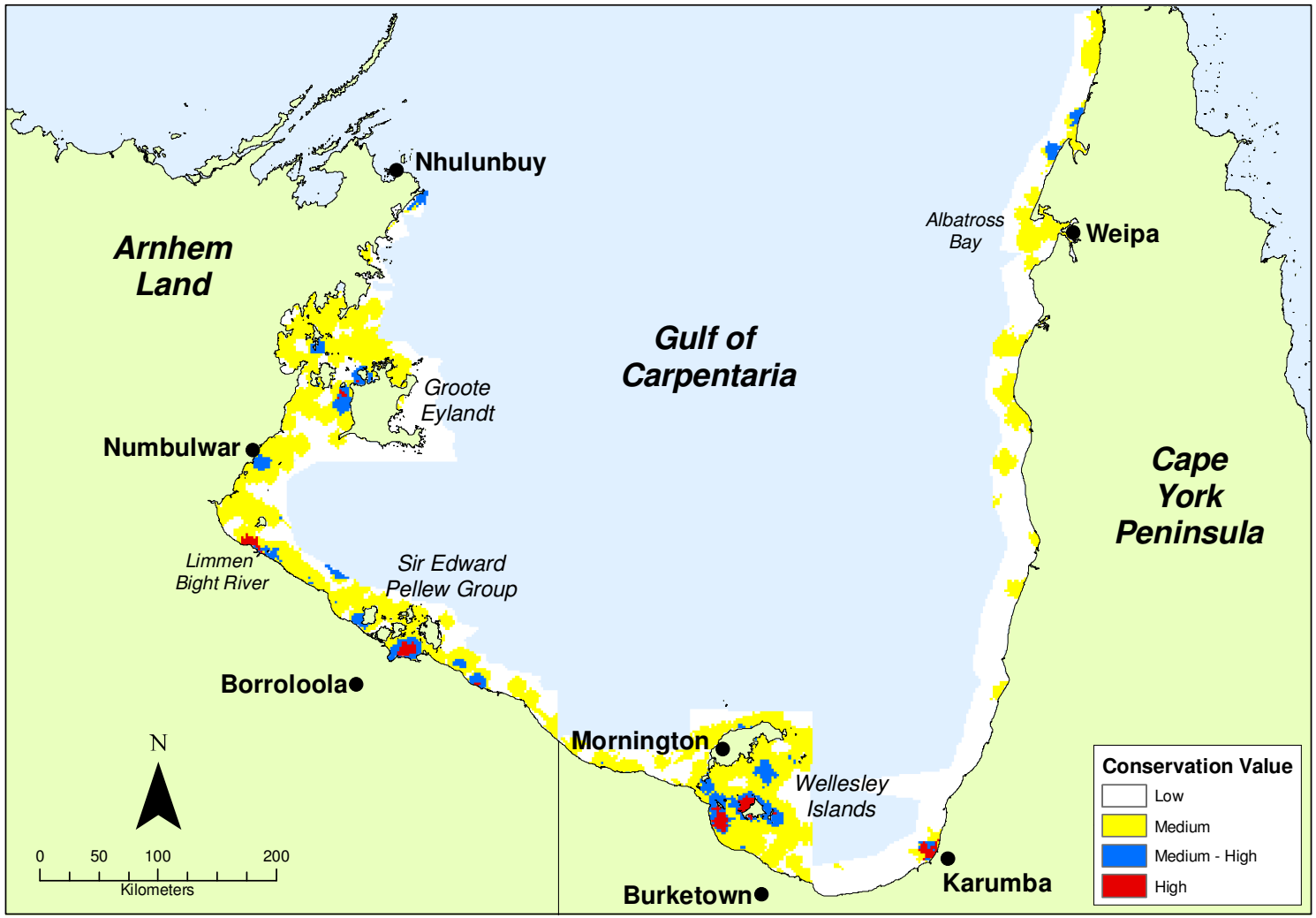
Appendix 2: Model of dugong distribution and relative density in the Gulf of Carpentaria based on the dugong sightings from aerial surveys conducted between 1991 and 2007.



