

## Critical Issues

Multiple objectives  
Multiple stakeholders  
Conflicting objectives  
Complex planning issues

## Benefits

Decision support framework  
Clear objectives  
Improved transparency  
Integrated planning  
Clear costs and benefits  
Stakeholder involvement  
Better NRM outcomes

Photo courtesy of DEC



NHT National Competitive Component research project 53414:  
*Developing an integrated planning framework and decision  
support methods for biodiversity conservation and  
sustainable natural resource management  
across the marine-terrestrial interface.*  
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# FINAL REPORT

incorporating  
Milestone Five Progress Report

## NHT National Competitive Component research project 53414

*Developing an integrated planning  
framework and decision support methods  
for biodiversity conservation and  
sustainable natural resource management  
across the marine-terrestrial interface.*

Professor Hugh Possingham,  
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June 2008



THE UNIVERSITY  
OF QUEENSLAND  
AUSTRALIA



Australian Government



Applied Environmental Decision Analysis  
Queensland Environmental Research Facility

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## **Summary**

Working closely with natural resource management (NRM) practitioners, this project develops the capacity of existing systematic decision support software tools to address questions that NRM bodies ask, such as what riparian systems most need protection, which areas are suitable for aquaculture expansion, or how best to balance competing objectives across conservation and socio-economic objectives. The project has delivered outputs in the following key areas:

- Modification of existing computer-based decision support methods for release as new software : Marxan with Zones;
- Development of education and training materials to assist NRM practitioners in the use of the software ; and
- Preparation of case studies as example applications of the systematic decision framework and modified software to local NRM type problems.

Collectively, these outputs support adoption of best planning practices that promote sustainable natural resource management and biodiversity conservation. The new software: Marxan with Zones, user manuals and education and training materials are all freely available and documented for NRM regions elsewhere for broader use in planning and community engagement.

<http://www.uq.edu.au/marxan/>

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## **1. Achievements in Stage One**

### ***Develop a Planning Framework***

#### *Contractual Requirements*

**1A The Organisation will review past and present applications of decision support software to determine current limitations and identify demand (i.e. priority need) for modifications**

**1B The Organisation will consult with key stakeholders to develop a framework for systematic natural resource management planning in marine and coastal areas**

**Outputs:**

- A more effective planning framework for natural resource management in coastal and marine areas;
- Identification of priority needs for modification and future development of decision support methods to meet NRM requirements; and
- Proceedings of the workshops (both 1A & 1B) published in a summary report.

The key outputs from the research in this Stage 1 were:

1. development of a planning framework to deal more effectively with natural resource management issues in coastal and marine areas;
2. the analysis of changes that were needed in Marxan to better support the improved planning framework; and
3. the outputs from two workshops summarised and made publicly available.

To facilitate an effective interface with local (Swan Region) NRM managers and stakeholders a Steering Committee for the project was established. This Committee (Appendix 1) met three times during the life of the project, providing guidance and feedback about matters of content in the project and information about current NRM activities in the region.

### ***1.1 Improved Planning Framework***

Natural resource management (NRM) deals with the problem of how to sustainably manage the use of biophysical resources in the face of many complex pressures from a range of sources. Planners and managers face issues about land degradation, habitat destruction, water pollution and species decline. Managing the sustainability of natural resource use is a challenging and complex problem which cannot be considered independently of social and economic values. This means that natural resource management (NRM) decisions are often characterized by multiple objectives, multiple stakeholders and the likelihood of conflicting objectives, all in the face of considerable scientific uncertainty.

To reduce the complexity of NRM decisions to a manageable level many decision-makers are turning to systematic decision support methods. These methods aim to provide the decision-maker with a framework that defines the problem with clearly stated objectives, synthesises information of varying levels of complexity, and provides for an informed decision that explicitly recognises the trade-offs involved. The trade-offs required will often involve detailed consideration of the on- and off-reserve conservation of species and habitats, the sustainable use of biological resources, and maintenance of wealth-generation for local and regional communities.

Systematic decision support methods can provide an effective means of evaluating a large number of alternatives against a set of multiple and conflicting objectives. They have arisen from the need for improved transparency, greater public accountability and the equitable and efficient use of natural resources. So it is important that any DSS for NRM is structured so that at each step the relevant assumptions, procedures and knowledge-base are explicit and clear for all stakeholders and interests.

For an NRM planning framework to be effective it needs to structure and facilitate a systematic approach to each of the important elements involved in the decision support problem. For example, the framework needs to enable:

- a balance to be struck between conservation and sustainable use objectives, recognizing the imperative of long term planning and the need for basic standards to be achieved and maintained;
- conflicting activities to be separated in space and/or time (such as through zoning of permitted uses);
- planning within the various sectors of activity in the decision problem to be integrated;
- NRM management activities within the sea/landscape to be coordinated and prioritized.

The framework below has been developed as the basis for a systematic approach to coastal and marine NRM decision-making.

#### **A Planning Framework for Systematic Decision Support in Coastal and Marine NRM**

- |   |
|---|
| <ol style="list-style-type: none"> <li>1. Specify the management scope</li> <li>2. Determine management options</li> <li>3. Specify the system properties (describe state of system)</li> <li>4. Specify constraints</li> <li>5. Specify the uncertainties (what don't we know)</li> <li>6. Find solutions</li> <li>7. Review and assess solutions</li> </ol> |
|---|

This basic framework has been used as the platform for engagement with NRM practitioners in the case studies (discussed below). A more detailed application of this DSS framework is described in several of the publications and conference workshops resulting from this project (described below).

## **1.2 Upgrading the Marxan Software**

A major limitation of the existing systematic decision support methods is that they can not simultaneously consider multiple types of management zones and activities. In the original Marxan software there are only two possible zones that a planning unit could have. It was either reserved or not. In reality, areas are being considered not only for reservation but for a range of management activities (eg. restoration, fire management, recreational use). The need for a more realistic and comprehensive definition of the problem, more compatible with conservation planning and natural resource management, has been highlighted for a number of years (Sabatini, Verdiell et al. 2007). Zoning in particular, is a desirable management practice to spatially and temporally designate areas for specific purposes.

Substantial upgrades have been made to the Marxan software throughout the project. The new software; Marxan with Zones, expands on the basic reserve design problem to incorporate new functionality and broaden its utility for practical application. By allowing zoning, a whole series of new considerations are formulated as part of the problem definition. Each zone has the option of having its own objectives and constraints, with the flexibility to define the zone contribution to feature targets and the capacity to accept multiple costs to better quantify the cost of implementing each zone.

The process of upgrading Marxan is continuing beyond this project, and the current state of development is described in more detail under Stage 3 below. The current version of Marxan with Zones is freely downloadable from the Marxan website that has been constructed as part of this project (<http://www.uq.edu.au/marxan>) (see Stage 3 below).

## **1.3 Outputs From Workshops**

### *Marxan Good Practice Handbook*

Between 2005 and 2007, two major workshops were held to review the current state of knowledge on Decision Support Systems and identify how they can be better employed to support conservation planning. The subsequent outcomes from the workshops developed in the form of a Marxan Good Practices Handbook. Led by Pacific Marine Analysis and Research Association (PacMARA), together with The University of Queensland, the guide presents examples of Marxan applications, discusses the selection of appropriate values and provides guidance for applying robust analyses. The Marxan Good Practices Handbook will be released mid 2008 and be available online <http://www.uq.edu.au/marxan/index.html?page=77823&p=1.1.4.2>

A summary of the workshops is presented below.

### *The IMPAC DSS Workshop*

The inaugural International Marine Protected Areas Congress (IMPAC), held in Geelong in October 2005, provided the opportunity for a satellite workshop on Decision Support Systems to be attended by a range of international experts.

The workshop structure included:

- Introduction to the issues  
Speakers: Jon Day, The Practical Experience: Challenges in transferring DSS

from research to the real world

Speakers: Jeff Ardron, Hussein Alidina, Jen Smith, Nohora Galvis.

- DSS in Theory: Future challenges for research and development  
Speakers: Bob Pressey, Amanda Lombard, Adam Lewis, Peter Harris, Hedley Grantham and Eddie Game.

Each session involved a series of brief presentations followed by group discussion principally focusing on the issues identified. These discussions were used to highlight the challenges and limitations faced by DSS in real-world MPA applications. The workshop discussed various current and future demands of DSS in the planning and implementation of MPAs, and concluded that there was a need for a synthesis of the 'best practice' for the use of such tools.

#### *International Marxan Best Practices Workshop*

The University of British Columbia and PacMARA hosted the International Marxan Best Practices Workshop on April 2-5 2007. Keynote speakers, Dr Daniel Pauly and Professor Hugh Possingham, led discussions on the current state of marine and terrestrial ecosystems and then outlined changes and new tools needed to better manage these ecosystems. The presentations presented a vision for new approaches to science and decision-making, and new relationships between scientists and decision-makers to ensure more sustainable marine and terrestrial management.

The outputs from other workshops conducted as part of this project are covered under section 2.2 below.



## **2. Achievements in Stage Two**

### ***Problem Formulation and Decision Support System (DSS) Development***

#### *Contractual Requirements*

##### **2A Undertake basic research to mathematically formulate the problem**

Research will be conducted to mathematically formulate the objectives and constraints of the planning problem. Issues considered will include how best to address planning requirements for protected areas and the surrounding landscape/seascape within an integrated framework.

##### **2B Re-engineering of existing decision support tools to enhance their capacity for NRM planning frameworks**

Computer programming will be undertaken to modify existing software and improve their capacity to support decision making for biodiversity conservation and sustainable natural resource management. Re-engineering of the software is preferential to providing add-on modifications and will ensure that the decision support tools remain easy to use. The software is to provide sufficient flexibility for application to a broad range of planning problems with varying levels of complexity, though must be kept simple enough such that practitioners with only a basic level of training can apply them.

##### **2C Development of training module and materials to ensure ease of use**

The Organisation will provide ongoing support and education in both the application of these methods, and in the scientific principles behind them. The training will assist in the effective delivery of best practice scientific methods to on the ground practitioners. The development of these materials will present examples and exercises with a strong focus on applied planning problems to demonstrate how these methods can support decision-making and direct cost effective actions to achieve NRM targets.

##### **Outputs:**

- Development of work specifications for software development that are closely aligned to NRM requirements
- Improved decision making tools that can address a range of NRM planning requirements; and
- Production of education and training materials for regional capacity building.

The key outputs from this stage were:

- Identification of the areas where Marxan needed further development to meet the needs of NRM practitioners;
- Refinement of the software to meet those needs; and
- Development of training and education material for practitioners on how to best use computer-assisted DSS, and Marxan specifically.

These three areas of output were all serviced through the process of developing and delivering workshops for practitioners that provided hands-on training in the application of the Marxan software and related tools. They were invaluable in generating useful feedback on the functionality and utility of the software, as well as identifying practical problems such as the use of technical jargon and the use-friendliness of software interfaces. To deal with the more technical specifications of software development, a workshop was held to review and advance research relating to the decision support software Marxan. In attendance were leading Marxan experts from around Australia and the world.

In the sections below, we identify some of the outputs and provide examples of the workshops and their processes. As with all aspects of Marxan, supplementary material (including training materials) is freely available at the Marxan website [www.uq.edu.au/marxan](http://www.uq.edu.au/marxan)

## **2.1 The Improved Marxan Software**

To provide for improved user access to the software and to increase the capacity of NRM users to interpret and implement the outputs of the software, the following areas were targeted for software enhancement:

- provide for multiple zones, with each zone able to have its own objectives and constraints;
- able to integrate more complex cost data into the analyses to more accurately model the zoning costs of planning projects and better integrate conservation and socio-economic requirements;
- develop new target criteria so that targets and contributions to targets can be attributed to planning zones to facilitate evaluation of more complex multiple simultaneous objectives;

Practitioners also expressed the desire for a user-friendly interface to enable editing of Marxan files directly, to assist with calibrating parameters and to facilitate display of Marxan outputs in GIS. Areas targeted for development included;

- creation of a graphical user interface to improve ease of use with data sensitivity analysis and calibration through editing of Marxan input files;
- further enhancing the GIS interface for ESRI ArcView 3 with improved reporting capabilities provided to users through spatial database queries of social, economic, and ecological information;
- building a graphical user interface using open source GIS to facilitate improved access for users, without necessitating the need for costly software licences.

Developing the technical specifications for software development was ongoing throughout the project. A workshop was held in January 2008 and attended by leading researchers in Marxan and systematic conservation planning to review and advance research undertaken by AEDA relating to the decision support software, Marxan (<http://www.ecology.uq.edu.au/marxan.htm>). A major output of the workshop is the development of scientific papers to describe current and future issues relating to systematic conservation planning, with a particular focus on software development. We identified a number of research themes where work is ongoing. These themes are: zoning, probabilistic treatment of data, the treatment of connectivity, options for reporting alternative solutions, and the dynamic reserve

selection problem. Details of the scientific papers arising from this workshop are reported in Appendix 2.

## 2.2 Education and Practitioner NRM Workshops

Three major NRM practitioner workshops were conducted under the auspices of this project, and one further related workshop will be conducted by the end of 2008 (Table 2.1). These practitioner workshops have been designed to achieve three objectives within this project:

1. provide a focus for NRM agency engagement and awareness-raising about Marxan and the potential for the use of DSS to improve planning outputs;
2. secure data for use by the project in internal case studies that demonstrate the efficacy of the improved software; and
3. provide example NRM problems and data that are both realistic and familiar to Swan Region NRM managers to be used as a training platform for them in the use of Marxan in NRM DSS.

**Table 2.1 NRM Practitioner Training Workshop Schedule**

<i>Rottnest marine conservation</i>	November 2006, UWA, Perth	marine sanctuary zones and conservation values in the context of recreational fishing pressures <a href="http://www.aeda.edu.au/index.html?page=69890">http://www.aeda.edu.au/index.html?page=69890</a>
<i>Department of Environment &amp; Conservation; marine conservation</i>	May 2007, DEC Perth	marine park design in the context of multiples competing uses, including mining, fishing and coastal development <a href="http://www.uq.edu.au/marxan/?page=78494&amp;pid=77690">http://www.uq.edu.au/marxan/?page=78494&amp;pid=77690</a>
<i>Cockburn Sound resource management</i>	November 2007, UWA, Perth	multiple use planning for Cockburn Sound in the context of competing uses for new ports and marinas, coastal development, recreation, and biodiversity conservation <a href="http://www.uq.edu.au/marxan/?page=78499&amp;pid=77690">http://www.uq.edu.au/marxan/?page=78499&amp;pid=77690</a>
<i>Kimberley region resource management</i>	to be conducted 10-11 July 2008, Broome	Multiple use planning and conservation planning in the context of competing uses and limited data <a href="http://www.aeda.edu.au/index.html?page=80919">http://www.aeda.edu.au/index.html?page=80919</a>

All workshops were conducted in close association with the relevant NRM management agency. The agencies have made available free access to their internal data and information for the purposes of the workshop exercises and development of the case studies. Assembly of datasets into suitable format and structure for DSS and for the workshops, involving some considerable work, has been conducted jointly by the staff of this project and agency staff.

Each workshop used relevant and realistic scenarios designed to reflect at least one aspect of the management issues facing the agency at the time. Although this involved using the actual data made available to the project, which typically was the agencies own data that would be available for their internal decision-making supplemented by readily available public-domain data, each of the workshops was

considered to be a purely hypothetical exercise based on real data to support the primary purpose of each workshop: training and software development. The workshops also admitted staff from other agencies and institutions (and some from interstate), and it was not considered appropriate to supplant an agency's internal scenario building and decision-processes with outcomes from a training workshop that selectively considered specific matters designed for training.

An additional set of workshops conducted under the auspices of the project have been designed to broaden the base of technical training to a range of stakeholders (Table 2.2). These workshops cover basic Marxan training and were conducted at the University of Queensland and overseas in conjunction with a major international scientific conference.

Workshop materials and course manuals are available online at the Marxan website.

**Table 2.2 Education and Training Workshop Schedule**

<i>Society of Conservation Biology Marxan Workshop</i>	July, 2007, Port Elizabeth – South Africa	Four day course on Systematic Conservation Planning presented as an adjunct to the Society for Conservation Biology 21 <sup>st</sup> International Conference. Exercises featured example problems using datasets from Western Australia, Tasmania and New South Wales <a href="http://www.aeda.edu.au/?page=66533&amp;pid=0">http://www.aeda.edu.au/?page=66533&amp;pid=0</a>
<i>Marxan 101</i>	April 2007, Brisbane	An introductory two day workshop on systematic conservation planning and Marxan <a href="http://www.uq.edu.au/marxan/marxan-101">http://www.uq.edu.au/marxan/marxan-101</a>
<i>Introducing Marxan</i>	Nov & Dec 2007, Brisbane	An introductory two day workshop on systematic conservation planning and Marxan <a href="http://www.uq.edu.au/marxan/?page=78496&amp;pid=77690">http://www.uq.edu.au/marxan/?page=78496&amp;pid=77690</a>
<i>Systematic Conservation Planning</i>	to be conducted 4-5 June, 2008 Hobart  11-12 June 2008, Canberra	<i>Department of Environment, Water, Heritage and the Arts</i> Two, 2-day courses will be held to develop capacity in support of large scale systematic conservation zoning for Australia's commonwealth waters. In attendance will be GIS technicians, senior planners and managers.

## **NRM Stakeholder/Practitioner Workshop Summary**

### *Stakeholder/Practitioner Workshop #1*

A workshop of stakeholders in this project was held at UWA on 23 November 2006 to begin the process of raising awareness of both the research project and the capability of DSS tools amongst the NRM practitioner community in the Swan NRM Region of WA. The workshop was designed and conducted in consultation with the Steering Committee established for this project (Appendix 1), and involved four separate modules:

1. background to the research project, objectives and the Swan Region case study;
2. introduction to DSS and an interactive exploration of a simple hypothetical systematic planning problem using a development version of Marxan;
3. an interactive exploration of the sensitivity of DSS outcomes to data inputs, such as spatial scale, targets and costs;

4. feedback and response session — information for the researchers and practitioners about Swan region data availability, type and limitations; issues that need to be resolved and possibly amenable to DSS processes; and potential for use of Marxan in local and regional situations.

Eighteen participants, drawn from a range of organisations operating in the Swan NRM region, and including the organisations represented on the Steering Committee, attended the workshop:

- Swan Catchment Council
- Cockburn Sound Management Council
- Department of Environment and Conservation
- Department of Fisheries
- Department of Planning and Infrastructure
- Rottnest Island Authority
- CSIRO Marine and Atmospheric Research
- Australian Marine Sciences Association
- Greening WA
- Commonwealth Defence Support
- Marine Parks and Reserves Authority

The workshop used five hypothetical scenarios constructed from data to develop marine sanctuaries for Rottnest Island. The data inputs included 30 marine biodiversity features. The effect of choosing different target levels for reservation and different costs of fishing and other recreational activities was explored by the participants using a pre-release version of the Marxan with Zones software developed on this project.

Key outcomes from the workshop included:

- Greatly increased awareness of the structure of a planning framework and DSS of utility for NRM issues;
- Increased awareness of the spatial complexities of dealing with competing uses and biodiversity conservation;
- Feedback from participants about the nature and availability of data that could be used in a Swan region DSS situation, such as analysis of issues in Cockburn Sound, and an analysis of issues for Swan region planning;
- Data custodians and possible issues with access to data in the Swan region;
- Specific feedback about the types of issues likely to be encountered in the Swan region, and the likely types of outputs that might be required from a DSS;

Twelve participants provided completed feedback/evaluation sheets at the end of the workshop. These were universally supportive of both the workshopping process, and the clarity and quality of the content. A number of very useful constructive comments were included, such as the need for a drop down glossary of terms to be included in the interface to help novice users to overcome the jargon barrier. All these were considered in the ongoing development the software, and in such areas as the development of specific types of outputs.

#### *Stakeholder/Practitioner Workshop #2*

A Training workshop was conducted for the Department of Environment and Conservation (WA) on 21 and 22 May 2007. The course materials and training examples are available at UQ website; [Systematic Conservation Planning with Marxan](http://www.uq.edu.au/marxan/index.html?page=77690) (<http://www.uq.edu.au/marxan/index.html?page=77690>)

This workshop was attended by 16 staff from the Department of Environment and Conservation (WA) Marine Policy and Planning Branch and the WA Department of Fisheries. The focus of this workshop was on the practical use of Marxan with Zones to current marine park planning issues faced by the WA NRM managers. Case studies developed for earlier workshops were used to demonstrate the issues and potential solutions, including the role that variable data quality and content could play in achieving quality outcomes of marine planning processes.

