Theme 6: Resource allocation – decision support for sharing of natural resources and environmental assets

Abstract

Profound uncertainty, lack of succinct property rights and the contested values of key stakeholders make the allocation of marine resources a wicked problem. This paper outlines four fundamental challenges to effective decision-making: (1) poor problem formulation, (2) complexity in socio-ecological systems, (3) misplaced emphasis on strict optimisation, and (4) inadequate governance arrangements. We identify how these challenges can be addressed by the research community through co-ordinated case studies, synthesis of learnings and targeted training.

Background

The lack of clear and precise property rights relating to marine resources and environmental assets results in the need for active management intervention to ensure resource allocations are consistent with broader societal objectives and values. The traditional cornerstones of research concerning the allocation of marine resources in Australia have been fisheries biology and resource economics. Increasing recognition of system complexity and the multitude of values at stake have seen the emergence of a greater emphasis on interdisciplinary research. Research programs now often include contributions from sociologists, conservation biologists, political scientists and anthropologists, among others.

Research in marine resource allocation is currently undertaken by:

- University-based research – including the Australian National Centre for Ocean Resources and Security (ANCORS) at the University of Wollongong, the ARC Centre of Excellence for Coral Reef Studies and others at James Cook University, the University of Queensland, Queensland University of Technology, the Oceans Institute and others at the University of Western Australia, the Australian National University's Crawford School of Public Policy, and the Institute for Marine and Antarctic Studies at the University of Tasmania, among others.
- Federal and state research agencies including CSIRO, AIMS, ABARES, Geoscience Australia and SARDI, as well as the R&D arms of other state and territory fishery and environment departments
- Consultants; and
- Various consortia of the above, principally through the National Environmental Research Program, administered by the Department of the Environment.

Funding is fragmented and lacks co-ordination. Sources include:

- ARC and grants to universities
- Core funding for federal and state research agencies
- NERP, NESP FRDC
- AusAid, ACIAR

- Commissioned research by industries, non-government organisations, philanthropic foundations, and other sector-specific interests
- Commissioned research by State and Commonwealth departments and management agencies.

The way in which expertise in resource allocation is accommodated in research institutions is typically diffuse. Most marine focused centres (university and research agencies) have an overarching emphasis on marine science, with social science and economic expertise derived from external or associated departments or agencies. Few institutions have fully integrated capability in biophysical science, social science and economics.

The international standing of elements of this research effort is high. For example, the ARC Centre of Excellence for Coral Reef Studies enjoys an outstanding reputation internationally. Australian research in ecosystem-based management is highly regarded. Significant globally recognised research on international fisheries governance and economics has been done by ANCORS, ANU's Crawford School, CSIRO, the University of Tasmania, and others.

Relevance

The aim of resource allocation is to ensure that the use of natural and environmental resources provides the greatest sustainable benefit to society as a whole. The beneficiaries of research into resource allocation are hence those with a stake in the use of the resources, and those responsible for the management of the marine estate. A coarse collation is shown in Table 1.

Table 1. Major beneficiaries and users of research focussed on improved resource allocation methods and governance

Federal government • Major departments and agencies (fisheries, environment, mining, transport) • Marine bioregional planning processes, GBRMPA • International issues (RFMOs, regional engagement, Coral Triangle Initiative)	State and Territory governments • State planning departments • Coastal zone management processes • Spatial allocation issues – recreation, conservation, renewable energy, aquaculture, ports etc.
Local governments and NRM regions • Management of coasts and estuaries • Complimentary management of land resources, especially regulation of water resources and agricultural practices.	Individual industries and sectors • Fisheries (commercial, recreational, indigenous), aquaculture • Offshore oil and gas • Seabed mining • Renewable energy • Ports and shipping • Tourism
International development agencies and inter-governmental organisations • World Bank and other development banks • United Nations institutions (UNDP, FAO, UNEP, DOALOS, etc.) • Regional institutions (Pacific Islands Forum Fisheries Agency (FFA), Secretariat of the Pacific Community (SPC), etc.)	Public interest groups • National and International NGOs • Indigenous groups • Regional and local community-based conservation groups • Other public interest groups • The general public, including future generations

