The contested ocean: A research and education vision on the economics of coastal and marine ecosystems

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1 My focus in research and education

My work as an academic focuses on the economics of coastal and marine ecosystems. In my research I develop applied bioeconomic models of fisheries management, marine invasive species management, trade-offs between conflicting objectives in coastal zones, and other economic problems in the coastal and marine environment. In my education I teach students economic knowledge and skills to become the next generation of coastal and marine resource managers, such as the theories, methods and applications of natural resource economics, institutional economics, bioeconomic modelling, and non-market valuation.

2 Research

2.1 Main research issues

The methods and models I develop in my research serve either of two purposes in coastal and marine ecosystem management: (1) facilitating policy makers to set the right policy objectives; and (2) developing and analysing innovative policy instruments.

2.1.1 Policy objectives in management of coastal and marine ecosystems

Marine and coastal ecosystems are characterised by a variety of uses, many of which are often conflicting, such as shrimp farms and nature conservation in mangrove forests (Zavalloni et al., 2014), or fisheries and wind energy in the North Sea (Punt et al., 2009). Balancing conflicting uses of an ecosystem in this situation requires a quantitative representation of the trade-off between them: for example, how much resource rent from fishing is lost by the construction of an additional wind farm? How much of a nursery function from a mangrove ecosystem is lost by a given increase in aquaculture production? A quantitative analysis of such trade-offs requires the use of spatial bioeconomic optimisation models. As a co-supervisor I developed jointly with PhD candidate Maarten Punt a spatial optimisation model of wind farm allocation in the Dutch Exclusive Economic Zone (Punt et al., 2009). The model demonstrates that careful spatial planning of wind farms can prevent major harm to bird populations at very low costs. A more recent publication with Matteo Zavalloni (University of Bologna) and Paul van Zwieten (Aquaculture and Fisheries Group, Wageningen University) presents a spatial optimisation model of shrimp aquaculture allocation in a mangrove ecosystem, taking into account the mangrove's nursery function for wild shrimp. The analysis demonstrates that in mangrove ecosystems it is pivotal that such trade-off analyses take into account the spatial connectivity of mangrove patches (Zavalloni et al., 2014).

Some policy objectives require careful consideration of the dynamics and uncertainties in an ecosystem. The canonical deterministic fisheries-economic models yield a biomass or harvest that maximizes the net present value of a fishery in a steady state. Real-world coastal and marine ecosystems, however, are subject to many unpredictable factors such as temperature shifts, climatic oscillations, and nutrient availability, which prevent the system from reaching that steady state. Therefore, adaptive management strategies need to be developed, usually referred to as Harvest Control Rules (HCRs) in the fisheries management literature (see e.g. Restrepo and Powers, 1999; Eikeset et al., 2013). HCRs define fisheries policy as a mapping from estimated stock size to a policy variable, such as Total Allowable Catch (TAC) or a number of vessel days: in other words, the policy is not represented by a single number, such as an optimal TAC that is constant over time, but by a TAC that varies with estimated stock size. This approach enables managers to deal with natural variability of fish stock abundance, observation errors, and unobserved behaviour of resource users. Developing an optimal HCR requires the use of stochastic dynamic optimisation models. In a recent publication with former PhD candidate Diana van Dijk, whom I co-supervised, we present optimal HCRs under uncertainty, capital inertia, and management costs (van Dijk et al., 2013). My recent publication with Christopher Costello (University of California, Santa Barbara) and Michael Springborn (University of California, Davis) analyses the optimal decision on an activity that risks crossing an unknown threshold and triggering a discrete adverse event (Groeneveld et al., 2014). This study suggests that a high discount rate induces a more cautious policy, i.e. one tries harder to avoid crossing the threshold. Although this result may seem counterintuitive, it is driven by the effect that crossing the threshold yields information that is valuable for future decisions. Adam Walker, a

PhD candidate whom I co-supervise, works on optimal management strategies of marine invasive species under the FP7-funded VECTORS project; another PhD student whom I co-supervise, Shinta Yuniarta, studies the value of improved data collection systems and stock assessment methods in the data-poor Indonesian tuna fishery, as well as trade-offs between economic efficiency and poverty alleviation.