#### *Stakeholder/Practitioner Workshop #3*

The Perth Practitioner workshop #3 was delivered on 22 and 23 November 2007, at UWA in Perth. The approach focused on multiple use and systematic conservation planning within the WA NRM context. It featured applications of Marxan with Zones to example marine datasets developed for earlier workshops (the Rottnest Island dataset), and scenarios specifically developed through this project for NRM planning problems in Cockburn Sound (which lies within the Swan NRM Region, near Perth). The workshop was fully attended (30 attendees), and included people from a range of the NRM organisations in WA as well as two attendees from the Department of Environment and Heritage in South Australia. Details of the course material presented at this workshop are available online at [Systematic Conservation Planning, Marxan and MarZone](http://www.uq.edu.au/marxan/index.html?page=77690) (<http://www.uq.edu.au/marxan/index.html?page=77690>)

### **Education and Training Workshop Summary**

#### *Society for Conservation Biology, South Africa*

Members of the project team participated in three separate workshops/short courses in association with the 21st Meeting of the Society for Conservation Biology in South Africa, 26-29 June 2007. This involved extensive planning and preparation for this important opportunity to develop and demonstrate the Marxan concept and its application to NRM problems.

The events were:

- (1) Four day short course (26-29 June) in Systematic Conservation Planning and the role of software: from data to implementation and management. This was an introductory course to systematic conservation planning, suitable for people with a range of backgrounds and expertise. The course is complementary to introductory course being presented by the Ecology Centre at the University of Queensland (see below). Project team members attended as course co-organisers (Matt Watts) and guest presenters (Hugh Possingham, Romola Stewart).
- (2) A one-day workshop (30 June) in Systematic conservation planning and use of Marxan. The one-day course focused on developments, applications and challenges of the conservation planning software, Marxan. We introduced new developments of the software, in particular the newly released versions of Marxan. The course highlighted the additional functionalities of Marxan and introduced the NRM applications developed as part of this project. The project staff were closely involved

with development of the course materials, and several members taught the course (Hugh Possingham, Matt Watts and Romola Stewart).

(3) A one-day symposium (2 July) Developing marine protected area networks: biological, socio-economic and technical challenges in the 21st Century. Project members delivered research papers as part of a session on planning tools and the challenge of integrating marine, freshwater and terrestrial conservation planning. The symposium examined the challenge of turning ecological theory into tools, with an emphasis on practical applications.

#### *Introducing Marxan*

April 2007, Brisbane

#### *Marxan 101: application of Marxan to systematic conservation planning*

21 and 22 November 2007, Brisbane and 5 and 6 December, 2007, Brisbane.

These two day courses focused on providing attendees with the basic knowledge and skills necessary to use Marxan in a conservation planning exercise. Project team members attended as course co-instructors (Matt Watts, Lindsay Kircher) and guest presenters (Hugh Possingham). The course covered the following topics:

- Key concepts in systematic conservation planning
- Creation of planning units
- Creating the essential Marxan input files
- Parameter setting in Marxan
- Understanding and using Marxan results

The course was attended by university researchers, conservation organization employees, and government agency employees. Details of the course material presented at this course are available online:

<http://www.uq.edu.au/marxan/?page=78496&pid=77690>

#### *Department of Environment, Water, Heritage and the Arts*

Staff of the project (Matt Watts) are conducting workshops in systematic conservation planning for the Department of Environment, Water, Heritage and the Arts. A 2-day course will be held in Hobart (4-5 June 2008) and in Canberra (11-12 June 2008) to develop capacity in support of large scale systematic conservation zoning for Australia's commonwealth waters. In attendance will be GIS technicians, senior planners and managers.

#### **Papers at Science Conferences**

Throughout this project staff have attended a number of national and international conferences and delivered papers about Marxan and the improvements in the software and its potential for better NRM application. Tables 2.3 and 2.4 provides a summary and some examples of the conference and science papers both presented and in development that have been derived from work carried out (wholly or partly) by staff of this project.

**Table 2.3. List of papers delivered at science conferences**

<i>title</i>	<i>conference or journal</i>	<i>content description</i>	<i>lead author or presenter</i>
<i>Adapting decision support tools to natural resource management planning problems</i>	Society for Conservation Biology	Discusses systematic approach to address NRM type problems	Romola Stewart
<i>Marxan with Zones: A systematic decision support tool for Natural Resource Management problems</i>	Ecological Society of Australia	Summarises improvements to Marxan with Zones, and demonstrates with example	Romola Stewart
<i>Optimising Choices in Coastal Management using the Marxan with Zones Software</i>	Climate Change and the Coast Conference, Mandurah	Application of DSS to coastal management problems with conflicting objectives and multiple stakeholders	Matt Watts

**Table 2.4. Science journal papers in preparation**

<i>title</i>	<i>content description</i>	<i>lead author or presenter</i>
<i>Marxan with Zones – optimised zoning with spatially explicit annealing</i>	Formulates the problem mathematically and introduces the new software “Marxan with Zones” using case studies to demonstrate its application to complex planning problems	Matthew Watts
<i>A marine zoning plan for Rottnest Island; a multiple-use marine park</i>	Highlights the goal of maximising conservation benefits while minimising costs to recreational users	Romola Stewart
<i>Applying systematic tools for regional planning &amp; integrated management in Cockburn Sound, WA</i>	Examines the complex problem of integrated management for an area of intensive use and competing interests, while satisfying conservation objectives.	Romola Stewart

In addition, staff of the project organised two free public lectures to raise the profile of systematic planning frameworks and the capacity of decision support tools to assist institutions in dealing with complex natural resource management problems. Both lectures were extremely well attended, with government agencies, NRM bodies and non-government organizations represented.

Public Lecture - Dr Bob Pressey

The University of Western Australia 26 September 2006

*Systematic conservation planning – some achievements and remaining challenges*

Bob Pressey is an internationally renowned researcher in the field of systematic conservation planning, is credited with revolutionizing the identification and planning of priority areas for nature conservation.

Public Lecture – Professor Hugh Possingham

The University of Western Australia, 6 September 2007

*Conservation – What is the Problem ?*

Professor Hugh Possingham, an ARC Federation Fellow and Director of Applied Environmental Decision Analysis Centre (a CERF hub). The importance of



Possingham's contribution to science is providing a quantitative dimension to ecology and conservation biology. His presentation discussed the application of decision theory to problems in conservation and environmental management.

## **2.3 Education and Training Materials for Regional Capacity Building**

The development of education and training materials to enable NRM practitioners to develop the skills and understanding to implement Marxan and Marxan with Zones and been a major focus of this project. Workshop materials, including course manuals and exercises, distributed at all practitioner workshops and courses are available online. This provides attendees with the capacity to review and revisit at their own pace any of the NRM examples, and to download the Marxan software to further explore NRM issues within their own context. An example of the course manual is included as Appendix 3 to this report.

In addition to this freely available material distributed at the workshops and courses, there is a considerable wealth of technical material supporting the use and applications of Marxan and Marxan with Zones available at the Marxan website. Much of this additional material has been developed partly or wholly by the staff of this project, or by staff of the Applied Environment Decision Analysis (AEDA). An online tutorial is also under development to support regional NRM practitioners who have limited opportunities to attend workshops held in Perth and Brisbane. The online tutorial will be available mid-2008 from the Marxan website.

### *Marxan with Zones User Manual*

[http://www.uq.edu.au/marxan/docs/Marxan\\_with\\_Zones\\_v101.pdf](http://www.uq.edu.au/marxan/docs/Marxan_with_Zones_v101.pdf)

Project staff, together with AEDA staff have prepared a user manual for Marxan with Zones. It provides the documentation for the software functions and outlines the basic information necessary to understand and use Marxan with Zones, together with additional technical details.

### *Marxan Website*

<http://www.uq.edu.au/marxan>

Staff from the project conducted an online survey of Marxan users to identify their needs for online information, education materials and support. The results of the survey led to a substantial redevelopment of the Marxan website. This website presents content from the previous website together with new content with a user friendly navigation system and updated graphics and design. The website will serve as a way to interact with users of the software from around the world.

### *New Marxan User Manual*

[http://www.uq.edu.au/marxan/docs/Marxan\\_User\\_Manual\\_2008.pdf](http://www.uq.edu.au/marxan/docs/Marxan_User_Manual_2008.pdf)

Staff from the project were involved in the production of the new Marxan User Manual, written by Eddie Game and Hedley Grantham from AEDA and The University of Queensland. The new manual is written in a much more user-friendly style and incorporates new material such as tutorials and courses that have been developed since Marxan's creation. Production of the new manual was funded by the Packard Foundation.

#### *Marxan Best Practices Guide*

<http://www.uq.edu.au/marxan/index.html?page=77823&p=1.1.4.2>

Led by Pacific Marine Analysis and Research Association (PacMARA), together with The University of Queensland, this guide presents examples of Marxan applications, discusses the selection of appropriate values and provides guidance for applying robust analyses. The Marxan Good Practices Handbook will be released mid 2008.

#### *Marxan DSS: Manual For Managers*

Staff from the project are developing a manual that will give practical guidance to managers about experiences of designing and conducting Marxan-based DSS for regional applications. This manual builds on work of this and other projects, and is directed at the use of Marxan for DSS. The manual will complement the Marxan User Manual and explore the very practical day-to-day issues confronting managers attempting to implement computer-assisted DSS in marine/coastal NRM issues.

#### *ESA Annual Conference*

A paper summarising the improvements to Marxan, and the current and expected capabilities of Marxan was prepared and presented to the 2007 annual conference of the Ecological Society of Australia, held in Perth in November: *MarZone: A systematic decision support tool for Natural Resource Management problems* (Stewart, Watts, Ward and Possingham).

#### *Climate Change and the Coast*

A poster was prepared and presented to the Mandurah (WA) Climate Change and the Coast Conference: "Optimising Choices in Coastal Management using the MarZone Software" (20 August 2007) (Watts, Stewart and Ward). This series of ongoing conferences is an important venue for engagement with local government and the private sector organisations involved with coastal management issues.

### **3. Achievements in Stage Three**

#### ***Capacity Building for NRM Managers and Practitioners***

##### *Contractual Requirements*

#### **3A Regional education and training in decision support methods**

The Organisation will disseminate and transfer knowledge to NRM practitioners so as to ensure successful adoption and delivery of best planning practices. This task will make available new science and methodologies required by decision-makers to prioritise efforts for natural resource management in the coastal zone where the case study is proposed. A number of workshops will be held using the education and training materials developed above. 'Capacity-building' and training is to be conducted by the University of Queensland in conjunction with the Institute for Regional Development at the University of Western Australia and the CSIRO. The key outcome will be to enable NRM practitioners and managers to have effective access to, and capacity to implement, the decision support methods to achieve NRM targets.

#### **3B Application of decision support methods to NRM planning and management**

The Organisation will develop the project to complement existing regional planning initiatives that are proposed for the Swan Region of Western Australia and the development of regional marine plans nationally. The project will engage in the implementation of regional planning initiatives and to provide assistance to agencies and NRM regions in the application of decision support methods. The CSIRO will assist in defining the objectives and constraints of the planning framework for parameterisation of the decision support software and application to NRM regions in Western Australia. Scientific support will be provided to assist in the compilation and synthesis of data and in performing spatial modelling to capture the key dynamic processes that characterise the ecological and economic systems (eg habitat degradation, environmental flows, fish movement and recruitment, opportunity costs, displaced fishing effort) as input parameters. Evaluating the consequences of alternative planning outcomes will be a key focus that will enable NRM bodies and lead agencies to make informed decisions and support broader community engagement.

#### **Outputs:**

- Training of Swan Region NRM coastal practitioners in the principles and practice of decision support methods. A DEH representative will be invited to attend this workshop also; and
- Decision support for the development of a natural resource management plan for the Swan region, Western Australia, as the basis for community engagement, and as a model for future planning initiatives.

### **3.1 Regional Education and Training**

The project has used practitioner workshops and education/training workshops as the main approach to delivering regional education and training in DSS and for Marxan specifically. These workshops are described in section 2.2 above.

### **3.2 Decision Support Case Studies**

The two main case studies that have been undertaken in the project are within the Swan NRM Region in WA. The first relates to the issue of marine conservation and examines options to achieve a balance between recreational activities and biodiversity conservation at Rottnest Island, near Perth in WA. The second is concerned with the multiple use issues of Cockburn Sound, also near Perth in WA, where there are high priority port and coastal zone development in conflict with coastal and marine conservation issues, all set in the context of major impacts of nutrient marine pollution and seagrass destruction for sand mining.

These case studies have been developed through close interactions with relevant agency staff and aim to serve a practical illustration of the new functionalities of Marxan with Zones as a model for future planning initiatives.

#### **3.2.1 Rottnest Island Marine Conservation**

This case study highlights the application of the software: Marxan with Zones, for marine park planning at Rottnest Island, Western Australia. It serves to highlight new functionalities of Marxan with Zones, with particular emphasis given to its capacity to define multiple zones that can incorporate zone-specific targets and assign weighting to govern the importance placed on satisfying feature targets.

The primary objective was to identify a multiple-use marine park zoning configuration that comprised marine sanctuaries to conserve marine biodiversity whilst providing for ongoing recreational and fishing activities to the extent that they do not conflict with the conservation objectives. This emphasises the requirement to spatially separate areas dedicated for the conservation of marine biodiversity, from recreational and fishing activities. A theoretical multiple-use zoning scheme was proposed as shown in Table 3.1.

*Table 3.1 Proposed Zoning Categories for Rottnest Island Case Study*

<b>Zone Name</b>	<b>Zone Definition</b>
Zone 1 – General Use (eg IUCN VI)	Permits recreational and fishing activities
Zone 2 – Restricted Use (eg IUCN IV)	Permits non-fishing recreational activities
Zone 3 – Marine Sanctuary (eg IUCN II)	Managed for high biodiversity protection

The dataset for the case study consisted of 28 coastal and marine biodiversity features and 22 recreational features occurring at Rottnest Island (Appendix 4 provides a detailed description). Data was originally compiled by the Department of Environment and Conservation for the Rottnest Island Authority to assist in the development of the Rottnest Island Marine Management Strategy. Coastal and

marine biodiversity data included information on twenty-eight biodiversity features, including benthic habitats, coastal landforms and marine species such as invertebrates. Recreational features were categorised as either non-fishing activities (surfing, SCUBA diving, recreational boat moorings and shipwrecks), or recreational fishing activities (trolling, gamefishing, and shorebased fishing). Shorebased fishing data was further delineated according to the type of fish species targeted by recreational anglers (16 different species) and the areas where they are targeted.

The planning problem was defined around the conservation of coastal and marine biodiversity in marine sanctuaries, with existing recreational activities accommodated in zones managed for general use (recreational fishing) and restricted use (non-fishing recreational activities, i.e. diving, surfing, moorings, shipwrecks). The assignment of features into these three zones is intended to deliver the following key outcomes:

- Dedicated areas for high biodiversity protection;
- Spatially separate areas for fishing and non-fishing recreational activities which can be in spatial conflict, both with each other and with biodiversity conservation
- Spatially separate areas for fishing and non-fishing recreational activities to allow contributions to biodiversity targets from the Restricted Use zone

*Table 3.2 Zone-Specific Targets for the Rottnest Island Case Study*

<b>Zone Name</b>	<b>Zone Target</b>
Zone 1 – General Use	Maintain fishing activities at 80% current usage (19 defined features for recreational fishing)
Zone 2 – Restricted Use	Maintain recreational activities at 80% current usage (4 defined features for non-fishing recreational activities)
Zone 3 – Marine Sanctuary	Achieve 30% marine biodiversity features (28 defined features for coastal and marine biodiversity)

Marxan with Zones was used to meet zone-specific targets for delineated features, meaning that a target amount of a certain feature must be achieved in a particular zone. Since not all targets could be met, the analysis was run to demonstrate the capacity of the software to allow the user to prioritise which feature targets are satisfied. In effect, this means prioritising how trade-offs are made when configuring a solution, an important function to inform and support decision-making where there are multiple competing objectives for resource use and conservation. This is implemented in Marxan with Zones by assigning a penalty for shortfalls in penalty targets. When high penalties are applied by the user to features, the target is required to be met with a high priority. Lower penalties are applied to features with lower priority targets.

Three scenarios were defined as follows.

1. Scenario One assigned high penalties for unmet biodiversity feature targets;
2. Scenario Two assigned high penalties for unmet biodiversity feature targets and moderate penalties for unmet recreational features (i.e. minimise trade-offs of biodiversity features for recreational features);
3. Scenario Three assigned high penalties for unmet biodiversity feature targets and moderate penalties for unmet fishing features (i.e. minimise trade-offs of biodiversity features for fishing features).

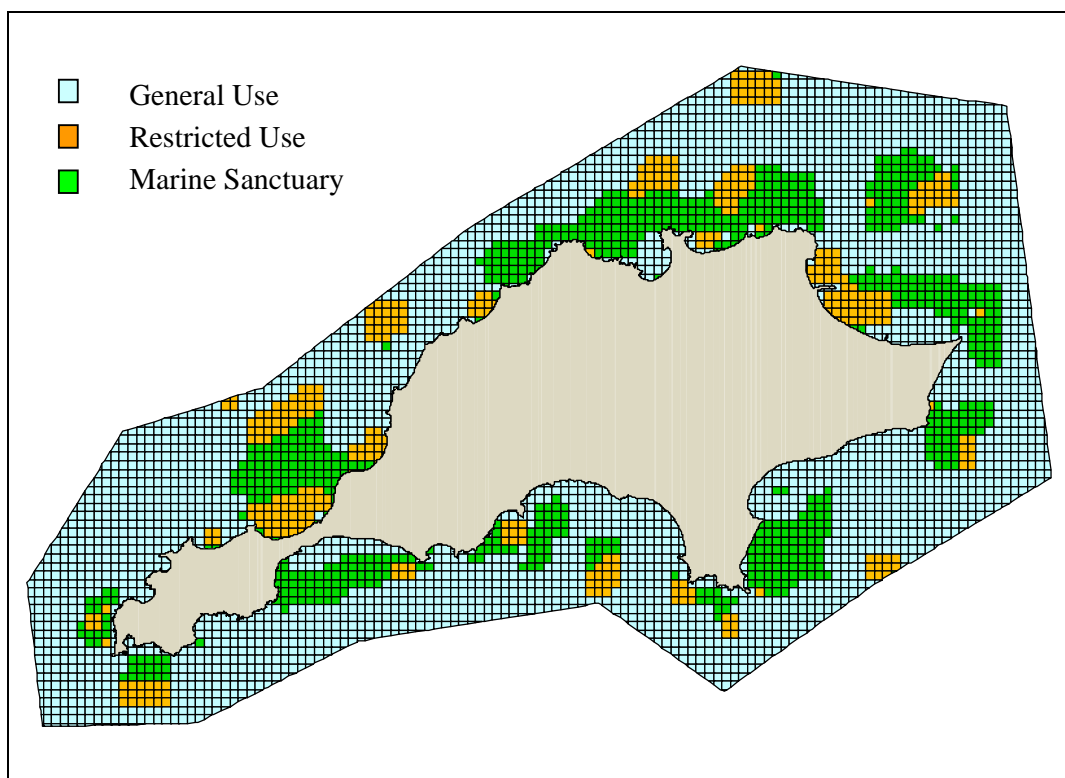
Each scenario was run 100 times using Marxan with Zones, with the best solution identified as the run with the lowest score (i.e. the minimum objective function score – the mathematical basis for the Marxan algorithm).

## Results

Marxan with Zones generated many multiple-use zoning configurations for a marine park at Rottnest Island for each of the three scenarios examined. An example of the best zoning proposal for Scenario One is presented (Figure 3.1). Figure 3.1 illustrates the capacity of the software to respond well to the requirement for spatially compact zones. Marxan with Zones was also responsive to the requirement to buffer the Marine Sanctuary zones by locating them adjacent to the Restricted Use zones, in preference to the General Use zones.