The imperative for development of more technically and socially robust approaches to resource allocation is evident in the declining trend of some biological stocks and other natural capital, and the commensurate intensification of debate over depleted resources (GBRMPA 2014, SoE 2011). In particular, the acute reliance of Australian fisheries on estuarine and near-shore stocks and the decline of coastal habitats have seen heightened politicisation of management decisions. Controversies around port development adjacent to the Great Barrier Reef World Heritage Area, oil and gas extraction on the north west shelf, and debate over the legitimacy, representativeness and ongoing management of marine protected areas all stem from inherently difficult resource allocation problems. At the Commonwealth level, we note that implementation of the broadly supported Oceans Policy and its emphasis on integrated oceans management has essentially stalled (Vince 2014).

Ineffective governance and management plans that are opposed by key stakeholders inevitably lead to high transaction costs and rent-seeking, as stakeholders dedicate more of their resources to lobbying and positioning, and less to production and enjoyment. Costs are also borne by taxpayers as bureaucracies struggle with crippling complexity. Where poor decision-making stems from alarmism, the costs are disproportionately borne by industry. Where decisions are underpinned by false assurance, overconfidence, or undue optimism, the costs are borne mainly by the environment, and those who seek to protect it (Burgman 2005). Investment in improved methods and frameworks for resource allocation is vital for management of Australia's marine estate.

Science needs

We see four major challenges to effective decision-making in resource allocation:

1. Poor problem formulation
2. Complexity in socio-ecological systems
3. Misplaced emphasis on strict optimisation
4. Inadequate governance structures

1. Poor problem formulation

Any decision to allocate resources one way or another involves consideration of three elements (Howard 2007):

- Identification of the multiple objectives and stakes within the scope of the decision problem, and resolution of inherent trade-offs via articulation of preferences or ***values***;
- ***Alternative*** configurations of resource allocation across space and time; and
- ***Predictions*** of the performance of alternatives against each of the multiple objectives and interests.

Many organisations with an evidence-based management emphasis feel uneasy about the lack of data underpinning predictions. The task of prediction is substantial and may invoke a sense of overwhelming complexity, as noted below. But before considering prediction, the more fundamental requirement of effective decision-making is elicitation of relevant objectives and capture of creative alternatives. Sometimes, when the broad canvas of the problem is acknowledged, the importance of uncertainty in prediction is diminished.

Articulating objectives can be difficult (Bond et al. 2008, Game et al. 2013). With the benefit of hindsight, many allocation decisions are seen as short-sighted because of failure to recognise the interests of some legitimate stakeholders. There is broad recognition that non-market values are under-represented in formal analyses. Environmental concerns are prominent among organisations charged with environmental protection, but trade-offs with other interests are often ignored or treated as second-order issues in such organisations. Treatment of social and cultural concerns seems particularly deficient. To some extent this may be exacerbated by the perceived need for scientifically credible predictions. The limited research on identification and development of sound indicators, attributes or metrics may inadvertently compromise inclusion of many social and cultural values. But the protected or 'sacred' values (Tetlock 2000) underpinning social and cultural concerns, including those around equity, are often the source of protracted disputes and unstable policy (Gregory and Keeney 1994). In this context, we note especially the acute need for improved capture of the social and cultural values of indigenous interests in marine resources, including the contribution small, localised fisheries make to financial viability, social stability and cultural connection to country.

2. Complexity in socio-ecological systems

The allocation of marine resources is a wicked problem (Churchman 1967), involving complex interactions, feedback, thresholds and surprise events among a raft of social, economic and ecological variables. How individuals, and through their actions ecological systems, respond to allocation decisions may result in outcomes far from those expected. Many organisations can be understandably overwhelmed by this complexity. The paucity of information may be used as an excuse for vacillation, procrastination, or justification for the status quo (Hammond et al. 2006).

