Kimberley Marine Research Program

WAMSI Project 2.2.8

Modelling the future of the Kimberley region

By the end of the WAMSI Kimberley Marine Research Program, a staggering 25 research projects will have generated new information about the bio-physical, ecological and social processes affecting the Kimberley marine environment. An international team of researchers from CSIRO and ALCES (based in Canada) has been building a modelling tool to help condense all this information to answer management questions and enable better decisions to be made on the future of the region.

Background

Management decisions for the Kimberley marine environment aim to find a sustainable compromise between protecting one of the few remaining pristine coastal environments in the world, while supporting the region's social and economic development.

However, very little was known about how this ecosystem functions and we could only speculate on how a challenging macrotidal (tidal range >4 m) environment might affect it.

Environmental management is also fundamentally about the future. The future of the Kimberley system will be determined by the interaction between many forces (economic, ecological and social processes, climate change, human population dynamics, resource extraction and others) as well as by the management strategies we implement.

As a result, meaningful decision-making requires prediction. The important question is: What type of prediction best supports decision-making?

Computer models allow us to integrate a large amount of data, knowledge and state-of-the-art understanding of social, economic and ecological processes while accounting for uncertainty and missing information.

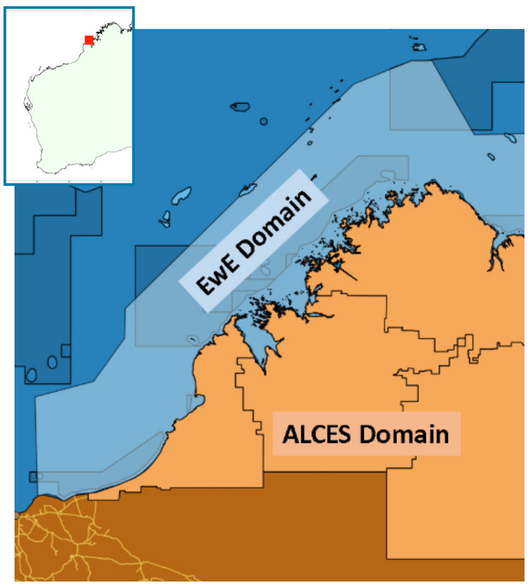

Figure 1. The Ecopath with Ecosim and ALCESs model domains

More importantly, models are the best tools we currently have to explore the possible consequences between a large number of natural processes and human actions. They help us to understand a system and make better decisions.

Research Objectives

The knowledge integration and management strategy evaluation (MSE) modelling project is considering the future of the Kimberley, the possible scenarios and the increasing pressures that each scenario may generate in the marine environment.

Key objectives of this research project in relation to the Kimberley marine environment are to:

- improve our understanding of the likely impacts of increasing human pressure and climate change at a regional scale;
- integrate the knowledge and information generated by other projects into a unified modelling framework; and
- communicate the modelling results to key decision makers in such a way that their results are understood and can be incorporated into the decision making process.

To achieve these objectives, the research team has implemented two models (Ecopath with Ecosim [EwE] and ALCES) to simulate land and marine processes in the Kimberley region.

western australian marine science institution

CSIRO

Curtin University

ALCES

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WAMSI Project 2.2.8 Modelling the future of the Kimberley region

It's important to recognise that models don't make decisions and don't provide prophecies of what will happen, but can provide some guidance as to what may happen to the region under a wide range of conditions.

The Approach

Ecopath with Ecosim (EwE) & ALCES

The two computer models, Ecopath with Ecosim (EwE) and ALCES integrate existing knowledge about the Kimberley system to provide an estimation of the likely impacts of different stressors on the land (ALCES) and marine (EwE) environments.

The model boundaries have been set based on existing information and data collected from Kimberley Marine Research Program (KMRP) projects.

EwE has been used to characterise the impact of fishing, tourism, other human uses and climate change on the Kimberley marine ecosystem as well as how different management options, such as controls on fishing effort and spatial closures, can mitigate these stressors.