*Figure 3.1 – Zoning Plan for a Multiple-Use Marine Park at Rottnest Island*

*(example for illustrative purposes only)*



Because the zoning problem is constrained around achieving multiple objectives, minimising cost and meeting spatial requirements, the best solution does not always satisfy all feature targets. Marxan with Zones generates a missing values report that contains information on the extent to which each solution achieved each feature's target. Table 3.3 reports on the shortfall in meeting feature targets for the best solution identified in each scenario, by identifying how many zone-specific features targets were unmet in each zone (Table 3.3A). Results show that for all three scenarios, the Marine Sanctuary zone performed best, with the fewest number of unmet targets. This is expected because in these scenarios missing the biodiversity

features attracted a higher penalty than for other unmet features, to reflect the primary goal of biodiversity conservation.

Scenario Two delivers the best conservation outcome, with the least number of biodiversity targets unmet of all the scenarios. It demonstrates the capacity to accommodate recreational activities in the Restricted Use zone at no cost to conservation objectives. However, Scenario Two fails to improve on the number of unmet fishing targets in the General Use zone. This is not surprising as the penalty incurred for not satisfying the recreational fishing features targets is minimal. Scenario Three explores the effect of the penalty weighting and unlike Scenario Two, which favours meeting recreational targets, priority in Scenario Three is given to meeting fishing feature targets by assigning a moderate penalty for fishing feature targets in the General Use zone. We see from the results that the software greatly improves on meeting the General Use targets, with only 6 of the 18 features unmet. However a trade-off results, with a higher number of unmet targets for the recreational features in the Restricted Use zone and a small increase in the number of unmet biodiversity features in the Marine Sanctuary zone. This trade-off occurs despite Scenario 3 delivering the fewest number of unmet targets overall.

*Table 3.3 Shortfall in satisfying zone-specific feature targets when different penalties are used. Results report features as unmet if the shortfall is more than one percent from target. General Use zone reports on number of fishing features. The Restricted zone reports on the number of non-fishing recreational features and the Marine Sanctuary zone reports on the number of biodiversity features. Shading emphasises the higher penalties given in each scenario when targets are unmet: heavy shading denotes high penalty. Part A summarises the information by individual zones; Part B summarises the information for Sanctuary and Restricted zones combined and assumes a 20% contribution from the Restricted zone to the overall biodiversity feature target.*

**A**

<b>Zone</b> (N = number of features with defined target)	<b>Scenario 1 -</b> Conservation features prioritised	<b>Scenario 2 –</b> includes weighting for Recreational features	<b>Scenario 3 –</b> includes weighting for Fishing features
General Use (N=18)	13 unmet	13 unmet	6 unmet
Restricted (N=4)	4 unmet	1 unmet	4 unmet
Marine Sanctuary (N=23)	2 unmet	1 unmet	3 unmet

**B**

(N = number of features with defined target)	<b>Scenario 1 -</b> Conservation features prioritised	<b>Scenario 2 –</b> includes weighting for Recreational features	<b>Scenario 3 –</b> includes weighting for Fishing features
Combined Marine Sanctuary and Restricted zones (N=23)	2 unmet	1 unmet	0 unmet

Marxan with Zones can also specify a contribution rate for each feature in each zone to the overall target. This means that a feature's overall target can be met by contributions from multiple zones. We examined this by accepting an additional contribution towards biodiversity feature targets from the Restricted Use zone set at 0.2. The overall biodiversity feature target is therefore determined as the total amount held in the Marine Sanctuary and 20% of the amount held in the Restricted Use zone. The biodiversity feature target shortfall was adjusted to account for this contribution and results are reported in Table 3.3B. Scenario 3 achieved the best result towards satisfying the biodiversity feature targets of 30% with all targets met. This was unexpected as Scenario Three placed greater emphasis on meeting fishing objectives than recreational objectives and yet by spatially separating fishing and recreational activities into purpose-built zones, a net benefit was achieved for conservation objectives.

### Summary

The Rottnest Island case study presents a practical application of the software Marxan with Zones for marine park planning at Rottnest Island. This class of problem more closely resembles the conservation problem encountered by park managers and planners and Marxan with Zones offers them a systematic framework and decision support tool to underpin their planning and decision-making process.

The key improvements to the software are the capacity to configure a user-defined zonation scheme that offers great flexibility for achieving conservation and socio-economic objectives and for examining options for trade-offs that may arise when balancing competing interests. A further advance is the ability of the software to accept contributions to overall targets from a combination of zones. This function will be of interest to natural resource managers in off-reserve planning where they encounter a range of management options that could deliver different biodiversity protection outcomes outside of formal reserves.

### 3.2.2 Cockburn Sound Multiple Use

Cockburn Sound is located in the Swan Natural Resource Management region, approximately 20 km south of the Perth-Fremantle area. It is the most intensively used marine embayment in Western Australia, with many, sometimes competing, uses placing increasing pressure on the Sound. The range of uses includes a port, heavy industrial area and a strategic naval base, together with recreational swimming, sailing and fishing, commercial aquaculture and tourism.

*"... The need to manage these complex, multiple uses and the associated environmental impacts has never been greater." (Cockburn Sound Management Council 2005)*

A key function of the Cockburn Sound Management Council (CSMC) is to facilitate multiple-use of Cockburn Sound and its foreshore. The focus of the CSMC is on the provision of advice and comment on proposals to ensure the environmental values of Cockburn Sound are maintained. This case study examines options for development of a multiple-use framework that provides for integrated planning across the region to



support the management of multiple uses of coastal and marine resources. In particular, the Cockburn Sound Management Council expressed a desire for the case study to examine the application of Marxan with Zones to support the assessment of development proposals on the conservation objectives of the Sound.

Working closely with the CSMC, the study objectives were defined as follows:

- To conserve and where possible, enhance the regions biodiversity, both marine and terrestrial, for conservation and to better manage areas of multiple-use and potential conflict.
- Examine options for conservation of locally significant biodiversity
- Consider how locally significant biodiversity is potentially affected by development proposals (described below) :
  - Marina development at Port Rockingham ;
  - Marina development at Mangles Bay;
  - Port development - construction of an artificial island and access bridge ;
  - Development proposal - Aquaculture expansion area
- Consider the existing activities occurring within the Cockburn Sound region with potential for conflict for achieving the conservation objectives.

The key data requirements for the study are the biodiversity features, together with an assortment of socio-economic features representing existing uses, development proposals and recreational uses. These are documented in Appendix 5.

A zonation scheme was devised to support a multiple-use planning framework for the purposes of this case study (Table 3.4). The scheme sought to satisfy conservation objectives by assigning planning units to a conservation zone. Objectives were defined for socio-economic features by using zone-specific targets for existing uses (ports and infrastructure), development proposals and recreational uses. In this way, the proposed zones can better manage areas of multiple-use and minimise potential for conflict. A detailed definition of feature targets is presented in Appendix 5.

*Table 3.4 Proposed Zonation Scheme for Cockburn Sound*

Zone Name	Zone Objective
Zone 1 – General Use	Managed for recreational activities and general use (4 features each requiring 80% representation)
Zone 2 – Existing Uses	Managed for existing uses (12 features each requiring full representation)
Zone 3 – Conservation	Managed for conservation (23 biodiversity features with targets varying)
Zone 4 – Recreational Fishing	Managed for recreational fishing (3 features each requiring representation target of 80%)
Zone 5 – Development Proposals	Development Proposals (requires full representation of development proposals).

Marxan with Zones was used for a number of defined scenarios to examine the extent to which conservation objectives could be met when development proposals are introduced to the Sound. For all scenarios, high priority was given to meeting objectives for the development proposals and the existing uses. This means that conservation objectives could only be achieved in areas where development proposals

and existing uses do not occur. Furthermore, targets were set for other types of uses (eg recreational fishing and general use), however they were given a lower priority weighting than for the conservation objectives.

Scenario One examined how well the conservation objectives were met when taking account of the existing uses. Scenario Two considered the cumulative effect of all development proposals on achievement of conservation objectives in the Sound. Each scenario was run 100 times using Marxan with Zones. Existing uses were locked-in to the Ports and Infrastructure zone in both Scenario One and Scenario Two (i.e. planning units with existing uses are not available to assign to other zones). Scenario Two had the additional constraint of locking-in the development proposals to the Development Proposal zone. The performance of both scenarios in achieving conservation objectives was reported from output generated by Marxan with Zones.

## Results

An example of a multiple-use zoning configuration for Cockburn Sound is shown in Figure 3.2. It presents the best solution for Scenario Two, in which the Development Proposal zone satisfies objectives for all five development proposals and the Ports and Infrastructure zone meets all the objectives for existing uses. Both Scenario One and Scenario Two failed to meet all conservation objectives, a result which is not surprising, given the CSMC's requirement for 100% targets for many of the biodiversity features, combined with the limited spatial options for achieving those targets within the framework of existing uses in the Sound. The multiple-objective problem as defined here for Cockburn Sound means that biodiversity feature targets can only be achieved after the objectives for the existing uses and the development proposals are satisfied.

For each scenario, Marxan with Zones reports on the amount of each feature held in the different zones. This data shows how well the two scenarios performed in meeting the conservation objectives (Table 3.5). Both scenarios delivered conservation objective shortfalls with 12 of the 23 biodiversity features unmet in Scenario One and 13 of the 23 biodiversity features unmet in Scenario Two. At best, this shortfall was just 2% of the features occurrence (eg. *Posidonia angustifolia*) and at worst it was 97% (Shoreline habitat – Limestone Cliffs).

The finding that biodiversity feature targets could not be met when existing uses are considered indicates that to some extent these two classes of features are found to co-exist in a sub-optimal manner. This issue can be addressed in two ways. Either we assume that existing uses exclusively occupy the area, fully displacing biodiversity features and their values. In this case, data on the biodiversity distribution and feature targets need to be revised downwards to reflect a smaller distribution across the region. Alternatively, we could assume that the existing uses have only a partial effect on the biodiversity features (either due to active management or resilience to the threats presented by the specific uses). If this is so, then the assumptions of the scenario could be reviewed to rerun Marxan with Zones and accept contributions to overall biodiversity targets from the Ports and Infrastructure zone (ie. existing uses). In any case, the issue is brought to the attention of the CSMC and can be further explored in Marxan with Zones to achieve an explicit set of management outcomes that recognise the achievable objectives for biodiversity features in the context of existing and planned uses.

*Figure 3.2 – Zoning Plan considering proposed developments to support integrated natural resource management of the Cockburn Sound*

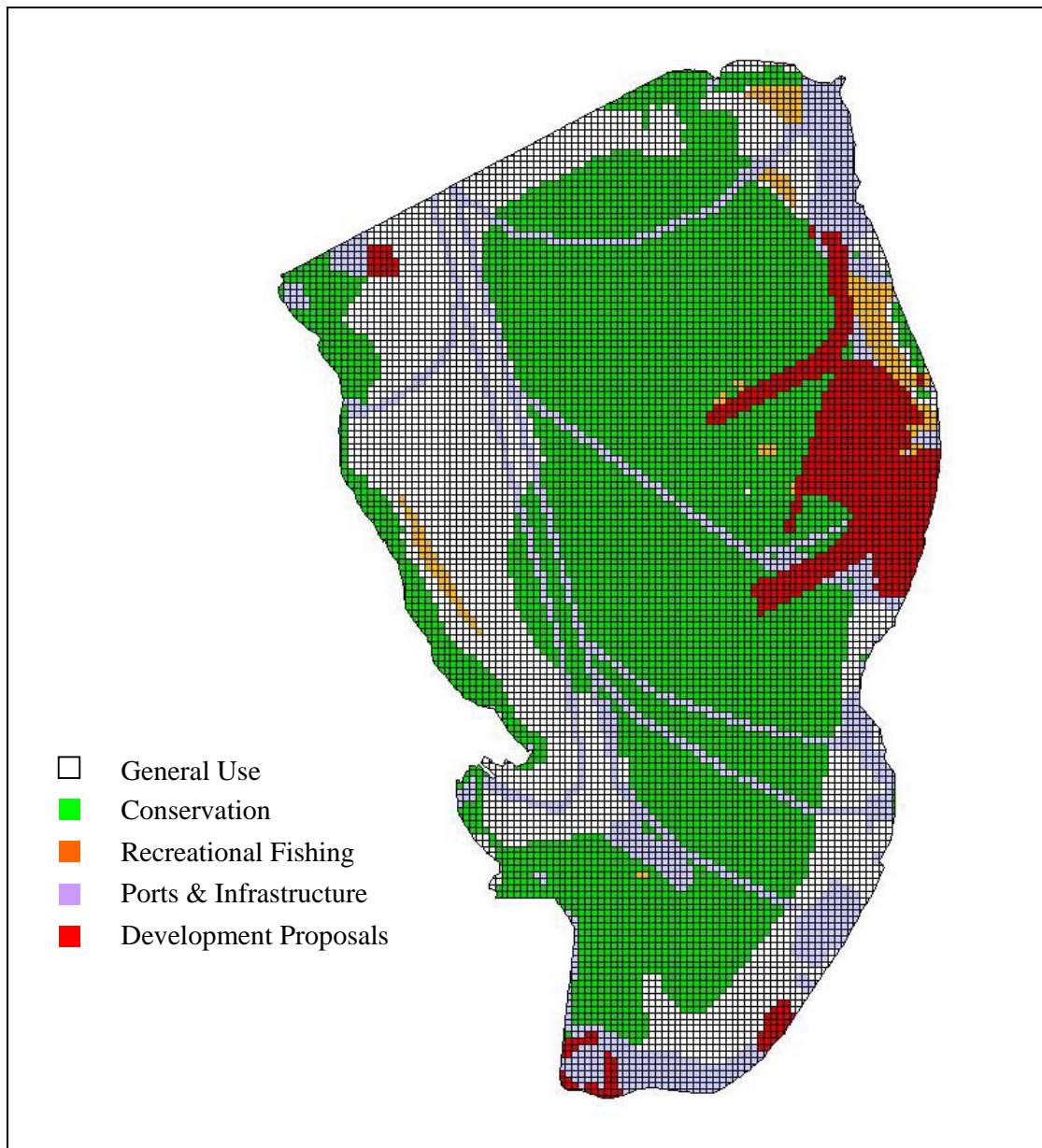


Table 3.5 The amount of biodiversity features held in the Conservation zone when existing uses are locked-in (Scenario One), and development proposals together with existing uses are locked-in (Scenario Two). Unmet feature targets are reported in bold. Shaded cells indicate biodiversity features that are adversely affected by the development proposals.

Feature ID	Feature Target	Scenario One	Scenario Two	Conservation Trade-off effect from Development Proposals
<b>Benthic habitat</b>				
1. Vegetated	30 %	33 %	45 %	
2. Wrack	30 %	53 %	67 %	
3. Cobble	30 %	89 %	49 %	
4. Pavement reef	30 %	59 %	55 %	
5. Fine sediment	30 %	55 %	47%	
6. Limestone reef	30 %	82 %	82 %	
<b>Seagrass meadows</b>				
7. Mixed seagrass	100%	<b>96 %</b>	<b>96 %</b>	
8. <i>Amphibolis</i> & <i>posidonia</i> spp.	95 %	96 %	96 %	
9. <i>Halophila</i> spp.	100 %	<b>95 %</b>	<b>47 %</b>	<b>48 %</b>
10. Patchy <i>Posidonia</i>	100 %	100 %	100 %	
11. <i>Posidonia</i> spp.	100 %	<b>98 %</b>	<b>96 %</b>	<b>2 %</b>
12. <i>P.sinuosa</i> & <i>P.australis</i>	100 %	<b>37 %</b>	<b>30 %</b>	<b>7 %</b>
13. <i>P.sinuosa</i>	100 %	<b>81 %</b>	<b>76 %</b>	<b>5 %</b>
14. <i>P. angustifolia</i>	100 %	<b>98 %</b>	<b>98 %</b>	
<b>Shoreline habitat</b>				
15. Sandy beach	100 %	<b>55 %</b>	<b>31 %</b>	<b>24 %</b>
16. Limestone cliff	100 %	<b>3 %</b>	<b>3 %</b>	
<b>Other</b>				
17. Coral areas	75 %	75 %	75 %	
18. Potential coral areas	50%	83 %	75 %	
19. Snapper spawning area	100%	<b>90 %</b>	<b>88 %</b>	<b>2 %</b>
20. Little Penguin colony	100%	<b>66 %</b>	<b>66 %</b>	
21. Little Penguin foraging area	90%	90 %	<b>86 %</b>	<b>4 %</b>
22. Seal	100%	<b>82 %</b>	<b>82 %</b>	
23. Dolphin	100%	<b>89 %</b>	<b>87 %</b>	<b>2 %</b>

When development proposals were included together with the existing uses (Scenario Two), the additional trade-offs required reduced the levels of achievement of a number of conservation features. This was measured as the difference between the amount of biodiversity features held in the Conservation zone when existing features are considered (Scenario One) and the amount held when development proposals are added (Scenario Two). The greatest trade-off effect attributed to the development proposals was to the biodiversity feature *Halophila* spp (48%). Trade-off effects were also reported for other seagrass features (*Posidonia* spp. ,2%, *P. sinuosa* & *P. australis*, 7%, *P.sinuosa*, 5%), to the shoreline habitat (Sandy beach, 24%), to Little Penguin Foraging areas (4%) and to Dolphin nursery areas (2%). It indicates that biodiversity features could not be found in planning units within the Sound that were available for allocation to conservation zoning.

## **Summary**

We applied Marxan with Zones to specify a multiple-use planning framework for Cockburn Sound that integrates different types of resource uses, ranging from high level protection (eg. conservation) to exclusive types of use (eg ports). We found that Marxan with Zones provides the flexibility to deal with a wide range of problems by allowing the user to specify objectives for economic, social and ecological features. In this case study, the problem was constrained around the requirement to meet objectives for existing uses and to examine the potential impact of development proposals for conservation of biodiversity features in the Sound. Marxan with Zones can then identify a zoning configuration that delivers the optimal trade-off of existing and proposed uses with biodiversity features. This involves identifying efficient spatial solutions for conservation zones that will optimise the retention of biodiversity features in the Sound. Marxan with Zones also provides the platform for exploring the different alternative configurations of proposals to optimally retain the existing biodiversity features of the Sound, even where complete retention of those features cannot be achieved because of the development pressures.

#### 4. NIS Outcomes

<i>Contractual Requirements</i>	
Principle NIS Outcome	Establishing institutional and organizational frameworks that promote conservation and ecologically sustainable use and management of natural resources
Other NIS Outcomes	<p>Institutional and organizational frameworks that promote improved management and conservation of natural resources and biodiversity.</p> <p>A farm systems approach to NRM incentives which encourage best-practice land and conservation management beyond duty of care and provides financial assistance to bring about accelerated change in land management practices.</p>

The approach and framework developed in this project to guide practitioners is specifically directed towards improving the use and management of natural resources taking account of the need for more effective conservation of natural resources and biodiversity. Amongst other key aspects, datasets needed to apply the framework developed in this project are typically sourced from across a number of NRM agencies, and so a commitment to computer-assisted DSS in NRM is a commitment to an expanded institutional and organisational framework.

The staff of the project have been heavily involved with a number of the scientific practitioners and government agencies in conservation planning and management in the Swan Region. For example, many of the attendees at the Perth Practitioners Workshops (November 2006, May 2007 and November 2007) are conservation and natural resource planners and managers from the WA Department of Environment and Conservation, Department of Fisheries, CSIRO, the Cockburn Sound Management Council, and the private sector. The staff of the project are also involved in conducting workshops in systematic conservation planning for the Department of Environment, Water, Heritage and the Arts. A 2-day course will be held in Hobart (4-5 June 2008) and in Canberra (11-12 June 2008) to develop capacity in support of large scale systematic conservation zoning for Australia's commonwealth waters.

This involvement is regional, national and international. The staff of the project have been heavily involved with the planning and delivery of the 21st Meeting of the Society for Conservation Biology in South Africa (26-29 June 2007). This is the global pre-eminent forum for conservation professionals to exchange information and ideas about conservation tools and frameworks, and the project staff have made a major contribution to establishing and enhancing international institutional engagement for the promotion of more ecologically sustainable use, conservation and management of natural resources and biodiversity. This includes institutions within Australia, since Australia has a strong contingent of conservation planners who are involved with the Society.

## 5. Communication Outcomes

### *Contractual Requirements*

At the end of Stage 1 (see Table 1 in next Section), both the findings of the workshop in association with the inaugural International Marine Protected Areas Congress (IMPAC –October 2005) and the findings of the NRM engagement workshops, will be published and accessible. These findings will be passed to the Department in Progress Report 1 and both in hard copy and electronically in MS Excel/MS Word format.