There are costs to indecision and to the capture and collation of data. In a conservation context, inaction can lead to a loss of biodiversity (Martin et al. 2012). In contested settings, delay may only serve to intensify confrontation. The advantages of greater clarity through data acquisition need to be weighed against the disadvantages, including the direct monetary costs. Improved collation, management and retrieval of existing and new data can alleviate information bottlenecks to some extent. But the more substantial challenge is mature formulation of resource allocation problems to enable sensitivity analyses and identification of areas where data can be acquired cost-effectively, with greatest returns on investment through tangible reductions in key uncertainties for decision makers.

3. Misplaced emphasis on strict optimisation

The ultimate aim of resource allocation is to derive the most benefits possible from use of the resource to society as a whole. But society comprises many different competing user groups, and any allocation of direct or indirect benefit from resources will result in some (it not all) groups receiving less access than they may wish. Claims of optimality can be especially grating among those whose access has been denied or diminished, or whose values have been subjugated. Dissatisfied groups may attempt to undermine the process through lobbying or other approaches to tip the accrual of benefit more in their favour.

Determining an 'optimal' allocation is not straightforward. A range of different approaches are available to derive optimal allocation of marine resources, each with different issues in terms of defining and deriving outcomes. Formal treatment of optimisation in decision theory assumes a single decision-maker who is able to crisply articulate their values. In mathematical programming, the optimization problem is distilled into a single objective function, with all other considerations reduced to constraints, or an achievement function which balances a range of multiple objectives, but again assuming a single set of values. While these values may be derived from a larger group, the optimal outcome is based on a single aggregated (or average) preference structure. As such, the impact of differences in value structures by different groups on optimal outcomes may be lost, and the resultant compromise outcome may be sub-optimal from all groups' perspective. Such approaches also require quantitative information about all inputs, including measures of social value, non-market and market economic values and ecological sustainability metrics. Many of these data are difficult, if not impossible, to capture accurately, so any optimisation-based outcome will be potentially influenced by biases in the data that can be incorporated into the models.

Conversely, in simulation based approaches such as management strategy evaluation and viability analysis, there is no explicit weighting of objectives, and the methods highlight trade-offs across competing objectives (Fulton et al 2014) or feasible sets within objective boundaries. However, these approaches also require the same data as needed for optimisation models. Further, the final decision as to which option to choose becomes more subjective, less transparent, and will be based on the values of the decision maker rather than (potentially) values derived from a broader group. In multi-criteria decision analysis (MCDA), weights are generally used to reflect the relative importance of competing objectives, but the reliance on quantitative data is often less than in more formal approaches. It is often based on subjective expectations of outcomes using expert or stakeholder opinion rather than formal models of processes to derive estimates of the performance of alternatives against objectives. While subjective, the expected outcomes may be able to consider a broader range of (quantifiable and non-quantifiable) interactions than formal quantitative models. MCDA typically focuses the attention of the analyst and decision-maker on value judgments among a small sub-set of alternatives. However, MCDA is also often based on the views and subjective judgements of a sub-set of stakeholders, and it is unlikely that any outcome will fully satisfy all groups.

In public policy, the theory and conventions of welfare economics have often been used to aggregate demand and values across multiple concerns for the whole of society in benefit-cost analyses. But challenges remain, including a tendency to conceptualise welfare narrowly, and in decision makers' limited awareness of stated and revealed preference techniques, and a lack of time and resources to be able to use these techniques in policy making (Rogers et al. 2014).

The level and quality of information used in all of these approaches, and the ability to interact effectively with stakeholder groups, is a function of the resources available to do appropriate and relevant science. Constraints in decision support imply that strictly optimal solutions are elusive. But near-optimal solutions need not be out of reach. While recognising their limitations, we advocate broader recognition of the value and insights of structured analytical tools. The merits of considered analysis need to be made more visible, and the frailties and deficiencies of frequently employed ad hoc processes laid bare (Hammond et al. 2006). We see immediate potential in methods that identify

broadly socially acceptable or viable alternatives, and solutions that are robust to pervasive uncertainty.