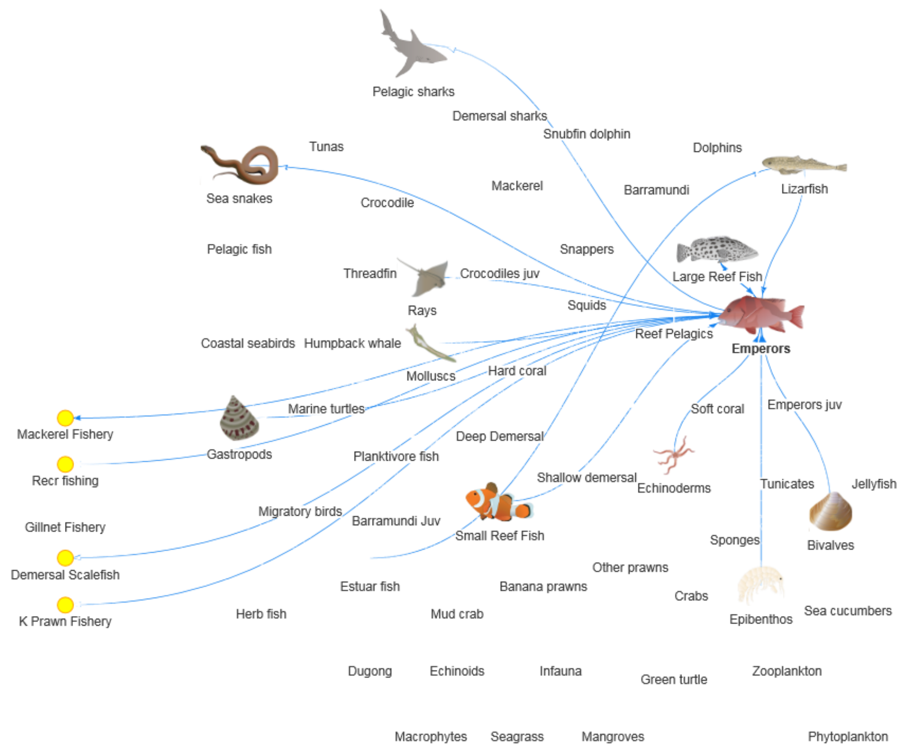

Figure 2. The Ecopath with Ecosim foodweb

Figure 2 shows a schematic representation of an EwE foodweb. An interactive version of this foodweb, together with more information about this project and the data used to define the parameters. The model can be found at www.per.marine.csiro.au/staff/Fabio.Boschetti//KimberleyMSE/EwE.htm.

The ALCES model has been used to characterise terrestrial land use and landscape dynamics and how these connect with the marine ecosystem.

Based on available information on likely future trajectories for each land use in the Kimberley (e.g. mining, energy, aquaculture, commercial fishing, crops, livestock, settlements, tourism, transportation), ALCES simulates how land based processes affect the marine environment via sediment and pollution flows, infrastructure and localised human pressure.

More information about ALCES implementation for the Kimberley region as well as its input data and parameters can be found at www.per.marine.csiro.au/staff/Fabio.Boschetti//KimberleyMSE/Alces.htm.

What we've found

Modelling is fundamentally about asking questions which need to be formulated carefully before modelling is executed (Figure 3).

In this project, we ask what events may occur in the future and, given the uncertainty about the processes we study, we also try to assess how confident we can be about the model results.

What kinds of questions can we ask about the future? Absolute questions like "what will happen?" are not possible as the future is not pre-determined and our actions will affect it.

Hypothetical or conditional questions like, "If this event occurs, then what may the future look like?" are asked instead. This is a better approach to describing the future because it forces us to focus on the events and conditions that may affect it.