2.1.2 Policy instruments in management of coastal and marine ecosystems

A common truism in the fisheries management community states that "fisheries management is the management of people, not fish" (Jentoft, 1997). The history of fisheries management provides many examples of policy interventions resulting in the opposite of their intended effect because human behaviour was not accounted for (Branch et al., 2006). In the most cited example restrictions on season length in the Alaskan halibut fishery led to massive overcapitalisation, dangerous fishing practices, and ghost fishing by unretrieved fishing gear, as fishers engaged in a "race to fish" to maximize their catch within the limited time frame offered by the policy. Therefore, the decisions made by resource users, as such or in reaction to policy interventions, are an essential consideration in the development and analysis of policy instruments in coastal and marine ecosystem management. In two recent publications Diana Van Dijk and I, together with experts of the Operations Research and Logistics Group (ORL), developed stochastic dynamic optimisation models to estimate the opportunity costs of restrictions on the flexibility of adaptive management strategies in fisheries, taking into account fishers' decisions with respect to the allocation of fishing effort and investments in capital (van Dijk et al., 2013; van Dijk et al., 2014). In other cases the responses of aggregate users, such as markets, are relevant. A recent working paper I wrote with Martin Quaas of Kiel University analyses whether certification of tuna caught with more selective techniques could adversely affect the fishery through an increase in overall fishing pressure (Groeneveld and Quaas, 2013). We find that the price elasticity of overall demand for tuna is crucial in this respect.

2.2 Bioeconomic modelling in the wider context of coastal and marine science

The multitude of valuable goods and services provided by coastal and marine ecosystems (Agardy et al., 2005; Barbier et al., 2011) and the increasing pressure on these systems (Halpern et al., 2008; Crain et al., 2009) have led to the emergence of Ecosystem-Based Fisheries Management (EBFM) (Pikitch et al., 2004). EBFM is an innovative approach that considers the entire coastal and marine ecosystem with all uses, stakeholders, disciplinary perspectives, the complex links between uses, and the fundamental and scientific uncertainties. This approach has also led to the development of extensive dynamic ecosystem models, also referred to as End-to-End models (Fulton, 2010). These models typically describe the dynamics of multiple species, economic sectors, and their interactions, and are increasingly used in evaluations of long-term fisheries management plans. Economists have made important contributions to this research, but much unexplored terrain remains.

Economics currently contributes to EBFM in four respects. First, economists have developed applied models of human behaviour that can be implemented in End-To-End models to describe, for example, spatial allocation of fishing effort (see e.g. Hicks and Schnier, 2008; Poos et al., 2010). Second, first steps have been made to integrate monetary valuation of ecosystem services in End-to-End models (Nunneri et al., 2007; Börger et al., 2014). Third, more or less independently of the large-scale End-to-End models, economists have developed applied bioeconomic fisheries models that place more emphasis on economic aspects than End-to-End models do (Prellezo et al., 2012). The fourth contribution to EBFM regards the insights provided by economic theories and theoretical models. Economics has contributed to the formulation of policy objectives with the introduction of concepts such as maximum economic yield (see e.g. Clark, 1990), and of a welfare theoretical framework to analyse trade-offs between different ecosystem goods and services (see e.g. Lester et al., 2013). Moreover, micro-economics and institutional economics help explain the role of institutions such as different property rights regimes (see e.g. Costello and Kaffine, 2008), and have inspired innovative policy instruments such as Payments for Ecosystem Services (Wunder, 2005) and rights-based fisheries management (Costello, 2012).

Hence, two strands can be distinguished in the economic literature on bioeconomic models of coastal and marine ecosystems. The first strand is that of applied quantitative models: these are the End-to-End models with economic components, and the applied bioeconomic models. These models take into account many of the relevant variables and mechanisms, which makes them particularly suitable for policy analysis. The main limitation of these models is that their high level of detail also limits their transparency: one can obtain results from these models, but it is difficult to explain what is driving these results, or to what extent the results are driven by the assumptions made. The second strand is that of

theoretical microeconomic analyses (see, e.g., Costello and Kaffine, 2008, and Hatcher, 2014; Kronbak et al., 2013 gives an overview of the state of the art). Theoretical analyses can provide useful insights into the mechanisms at work in natural resource management, but these insights are usually subject to strong assumptions necessary to enable formal mathematical proofs.

In addition to these two large strands in the literature, a relatively new approach is emerging that combines the transparency of the theoretical analyses with the realism of applied analyses. In this approach computational methods are used that are common in such fields as financial economics and macro-economics (Judd, 1998; Miranda and Fackler, 2002), such as value function iteration (see e.g. Da Rocha and Gutiérrez, 2012), perturbation (see e.g. Kompas and Chu, 2012), and collocation (see e.g. Sanchirico and Springborn, 2011). These approaches can potentially narrow the gap between the applied and theoretical approaches as they enable researchers to gain insight into theoretical models that are too complex to derive closed-form solutions. Further application of such computational methods to issues in coastal and marine ecosystem management will enable the development of models that are realistic as well as insightful.