4. *Inadequate governance arrangements*

Australian fisheries are considered to have strong governance regimes, yet allocation is a significant issue for commercial, recreational and traditional fishers, tourism, the oil and gas industry, conservation agencies and NGOs, along with other sectoral interests and the broader community, including future generations. Current discussion on resource allocation and sharing arises against a background of changing and expanding pressures on fisheries and marine ecosystems – population growth, demand for seafood, impacts on marine systems, and changes in global biophysical and economic systems. It also occurs in the context of increasing demand to reduce regulatory costs, which sometimes results in diminished demand for or reliance on information, analysis, data and research (deliberately or inadvertently), without consideration of whether such diminution undermines robust decision making.

A key challenge is to develop transparent and equitable frameworks for allocation of marine resources in Australia. A core underpinning of this challenge is the ability of governance arrangements to simultaneously achieve acceptable resource shares across a range of resource futures and maintain the sustainability and resilience of fisheries and other industries that rely on ecological communities.

Perspective

Here we outline interdisciplinary research to address the four overarching challenges to effective decision-making.

1. *Poor problem formulation*

Research priorities here involve integration of social and economic interests with environmental issues and concerns, including development of tools and platforms that are open to wide stakeholder engagement. Specific areas that are likely to be fruitful include:

- Exploration and application of techniques from 'soft' operations research, including soft systems methodology, cognitive mapping and the strategic choice approach (Mingers 2011). These non-mathematical techniques have emerged over the past 40 years in response to wicked problems in other domains. Their use in marine settings has been limited, despite considerable potential.
- The further development of social and cultural indicators and attributes (e.g. Dichmont et al. 2012) to characterise the consequences of alternatives and enable informed trade-offs alongside established metrics for environmental and direct economic consequences.

2. *Complexity in socio-ecological systems*

In settings in biophysical and social flux, it is counter-productive to invest long periods of time collecting and collating baseline information, and developing detailed predictive models. Investment in data acquisition, both ex ante and ex post, should be subject to a vigorous evaluation. It should be clear how better or more information will improve the outcomes of policy. Formal tests of

the value of information are available (Pratt et al. 1995), but rarely used in natural resource management. Research aimed at testing and refining value of information tests for marine science is a priority.

At times, there may be a tendency to over-complicate decisions, leading to 'paralysis by analysis'. Accessible, simplified tools for estimating the cost-effectiveness (Joseph et al. 2008) or the cost-benefit ratio (Pannell et al. 2012) of alternative policies or actions are available. These tools help users to avoid serious errors encountered in many decision support protocols used routinely by agencies in natural resource management (Pannell and Gibson 2014). Further refinement of these tools, including road-testing their merits in marine settings, is another priority.

These tools require environmental and other non-market economic values relating to marine resource use. Such measures are particularly sparse in Australia, but essential when assessing the relative costs and benefits (or cost effectiveness) of alternative uses of a resource when incorporated into these tools. Similarly, determining appropriate quantitative metrics for social and cultural values is also important, as is determining how these measures can be captured in such tools. A premium therefore needs to be placed on interdisciplinary research that bridges traditional divides.

In more complex and high-stakes decision settings, there is an acute need for advances in statistical and mathematical modelling of biophysical processes to be coupled with improved sophistication in socio-economic modelling. Models need to capture chronic and cumulative impacts of multiple pressures and stressors. The insights from sparse data across multiple studies need to be synthesised using the latest techniques in meta-analysis.

3. Misplaced emphasis on strict optimisation

Many resource allocation problems are not readily amenable to traditional optimisation methods. Poor resource allocation may stem from failure to recognise the full suite of social, cultural and economic interests in the resource and reluctance to confront difficult trade-offs. Approaches that make these trade-offs more visible and more salient to decision-makers and stakeholders may be more effective than those that submerge the need for compromise and rely purely on loosley structured negotiation with limited stakeholder representatives.