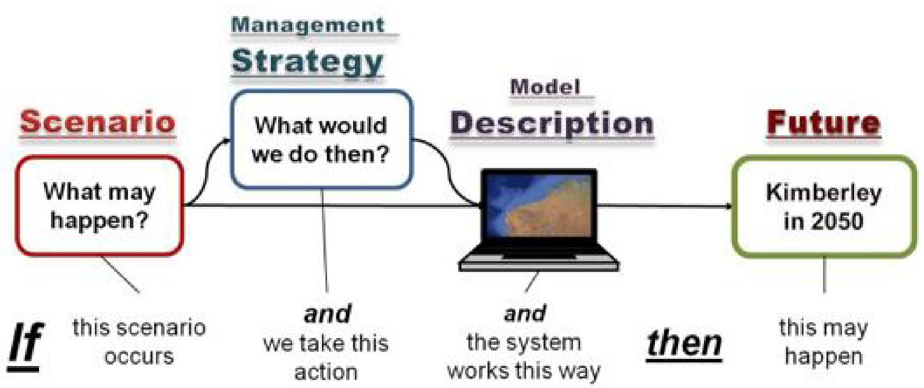

Figure 3. Our modelling approach is based on asking what may happen to the Kimberley region if specific events (scenarios) occur and specific initiatives (management strategies) are adopted

To achieve this, our approach has required four stages (Figure 3):

1. A ***development scenario***: Defines what event(s) may occur or how different trends may play out into the future. Scenarios describe events or processes considered external to the Kimberley system, like extreme natural events, demographic changes, global and national economic crises, industrial and infrastructure development etc.
2. A ***management strategy***: A course of action, policy or intervention we can use to respond to various scenarios. It constrains or promotes specific human activities to achieve agreed environmental, social or economic objectives.
3. A ***model description***: We do not know precisely how the Kimberley system works, but we have a few working hypothesis. These are captured in the EwE and ALCES model implementations and represent a snapshot of how we believe the Kimberley system works. Uncertainty is represented via alternative ***model specifications***, which are implemented by varying the model structure, input parameters and specific model components.
4. ***A future*** is an estimation of what the system may look like several years down the track, according to the model. It is the answer to the question 'If a specific scenario occurs and we implement a specific management strategy and the system works according to our current knowledge, then how will the system likely respond?".

The first three components have been developed, with the fourth stage to be delivered by October 2017.

The development scenarios

Scenarios are generally defined as 'plausible, challenging, and relevant stories about how the future might unfold'.

To be relevant to this study, a scenario needs to be pertinent to the ecological, economic and social development of the Kimberley region, including the marine environment and amenable to computer simulation.

The number of scenarios that may occur is too large to model exhaustively and to analyse comprehensively. A careful selection of a small sub-set of scenarios which is representative of the overall range of 'relevant stories' of interest has occurred.

The approach we follow in this work is based on the observation that events in the real world do not happen randomly or even independently. For example, weather events are highly correlated, which is why the concept of 'climate' is useful.

Similarly, population growth, economic growth, resource use and development are often correlated, which is why at times we talk of political or economic 'climate'.

Even more important, at the temporal and spatial scales we address in this study, individual events often average out and it is the broader trends resulting from their correlations which matter most.

As a result, a 'double uncertainty' approach in which trends in Climate Change and Economic Development are identified as the two most critical and uncertain drivers of change. These are acknowledged as the most important stressors on the Kimberley marine environment by most of the stakeholders surveyed and reflect the core aspiration of ensuring i) environmental and cultural sustainability, ii) economic and social progress and iii) resilience to climate change.

The Climate Change and Development drivers define the axis of the Future Plane shown in Figure 4. Each axis is subdivided into three levels of increasing pressure: low, medium and high, which results in 9 (3 by 3) scenarios, the most significant of which will then be further subjected to sensitivity analysis.