At the end of Stage 2, the findings regarding the work on problem formulation and decision support development will be relayed to the Department in a progress report both in hard copy and electronically in MS Excel/MS Word format.

As part of Stage 3, training workshops in the use of the decision support tools will be conducted for partner organisations and NRM Councils (WA and possibly Qld). A website will be developed with freely downloadable software, training module and materials. Media releases and interviews will be given to increase the understanding of the science and application of spatial decision support systems for sustainable resource use and biodiversity conservation. In addition, scientific papers will be published in international journals to promote Australia's leadership in this field. One copy of each of these papers will be provided to the Project Manager through the Contact Officer in DEH (Section 16 in Schedule).

Communication matters have been reported above, in Sections 2 and 3.

One of the key initiatives to report is the redevelopment of the Marxan website [www.uq.edu.au/marxan](http://www.uq.edu.au/marxan). While its primary purpose is to provide the freely available software and technical background information about Marxan, a recent user survey highlighted a number of key features required to better meet the needs of conservation and NRM practitioners. The website now places greater emphasis on featuring applications of Marxan at work, with more references, case studies and background information relating to systematic conservation planning and natural resource management issues. It has incorporated a new Teaching and Learning section dedicated to better equip new and existing users with the basic skills and understanding to apply Marxan to a wide range of natural resource management problems.

In addition, a number of media articles raising the profile of Marxan have featured in the AEDA (Applied Environmental Decision Analysis –CERF) news magazine, which has around 380 subscribers.

Media articles are available online at <http://www.aeda.edu.au/news> and include:

Decision Point Issue 18/May 2008 AEDA News

*A new tag – for a trusted old name* – article announcing the new Marxan slogan - *informing conservation decisions globally*. Suggestions were canvassed from the Marxan community to devise a new slogan to better define Marxan's core values. p3.

Decision Point Issue 17/April 2008 AEDA News

*Making more of Marxan* – article reporting on the Marxan workshop held in Brisbane in January 2008, which reviewed current and new initiatives in the development of new Marxan software. p8.

Decision Point Issue 17/April 2008 AEDA News

*A new user manual for Marxan*- article announcing the release of the new Marxan User Manual. The new manual is written in a more user-friendly style and incorporates new materials such as tutorials and courses that have been developed since Marxan's creation. p9.

Decision Point Issue 15/December 2007 AEDA News

*Why don't we sell Marxan?*- article discussing why the University of Queensland and Marxan developers are committed to ensuring this software is freely available – and reflects on how this has fostered a strong community of Marxan users. p1-2

Issue 14/November 2007

*A new crop of users for Marxan* – article reporting on the Introduction to Marxan courses held in November and December, 2007. In attendance were conservation managers and researchers from Mexico, Norway, Palau, Indonesia, the USA and New Zealand. Australian participants included representatives from government departments, agencies, universities and NGOs. p2.

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## **References**

Cockburn Sound Management Council (2005). Environmental Management Plan for Cockburn Sound and its Catchments, Department of Environment, Perth 2005.  
Sabatini, M. D., A. Verdiell, et al. (2007). "A quantitative method for zoning of protected areas and its spatial ecological implications." Journal of Environmental Management 83(2): 198-206.



**Appendix 1**  
*Steering Committee*  
(Agenda for meeting #3)

**Steering Committee**  
NRM DSS Project

*Developing an integrated planning framework and decision support methods for  
biodiversity conservation and sustainable natural resource management across the  
marine terrestrial interface*

**Steering Committee Meeting #3**  
**Thursday, 14 June 2007**  
**1000 to 1230 hrs**

**Venue:** 1<sup>st</sup> Year Geography Lab; 1<sup>st</sup> Floor, Geography Building, University of WA  
(grid ref I-17 on UWA map ([maps.uwa.edu.au/crawley/display/6](http://maps.uwa.edu.au/crawley/display/6)); enter from the  
eastern side of building, take the stairs to 1<sup>st</sup> flr, turn right/right into the main  
corridor)

**Parking:** Parking is free for non-parking permit holders in the Yellow Student parking areas  
(note this ONLY applies to the Yellow Parking Zones; Red zones remain reserved for staff  
permit holders, and all coin parking applies as usual))

**Agenda**

1000-1015: briefing on WA regional marine planning (Ian Eliot)

1015-1115: report from Practitioner Workshop #2, update on Marzone software  
development, report on CERF project and Brisbane workshop (Rom Stewart/Trevor  
Ward)

1115-1215: planning for DSS Cockburn Sound NRM issues (Trevor Ward)

1215-1230: any other business

Trevor Ward  
041 990 2571

**Members and Observers**

***Chair*** Ian Eliot, DEC

Barbara Pedersen, DPI

Craig Wilson, Swan Catchment Council

Chris Simpson, DEC

Claire Wright, RIA

Fiona Valesini, Murdoch, Swan Marine and Coastal Reference Group

Jenny Shaw, DOF

Representative to be advised: DEW/AFFA

Matthew Tonts, IRD, UWA

Rosh Ireland, DPC

Ray Wills, SMEC

Mat Vanderklift, CSIRO

Russ Babcock, CSIRO

Rom Stewart, UOQ

## Appendix 2

### *Research papers arising from the Marxan Workshop January 2008 (AEDA News - Decision Point Issue 17)*

## Making more of Marxan

**Marxan is the most widely used conservation planning software in the world. It finds reasonably cost-efficient solutions to the problem of selecting a system of spatially organised areas that meet a suite of biodiversity targets. AEDA and the Spatial Ecology lab at the University of Queensland are currently working to refine and further develop the program. However, it's a task that is also being embraced by a much wider international community of users.**

In January, a number of people from this Marxan community gathered at the University of Queensland for a four-day workshop hosted by the Brisbane node of AEDA. The focus of the workshop was to write up developments in new Marxan software to support the release of the new software later in the year. There was also a review of ongoing research themes in systematic conservation planning.

In attendance were leading Marxan experts from around Australia and the world, with funding provided by AEDA and the Natural Heritage Trust (with in-kind support from participants).

The following research themes for ongoing work were identified: multiple use zoning, probabilistic treatments of threats and species distributions, connectivity, decision support systems and open source GIS, next generation database management systems, options for reporting alternative solutions, and the dynamic reserve selection problem.

There were thirteen scientific papers arising from this workshop (each are in various stages of preparation), and they are outlined below.

*Matthew Watts and Romola Stewart*  
Brisbane Node, AEDA  
m.watts@uq.edu.au, r.stewart@uq.edu.au  
For more info on Marxan please visit  
<http://www.ecology.uq.edu.au/marxan.htm>

### **1. Marxan with zones – optimised landscape and seascape zoning using spatially explicit annealing**

Many agencies would like to be able to create plans that zone the sea or land, rather than merely assigning sites to 'reserved' or 'not reserved'. In this project we define the problem of conservation planning with multiple zones. The paper formulates the problem mathematically and introduces the new software "Marxan with zones" using case studies to demonstrate its application to complex planning problems.  
*Contact: Mathew Watts, m.watts@uq.edu.au*

### **2. A marine zoning plan for Rottne Island; a multiple-use marine park**

This paper presents a novel approach for the design of a multiple use marine park, using Marxan with zones. The case study of marine ecosystems around Rottne Island highlights the goal of maximising conservation benefits while minimising costs to recreational users.  
*Contact: Romola Stewart, r.stewart@uq.edu.au*

### **3. Conserving South East Asian mammals: what to do where?**

This paper outlines zonation of alternative land uses for prioritising conservation investments in a cost-effective manner with South East Asian mammals sensitive

to forest conversion. The method accounts for enabling conditions and socioeconomic factors to optimize the likelihood of success of conservation investments in East Kalimantan, and addresses the questions of where to act and how to act to conserve these species.  
*Contact: Kerrie Wilson, kwilson@tnc.org*

### **4. Supporting the design of marine protected areas in California**

Using Marxan with zoning we produced several possible zoning configurations that satisfy biodiversity and socioeconomic goals, and objectives of multiple stakeholders. The zone assignments are driven by the fishing restrictions in each zone and informed by fine-scale spatially explicit information across several commercial and recreational fisheries.  
*Contact: Carissa Klein, c.klein@uq.edu.au*

### **5. Systematic Zoning applied to Biosphere Reserves, protecting the Pantanal wetland heritage**

This paper provides guidelines to UNESCO's Man and the Biosphere Program in regards to the zoning principles of the biosphere reserves. The case study compares the existing allocation of zones of the Pantanal Biosphere Reserve to a reserve that target the fulfilment of social, biodiversity and sustainability objectives.

*Contact: Reinaldo Lourival, r.lourival@gmail.com*

### **6. Systematic zoning in conservation planning, a review of principles**

A review of the literature around the issue of zoning and its principles. Expanding and adapting them to the developments in systematic conservation planning. We evaluate some case studies where zoning was used in ad hoc fashion highlighting the necessary steps to engage in systematic zoning.

*Contact: Reinaldo Lourival, r.lourival@gmail.com*

### **7. The use of probability in conservation planning**

Describes the various types of probability data that may be encountered in conservation planning applications, the important distinction between uncertainty and probability, and identifies different ways with which probabilistic data may be used within a Marxan framework.

*Contact: Eddie Game, e.game@uq.edu.au*

### **8. Asymmetric connectivity in Marxan**

Formulates the problem of asymmetric connectivity to better represent spatial relationships occurring across land and seascapes.

*Contact: Maria Beger, m.beger@uq.edu.au*

### **9. Conservation planning with connectivity for coral reefs**

Presents a novel approach for incorporating connectivity in coral reef planning to deliver more efficient solutions that meet the goal of adequacy.

*Contact: Maria Beger, m.beger@uq.edu.au*

### **10. Boundary surrogates for producing network connectivity for reserve configurations**

This paper defines the types of connectivity that arise in marine (and terrestrial?) and considers a number

AEDA  
workshops



of formulations of connectivity measures drawn from graph theory that can be applied using Marxan.  
Contact: Maria Beger, [m.beger@uq.edu.au](mailto:m.beger@uq.edu.au)

#### **11. River conservation planning: alternative formulations using existing tools**

This paper compares three different ways of formulating the problem of riverine connectivity in Marxan.  
Contact: Simon Linke, [simon.linke@gmail.com](mailto:simon.linke@gmail.com)

#### **12. Evaluating alternative solutions in conservation planning using Marxan and multivariate techniques**

Marxan normally produces two outputs, good reserve systems and a map of the frequency with which any site is selected amongst the good reserve solutions. Some users have expressed an interest in automatically obtaining several good but very different solutions for presentation to decision-makers. This paper describes the classification and ordination techniques implemented in conjunction with Marxan to evaluate

alternative scenarios.

Contact: Simon Linke, [simon.linke@gmail.com](mailto:simon.linke@gmail.com)

#### **13. The generalised dynamic reserve selection problem**

Describes the maths and reasoning behind using a dynamic version of the reserve selection problem that considers both state and control variables rather than confounding them. In addition, we examine the contribution of off-reserve areas to meeting our conservation goals. The paper explains why this is an important extension of the current problem and illustrates how easy it is to generalise from current reserve problems to dynamic problems which capture in a far better way the nature of conservation planning.  
Contact: Hugh Possingham, [h.possingham@uq.edu.au](mailto:h.possingham@uq.edu.au)

### **A new user manual for Marxan**

**How do you make Marxan easier to use? One way is by quizzing existing users on their experiences with Marxan and identifying where things might be improved. And that's just what PACMARA has done.**

Last year Natalie Ban and Jeff Ardron from the Pacific Marine Analysis & Research Association (PACMARA) developed a questionnaire on people's experiences and problems when using Marxan. Respondents, who included representatives from governmental agencies, NGOs and academia, identified a number of areas where they thought Marxan might be improved. They suggested that current weaknesses included insufficient guidance on preparing input files, adjusting settings and dealing with errors.

In response to this, PACMARA together with The University of Queensland and AEDA are developing a range of products to help people using Marxan. This includes the development of a 'Best Practices Handbook' (due later this year), a set of detailed case studies of people who have used Marxan and, just released, a new user manual.

Production of the new manual was funded by the Packard Foundation through the Marine Ecosystem-Based Management Tool Innovation Fund (<http://mgel.env.duke.edu/proj/mebm>). It was written by Eddie Game and Hedley Grantham from The University of Queensland and edited by a range of people including Jeff Ardron (from PACMARA), Carissa Klein, Matt Watts and Hugh Possingham (from Queensland Uni), and Dave Nicolson (from The Nature Conservancy, Canada).

The new manual is based on the original manual (written by Ian Ball and Hugh Possingham), however, it's written in a more user-friendly style and incorporates new material such as tutorials and courses that have been developed since Marxan's creation. And most of the technical descriptions have been moved into an appendix so as not to frighten new users.

The new manual also expands on what each parameter and input file does, how to develop these files, and what to do to set up an analysis. There's also a new section on practical advice to develop input files

and display the results using GIS software, and a new section on troubleshooting to help people deal with common problems.

While there is some discussion in the introduction on whether or not Marxan might be an appropriate tool for particular applications, the manual is more descriptive than prescriptive. Selecting appropriate values and applying robust analyses will be discussed in more detail in the Marxan Best Practices Handbook.

In keeping with the international flavour of the manual's development, the launch of the publication was at an international internet conference where nearly 50 participants from around the world phoned in on a conference call line to hear presentations by Jeff Ardron, Hugh Possingham and the authors. The visual presentation was based on a desktop sharing program that beamed the presentation to everyone's personal computer in real-time.

The new manual can be downloaded from the UQ Ecology Centre <[www.ecology.uq.edu.au/marxan.htm](http://www.ecology.uq.edu.au/marxan.htm)> or PACMARA <[www.pacmara.org](http://www.pacmara.org)>.

PACMARA has also set up an experimental Wiki site (<http://pacmara.org/tikiwiki/tiki-index.php>) in an effort to facilitate further improvement by the community of Marxan users.

Hedley Grantham and Eddie Game  
Brisbane Node, AEDA  
[h.grantham@uq.edu.au](mailto:h.grantham@uq.edu.au), [e.game@uq.edu.au](mailto:e.game@uq.edu.au)



Part of the international community of researchers and managers working to make more of Marxan (at a 'Marxan Good Practices' workshop in Vancouver last year).

## Appendix 3

### *Course Manual*

Natural Heritage Trust National Competitive Component Research Project  
53414

# Systematic conservation planning with Marxan/Marzone Course Manual

Romola Stewart, Matthew Watts, Lindsay Kircher and Trevor Ward  
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22 & 23 November 2007  
*The University of Western Australia*

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Heritage Trust, University of Queensland and the Commonwealth  
Environmental Research Facility

*^ Workshop Disclaimer: all data used in this workshop must be considered to be fictitious. The scenarios are purely hypothetical, and have been developed specifically for demonstration purposes at this workshop. No input data or outcomes should be considered to represent any aspect of the real world or any actual marine NRM, Swan region situations. The project team wishes to thank the Rottnest Island Authority, Cockburn Sound Management Council and the Government of Western Australia for permission to access their data for use in these hypothetical exercises.*

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- 2.2 *Scenario 2*-Identify Systems of Marine Sanctuaries At A Range Of Conservation Targets.
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## **Appendix 1. Demonstration Session, Marxan outputs & the GIS**

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- A1.8 Summed Solution (output\_sum.csv)

## 1. Getting Started

**Note:** When we refer to drive D:\ in this document, substitute another drive on your computer if you have the course data and applications installed on a drive other than D:\. For example, if you have the course installed on E:\courses\ then D:\ should be replaced with E:\courses\.

There are many ways to create and view Marxan files. For the purpose of this class, we present just one method using our custom build MarZone interface software linked to ArcView3.

- Login to the computer using your password and username.
- Navigate to folder D:\rotnest\ and where the course data and applications have been installed.
- This is where you will launch the applications for Interactive Session 1.

## 2. Interactive Session 1, Marxan Exercises

### Scenario 1-Identify a system of marine sanctuary zones

*Create a system of marine sanctuaries based on mapped marine habitat features and marine biodiversity surrogates, ignoring other users/uses*

The goal is to identify a system of sanctuary zones that achieve a 15% target level of representation of each biodiversity feature while limiting the size (i.e. area) of sanctuary zones. Other uses/users are ignored (cost is based on area only).

- \* A conservation target of 15% requires biodiversity features to be represented in sanctuary zones at 15% of their occurrence/distribution.
- \* Examine the effect of different spatial constraints by modifying the BLM parameter which varies the importance placed on compact versus fragmented systems.
- \* Identify the best solution configured with:

BLM set at 0	(no requirement for compact systems)
BLM set at 0.1	(requirement for moderately compact systems)
BLM set at 1	(requirement for highly compact systems)
BLM set at 10	(requirement for highly compact systems)
- \* Instructions are outlined below.



## Scenario 1

1. Open the ArcView project.



Navigate to D:\rotnest\MarZoneInterface.apr by double clicking on **My Computer**, double click **D:\** drive, double click **rotnest**, double click **Marzone Interface** (Apr File).

2. Open the MarZone Interface program.



Navigate to D:\rotnest \MarZoneInterface.exe as above but double click **Marzone Interface** (exe File).

3. Locate the command file for Scenario 1

In the MarZone Interface program, set the **MarZone Database Path** for Scenario 1. To do this, browse to the location of Scenario 1's command file 'input.dat' . The file should be located in the directory:

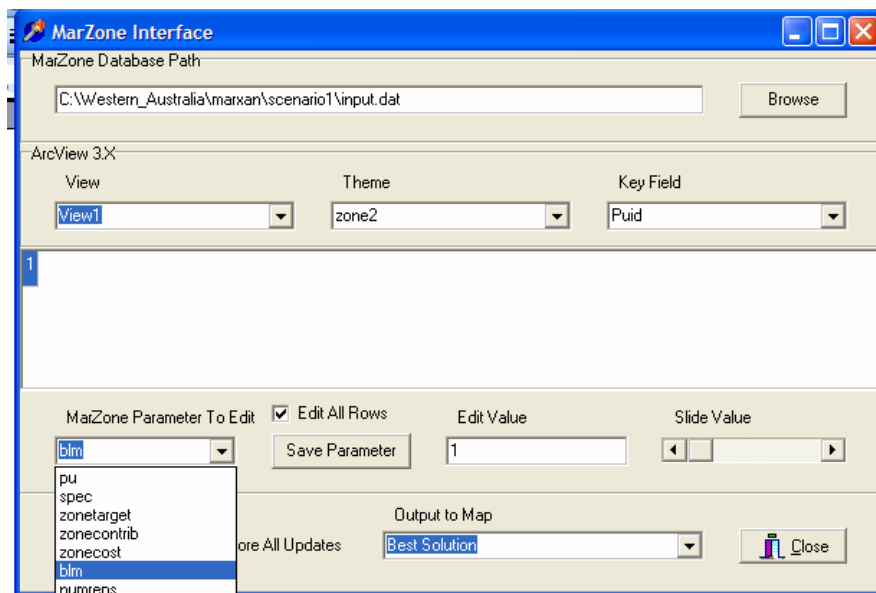
**D:\rotnest\marxan\scenario1\input.dat**

4. Set the ArcView3 properties

Click on the drop down list box under **View** and select View1. Click on the drop down list box under **Theme** and select zone2. Click on the drop down list box under **Key Field** and select Puid.

5. Edit BLM Parameter

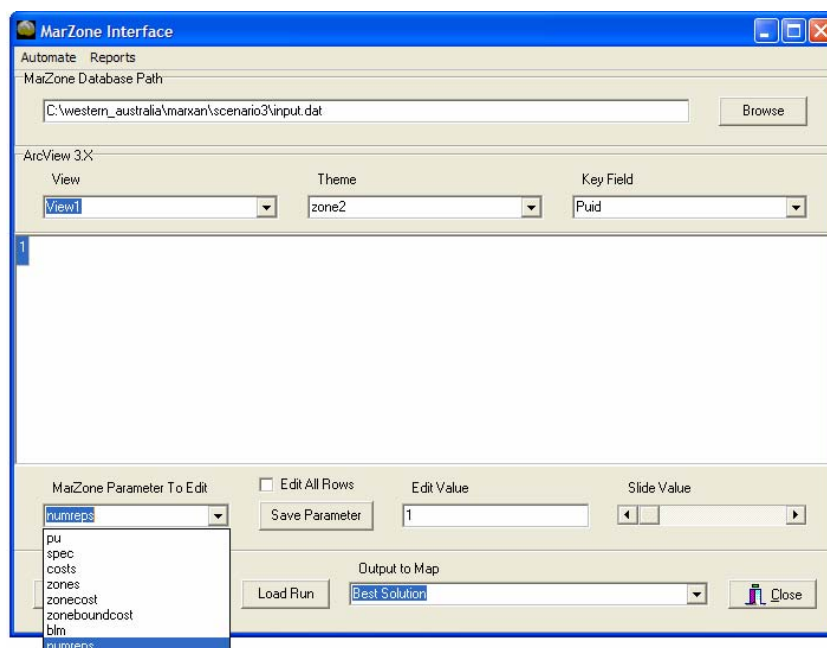
In the MarZone Interface click on the drop down box under **MarZone Parameter to Edit** and select the parameter '**blm**' as shown below



6. Next, go to the **Edit Value** field and enter the required value. Enter 0 to start

7. Edit **NUMREPS** Parameter

Again, go to the **MarZone Parameter to Edit** drop box and select the parameter '**repeat runs**'. This displays the number of runs currently selected.