While quantitative models and MCDA methods are useful for increased transparency in resource allocation, they are not always appropriate, and in some cases structured deliberative negotiations may be required to achieve acceptable resource allocations. For example, negotiating co-management of trans-boundary fisheries is not a single decision-maker optimisation problem. Ongoing global overfishing and declining fish stocks is often a result of unresolved conflicts over distribution of conservation burdens and allocation of fishing rights. The negotiation over the scope and application of a fisheries conservation and management measure is often a negotiation over how the burden of conservation is distributed. Implementation of conservation and management measures may apply direct or indirect costs onto a sovereign state or territory. In fisheries suffering from overfishing or broader conservation concerns, some or all stakeholder states may need to compromise some of their vested interests and take on a share of the conservation burden in order to achieve long term

conservation or sustainable use goals, and enjoy long term conservation benefits. While some States may quickly or immediately benefit from conservation and management measures that increase fisheries productivity or protect their fishing opportunities, other States may experience a mix of benefits and costs, or obtain no benefits at all.

Trade-offs and negotiation in multi-party contests may be more fruitfully addressed using deliberative techniques in structured decision-making (Gregory et al. 2012). However, such approaches are also not without problems. In particular, they rely on those involved in the negotiations being truly representative of their constituents and the broader society. At international levels, the interests of the country as a whole is appropriately represented through government based negotiations. At local levels, there is substantial potential for particular vested interests to dominate, and the issue of appropriate representation of interests becomes more acute. Where conflicting priorities exist between groups who are unwilling to compromise, negotiations may result in substantial delays in decisions – at a cost to the community as a whole.

Developing and communicating sound allocation decisions to disparate stakeholder groups is itself a complex problem, and requires a range of approaches. Together with mutual appreciation of the constraints and priorities of different stakeholders, research into these techniques might usefully explore how qualitative and deliberative methods may be combined to arrive at near-optimal or satisfactory outcomes as well as facilitate outcome implementation and stakeholder acceptance.

4. Inadequate governance arrangements

There is a need to develop governance arrangements and institutional capacity for allocating marine resources in a way that generates socially, economically, ecologically and politically viable solutions that are robust to a range of plausible futures.

Many fisheries and marine conservation challenges are a problem of governance and distribution. Applied research is required into new participatory and consultative approaches to ocean governance and effective institutions that can resolve conflicts over conservation distributions and rights allocations and ensure long term conservation goals with the full engagement and support of stakeholders. Cooperative and interdisciplinary international research is needed to study the multi-lateral distribution of conservation limits in trans-boundary oceanic fisheries and develop new transparent and equitable rules and frameworks for assessing and distributing conservation burdens in transboundary fisheries.

Given the transboundary nature of many of Australia's fisheries, and the increasingly globalised operations of industrial fishing fleets, Australia has long played an influential and important role in international fisheries management – hosting important international workshops, driving developments in international policies and regulations, and providing significant leadership at global and regional levels. These international initiatives were important to the effective conservation and management of Australian fisheries, from the tropics to the Antarctic. However, in recent years, the Australian Government has significantly reduced its international engagement and now provides little strategic input into international fisheries governance. This reduced engagement has weakened the

development of important regional initiatives and undermined Australian interests in reducing the over-capacity of the global fishing fleet and strengthening management initiatives.

Resource allocation is not a static problem. It demands continuous reformulation and continuous improvement. While there is much emphasis on the technical dimensions of adaptive management, formal recognition of the role shifting social values and priorities play in the dynamics driving review of allocations is seemingly underappreciated. In this context, the commitment and co-operation of key institutions are vital. Part of the reluctance to engage in adaptive change may be the dearth of management frameworks for re-allocation, and clarity in the rules by which parties that stand to lose (or gain) are compensated (or taxed). An exception is the South Australian Fisheries Management Act 2007 which contains provision for compensation among recreational and commercial fishers upon reallocation. The merit of this approach needs to be considered beyond issues around fisheries access and beyond South Australian waters. The research expertise of political scientists, sociologists and behavioural economists can generate and test ideas around socially robust multi-party governance arrangements.