Kimberley Marine Research Program

WAMSI Project 2.2.8 Modelling the future of the Kimberley region

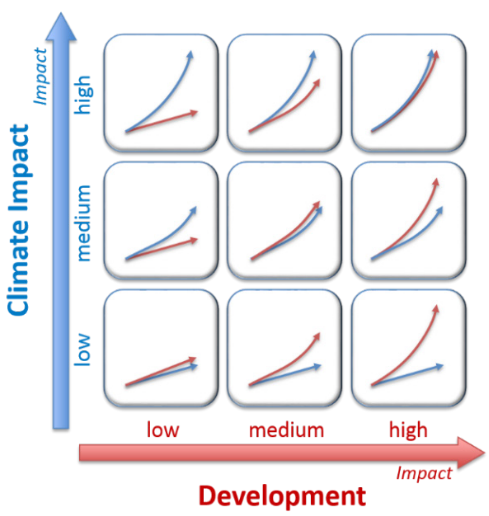

Figure 4. The '3 by 3' Future plane consisting of The Climate Change and Development axes. Each axis is subdivided into low, medium and high impact, resulting in 9 scenarios describing the interplay between climate change and economic development stressors

For each axis, how each specific process related to that driver contributes to that level of pressure is detailed. For example, the Climate Change scenarios shown in Table 1 are based on the simulations produced within CSIRO and the WAMSI2 KMRP 2.2.7 Project 'Knowledge integration and predicting biophysical response to climate change'.

The economic development scenarios shown in Table 2 account for a large number of sectors, including population, housing, tourism, agriculture (including the Ord River Irrigation Scheme and other forage and horticultural crops), cattle farming, aquaculture (pearl, prawns and barramundi), transport, infrastructure, mining (iron ore, diamonds, gold, copper zircon and gravel) and Oil & Gas.

The management strategies

Management strategies include actions which can be taken to pre-empt or react to stressors and events which may affect the Kimberley marine environment.

Five broad levels of regulation pressure are defined which reflect political and social attitudes towards environmental conservation (columns in Table 3), 'high', 'medium', 'low', 'reversed' and 'worst case':

1. '***Low***' regulation pressure is based around current regulations, in which the proposed regulations currently in the pipeline do not materialise.
2. '***Medium***' regulation pressure is based around current regulations and expectations about proposed regulations currently in the pipeline.
3. '***High***' regulation pressure is based around an increasing appetite for environmental conservation.
4. '***Reversed***' regulation pressure describes a U-turn in political and social mood which reverses most current conservation initiatives and reflects a society which is increasingly unconcerned or sceptical towards environmental conservation, or one where other considerations (e.g. food security) have come to overrule conservation concerns.

'***Worst case***' represents the collapse of most forms of regulation.

Within these broad levels of regulation pressure, it is assumed that interventions under management control are based around three broad management tools.

The first tool consists of the existing and proposed marine parks, including the application of restrictions on activities allowed through a zonation scheme (Table 3).

The second management tool consists of regulations on fishing (as one of the key pressures on marine resources), which include the amount of virgin (or spawning) biomass that is allowed to be taken through commercial or recreational fishing across the region, as well as strategies such as reducing bag and size limits for specific species (Table 4).

Table 1. Description of the Climate Change scenarios

Scenarios	Average global warming (°C) by mid-century	Average global sea level rise (m) by mid-century
Low (RCP2.6)	1.0 [0.4-1.6]	0.24 [0.17-0.32
Medium (RCP4.5)	1.4 [0.9-2.0]	0.26 [0.19-0.33]
High (RCP8.5)	2.0 (1.4-2.6)	0.30 (0.22-0.38)

Table 2. Brief description of the Development scenarios. More details can be found in document 'A Synopsis of ALCES Online Methodology and Key Land Use Trajectories Coefficients for the WAMSI Kimberley Project'