8. In the **Edit Value** box input a value for the number of repeat runs. For example, a value of 10.
9. Now go to the **Output to Map** field and select **Best Solution** as highlighted in the figure above
10. Select **Run** and when prompted to **save parameter** select **yes**, and Marxan will run automatically. This should take 20-30 seconds, after which ArcView will display the best solution for the defined problem as coloured planning units.
11. As Marxan generates many good solutions, you also have the option of viewing the alternative solutions. To view these in the MarZone Interface **Output to Map** field select the **Solution** number (from 1-10). ArcView will then automatically display the selected solution. **Hint**, after entering the **Output to Map** box, press the up and down arrow keys to quickly switch between different display modes.


12. Repeat steps 6 to 11 using alternative BLM values (e.g. (0.01, 0.1, 1, 10))

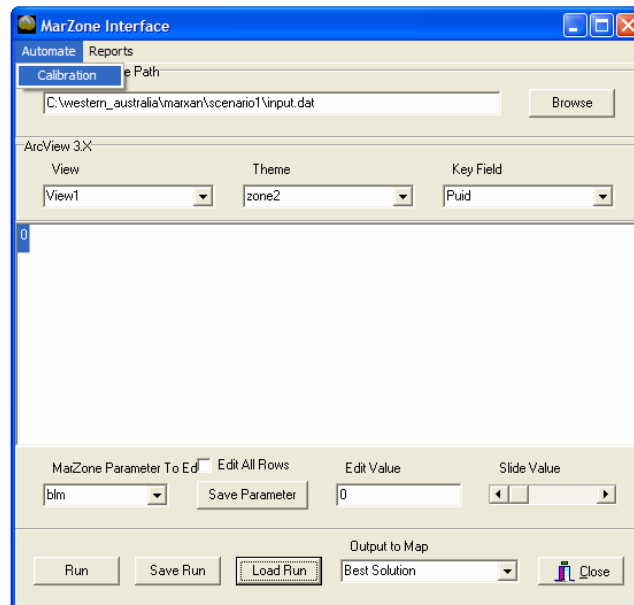
## Calibration Exercise

Calibration is the process of achieving the desired output (eg minimum cost) by varying the input parameter. So in Marxan, calibration involves varying the input parameter to achieve the desired result. In this scenario, we showed how varying the BLM leads to reserves with different levels of compactness. Too little compactness and reserves are highly fragmented (and unmanageable). Too much compactness and the reserves become large and costly to other uses.

Continuing from the previous exercise, calibrate the BLM parameter to achieve a level of compactness at reasonable cost.

13. In the MarZone Interface program.

Navigate to the header menu (located beneath the MarZone Interface  symbol) and click on **Automate**. A drop down menu showing **Calibration** will appear (see below)



14. Set the **Calibration** properties.

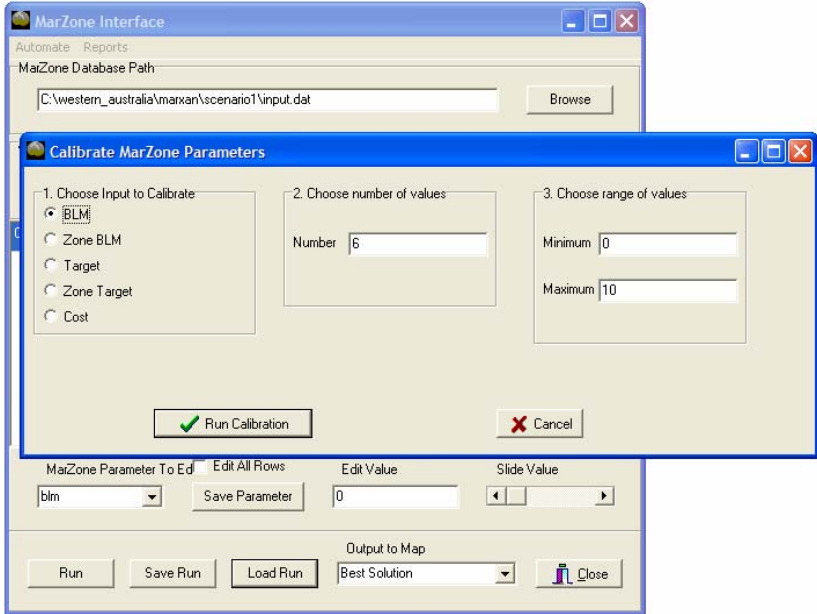
Click on **Calibration** and the **Calibrate Marzone Parameters** which provides you with options for calibration.

Set 1. **Choose Input to Calibrate** to BLM

Set 2. **Choose number of values** to 9

Set 3. **Choose range of values** and set **Maximum** to 0.2

Next enter **Run Calibration**



The screenshot shows two overlapping windows from the MarZone software. The background window is the 'MarZone Interface' with a 'MarZone Database Path' field containing 'C:\western\_australia\marzan\scenario1\input.dat' and a 'Browse' button. The foreground window is the 'Calibrate MarZone Parameters' dialog box. It contains three sections: 1. 'Choose Input to Calibrate' with radio buttons for 'BLM' (selected), 'Zone BLM', 'Target', 'Zone Target', and 'Cost'. 2. 'Choose number of values' with a 'Number' field set to '6'. 3. 'Choose range of values' with 'Minimum' set to '0' and 'Maximum' set to '10'. At the bottom of this dialog are 'Run Calibration' (with a green checkmark icon) and 'Cancel' (with a red X icon) buttons. Below the dialog, the 'MarZone Parameter To Edit' dropdown is set to 'blm', with 'Edit All Rows' and 'Save Parameter' buttons. The 'Edit Value' field shows '0' and the 'Slide Value' control is visible. At the very bottom are 'Run', 'Save Run', and 'Load Run' buttons, along with an 'Output to Map' dropdown set to 'Best Solution' and a 'Close' button with a magnifying glass icon.

Marxan will generate solutions using BLM values between the range specified. This may take a few minutes. While you wait you can see that reserve systems configured at the different BLM values will be updated to the **ArcView View1**. Once calibration is complete, the **Summary Report** should automatically appear. (If not this can be located under the Marxan interface Reports dropdown menu >Calibration). We are interested in learning which BLM value achieves the desired result.

#### 15. View Calibration Summary Report

The **Calibration Summary Report** presents the reserve system cost at different BLM values. The general trend observed is that cost increases as BLM values increase. This is the penalty paid for a highly compact and manageable reserve. The skill is in selecting the BLM value that maximises compactness (aka minimises boundary length) while minimising the cost trade-off. Plotting results in excel can help to determine the minimal trade-off point.

#### 16. Plot Calibration Summary Report results in Excel

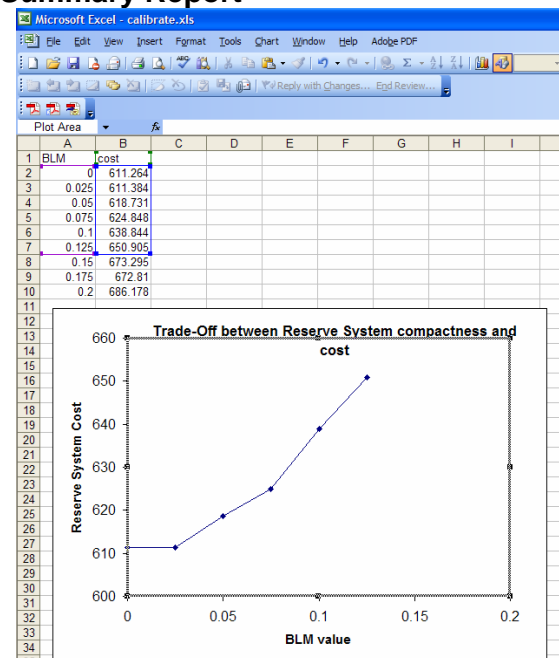
Open **Excel** and navigate to

**D:\rotnest\marxan\scenario1\calibrate.xls.**

Type in the results from your **Calibration Summary Report** into the table provided in excel.

Your results should automatically appear in the plot. See if you can determine the BLM value that is the trade-off point. This is indicated as the point where you Achieve good gains in compactness (small boundary length) yet minimal increases in reserve system cost. At this point the BLM value achieves the desired result.

End of Scenario



## **Scenario 2-Identify Systems Of Marine Sanctuaries At A Range Of Conservation Targets.**

*Create a system of marine sanctuaries based on mapped marine habitat features and marine biodiversity surrogates that meet a defined set of constraints. Familiarise with formulating different conservation targets. The relevant outputs will be irreplaceability maps.*

The goal is to create systems of sanctuary zones that achieve different target levels of representation while limiting the size (i.e. areal extent) of sanctuary zones. The cost objective is to minimise the areal extent of the sanctuary zones, (i.e. other uses/users are ignored)

- \* Examine the effect of different targets on the configuration of sanctuary zones by prescribing different target levels of representation of biodiversity features
- \* Identify the best solution configured with:
  - target set at 15%
  - target set at 30%
  - target set at 50%
- \* Examine how a planning unit's irreplaceability value varies with the representation target
- \* Instructions follow

## Scenario 2

1. In the MarZone Interface program, set the **MarZone Database Path** for Scenario 2. To do this, browse to the location of Scenario 2's command file 'input.dat'. The file should be located in the directory:  
**D:\rotnnest\marxan\scenario2\input.dat**
2. In the **MarZone Parameter to Edit** drop box select the parameter '**spec**'. This brings up a table showing information about the biodiversity features. Features identified in the **spec** file are described in more detail in Table 2.1 below.

**Table 2.1** Description of biodiversity features for the Rottnest Island dataset

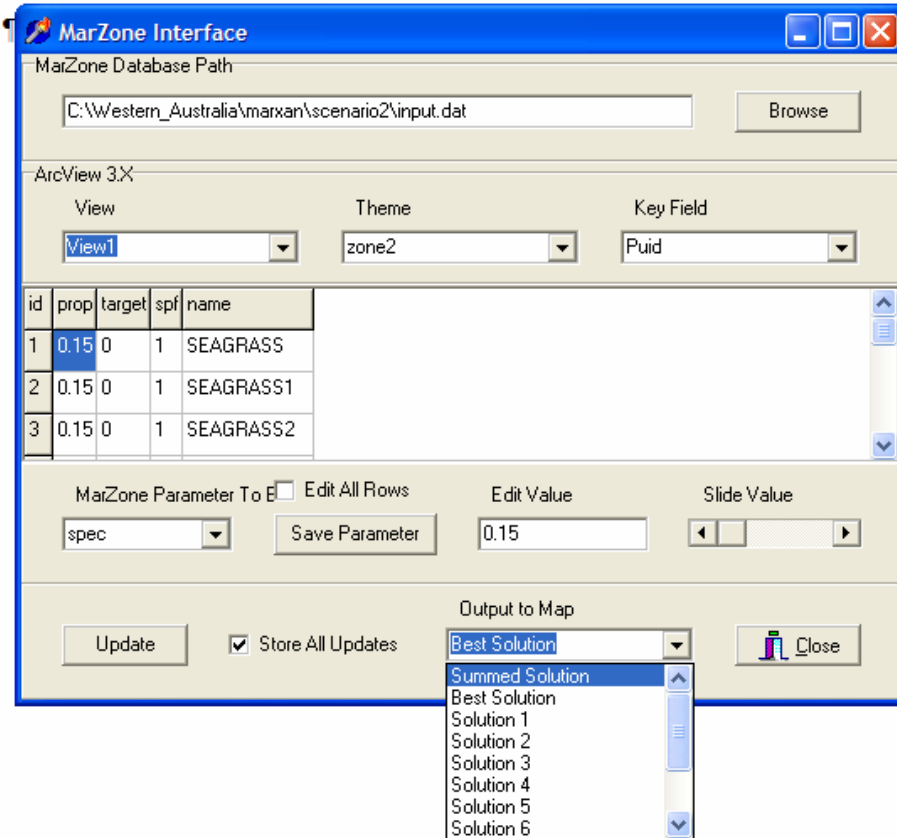
Name	Biodiversity feature	Description
SEAGRASS	seagrass	areas of high conservation
SEAGRASS1	seagrass type 1	areas of high conservation
SEAGRASS2	seagrass type 2	areas of high conservation
FISH1	tropical fish area 1	areas of high conservation
FISH2	tropical fish area 2	areas of high conservation
FISH3	tropical fish area 3	areas of high conservation
INVERT	marine invertebrates	areas of importance for
SHALLOW	0-5m depth	bathymetry
MEDIUM	5-10m depth	bathymetry
DEEP	10-15m depth	bathymetry
ABAS	active blowouts and sanddunes	coastal landforms
APUF	active partially unstable fordune	coastal landforms
BEACH	beach	coastal landforms
PUD	parabolic and undulating dunes	coastal landforms
PARDUNES	parabolic dunes	coastal landforms
RSF	relatively stable fordunes	coastal landforms
CORAL1	Coral area 1	coral distribution
CORAL2	Coral area 2	coral distribution
CORAL3	Coral area 3	coral distribution
INTERLEDGE	intertidal ledge	intertidal ledge
ISLANDISLET	island and islets	island and islets
SEAGR_REEF	mixed seagrass and reef	mixed seagrass and reef
MOLLUSCS1	molluscs area 1	molluscs (zooanthids)
MOLLUSCS2	molluscs area 2	molluscs (zooanthids)
REEF	reef	reef
REEFAWASH	reef awash	reef awash
SAND	sand	sand
ECHINODERM	tropical echinoderms	tropical echinoderms

- The fields 'id', 'prop', 'target', 'spf' and 'name' are shown. Select the '**prop**' field. This field is the proportion at which features must be represented if targets are to be met. A value of 0 means that no part of the biodiversity feature is required in sanctuary zones. A value of 1 means all of that biodiversity feature must be reserved to meet targets (i.e. 100%).

id	prop	target	spf	name
1	0.15	0	1	SEAGRASS
2	0.15	0	1	SEAGRASS1
3	0.15	0	1	SEAGRASS2

- Select the **Edit All Rows** box, then in the **Edit Value** box input a value between 0 and 1 (for example, 0.15).
- Select **Run** (Answer **Yes** to save prompt) and Marxan will run automatically. This should take 20-30 seconds, after which ArcView will display the best solution for the defined problem.
- In addition, Marxan generates an irreplaceability map that identifies the solution space for each defined problem. To view irreplaceability select the **Summed Solution** in the MarZone Interface **Output to Map** field as shown below.





The screenshot shows the MarZone Interface window. At the top, the title bar reads 'MarZone Interface'. Below it, the 'MarZone Database Path' is set to 'C:\Western\_Australia\marxan\scenario2\input.dat'. The 'ArcView 3.X' section shows 'View' set to 'View1', 'Theme' set to 'zone2', and 'Key Field' set to 'Puid'. A table displays the following data:

id	prop	target	spf	name
1	0.15	0	1	SEAGRASS
2	0.15	0	1	SEAGRASS1
3	0.15	0	1	SEAGRASS2

Below the table, the 'MarZone Parameter To Edit' is set to 'spec', and the 'Edit Value' is '0.15'. The 'Output to Map' dropdown menu is open, showing options: 'Best Solution', 'Summed Solution', 'Solution 1', 'Solution 2', 'Solution 3', 'Solution 4', 'Solution 5', and 'Solution 6'. The 'Best Solution' option is currently selected.

7. Repeat steps 3 to 8 using alternative (0.15, 0.3, 0.5) **prop** values
8. Review the **Summary Report** generated for your scenario. To do this go to the MarZone Interface menu and click on **Reports**. Click on **Summary** and a **Summary Report** will be generated. This reports on the performance of each of the runs generated in your scenario. The last field - **Missing Values** shows the number of targets that have not been met. By setting a higher penalty using the species penalty factor '**spf**' (see below) we can reduce the number of missing values.

7. Repeat steps 5 to 6 using a

review the  
ie MarZon

**MarZone Interface**

Automate Reports

MarZone Database Path  
C:\western\_australia\marxan\scenario2\input.dat

ArcView 3.X  
View: View1 Theme: zone2 Key Field: Puid

id	prop	target	spf	name
1	0.5	0	1	SEAGRASS
2	0.5	0	1	SEAGRASS1
3	0.5	0	1	SEAGRASS2
4	0.5	0	1	FISH1
5	0.5	0	1	FISH2

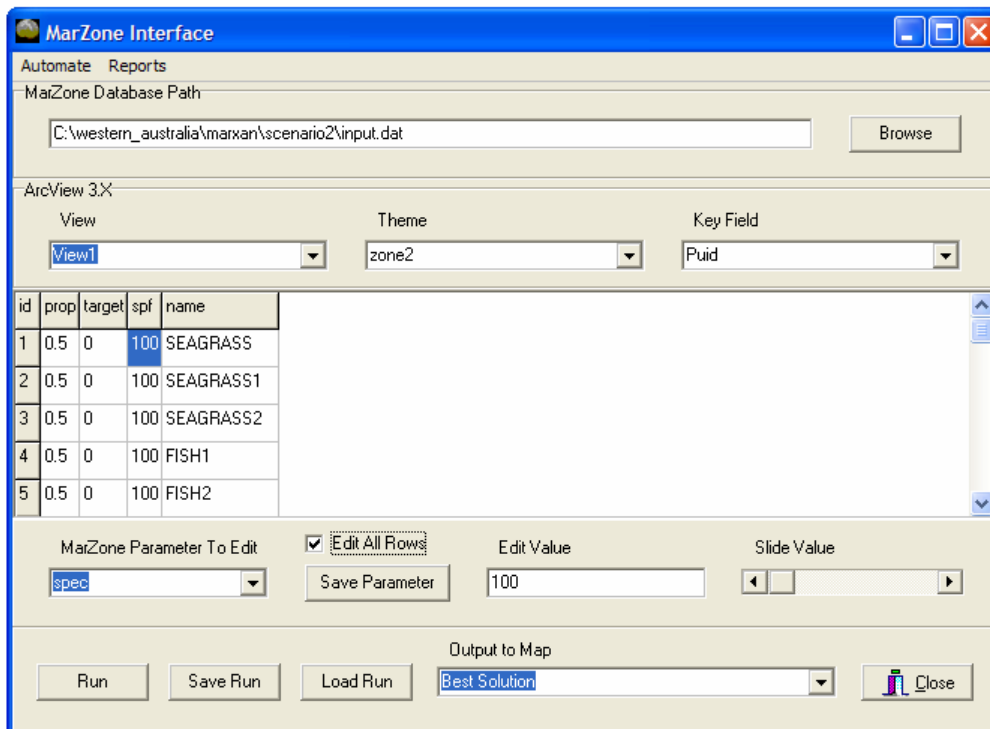
MarZone Parameter To Edit  
spec

Run Save Run

**Summary Report**

Run Number	Score	Cost	Planning Units	Boundary Length	Penalty	Shortfall	Missing Values
1	53235.600439	1448.690000	1519	51764.248400	22.662039	0.055000	1
2	50967.328100	1565.470000	1625	49401.858100	0.000000	0.000000	0
3	55313.805250	1395.770000	1474	53814.843200	103.192050	0.040000	1
4	55422.736132	1522.870000	1599	53652.922900	246.943232	0.095000	3
5	57649.575646	1443.040000	1531	56173.958800	32.576846	0.010000	2
6	54181.178951	1591.120000	1678	52292.841300	297.217651	0.090000	2
7	56921.756121	1519.600000	1599	55014.791200	187.364921	0.070000	3
8	55465.912188	1417.080000	1491	53847.909600	200.922588	0.070000	2
9	54230.290904	1430.720000	1509	52787.218200	12.352704	0.005000	1
10	54178.700950	1662.810000	1729	52412.698900	103.192050	0.040000	1

9. Edit the 'spf' . In the **MarZone Parameter to Edit** drop box select the parameter 'spec'. Click on the **spf** column, then select the **Edit All Rows** box and enter a value of 100. This means that a higher penalty cost is now placed on a missing value. Now **Run** your scenario and Marxan will run automatically.