We note that a consuming focus on integration across jurisdictions may mask the opportunity more readily available in integrating land use planning and marine planning within jurisdictions. Research addressing cross-realm threats may pay immediate and substantial dividends.

Realisation

Collectively, the research outlined above can secure clear gains in efficient and equitable allocation of resources, reduced transaction and rent-seeking, streamlined planning and approval processes, improved transparency for decision processes, better social, economic and environmental outcomes via enduring policy, stable governance and social and economic stability, and improved social license to operate. These gains will be magnified to the extent that governments and other decision-makers commit to coherent and structured approaches to resource allocation.

Many stakeholders involved in the preparation of this paper articulated support for Oceans Policy and its emphases on jurisdictional integration and ecosystem-based management, despite its modest outcomes (Vince 2014). But in the short term, we see little prospect of a centralised bureaucracy providing the creativity, leadership and authority to drive the research agenda we have described here, or its application to policy, decision making and regulation. We see the main vehicle for advancing resource allocation and the sentiment underpinning Oceans Policy to be highly visible and substantial case studies, periodically reviewed and synthesised via structured cross-examination of successes and failures. These case studies can build on the experience of SARDI's Great Australian Bight research program and the Spencer Gulf Ecosystem and Development Initiative, among other initiatives throughout Australia, including those at a local scale.

We see a host institution dedicated to synthesis and analysis of marine resource allocation experiences. The structure and function of the host institution could borrow from the Unites States' National Center for Ecological Analysis and Synthesis www.nceas.ucsb.edu and the Cochrane Collaboration www.cochrane.org, an international consortium dedicated to synthesis and meta-

analysis for evidence-based allocation of public health resources. As robust decisions and enduring frameworks emerge for case studies, we see government agencies, NGOs, industry and other stakeholders harnessing benefits and adopting and deploying tools and techniques.

The host institution might also play a co-ordinating role in training. Skills and experience are needed in interdisciplinary integration, complex systems thinking, soft operations research, stakeholder engagement and communication, and applied quantitative and qualitative analysis. As case studies mature, opportunities will arise for refining and extending the skills of trainees.

This paper has emphasised that greater investment in problem formulation and tools and techniques for decision-making under uncertainty may offer remedies to ineffective decision-making. Nevertheless, the information bottleneck needs to be recognised. Decisions around the use and management of marine natural resources could be much better informed through the development of an advanced national data search, retrieval and analysis system that can deliver both relevant fundamental data and derived information that is targeted to the specific needs of government, offshore industries (e.g. petroleum, fisheries) and other key stakeholders. With recent developments in information technology, it is now feasible to efficiently access widely distributed sources of marine data. The emergence of high performance computing environments, such as Australia's National Computing Infrastructure, the major increase in the discoverability of marine data (e.g. via the Australian Ocean Data Network), and the development of software tools capable of manipulating and analysing large data sets, has created an unprecedented opportunity to recombine and analyse marine data. To enable this approach to generate significant national benefit, however, the specific information needs of priority users will have to be well defined and made readily accessible.

In the marine information sector we have strong links with internationally relevant marine agencies such as the British Oceanographic Data Commission and the United States' National Oceanic and Atmospheric Administration (NOAA). These organisations, as well as other partner members of the Ocean Data Interoperability Platform, have expressed a strong interest in finding ways of improving the interoperability and re-usability of marine data at a global scale.

Even with the research agenda and focus outlined here, a key challenge remains the effective uptake of research by government and other forums for decision making, and a strong ongoing commitment by decision makers and stakeholders to evidence-based decision making in the greater public interest.

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