Scenarios	Low	Medium	High
Avg population growth /year	1.5%	2%	2.5%
Cropland Area (1,000 ha) (Ord River by mid-century)	~40	~60	~100
Cattle - heads by mid-century (average growth /year)	600K (0%)	1.1M (1.25%)	1.24M (1.5%)
Roads	As current	Paving Cape Leveque Hwy Upgrade Gibbs River Rd	Paving Cape Leveque Hwy Upgrade Gibbs River Rd
Oil (m³/yr) & LNG (peak Mtpa)	As current	~400k Blina & Ungani Fields ~7.5 Browse Basin & Concerto	~600k Blina & Ungani Fields ~10 Browse Basin & Concerto

Table 3. Description of the proposed Management Strategies with regards to Marine Protected Areas

Management Tools / Regulation pressure	Worst case	Reversed	Low	Medium	High
80 Mile Beach Park	No	Yes	Yes	Yes	Yes
Lalang-garram / Camden Sound Park	No	Yes	Yes	Yes	Yes
Yawuru Nagulagun / Roebuck Bay Park	No	Yes	Yes	Yes	Yes
North Lalang-garram Park	No	Yes	Yes	Yes	Yes
Lalang-garram / Horizontal Falls Park	No	Yes	Yes	Yes	Yes
North Kimberley Marine Park	No	Yes	Yes	Yes	Yes
80Mile Beach Commonwealth Marine Reserve	No	No	No	Yes	Yes
Roebuck Commonwealth Marine Reserve	No	No	No	Yes	Yes
Kimberley Commonwealth Marine Reserve	No	No	No	Yes	Yes
Sanctuary Zone extension (% of total park area)	0	0	current	20%	30%

The third tool consists of regulating the impact of other human uses, such as tourism and mineral, oil and gas exploration and extraction (Table 5).

Table 3, Table 4 and Table 5 show how these three management tools may be implemented (rows) within the four levels of regulations pressure (columns). As for the scenarios above, we assume that the political and social acceptance of different levels of regulations will impose a strong correlation in the use and implementation of the available management tools.

However, different strategies can be tested independently should some scenario outcome require it so.

Model Specification - Input data and parameterisation of the model

Input data collection and model parameterisation are core elements of a modelling study. These are the steps that take models, designed to be generic (like EwE and ALCES), and ensure that their implementation is specific to the region and questions of interest. This is why securing access to data held by other Western Australian Marine Science Institution (WAMSI) funded KMRP Projects has been vital to provide both relevance and confidence to our models.

Data on a wide range of ecological functional groups (i.e. marine mammals; birds; commercial fish species; predatory fish; marine reptiles; invasive species, invertebrates; nekton and primary producer data, etc), ecological and biophysical processes (ocean circulation, primary production etc), human activities (housing, fishing, tourism, industrial development etc) and land based processes (exploration & mining, agriculture, infrastructure development, river flows, bush-fires, etc) has been collected and processed in anticipation of running the model scenarios.

A description of the input data related to EwE can be explored at www.per.marine.csiro.au/staff/Fabio.Boschetti//KimberleyMSE/EwE.htm#input while information about input data related to ALCES can be found at www.per.marine.csiro.au/staff/Fabio.Boschetti//KimberleyMSE/PDF/Alces%20Synopsis.pdf

It is important to note that input data and model parameterisation also represent the best and most updated snapshot of what we know about the Kimberley region today.

Not only does this snapshot include a wide range of essentially different information into a single dataset, but also it summarises this information in a codified manner that is readable by EwE and ALCES.

Table 4. Description of the proposed Management Strategies with regards to fishing regulations

Management Tools / Regulation pressure	Worst case	Reversed	Low	Medium	High
Fishing regulation (% virgin biomass)	90% (prawns) 70% (finfish)	90% (prawns) 70% (finfish)	90% (prawns) 70% (finfish)	Mixture of low and high regulations is different area	20%
Fish size limits	No limit	Status quo – ~15 cm	Status quo – ~10 cm	Current fish size (status quo)	Current fish size (status quo)
Bag size limits	10 * Current bag size (status quo)	10 * Current bag size	5 * Current bag size	2 * Current bag size	Current bag size (status quo)

Table 5. Description of the proposed Management Strategies with regards to Other Human Uses

Management Tools / Regulation pressure	Worst case	Reversed	Low	Medium	High
Accepted cumulative tourism-induced mortality[1]	No limit	No limit	5%[2]	1%	0.3%
Accepted cumulative mortality[3] from other marine uses	No limit	No limit	5%	1%	0.3%

[1]This includes overall mortality due to presence of tourism in remote region as a result of pollution from boats, human presence on reefs/coastline, etc.