MarZone Interface  
 Automate Reports  
 MarZone Database Path  
 C:\western\_australia\marxan\scenario2\input.dat Browse  
 ArcView 3.X  
 View Theme Key Field  
 View1 zone2 Puid  

id	prop	target	spf	name
1	0.5	0	100	SEAGRASS
2	0.5	0	100	SEAGRASS1
3	0.5	0	100	SEAGRASS2
4	0.5	0	100	FISH1
5	0.5	0	100	FISH2

 MarZone Parameter To Edit Edit All Rows Edit Value Slide Value  
 spec Save Parameter 100  
 Run Save Run Load Run Output to Map Best Solution Close

10. To review whether increasing the **spf** achieves a reduced number of missing values, repeat step 8 above to generate a **Summary Report** and compare the **Missing Value** field with that of your previous scenario.

### **Scenario 3- Identify A System Of Marine Sanctuaries Recognising Both Pre-Existing Sanctuaries And Absolutely Competing Use Requirement.**

*Create a system of marine sanctuaries that expand on the existing marine sanctuaries (located at Kingston Reef and Parker Point) without impacting existing recreational fishing grounds. Familiarise with planning unit status, the reporting of unmet targets and the different solutions generated.*

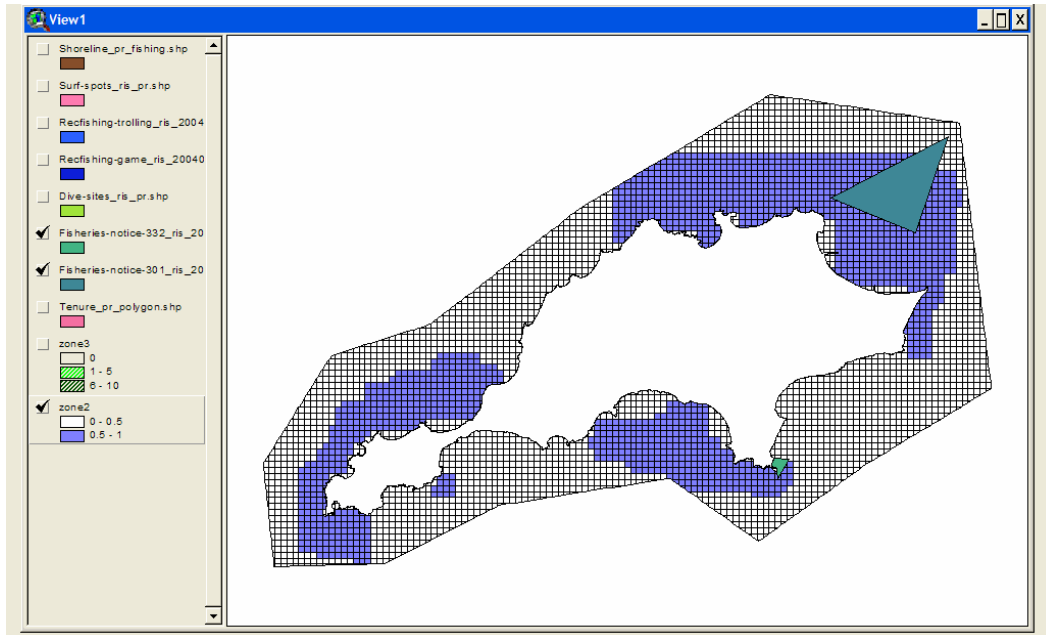
- \* The goal is to create a system of sanctuary zones that achieve defined targets.
- \* While the cost objective is again to minimise the areal extent of the sanctuary zones, the selection of planning units can consider pre-existing uses/values by locking-in or locking-out planning units. This determines whether planning units are available for selection.
  - \* Planning units located in the areas identified as the 'Kingston Reef Sanctuary Zone' or the 'Parker Point Sanctuary Zone' are locked-in. Hence, the design of a system of sanctuary zones must expand on these areas as the 'seed'.
  - \* Planning units located in areas identified as recreational fishing grounds (defined here as recreational gamefishing, shorebased recreational fishing, or trolling) are locked-out, meaning they are not available for selection. Examine whether targets can be met without impacting on these areas.
- \* Review the different configurations of marine sanctuaries under these constraints. Compare these solutions alongside the GIS layers for shorebased recreational fishing, trolling and gamefishing.
- \* Examine summary reports to determine whether targets are being met. Does lowering the conservation targets enable targets to be met?
- \* Instructions are provided below.

## Scenario 3

1. In the MarZone Interface program, set the **MarZone Database Path** to browse to the input.dat file for Scenario 3, located in the directory:  
**D:\rotnest\marxan\scenario3\input.dat**
2. In the **MarZone Parameter to Edit** drop box select the parameter 'spec'. Select the **Edit All Rows** box, then in the **Edit Value** box input a value for 'prop' between 0 and 1 (for example, 0.25).
3. In the **MarZone Parameter to Edit** drop box select the parameter 'pu'. This brings up a table with the fields: 'cost' and 'status'. Scrolling down the **status** field you will find individual planning units are assigned a value of 0, 2 or 3.
  - A value of 0 means it is available for selection.
  - A value of 2 means it is locked-in to every system solution.
    - \* Planning units assigned a status of 2 are located in the areas identified as the 'Kingston Reef Sanctuary Zone' or the 'Parker Point Sanctuary Zone'. These planning units are locked-in to the reserve. Hence, the design of a system of sanctuary zones must expand on these areas as the 'seed'.
  - A value of 3 means it is not available for selection (locked-out).
    - \* Planning units located in areas identified as recreational fishing grounds (defined here as recreational gamefishing, shorebased recreational fishing, or trolling) are locked-out, meaning they are not available for selection.
4. Select **Run** and MarZone will run automatically. In ArcView examine the best solution and compare with alternative solutions identified in the **Output to Map** field.

View contextual GIS layers. Go to **ArcView** and **tick** the box adjacent to the theme you wish to highlight (eg Fisheries Notices) as shown below

View the layers "Fisheries notice 301" and "Fisheries notice 332" which correspond to the Kingston reef and Parker point sanctuary zones. Planning units contained within the existing sanctuary zones are locked in (ie have a status of 2)



View the layers "Shoreline fishing", "Recfish trolling" and "Recfish game" which correspond to areas where recreational fishing occurs inside the marine park. Planning units contained within these recreational fishing areas are locked out (status 3)

5. Select the **summary report**. Click on the **Report** menu and select **Summary** generated for the best solution and examine whether all targets have been met. Scroll right to the missing value field to examine whether all targets have been met (missing values). By locking out areas under fishing, we are not able to meet all conservation targets.
6. Repeat steps 2-6, this time using a lower representation target (for example 0.1). To do this, in the **MarZone Parameter To Edit** drop box, select **spec** and highlight prop. Remember to check the **Edit all** box and enter a lower target, eg 0.1 and examine the **summary report** to see if targets are now met.
7. Repeat steps 3-5, this time highlighting the status field to edit individual planning unit status. Review the **summary report** as for step 6 to see if by making available some of the planning units that were previously locked-out you can meet all the targets.

## Scenario 4 - Identify A System Of Marine Sanctuaries Whilst Minimising Costs to A Range of Recreational Activities.

*Configure a system of zones permitting a range of uses and explore the definition and weighting of costs for uses/values across these zones.*

- \* The goal is to create a multiple use reserve system encompassing a range of management zones offering different levels of protection.
- \* In this scenario we have identified three types of protection zones
  - \* Zone 1 – unrestricted
  - \* Zone 2 – partial protection
  - \* Zone 3 – full protection (sanctuary)
- \* In this scenario we have identified two activity classes that will experience some level of restriction by the zoning exercise (e.g. zone 3 does not permit recreational activities of any kind).
  - \* Class 1 – Recreational Fishing; gamefishing, trolling and shorebased fishing.
  - \* Class 2 – Non-fishing recreational activities; diving, surfing, boat moorings and shipwrecks.
- \* Planning units must be assigned to one of the three alternative zones. A different cost is associated with a planning unit being in any one of the different zones, as outlined in the table below.

*A cost matrix represents this relationship between activity type and zoning option. The following weightings apply to calculate a planning unit's cost*

	Zone 1(fishing)	Zone 2 (No fishing)	Zone 3 (no fishing)
Class 1	0	1	1
Class 2	0.2	0	0.8

## Scenario 4

1. In the MarZone Interface program, use the **MarZone Database Path** to browse to the input.dat file for Scenario 4, located in the directory:  
**D:\rottnest\marxan\scenario4\input.dat**
2. In the **MarZone Parameter to Edit** drop box select the parameter '**spec**' and highlight **prop**. Enter the desired target (e.g. 0.3) in the **Edit Value** box. Remember to check the **Edit all box**.
3. In the **MarZone Parameter to Edit** drop box select the parameter '**pu**' ; the fields shown are 'status' and the costs assigned to individual recreational activities (e.g. 'trolling', 'kgw', 'dhufish', 'flathead'. You can review this cost data by using the scroll bars to the bottom and right of the table.

Note: In this scenario shorebased fishing is classed into 16 different target species (e.g. Dhufish, Squid, Herring, Spanish Mackerel etc), to minimise the impact of fully protected areas on all target species.

4. In the **MarZone Parameter to Edit** drop box select the parameter '**costs**' to view the different types of recreational activities that are being zoned. Information about the cost multipliers given to these activities can be viewed by selecting the **zonecost** field. These multipliers are zone dependent, so vary according to the zone the planning unit is allocated to.  
A multiplier of 1 incurs a high cost for an activity to be present in the zone  
A multiplier ~0 acts as a low cost for an activity to be present in the zone
5. Select **Run** and Marzone will run automatically. In ArcView examine the best solution and compare with alternative solutions and the **Summed Solution** identified in the **Output to Map** field. Select the **summary report** generated for the best solution and examine whether all targets have been met.



## Scenario 5- Identify A Marine Reserve System using Spatial Clumping, Separation and Zone Targets to accommodate a range of uses.

*Configure a system of zones that are spatially compact while different zones are spatially distinct from each other. Allow conservation targets to be set separately for each zone in the network of zones protected areas.*

- \* Planning units must be assigned to one of the three alternative zones. To be manageable, these zones must be spatially compact and also spatially separated from each other. We do this with the use of a zone boundary cost file, in effect setting a boundary length modifier (BLM) for interfaces between planning units of different zones, and a BLM for interfaces between planning units in a protection zone and the available zone.

*A zone boundary cost matrix represents this relationship between zones in our network of planning units. The following weightings apply to interfaces between planning units with a different zone.*

	Zone 1(fishing)	Zone 2 (No fishing)	Zone 3 (no fishing)
Zone 1	0	0.1	0.1
Zone 2	0.1	0	0.1
Zone 3	0.1	0.1	0

- \* There are targets for some species to be represented in zone 1, targets for other species to be represented in zone 2 and targets for still other species to be protected in zone 3.

*A zone target table represents the targets for species in particular zones. The following targets apply to species requiring different levels of protection in different zones. The targets are fictional and are included only for purposes of illustrating the utility of zone targets to set representation requirements for different zones.*

	Zone 1	Zone 2	Zone 3
Species 1	0	0	0.3
Species 2	0	0	0.3
Species 3	0	0	0.3
...	...	...	...
Species 29	0	0.8	0
Species 30	0	0.8	0
Species 31	0	0.8	0
...	...	...	...
Species 33	0.8	0	0
Species 34	0.8	0	0

## Scenario 5

1. In the MarZone Interface program, use the **MarZone Database Path** to browse to the input.dat file for Scenario 5, located in the directory:  
**D:\rotnest\marxan\scenario5\input.dat**
2. In the **MarZone Parameter to Edit** drop box select the parameter '**zoneboundcost**' and observe that the values are similar to the zone boundary cost matrix above. The zone target parameter is hidden, so we can't edit or look at this file.
3. In the **MarZone Parameter to Edit** drop box select the parameter '**numreps**' and enter the value 10 in the **Edit Value** box.
4. Select **Run** to run Marzone. In ArcView examine the best solution and observe the spatial compactness of individual zones, and the tendency for different zones to be separated from other zones.

## Day Two

### 3. Interactive Session 2, Cockburn Sound Exercises

#### Scenario 1 - Identify Marine Reserve Systems for Cockburn Sound

*The Cockburn Sound Environmental Management Plan (2005) presents the following recommendation*

##### 2.4.1-2 Natural and Cultural Heritage Uses

Work with the Marine Parks and Reserves Authority and the Department of Defence to investigate the benefit and constraints of extending the Shoalwater Islands Marine Park to include the seagrass meadows of the western waters of the Sound

Proceed to identify marine reserve systems for Cockburn Sound based on mapped marine habitat features, ignoring other uses/users.

- \* In this scenario we have two types of zones
  - \* Zone 1 – available
  - \* Zone 2 - marine reserve
- \* We require the marine reserve system to achieve a conservation target of 30%. This means conservation features must be represented at 30% of their occurrence/distribution
- \* Identify reserve systems configured with varying BLM values
- \* Review performance of the reserve systems
- \* Familiarise with Cockburn Sound and its natural values
- \* Instructions are outlined below.

## Cockburn Sound Scenario 1

1. Open the ArcView project



Navigate to D:\cockburn\_sound\MarZoneInterface.apr by double clicking on **My Computer**, double click **D:\** drive, double click **cockburn\_sound**, double click **Marzone Interface** (Apr File).

2. Open the MarZone Interface program.



Navigate to D:\cockburn\_sound\MarZoneInterface.apr by double clicking on **My Computer**, double click **D:\** drive, double click **cockburn\_sound**, then double click **Marzone Interface** (Apr File).

3. Set the MarZone Database Path.

In the MarZone Interface program, set the **MarZone Database Path** for Scenario 1. To do this browse to the location of Scenario 1's command file input.dat'. The file should be located in the directory:

**D:\cockburn\_sound\marxan\scenario1\input.dat**

4. Set the ArcView3 properties

Click on the drop down list box under **View** and select View1. Click on the drop down list box under **Theme** and select zone2. Click on the drop down list box under **Key Field** and select Puid.

5. Edit the Conservation (spec) Target

In the **MarZone Parameter to Edit** drop box select the parameter '**spec**' and highlight **prop**. Enter the desired target (0.3) in the **Edit Value** box.

Remember to check the **Edit all box**.

This file contains information on the different conservation features and their conservation target. It includes the field 'name' which identifies the conservation features of interest. These are described in more detail in Table 1.1. below.

**Table 1.1** Description of conservation features for the Cockburn Sound dataset

ID	Name	Description
1	CORAL	Coral features mapped by recreational divers
2	SG_MIXEDSP	Marine benthic habitat – mixed seagrass species
3	COBBLE	Marine benthic habitat - Cobble
4	DEPTHGT10M	Marine benthic habitat – Depth greater than 10m
5	FINE_SEDIM	Marine benthic habitat – Fine Sediment
6	SG_HALOPHI	Marine benthic habitat – seagrass, halophila spp
7	LIMESTONE	Marine benthic habitat – limestone reef
8	SG_REEF	Marine benthic habitat – seagrass and reef
9	SG_P_AUGUS	Marine benthic habitat – seagrass, Posidonia augustifolia
10	SG_PATCHYP	Marine benthic habitat – seagrass, patchy posidonia
11	PAVEMENT	Marine benthic habitat – pavement reef
12	SG_POSIDON	Marine benthic habitat – seagrass, Posidonia spp
13	SG_PS	Marine benthic habitat – seagrass, Posidonia sinuosa
14	VEGETATED	Marine benthic habitat – vegetated
15	WRACK	Marine benthic habitat – wrack
16	LP_COLONY	Little Penguin colony sites
17	LP_FORAGIN	Little Penguin foraging areas
18	PELICAN	Pelican roosting sites
19	CRESTED_TE	Crested Terns roosting sites
20	LITTLE_PIE	Little Pied Cormorants
21	FAIRY_TERN	Fairy Terns
22	SANDERLING	Sanderlings
23	GREY_PLOVE	Grey Plovers
25	ISO_0_10M	Depth gradient between 0 and 10m
26	ISO_10_20M	Depth gradient between 10m and 20m
27	ISO_20_50M	Depth gradient between 20 and 50m
29	PREV_HEATH	PreEuropean Vegetation – Heath communities
30	PREV_MOSAI	PreEuropean Vegetation – Mosaic vegetation
31	PREV_LOWFO	PreEuropean Lowform vegetation
32	WHALE_RIGH	Southern Right Whale distribution

## 6. Edit BLM Parameter

In the MarZone Interface click on the drop down box under **MarZone Parameter to Edit** and select the parameter '**blm**'. In **Edit Value** set the BLM value to 0.5

## 7. Now go to the **Output to Map** field and select **Best Solution**

## 8. Select **Run** to run Marzone and Marxan will run automatically. This should take 20-30 seconds, after which ArcView will display the best solution for the defined problem as coloured planning units. You also have the option of viewing the alternative solutions. To view these in the MarZone Interface

**Output to Map field** select the **Solution** number (from 1-10). ArcView will then automatically display the selected solution. **Hint**, after entering the **Output to Map** box, press the up and down arrow keys to quickly switch between different display modes.

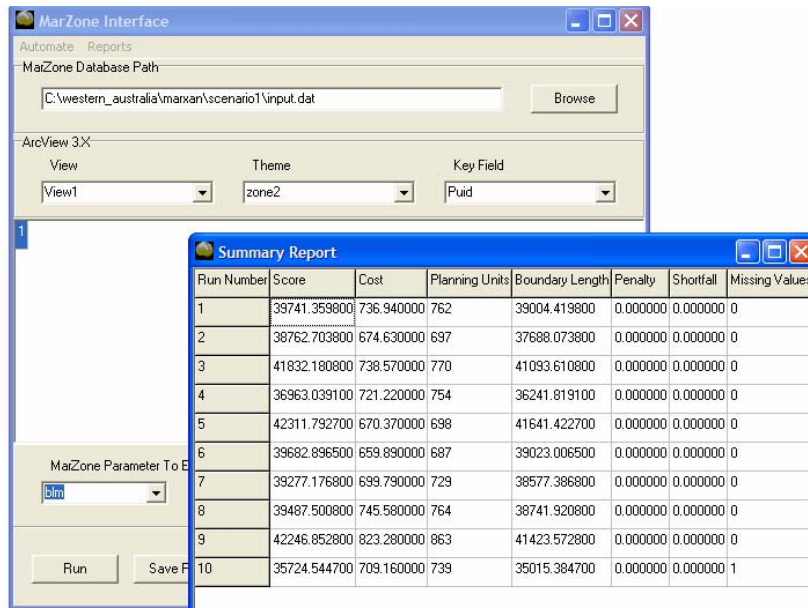
## 9. View Summed Solution

In addition, Marxan generates an irreplaceability map that identifies the solution space for each defined problem. To view irreplaceability select the **Summed Solution** in the MarZone Interface **Output to Map field**.

## 10. Review Targets Met.

Marxan generates a **Summary Report** that compiles information on the performance of each run. To review the Summary Report, go to the main menu of the MarZone Interface, select **Reports** and highlight **Summary Report** from the drop down menu.

An example is shown below. It reports on the performance of each individual run and includes information on a range of metrics used to assess each reserve system generated. Of interest for this exercise is the **Missing Values** column. **Examine your summary report** to see whether your conservation targets have been met.