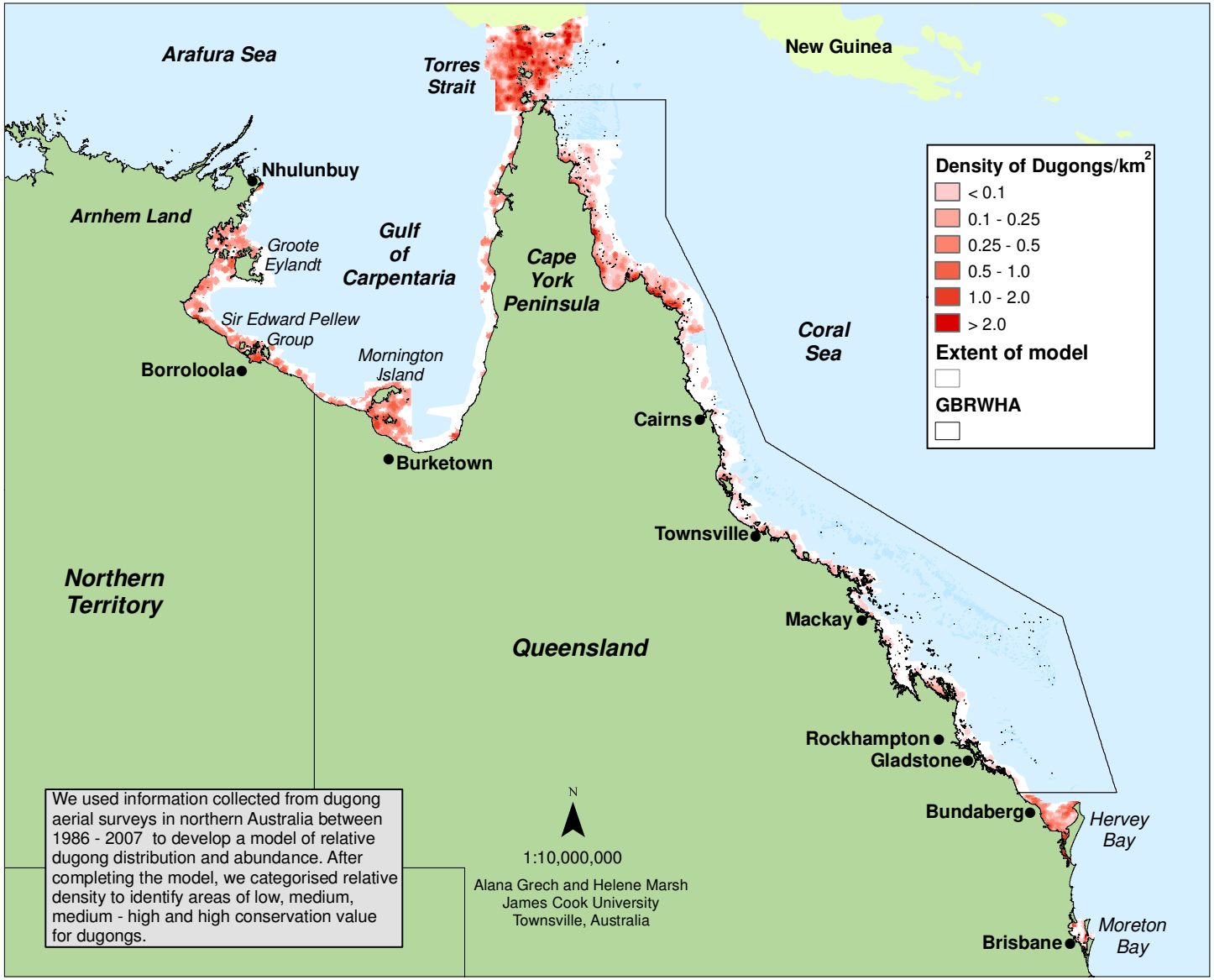
Appendix 3: Overlap of shallow water areas that are important feeding grounds to large green and flatback turtles and dugongs. We identified important feeding grounds as areas of high dugong density (> 0.25 dugongs/km^2) and high turtle density (> 0.5 turtles/km^2) in the Gulf of Carpentaria.



Appendix 4: Model of the ecological value of dugong habitats in the Gulf of Carpentaria based on the dugong sightings from aerial surveys conducted between 1991 and 2007.



Appendix 5: Models of dugong distribution and relative density in the Gulf of Carpentaria and east coast of Queensland created by Grech and Marsh.



Appendix 6: Model of dugong ecological value in the Anindilyakwa Aboriginal people's sea county and Warwick Shipping Channel and Alyangula port limits