[2]The mortalities in this section of the table are only guesses and will be better tuned during the first EwE runs

[3]This includes overall mortality due to other human uses, including Oil and Gas exploration and extraction, due to pollution, infrastructure, boat collisions, etc.

Kimberley Marine Research Program

WAMSI Project 2.2.8 Modelling the future of the Kimberley region

Should anyone in 20-30 years wish to look back at our study and explore what the state of the Kimberley system was and why we modelled it in this specific way, the most useful and accurate place to look at would be EwE and ALCES input data and model parameterisation.

Finally, the amount, reliability and currency of the input data is one of the criteria which determines a model's 'quality'.

Because the Kimberley region is so remote and unexplored, we may expect EwE and ALCES models to be largely under-parameterised, however, because of the considerable effort in securing data, this is not the case. For example, according to internationally accepted model standards, the Kimberley implementation of EwE has a quality well above an average marine ecological model (see www.per.marine.csiro.au/staff/Fabio.Boschetti//KimberleyMSE/EwE.htm#quality) which should increase our confidence in the output this project will generate.

Implications for Management

It is intended that the scenarios generated will help guide decision-making, planning and monitoring on the likely response of natural resources to increasing human and climate pressure.

Information generated as part of this research will be of relevance to the Kimberley Science and Conservation Strategy, and the proposed Great Kimberley Marine Park network of Marine Parks. In particular, we expect that this project's output will provide:

1. Improved capacity to plan and manage the regional network of Kimberley marine parks and reserves
2. Enhanced capacity to identify and manage current human impacts and predict risks in the coastal waters of the Kimberley.
3. Enhanced capacity to understand, adapt and mitigate climate change impacts in the coastal waters of the Kimberley.
4. Improved capacity to plan and manage tourism, recreational and commercial fisheries, pearling and aquaculture in the coastal waters of the Kimberley.
5. Increased capacity to assess the regional environmental significance of resource development projects.
6. Improved capacity for marine science knowledge transfer and uptake into policy, planning and management in Western Australia.
7. Enhanced capacity to determine 'value for money' and assess management efficiency and effectiveness of Government-funded conservation and management programs in the coastal waters of the Kimberley.
8. Improved community understanding and support for Government conservation and management programs in the coastal waters of the Kimberley.
9. Identification of useful ecosystem-level performance indicators and target reference points for the Kimberley region.

Type of data collected

This project will not collect any data, but will generate model output simulation products.

Data available in:

The metadata associated with this project can be viewed via the CSIRO and AODN metadata catalogues. Model simulation data will become available via Pawsey after the completion of the embargo period for the project.

Project Team

Fabio Boschetti[1,2], Michael Hughes[1,3], Hector Lozano-Montes[1,2], Catherine Bulman[1,4], Brad Stelfox[1,4], Joanna Strzelecki[1,2]

[1]Western Australian Marine Science Institution

[2]CSIRO, Ocean and Atmosphere, Western Australia

[3]Curtin Sustainable Tourism Centre, Curtin University, Western Australia

[4]CSIRO, Ocean and Atmosphere, Tasmania

[5]ALCES Group, Calgari, Alberta, Canada

Contact

Project Leader: Dr Fabio Boschetti

CSIRO

Email: Fabio.boschetti@csiro.au

Project webpage:

www.wamsi.org.au/research-site/modelling-future-kimberley-region

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