Another potentially valuable bridge between the applied and theoretical approaches is the development of a microeconomic theory of natural resource use in discrete time. Despite the extensive microeconomic literature on natural resource use, there is surprisingly little theory that provides insight into the behaviour and validity of applied bioeconomic models. Applied models and theoretical models differ fundamentally in their treatment of time: time is assumed discrete in virtually all applied models, but as continuous in most, although not all, theoretical models. Although this may seem like a detail, it has serious consequences for the results of both models. It also matters for policy-makers, who manage a continuous-time system by making decisions at discrete points in time. Developing a microeconomic theory of natural resource use in discrete time will help make the assumptions behind the applied models explicit, which will in turn help to interpret their results.

2.3 Niche within the international scientific arena and Wageningen UR

The main centres for research on coastal and marine ecosystems are in North America (National Oceanic and Atmospheric Administration; University of Washington, Seattle; University of California, Santa Barbara; University of British Columbia), Australia (CSIRO Hobart; Australian National University, Canberra), and Scandinavia (University of Iceland, Reykjavik; Norwegian School of Economics, Bergen; University of Southern Denmark, Esbjerg). Wageningen University can make a substantial contribution to this field because EBFM typically requires the "Wageningen approach": addressing complex problems with problem-oriented interdisciplinary research. Moreover, Wageningen University has long established links with universities and research institutes in regions where EBFM will become most urgent in the near future, such as Viet Nam, Indonesia, and the Pacific. Wageningen University has developed an impressive network on marine research and education in the natural and governance sciences, which can be complemented by research and education in marine economics.

The importance of the marine environment for The Netherlands far exceeds the mere 0.03% that commercial fisheries contribute to Dutch GDP[1]. The Dutch Exclusive Economic Zone (EEZ) covers about 58,000 km^2, which is about 10% of the entire North Sea area, and one and a half times the Dutch continental land mass. The Wadden Sea is a UNESCO World Heritage site due to its unique ecological status and its importance for many migratory bird species. Research institutes like LEI and IMARES have a strong reputation in applied research in fisheries science, including economics, as does the Centre for Maritime Research (MARE) in Amsterdam in maritime governance. So far, however, no Dutch university has developed a comprehensive research and education programme in the economics of the marine environment.

2.4 Developing a strong marine economics tradition at Wageningen University

My ambition is to develop the expertise in the economics of coastal and marine ecosystems necessary to complement the expertise in ecology and governance already present in other groups of Wageningen University. More specifically, my research in the following 5-10 years will entail the development of (1) computational bioeconomic models of coastal and marine ecosystem use; and (2) a microeconomic theory of coastal and marine resource use in discrete time.

[1] Statistics Netherlands, The Hague/Heerlen, http://statline.cbs.nl, 9 December 2012

Developing computational bioeconomic models will help to find effective and efficient solutions to complex problems in coastal and marine ecosystems, such as reducing bycatch and discarding in mixed fisheries, conflicts between mangrove ecosystems and aquaculture, and management of data-poor fisheries. I have established contacts with researchers at the Australian National University in Canberra (Tom Kompas, John Stachurski) and the University of California, Davis (James Sanchirico, Michael Springborn) who have ample experience with computational methods in the economics of coastal and marine ecosystems. I will develop joint research activities with these contacts to hone my own skills in computational models, apply them in innovative research projects, and transfer them to the new generation in PhD training and advanced courses. I have recently submitted an INREF preproposal entitled "Incentivized Management of Mangrove Ecosystems in South East Asia" (IMMESEA) together with, among others, James Sanchirico, Michael Springborn, Simon Bush (Environmental Policy Group, Wageningen University), and Paul van Zwieten (Aquaculture and Fisheries Group, Wageningen University), where we aim to develop applied bioeconomic models of mangrove conservation and aquaculture in Viet Nam and Indonesia[2].

Developing a microeconomic theory of coastal and marine resource use in discrete time will facilitate the understanding and further development of applied bioeconomic models and economic modules in End-to-End models. I will work with established fisheries economists such as Niels Vestergaard (University of Southern Denmark, Esbjerg), Quentin Grafton (Australian National University, Canberra), and Martin Quaas (Christian-Albrechts University, Kiel) on the development of a microeconomic theory that can help to understand and make explicit the assumptions behind these models, which in turn helps to assess their validity and suggest improvements. I have recently presented a paper with Jan-Jaap Poos (Wageningen IMARES) at the biannual conference of the International Institute of Fisheries Economics and Trade (IIFET) on the on-board microeconomic decisions on fishing effort and discarding of catch under a quota system in discrete time. In a recently submitted proposal to Horizon 2020, together with Andries Richter (Environmental Economics and Natural Resources Group) and other partners including Wageningen IMARES and the Christian-Albrechts University, Kiel, we will investigate the social and economic drivers of fishers' compliance with the EU's newly introduced obligation to land all catch.