Run Number	Score	Cost	Planning Units	Boundary Length	Penalty	Shortfall	Missing Values
1	39741.359800	736.940000	762	39004.419800	0.000000	0.000000	0
2	38762.703800	674.630000	697	37688.073800	0.000000	0.000000	0
3	41832.180800	738.570000	770	41093.610800	0.000000	0.000000	0
4	36963.039100	721.220000	754	36241.819100	0.000000	0.000000	0
5	42311.792700	670.370000	698	41641.422700	0.000000	0.000000	0
6	39682.896500	659.890000	687	39023.006500	0.000000	0.000000	0
7	39277.176800	699.790000	729	38577.386800	0.000000	0.000000	0
8	39487.500800	745.580000	764	38741.920800	0.000000	0.000000	0
9	42246.852800	823.280000	863	41423.572800	0.000000	0.000000	0
10	35724.544700	709.160000	739	35015.384700	0.000000	0.000000	1

## Scenario 2 - Identify Marine Reserve Systems for Cockburn Sound that recognises proposed and existing marine parks

*Investigate the proposal to extend the existing Shoalwater Island Marine Park and the proposed marine candidate area for waters of the Cockburn Sound as a basis for marine reserve systems design. Seagrass conservation features will be targeted for reservation consistent with the EMP recommendation below.*

### 2.4.1-2 Natural and Cultural Heritage Uses

Work with the Marine Parks and Reserves Authority and the Department of Defence to investigate the benefit and constraints of extending the Shoalwater Islands Marine Park to include the seagrass meadows of the western waters of the Sound

- \* The goal is to configure marine reserve systems that achieve defined targets.
- \* In this scenario, conservation targets are set at 30% for all seagrass features, other conservation features are set to 0.
- \* The objective is to preferentially locate marine reserve systems adjacent to the Shoalwater Island Marine Park. We will investigate the use of free boundaries to formally incorporate this type of adjacency constraint.
- \* In this scenario, the objective is to consider the proposal for the marine candidate area as part of the design for marine reserve systems in Cockburn Sound. This is achieved by using 'status' to define which planning units are available for selection.
  - \* Planning units located in areas identified as the candidate marine conservation area are locked-in with a status of 2. Hence, the design of marine reserve systems must expand on these areas as the 'seed'.
- \* Instructions are provided below.

## Scenario 2

1. In the MarZone Interface program, set the **MarZone Database Path** to Scenario 2. To do this, browse to the input.dat file for Scenario 2, located in the directory: **D:\cockburn\_sound\marxan\scenario2\input.dat**
2. In the **MarZone Parameter to Edit** drop box select the parameter '**spec**' and highlight **prop**. Uncheck the **Edit all box**. In the **Edit Value** box check the that seagrass conservation features have a value of 0.3. These are listed below and are identified by the prefix **SG\_**. For all other conservation features **Enter a target of 0** in the **Edit Value** box. This means that the objective is to achieve a target level of reservation of 30% for seagrass features only.

**Table 2.1** Seagrass features targeted for reservation

Name	Description
SG_P_SINUO	Posidonia sinuosa
SG_MIXEDSP	Mixed species
SG_HALOPHI	Halophila species
SG_P_AUGUS	Posidonia augustifolia
SG_REEF	Seagrass and Reef
SG_PATCHYP	Patchy Posidonia
SG_POSIDON	Posidonia species

### 3. Note on the Boundary File

The boundary file is a table with the fields: 'id1' 'id2' and 'boundary'. The 'boundary' field indicates the cost between two neighbouring planning units. It is in this table that free boundaries (i.e. boundary = 0) are given to planning units located adjacent to the Shoalwater Island Marine Park. Although this file isn't available for viewing, later we will see just which planning units are affected by this adjacency constraint.

**Table 2.2** Example boundary length costs between neighbouring planning units

id1	id2	Boundary (metres)
1	1	108.911
1	2	55.4613
1	21	93.7316
2	2	103.78



#### 4. View Planning Unit status

In the **MarZone Parameter to Edit** drop box select the parameter '**pu**'. This brings up the table with the fields: 'cost' and 'status'. Scrolling down the status field you will find individual planning units are assigned a value of 0, or 2.

- a value of 0 means it is available for selection
- a value of 2 means it is locked-in to every solution
- a value of 3 (though not featured) means it is not available for selection (locked-out).

#### 5. Select **Run** to run Marzone. In ArcView examine the best solution and compare with alternative solutions and the **Summed Solution** identified in the **Output to Map** field.

#### 6. View contextual GIS layers.

Go to **ArcView** and tick the box adjacent to the theme you wish to highlight as shown below

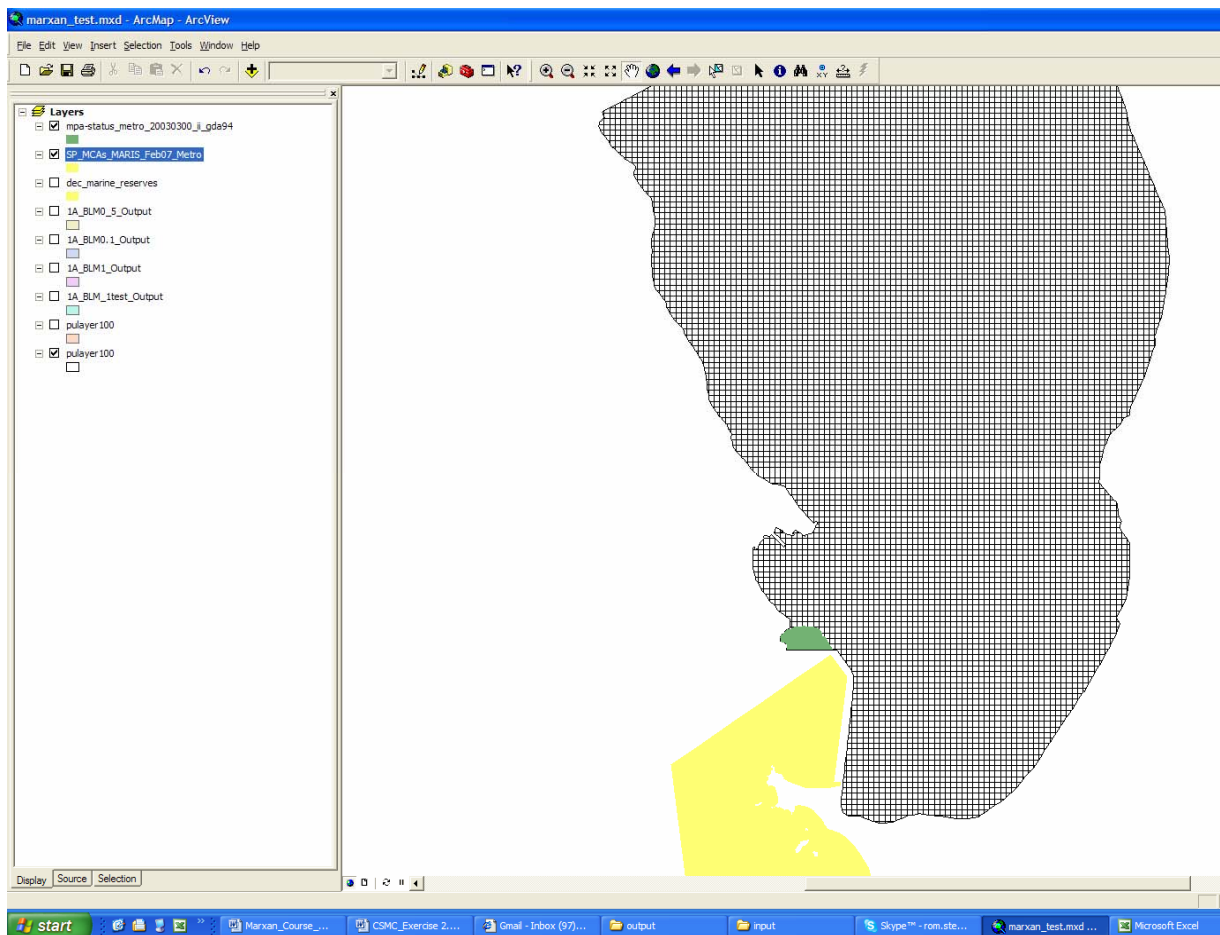
To view the proposed (candidate) marine reserve, click on

- **mpa-status\_metro\_20030300\_ii\_gda94**

To view the Shoalwater Island Marine Park, click on

- **SP\_MCAs\_MARIS\_Feb07\_Metro**

Planning units adjacent to this theme are allocated a free boundary



## 7. Review Targets Met

Marxan generates a **Summary Report** that compiles information on the performance of each run. To review the Summary Report, go to the main menu of the MarZone Interface, select **Reports** and highlight **Summary Report** from the drop down menu

8. If time allows, you can repeat step 2 and set conservation targets for additional conservation features to examine the sensitivity of marine reserve system design to the inclusion of conservation features and conservation feature targets. To do this, go to the **MarZone Parameter to Edit** drop box select the parameter '**spec**' and highlight **prop**. Uncheck the **Edit all box**. In the **Edit Value** box enter the desired target (e.g 0.3) for conservation features of interest. Select **Run** to run Marzone. In ArcView examine the best solution and compare with alternative solutions and the **Summed Solution** identified in the **Output to Map** field. Review the Targets Met by examining the **Summary Report** as outlined in step 7 above.

## Scenario 3 - Identify Marine Reserve Systems that Recognise Objectives of Existing Management Areas

*Configure marine reserve systems in Cockburn Sound consistent with the Multiple-Use Planning strategy for Cockburn Sound and its Foreshores.*

The Cockburn Sound EMP presents a Multiple Use Planning strategy for Cockburn Sound and its Foreshores as a basis for the long-term multiple use management of the region. This identifies the degree to which particular values are consistent with management objectives for areas across the Cockburn Sound as shown in Table 3.1 below.

**Table 3.1** – Multiple-Use Planning for Cockburn Sound and its Foreshore

Management Area	Natural/Cultural <sup>1</sup> (zone 2 – marine park)	Commercial <sup>2</sup> (zone 3 – aquaculture)	Industrial <sup>3</sup>	Defence
Garden Island	2	10	☒	✓✓
Rockingham	2	10	☒	n/a
Kwinana	2	2	✓✓	n/a
Challenger Beach/Ciffs	1	1	?	n/a
Jervoise Bay	2	2	✓✓	✓
Woodman Pt	1	2	✓	n/a
Central Basin	2	2	✓	✓

- ✓✓ *Priority use of a management area*
- ✓ *Use compatible with primary use and management area*
- ☒ *Use incompatible with management area*
- ? *Gap in knowledge*

- \* The goal is to configure marine reserve systems taking into consideration the objectives of management areas identified in Table 3.1. Where possible, marine reserve systems should be located in areas where natural values are compatible with management area objectives. Table 3.1 indicates that preference should be given to Challenger Beach/Ciffs and Woodman Point.
- \* These objectives have been interpreted into a cost matrix to reflect the compatibility between Natural/Cultural values and the Cockburn Sound Management Areas. The cost matrix is presented in Table 3.2 and applies a cost multiplier to planning units in accordance with the management area that they fall within.

**Table 3.2 – Cost matrix for Marine Reserve Design in Cockburn Sound**

Management Area	Cost multiplier for Natural/Cultural values
Garden Island	5
Rockingham	5
Kwinana	10
Challenger Beach/Cliffs	1
Jervoise Bay	5
Woodman Pt	1
Central Basin	5

- A cost multiplier of 1 indicates strong compatibility between the marine reserve system values and the management area objectives
  - A cost multiplier of 5 indicates compatibility between marine reserve system values and the management area objectives
  - A cost multiplier of 10 indicates incompatibility between the marine reserve system values and the management area objectives.
- 
- \* Conservation targets are set at 30% for seagrass features.
  - \* Free boundaries are provided to planning units located adjacent to the Shoalwater Island Marine Park.
  - \* Proposed/candidate marine parks are ignored.
  - \* Familiarise with input file structures that incorporate cost weightings between management areas and natural values in the Cockburn Sound.
  - \* Instructions are provided below.

## Scenario 3

1. In the MarZone Interface program, use the **MarZone Database Path** to browse to the input.dat file for Scenario 3, located in the directory:  
**D:\cockburn\_sound\marxan\scenario3\input.dat**
2. In the **MarZone Parameter to Edit** drop box select the parameter **spec** and review the targets specified for the conservation features. Note that a proportional target (prop) of 0.3 is set for seagrass features only.
3. Next view the parameter **costs** and observe that each of the management areas are represented in this file with a costname. Now view the parameter **zonecosts** to examine the cost weighting/multiplier that is applied to planning units located within these management areas.
4. Select **Run** to run Marzone. In ArcView examine the best solution and compare with alternative solutions and the **Summed Solution** identified in the **Output to Map** field. Select the **summary report** generated for the best solution and examine whether all targets have been met.
5. View contextual GIS layers.

Go to **ArcView** and tick the box adjacent to the theme you wish to highlight as shown below

To view the management areas, click on

- **manage\_area\_cs**

To view the Shoalwater Island Marine Park, click on

- **SP\_MCAs\_MARIS\_Feb07\_Metro**

Planning units adjacent to this theme are allocated a free boundary.

To view the distribution of seagrass across the planning region, click on

- **habitat-benthic\_cso\_20050101\_utm50\_gda94**

6. Repeat steps 2-5 and modify the cost matrix multiplier values shown in Table 3.2. See how changes to the cost multiplier for natural values across the different management areas alters the reserve system configuration.

## 4. Interactive Session 3, Cockburn Sound Exercise 2

### Scenario 4 - Identify A System of Zones to Accommodate Aquaculture, Marine Reserves and Recreational Values

*The Cockburn Sound EMP presents the following recommendation:*

2.2.4-2 Incorporate the requirements of aquaculture (relatively deep water, good circulation, low levels of faecal bacteria, contaminants and toxic phytoplankton species, and sufficient phytoplankton for good mussel growth) into future planning for Cockburn Sound.

Aquaculture use refers to mussel farming in Cockburn Sound. Currently two leases exist: Southern flats and Kwinina Grain Jetty.

- \* The goal is to identify a system of zones permitting a range of uses and explore the definition and weighting of costs for uses/values across these zones.
- \* In this scenario we have identified three types of zones
  - \* Zone 1 – general use  
*Objective is to accommodate recreational activities within general use zone at 80% of their current activity*
  - \* Zone 2 – marine park  
*Objective is to achieve 30% conservation targets for seagrass species*
  - \* Zone 3 – aquaculture  
*Objective is to expand on the existing aquaculture license areas to achieve a total area that is 250% of its current extent.*
- \* Planning units must be assigned to one of the three alternative zones. A different cost is associated with a planning unit being in any one of the different zones. A cost matrix represents the relationship between the zoning option and the management area objectives, defined previously in Scenario 3.

**Table 4.1 – Cost matrix for Multiple-Use Planning in Cockburn Sound**

Management Area	Recreation	Natural/Cultural	Commercial
Garden Island	5	5	10
Rockingham	1	5	1
Kwinana	5	10	5
Challenger Beach/Cliffs	1	1	1
Jervoise Bay	5	5	5
Woodman Pt	5	1	5
Central Basin	5	5	5

\* Guided by the EMP, a cost matrix was devised to inform the selection of planning units, as shown in Table 4.1.

\* To ensure the zones are spatially compact and also spatially separated from each other a zone boundary cost file must be defined. This effectively sets the BLM (boundary length modifier) for interfaces between planning units of different zones. A zone boundary cost matrix represents the relationship between zones to calculate boundary length costs for our network of planning units. The following weightings apply to interfaces between planning units with a different zone.

**Table 4.2 – Zone Boundary Cost Matrix for Spatially Compact zones**

	Zone 1 - general use	Zone 2 - marine reserve	Zone 3 - aquaculture
Zone 1	0.01	0.01	0.01
Zone 2		0	0.01
Zone 3			0

#### Note on aquaculture requirement

\* Aquaculture requirements are identified as relatively deep water (>10 metres depth) and excellent water quality. As no data on water quality was available, we limited aquaculture to areas in the High Protection Zone as a proxy for good water quality. A simple decision rule was devised to identify potential areas suited for aquaculture.

Decision Rule is water depth > 10m and in the High Protection Zone

\* Instructions provided below.



## Scenario 4

1. In the MarZone Interface program, use the **MarZone Database Path** to browse to the input.dat file for Scenario 4, located in the directory:  
**D:\cockburn\_sound\marxan\scenario4\input.dat**
2. In the **MarZone Parameter to Edit** drop box select the parameter **Zones**  
Review the three different zone types used to configure the Cockburn Sound multiple-use system.
3. In the **MarZone Parameter to Edit** drop box select the parameter **spec**  
Review the features described in the spec file. These include a combination of conservation features, recreation features and other activity types (eg. shipping routes). Note that the **prop** is set to 0, with no target defined for the spec features. For this scenario feature targets are defined in **zonetarget**
4. In the **MarZone Parameter to Edit** drop box select the parameter **zonetarget**  
Review the zone targets prescribed for the different features. These features are described in the **spec** file and include a combination of conservation features, recreation features and other activity types (eg. shipping routes).
5. In the **MarZone Parameter to Edit** drop box select the parameter **zoneboundcost**.  
Note that the zone boundary values shown in Table 4.2 (above) are tabulated into the **zoneboundcost** file format.
6. Select **Run** to run Marzone. In ArcView examine the best solution and compare with alternative solutions and the **Summed Solution** identified in the **Output to Map** field. Select the **summary report** generated for the best solution and examine whether all targets have been met.
7. View contextual GIS layers. Go to **ArcView** and tick the box adjacent to the theme you wish to highlight as shown below  
To view the management areas, click on
  - **manage\_area\_cs**To view the areas where aquaculture site requirements are met, click on
  - **Aqua\_Poss**To view the distribution of seagrass across the planning region, click on
  - **habitat-benthic\_cso\_20050101\_utm50\_gda94**



8. Repeat steps 4-5 and examine how either /decreasing increasing the **zoneboundcost** values affects the spatial configuration of the zones. See if you can achieve spatially compact and spatially separated zones.

**Table 4.2 – Zone Boundary Cost Matrix for Spatially Compact zones**

	Zone 1 - general use	Zone 2 - marine reserve	Zone 3 - aquaculture
Zone 1	0.01	0.01	1
Zone 2		0	0.01
Zone 3			0

**(Corrected zoneboundcost values for Scenario 4 above)**

## Scenario 5 - Identify A System of Zones to Accommodate Aquaculture, Marine Reserves and Recreational Values Whilst Recognising Existing Uses as Constraints

*Identify a system of zones for Cockburn Sound which achieves the following objectives:*

- *expansion of the aquaculture industry, within specified constraints;*
- *protection of seagrass values, preferably through the extension of the Shoalwater Island Marine Park;*
- *maintain existing recreational uses.*

In this scenario we configure a system of zones to implement a multiple use plan for aquaculture, conservation and recreation values as for Scenario 4. New to this scenario is the inclusion of constraints on where aquaculture areas are located. The Cockburn Sound EMP states that aquaculture is generally compatible with other uses, however in locating leases there is a need to consider navigation issues and the potential impact on benthic habitat.

- \* The following values/uses are likely to constrain aquaculture due to their requirement for safe navigation
  - *Shipping\_com (commercial shipping routes)*
  - *Shipping\_naval (naval shipping routes)*
  - *Pleasure\_Boating\_Destinations\_CockburnSound*
  - *WatercraftAreas\_CSMC*
  - *TCYC\_Course\_Area\_CockburnSound*
  - *RFBYC\_SailingArea\_CSMC*
- \* To incorporate these navigational constraints for locating aquaculture the following decision rules will apply
  - Minimise impact of aquaculture on all shipping/boating activities
- \* The following benthic habitat features are likely to constraint aquaculture
  - SG\_P\_SINUO    SG\_REEF
  - SG\_MIXEDSP    SG\_P\_AUGUS
  - SG\_HALOPHI    SG\_PATCHYP
  - SG\_P\_AUGUS    SG\_POSIDON
- \* To address these benthic habitat constraints on locating aquaculture the following decision rules will apply
  - Minimise impact of aquaculture on benthic habitat

## Scenario 5

7. In the MarZone Interface program, use the **MarZone Database Path** to browse to the input.dat file for Scenario 5, located in the directory:  
**D:\cockburn\scenario5\input.dat**
8. In the **MarZone Parameter to Edit** drop box select the parameter **Zones**  
Review the three different zone types used to configure the Cockburn Sound multiple-use system.
9. In the **MarZone Parameter to Edit** drop box select the parameter **spec**  
Review the features described in the spec file. These include a combination of conservation features, recreation features and other activity types (eg. shipping routes). Note that the **prop** is set to 0, with no target defined for the spec features. For this scenario feature targets are defined in the **zonetarget** file
10. In the **MarZone Parameter to Edit** drop box select the parameter **zonetarget**.  
Note that each zone has a unique set of features and feature targets. These reflect the different targets defined for varying features across each zone.
11. In the **MarZone Parameter to Edit** drop box select the parameter **zoneboundcost**.  
Note that each zone has a defined boundary cost with adjacent zones. These values are identified in a unique set of features and feature targets zone boundary values shown in Table 4.2 (above) are tabulated into the **zoneboundcost** file format.
12. In the **MarZone Parameter to Edit** drop box select the parameter **zonecost**.  
Note that this file identifies the cost multiplier that applies to different feature types across the different zone. Scroll down this file and note that cost weightings are now defined for an extended range of cost types. (Recall that in scenario 4 costs were identified as the management areas). These costs are identified in the **cost** file.  
  
