Spatial models and risk assessments to inform marine planning at ecosystem-scales: seagrasses and dugongs as a case study

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Abstract

Informing marine planning and the management of species at ecosystem-scales is difficult because data are generally lacking at that scale. Collecting empirical information on the distribution and/or abundance of species across broad spatial scales is expensive and logistically difficult. Accurate and efficient monitoring programmes that assess the response of species to management actions often cannot be conducted at ecosystem-scales due to time, expertise and cost constraints.

The Great Barrier Reef World Heritage Area (GBRWHA) of Queensland, Australia, is the world's largest World Heritage Area (approximately 348,000 km^2) and second largest marine protected area (MPA). The region supports a variety of habitats and species including coastal seagrasses and globally significant populations of the dugong (*Dugong dugon*), a threatened marine mammal. Seagrasses, dugongs and their habitats are exposed to multiple anthropogenic threats along much of the 2,300 km coastline of the GBRWHA. Assessing the effectiveness of the current management arrangements for seagrasses and dugongs and informing the design of new regimes is challenging due to the difficulties associated with data collection and monitoring at the scale of the coastal GBRWHA.

My thesis goal was to overcome the difficulties associated with informing the management of coastal seagrasses and dugongs in the GBRWHA by using spatial models and risk assessments in geographical information systems (GIS). My objectives were to: (1) develop spatial models of seagrasses and dugongs at the scale of the coastal GBRWHA; and, (2) use these models to estimate the risk to coastal seagrasses and dugongs from their anthropogenic threats. This approach allowed me to compare and rank the threats to identify the most severe risks, and to locate specific sites that require conservation actions.

I used spatial information on the distribution of coastal seagrasses and predictor variables along with ecological theory and expert knowledge to inform the design of a Bayesian belief network, and to develop a predictive seagrass habitat model. The Bayesian belief network quantified the relationship (dependencies) between seagrass habitats and eight environmental drivers: relative wave exposure, bathymetry, spatial

extent of flood plumes, season, substrate, region, tidal range and sea surface temperature. The outputs of the modelling exercise were probabilistic GIS-surfaces of seagrass habitat suitability for the entire GBRWHA coast in both the wet and dry seasons at a planning unit of 2 km * 2 km.

Quantitative information on the relative impact of the anthropogenic threats to coastal seagrasses is incomplete or unavailable, and the cumulative impact of multiple threats is difficult to measure and predict. In the light of this uncertainty, I used expert knowledge to evaluate the relative risk of coastal seagrass habitats to their hazards. Vulnerability scores derived from expert opinion, spatial information on the distribution of threats and the probabilistic GIS-surfaces of seagrass habitat suitability were used to delineate areas of low, medium and high relative risk to coastal seagrass habitats. I found that whilst most planning units in the remote Cape York region of the GBRWHA are classified as low risk, almost two thirds of coastal seagrass habitats along the urban coast are at high or medium risk from multiple anthropogenic activities. Reducing the risk to coastal seagrass habitats in 13 sites identified for conservation action would require: (1) improving the quality of terrestrial water that enters the GBRWHA; (2) mitigating the impacts of urban and port infrastructure development and dredging; and, (3) addressing the hazards of shipping accidents and recreational boat damage.

I derived a spatially explicit dugong population model from spatial information on the abundance and distribution of dugongs collected by a 20 year time-series of aerial surveys. Data from the aerial surveys were corrected for differences in sampling intensity and area sampled between surveys prior to the development of the model. I interpolated the corrected data to the spatial extent of the aerial surveys using the geostatistical estimation method of universal kriging. The model estimated the relative density of dugongs across the GBRWHA at the scale of 2 km * 2 km dugong planning units (the same spatial scale as the seagrass habitat model). I classified each dugong planning unit as of low, medium, or high conservation value on the basis of the relative density of dugongs estimated from the model and a frequency analysis.

I compared the spatially explicit dugong population model with information on the distribution of commercial gill-netting activities to estimate the risk of dugong bycatch in the GBRWHA. I found that new management arrangements introduced in the

GBRWHA in 2004 appreciably reduced the risk of dugong bycatch by reducing the total area where commercial netting is permitted. Restructuring of the industry further reduced the total area where netting is conducted. Netting is currently prohibited in 67% of dugong planning units of high conservation value, a 56% improvement over the former management arrangements. I identified four sites where netting is still conducted in dugong planning units of high and medium conservation value. Conservation actions including area closures or modified fishing practices should be considered for these regions.

In addition to commercial gill-netting, dugongs are threatened by Indigenous hunting, trawling, vessel traffic, and poor quality terrestrial runoff. I developed a rapid approach to assess the risk to dugongs from multiple anthropogenic threats in the GBRWHA, and evaluated options to ameliorate that risk. Expert opinion and a Delphi technique were used to identify and rank anthropogenic threats with the potential to adversely impact dugongs and their habitats. I quantified and compared the distribution of these threats with the spatially explicit model of dugong distribution and found that almost all dugong planning units of high (96%) and medium (93%) conservation value in the GBRWHA are at low risk from human activities. Decreasing the risk to dugongs from anthropogenic threats in four sites that I identified for conservation action would require netting or Indigenous hunting to be banned in the remote Cape York region, and the impacts of vessel traffic, terrestrial runoff and commercial netting to be reduced in urban areas.

The approach I developed in this thesis was able to overcome the difficulties associated with informing marine planning and management at ecosystem-scales by using spatial models and risk assessments in GIS to: (1) quantify the spatial distribution of species; and, (2) assess the risk to species and identify sites for conservation action. I was able to achieve this outcome in a data-inadequate environment by combining qualitative assessments on the relative impact of multiple anthropogenic threats with spatial models of species and threat distributions. Implementing conservation actions at the sites that I identified for management will provide the greatest positive result for coastal seagrasses and dugongs at the scale of the GBRWHA. Future research should be directed at understanding the constraints and opportunities for management in the region to ensure that effective implementation of conservation actions can be achieved.

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