I will seek to attract funding from sources aimed at developing countries, such as INREF and WOTRO, as well as industrialised countries, such as the European Union. The most urgent and interesting research questions apply to developing countries, where the quality of data and institutions is often limited, and poverty alleviation is at least as important as resource conservation. Because of the same factors, however, doing research in these regions is also more difficult, and developing countries should be able to learn from the more advanced fisheries management systems in industrialised countries. Therefore, I strive to complement research in developing countries with research in industrialised countries.

So far I have not been involved in research funded by private funding agencies, such as the Gordon and Betty Moore Foundation, the Packard Foundation, or Pew Environment. Nevertheless, these organisations have provided ample funding to economic research on coastal and marine ecosystems in the past, especially research done by universities in the United States. My ambition is to build on my collaboration with researchers at the University of California, Davis, and the University of California, Santa Barbara, to build partnerships with these private funding agencies.

I strive to publish the results of my own research and that of my PhD candidates mainly in interdisciplinary academic journals with a wide readership and a profound impact on academic and policy debates, such as the *ICES Journal of Marine Science*, *Ecological Economics*, and the *Journal of Environmental Management*, complemented with frequent publications in more theoretical journals, such as *Environmental & Resource Economics*. I strongly believe that 'Science for Impact' implies publication in the former class of journals, whereas academics also should expand the theories in their discipline by publishing in the latter.

3 Education

An explicitly interdisciplinary concept, EBFM has implications for education in both the natural science education programmes and the social science educational programmes. Students in the programmes BMW (BSc Environmental Science), MES (MSc Environmental Science), and MAM (MSc Aquaculture and Marine Resource Management) need to understand the human factor in marine policy. Students in the

[2] This proposal has been rejected by 15 September 2014. Nevertheless, I will persist in developing this line of research based on the network and material developed for this proposal.

programmes BEB (BSc Economics and Governance), MID (MSc International Development Studies) and MME (MSc Management, Economics, and Consumer Studies) need to understand that rent maximization is only one of the many objectives in natural resource management, especially in developing countries where fishing can provide a safety net to the poorest segment of the population (Béné et al., 2010). They also need to be aware of the moral assumptions behind utilitarianism, which is the dominant moral philosophy in non-market valuation and cost-benefit analysis. I discuss these issues in the courses Cost-Benefit Analysis and Environmental Valuation, and Marine Resource Management.

BSc and MSc theses enable students who are interested in coastal and marine management to delve deeper into the relevant theories and issues, and to further hone their analytical and modelling skills. Moreover, for me as a researcher, student theses offer the opportunity to explore new fields and topics. The MSc thesis of MID student Matteo Zavalloni has resulted in an article a peer-reviewed journal (Zavalloni et al., 2014), whereas an article based on the thesis of MID student Linda Veldhuizen, in collaboration with researchers at CSIRO Australia, has recently been submitted.

Besides teaching I can further integrate these issues in education in two more ways. I am a member of the programme committees of the economics programmes and the environmental programmes. I have also made a start with developing a course text on the economics of coastal and marine resource management. Such a text is lacking because the available educational material is either too narrowly focused on fisheries economics, or too broadly on the entire field of environmental and resource economics. The target group for this text are MSc students with little economic background, so that the text can be used in courses such as Marine Resource Management.

4 Communication with non-academics

Ecosystem management and fisheries policy are hotly debated issues in the public domain. They touch upon the food people eat, where they spend their holidays, and in some cases, how they earn their income. They are also highly complex issues where both science advocacy and contrarianism are prevalent. It is therefore of utmost importance that scientists engage with policy-makers and the wider audience.

My primary medium for such communication is my blog[3]. I believe blogs are by no means substitutes of academic journals, but rather complements, as they allow researchers to communicate their findings and ideas in an accessible and informal way. I use my blog to comment on new developments in marine science and policy, to develop and test my ideas, and to explain new publications in layman's terms. Besides the blog I use Twitter[4] to stay informed on the latest developments, and to attract attention to my blog posts.

I also regularly give lectures for policy makers from developing countries on ecosystem service valuation through a course of the Centre for Development Innovation, and I contribute to occasional courses on ecosystem services, such as a course at the Plymouth Marine Laboratory under the FP7-funded VECTORS project, and an upcoming course on ecosystem services and science advocacy organised by Jeffrey Harvey (Vrije Universiteit, Amsterdam).

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[3] http://grow-fins.blogspot.com
[4] @RolfGroeneveld

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