A general rule has been defined to relate different feature types to the system of zones, as shown below.

**Table 5.1** – Cost matrix for Multiple-Use Planning in Cockburn Sound in Scenario 5

Type of Cost	Zone 1 General use	Zone 2 Marine reserve	Zone 3 Aquaculture
environmental		0	10
recreation		1	5
fisheries		5	1
other		10	1

These cost multipliers have been defined to reflect the objective to spatially separate the location of aquaculture from benthic marine habitat (seagrass) and boating activities.

**13.** Select **Run** to run Marzone. In ArcView examine the best solution and compare with alternative solutions and the **Summed Solution** identified in the **Output to Map** field. Select the **summary report** generated for the best solution and examine whether all targets have been met.

**14.** View contextual GIS layers. Go to **ArcView** and tick the box adjacent to the theme you wish to highlight as shown below

To view the features that have requirements for safe navigation, click on

- *Shipping\_com (commercial shipping routes)*
- *Shipping\_naval (naval shipping routes)*
- *Pleasure\_Boating\_Destinations\_CockburnSound*
- *WatercraftAreas\_CSMC*
- *TCYC\_Course\_Area\_CockburnSound*
- *RFBYC\_SailingArea\_CSMC*

**15.** View the **zonecostbound** and edit the values to see if you can obtain spatially compact and spatially separated zones.

**Table 5.2** – Zone Boundary Cost Matrix for Spatially Compact zones

	Zone 1 - general use	Zone 2 - marine reserve	Zone 3 - aquaculture
Zone 1	0.01	0.01	1
Zone 2		0	0.01
Zone 3			0

**The End**

## Appendix

### A1. Demonstration Session, Marxan outputs and the GIS

#### A1.1 Scenario (output\_sen.dat)

The scenario file lists the input parameters that were used by Marxan to generate this set of output files. Browse to the folder **D:\rotnest\marxan\scenario1\output** and **double click** on the file **output\_sen.dat** to load it into the text editor. You can see the parameters **boundary length modifier**, **number of iterations** and **number of runs**.

#### A1.2 Log (output\_log.dat)

The **log** file contains all the text that Marxan prints to the screen while it is executing. Summary information about files loaded, temperature and cooling rate for each run of simulated annealing, and objective function values for the start and end of the annealing run and iterative improvement run are included

Browse to the folder **D:\rotnest\marxan\scenario1\output** and double click on the file **output\_log.dat** to load it into the text editor.

#### A1.3 Summary (output\_sum.csv)

The summary file lists information about each run such as the value of each term of the objective function and the number of missing features for the run.

Browse to the folder **D:\rotnest\marxan\scenario1\output** and double click on the file **output\_sum.csv** to load it into **excel**. **Select** the entire table and **auto fit** it to view all the text. **Close** the file down and **close excel** down before continuing.

#### A1.4 Best Solution (output\_best.csv)

The best solution file lists all the planning units that were chosen in the best solution. The best solution is the solution that has the lowest overall value for the objective function.

Click on the **Output to Map** control then select **Best Solution**. The best solution will then be displayed in the ArcView map display.

Browse to the folder **D:\rotnest\marxan\scenario1\output** and double click on the file **output\_best.csv** to load it into excel. Select the entire table and auto fit it to view all the text. **Close** the file down and **close excel** down before continuing.

### A1.5 Best Solution Missing Values (output\_mvbest.csv)

The best solution missing values file lists all the species in the dataset and the level of representation they have achieved in the best solution. It also lists other information such as the area and occurrences of each species and whether the species has reached target or not.

Browse to the folder **D:\rotnest\marxan\scenario1\output** and double click on the file **output\_mvbest.csv** to load it into excel. **Select** the entire table and **auto fit** it to view all the text. **Close** the file down and **close excel** down before continuing.

### A1.6 Solution N (output\_r0000N.txt)

The solution file lists all the planning units that were chosen in the solution. N is the solution number. There will be one of these files for each solution generated.

Click on the **Output to Map** control then select **Solution 1**. Solution 1 will then be displayed in the ArcView map display. The other solutions generated will be displayed if their relevant solution number is clicked on in the **Output to Map** control. **Tip:** clicking the up and down buttons will cycle through all the solutions and display them in turn in the ArcView map display.

Browse to the folder **D:\rotnest\marxan\scenario1\output** and double click on the file **output\_r00001.csv** to load solution 1 into excel. **Select** the entire table and **auto fit** it to view all the text. **Close** the file down and **close excel** down before continuing. The other solutions can be loaded into excel by loading their relevant solution file.

### **A1.7 Solution N Missing Values (output\_mv0000N.csv)**

The solution missing values file lists all the species in the dataset and the level of representation they have achieved in a particular solution. It also lists other information such as the area and occurrences of each species and whether the species has reached target or not. N is the solution number. There will be one of these files for each solution generated.

Browse to the folder **D:\rotnest\marxan\scenario1\output** and double click on the file **output\_mv00001.csv** to load the missing values file for solution 1 into excel. Select the entire table and auto fit it to view all the text. **Close** the file down and **close** excel down before continuing. The missing values tables for the other solutions can be loaded into excel by loading their relevant missing values file.

### **A1.8 Summed Solution (output\_ssoln.csv)**

The summed solution file lists all the planning units in the dataset and their selection frequency. That is, the number of times they were chosen in one of the solutions.

Click on the **Output to Map** control then select **Summed Solution**. The summed solution will then be displayed in the ArcView map display. The planning units with a dark colour have a high selection frequency. The planning units with a lighter colour have a lower selection frequency.

Browse to the folder **D:\rotnest\marxan\scenario1\output** and double click on the file **output\_ssoln.csv** to load the summed solution into **excel**. Select the entire table and auto fit it to view all the text. **Close** the file down and **close** excel down before continuing.

## Appendix 4

### *Data Requirements for the Rottneest Island Case Study*

#### Description of features and feature targets for the Rottneest Island case study

<b>Biodiversity Features</b>			
<i>Name</i>	<i>Feature</i>	<i>Description</i>	<i>Target</i>
SEAGRASS	seagrass	areas of high conservation	30%
SEAGRASS1	seagrass type 1	areas of high conservation	30%
SEAGRASS2	seagrass type 2	areas of high conservation	30%
FISH1	tropical fish area 1	areas of high conservation	30%
FISH2	tropical fish area 2	areas of high conservation	30%
FISH3	tropical fish area 3	areas of high conservation	30%
INVERT	marine invertebrates	areas of importance for	30%
SHALLOW	0-5m depth	bathymetry	30%
MEDIUM	5-10m depth	bathymetry	30%
DEEP	10-15m depth	bathymetry	30%
ABAS	active blowouts and sanddunes	coastal landforms	30%
APUF	active partially unstable fordune	coastal landforms	30%
BEACH	beach	coastal landforms	30%
PUD	parabolic and undulating dunes	coastal landforms	30%
PARDUNES	parabolic dunes	coastal landforms	30%
RSF	relatively stable fordunes	coastal landforms	30%
CORAL1	Coral area 1	coral distribution	30%
CORAL2	Coral area 2	coral distribution	30%
CORAL3	Coral area 3	coral distribution	30%
INTERLEDGE	intertidal ledge	intertidal ledge	30%
ISLANDISLET	island and islets	island and islets	30%
SEAGR_ REEF	mixed seagrass and reef	mixed seagrass and reef	30%
MOLLUSCS1	molluscs area 1	molluscs (zooanthids)	30%
MOLLUSCS2	molluscs area 2	molluscs (zooanthids)	30%
REEF	reef	reef	30%
REEFAWASH	reef awash	reef awash	30%
SAND	sand	sand	30%
ECHINODERM	tropical echinoderms	tropical echinoderms	30%
<b>Recreational Features</b>			
<i>Name</i>	<i>Feature</i>	<i>Description</i>	<i>Target</i>
DIVESITES	Divesites	SCUBA diving areas	80%
MOORINGS	boat moorings	Recreational boat moorings	80%
SURFING	Surfing	Surfing locations	80%
SHIPWRECK	Shipwreck	Shipwreck locations	80%
GAMEFISH	Gamefishing	Recreational Fishing –Offshore	80%
TROLLING	Trolling	Recreational Fishing –Offshore	80%
YELLKING	Yellowking	Recreational Fishing - Shorebased	80%
TAILOR	Tailor	Recreational Fishing - Shorebased	80%
SQUID	Squid	Recreational Fishing - Shorebased	80%
SPAMACK	Spanish Mackerel	Recreational Fishing - Shorebased	80%
SKIPPY	Skippy	Recreational Fishing - Shorebased	80%
SILBREAM	Silverbream	Recreational Fishing - Shorebased	80%
SANDPIKE	Sandpike	Recreational Fishing - Shorebased	80%



<b>Recreational Features</b>			
<i>Name</i>	<i>Feature</i>	<i>Description</i>	<i>Target</i>
SALMON	Salmon	Recreational Fishing - Shorebased	80%
SWHITING	Silver Whiting	Recreational Fishing - Shorebased	80%
MULLOWAY	Mulloway	Recreational Fishing - Shorebased	80%
HERRING	Herring	Recreational Fishing - Shorebased	80%
GARDIES	Gardies	Recreational Fishing - Shorebased	80%
FLATHEAD	Flathead	Recreational Fishing - Shorebased	80%
DHUFISH	Dhufish	Recreational Fishing - Shorebased	80%
KGW	King George Whiting	Recreational Fishing - Shorebased	80%

#### **Rottnest Island Data custodians**

RIA	Rottnest Island Authority
DEC	Department of Environment and Conservation
DoF	Department of Fisheries

## Appendix 5

### *Data Requirements for the Cockburn Sound Case Study*

#### Description of features and feature targets for the Cockburn Sound case study

<b>Biodiversity Features</b>			
<i>Name</i>	<i>Feature</i>	<i>Description</i>	<i>Target</i>
BH_veg	vegetated	Benthic habitat	30%
BH_wrack	wrack	Benthic habitat	30%
BH_Cob	cobble	Benthic habitat	30%
BH_Pave	Pavement reef	Benthic habitat	30%
BH_Fsed	Fine sediment	Benthic habitat	30%
BH_Mixed	Mixed seagrass	Seagrass meadows	100%
BH_AmPo	Amphibolis & posidonia spp.	Seagrass meadows	100%
BH_Halo	Halophila spp.	Seagrass meadows	100%
BH_PatchyP	Patchy posidonia	Seagrass meadows	100%
BH_Pos	Posidonia spp.	Seagrass meadows	100%
BH_PsPa	p. sinuosa & p. australis	Seagrass meadows	100%
BH_Ps	p. sinuosa	Seagrass meadows	100%
BH_Pa	p. augustifolia	Seagrass meadows	100%
coral	Existing coral locations	coral	75%
coral_bu	Potential coral locations	coral	50%
SH_Sandy	Sandy beach	Shoreline habitat	100%
SH_Lime	Limestone cliff	Shoreline habitat	100%
snapper	Snapper spawning area	Snapper	100%
Pen_for	Little Penguin- foraging	Little penguin foraging areas	90%
Pen_col	Little Penguin- colony	Little penguin colony areas	100%
Seal	Seal haulout areas	Seal haulout areas	100%
dolphin	Dolphin nursery areas	Dolphin nursery areas	100%
Bathy_10m	0-10 m depth zone	Depth zones	-
Bathy_20m	10-20 m depth zone	Depth zones	-
Bathy_50m	20-50m depth zone	Depth zone	-
Bathy_isl	island	Island areas	-
<b>Recreational Features</b>			
<i>Name</i>	<i>Feature</i>	<i>Description</i>	
Shipwrecks	Shipwrecks	Shipwreck locations	80%
Rec_finfish	Finfishing areas	Recreational Fishing –Finfish	80%
Rec_squid	Squid fishing areas	Recreational Fishing –Squid	80%
Rec_crab	Crab fishing areas	Recreational Fishing - Crab	80%
Beach_swim	Swimming beaches	Swimming beaches	80%
Rec_sail	Recreational sailing areas	Sailing	80%
Rec_boat	Recreational boating destinations	Boating	80%
Rec_water	Recreational water activities	Water-based recreation	80%
Rec_jetski	Recreational jetski use area	Jetski use areas	80%
<b>Existing Uses</b>			
Ship_comm	Commercial shipping routes	Shipping routes	100%
Ship_naval	Naval shipping routes	Shipping routes	100%
Wharves	Wharves	Wharves	100%
Boat_ramps	Boat ramps	Boat ramps	100%
Boat_lifters	Boat lifters	Boat lifters	100%

Jetty_rest	Restricted jetties	Jetties	100%
Jetty_pub	Public access jetties	Jetties	100%
Coastline	Coastline protection	Coastline protection	100%
Boat_harb	Boat harbours	Boat harbours	100%
Dredged	Dredged areas	Dredged areas	100%
Moorings	Recreational moorings	Recreational moorings	100%
Aqua_lic	Aquaculture license areas	Aquaculture license areas	100%
<b>Proposed Developments</b>			
DP_port1	Proposed port option 1	Development Proposal	100%
DP_port4	Proposed port option 4	Development Proposal	100%
DP_james	Proposed private port	Development Proposal	100%
DP_Rocking	Proposed marina Rockingham	Development Proposal	100%
DP_Mangels	Proposed marina Mangles Bay	Development Proposal	100%
DP_occo	Proposed octopus aquaculture site	Development Proposal	100%
<b>Other Features</b>			
<i>Name</i>	<i>Feature</i>	<i>Description</i>	
Low_Ep	Low ecoprotection zone	Ecoprotection zone	-
Mod_Epzone	Moderate ecoprotection zone	Ecoprotection zone	-
High_EPzone	High ecoprotection zone	Ecoprotection zone	-
Low_tbt	TBT testing site- low levels	TBT	-
Med_tbt	TBT testing site- medium levels	TBT	-
High_tbt	TBT testing site- high levels	TBT	-
MA_Rock	Rockingham Management area	Management areas	-
MA_Kwi	Kwinana Management area	Management areas	-
MA_Cha	Challenger Management Area	Management areas	-
MA_Jer	Jervois Bay Management Area	Management areas	-
MA_Woo	Woodman Point Management Area	Management areas	-
MA_GI	Garden Island Management area	Management areas	-
MA_CB	Central Basin Management Area	Management areas	-
Naval waters	Naval waters	Naval waters	-
Aqua_prop	Areas suitable for aquaculture	Areas suitable for aquaculture	-
Friars	Fremantle Rockingham Industrial Area Regional Strategy	Fremantle Rockingham Industrial Area Regional Strategy	-

### Cockburn Sound Data custodians

CSMC	Cockburn Sound Management Council
DEC	Department of Environment and Conservation
Oceanica	Oceanica (for Cockburn Cement)
DPI	Department for Planning and Infrastructure
FPA	Fremantle Port Authority
DMA	Department of Maritime Archaeology
Fisheries WA	Fisheries WA

## Appendix 6

### *DSS Brochure - Empowering Decision Makers*

# EMPOWERING DECISION MAKERS

A DECISION SUPPORT SYSTEM (DSS) FOR INTEGRATED NATURAL RESOURCE  
MANAGEMENT AT THE LAND-OCEAN INTERFACE

Critical Issues

- Multiple objectives
- Multiple stakeholders
- Conflicting objectives
- Complex planning issues

Benefits

- Decision support framework
- Clear objectives
- Improved transparency
- Integrated planning
- Clear costs and benefits
- Stakeholder involvement
- Better NRM outcomes




Photo courtesy of Clay Bryce

### Managing Natural Resources

Natural resource management (NRM) deals with the problem of sustainably managing the use of biophysical resources. Planners and managers face issues of land degradation, habitat destruction, water pollution and species decline. *Managing the sustainability of natural resource use is challenging and complex, and cannot be considered independently of social and economic values.* Natural resource management (NRM) decisions are characterised by multiple objectives, multiple stakeholders and the likelihood of conflicting objectives, all in the face of considerable scientific uncertainty.

To reduce the complexity of NRM decisions to a manageable level, many decision-makers are turning to systematic decision support methods. These methods aim to provide the decision-maker with a framework that defines the problem with clearly stated objectives, synthesises information of various complexities, and provides for an informed decision which recognises the trade-offs involved. *Decision support systems provide an effective means of evaluating a large number of alternatives against a set of multiple and conflicting objectives.* This has arisen from the need for improved transparency, greater public accountability and the equitable and efficient use of natural resources.

### Supporting Improved Decision-making

A common type of decision problem that can be addressed using systematic decision support methods involves spatial planning - the allocation of NRM activities into appropriate locations. This avoids the juxtaposition of conflicting land-uses to maximise the achievement of biodiversity objectives and to minimise the disruption to resource uses and the cost of NRM delivery.

Researchers from The University of Queensland, The University of Western Australia and CSIRO Marine and Atmospheric Research are undertaking a research project funded by the Natural Heritage Trust to help NRM decision-makers effectively and efficiently deliver NRM management objectives through systematic NRM planning. *The focus of the project will be on the development and application of a decision-making framework to complex spatial problems of most relevance to coastal NRM issues across Australia.*

Working with managers in the Swan NRM Region in Western Australia, the project will develop an approach to address NRM issues using systematic decision support methods. The objective is to develop improved procedures and software to allow managers to examine complex planning issues involving socio-economic and conservation trade-offs, and help set on-ground priorities for management.

Software development will focus on extending the capabilities of Marxan, a well established systematic planning tool developed by Australian researchers and now used globally for conservation planning in marine and terrestrial systems (for details on the Marxan software, see [www.ecology.uq.edu.au/marxan.htm](http://www.ecology.uq.edu.au/marxan.htm)).

The project will produce a framework for the use of Marxan in typical NRM planning and management problems, and will produce new DSS software packages for free distribution to NRM agencies across Australia. This software will be supported with training materials and operating guides that may be freely accessed at the University of Queensland web site by NRM practitioners Australia-wide.



Photo courtesy of DEC

NHT National Competitive Component research project 53414:  
Developing an integrated planning framework and decision  
support methods for biodiversity conservation and  
sustainable natural resource management  
across the marine-terrestrial interface.

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## Rottnest Island Sanctuaries: A Typical NRM Problem

The Rottnest Island Authority is facing the need to expand the island's marine sanctuaries to protect and restore marine biodiversity. This needs to be done in a way that will have minimum detrimental impact on recreational and commercial fishing, and provides the maximum (ecologically sustainable) benefit for tourism on the island. The decision problem involves:



Photo courtesy of Mick Eidam

- choosing a set of sites that can best provide for the recovery and long term maintenance of the island's unique marine habitats and species,
- providing for ongoing recreational and commercial fishing to the extent that it does not conflict with these biodiversity objectives,
- providing the best opportunity for tourism experiences,
- providing for boat anchorages while minimising the disruption to boating and other recreational activities, and
- decreasing waste discharge from visiting boats into island waters to reduce the public health risk and incidence of closure of the most popular bathing beaches.



Swan NRM Planning Region

Achieving all these objectives may involve dedicating some of the most highly valued fishing areas for biodiversity conservation, while retaining some sites for high quality fishing experiences for recreational fishers, creating valuable tourism opportunities for snorkellers and commercial tourism operators, and ensuring anchorages are suitably located to minimise the risk to bathing beaches. Full achievement of these objectives will inevitably create conflict over which sites can be dedicated to which type of use, since some objectives are competing (such as high densities of visitor boats with safe bathing beaches; conservation reserves with fishing access). The trade-offs amongst site-uses are complex, involving aspects of ecosystem and habitat ecology, fisheries management, tourism costs and benefits, visitor history and traditional practices, and bacteriological standards and water quality.



Photo courtesy of Martin Heller

The Natural Heritage Trust was set up by the Australian Government in 1997 to help restore and conserve Australia's environment and natural resources. The \$3 billion Natural Heritage Trust represents the biggest financial commitment to environmental action by any Australian Government in Australia's history.



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