FINAL REPORT (DEVELOPMENT AWARD)

AWARD CODE and TITLE

2008/314.30 People Development Program: 2012 FRDC International Travel Bursary – Klaas Hartman

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HOST ORGANISATION: Instute for Marine and Antarctic Studies

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ACTIVITY UNDERTAKEN

Klaas Hartmann visited Dr. Paul Armsworth and his group at the University of Tennessee in Knoxville for two weeks to consider impacts of fisheries management decisions such as MPA creation on global environmental outcomes. This work aimed to produce some short term academic outcomes (a paper) as well as establishing the basis for a larger future project.

OUTCOMES ACHIEVED TO DATE

A early career researcher application has been submitted to the Australian Research Council. If successful this will provide Klaas Hartmann with funding for three years to pursue this topic in great detail. An academic research paper has been drafted and will be submitted shortly. A Fulbright application will be submitted mid 2013, this would enhance the previously mentioned ARC grant if successful.

Acknowledgments

The University of Tennessee (Knoxville, USA) paid for my accommodation and flights from Los Angeles to Knoxville.

Background

MPAs are often promoted as a fisheries management tool, despite theoretical results and practical evidence that shows that often MPAs can only improve fisheries production in extremely poorly managed fisheries. Furthermore decreasing fishery production (e.g. through the introduction of an MPA) will increase demand for production in other food sectors. As wild fisheries are one of the most environmentally friendly food production methods, this shift can result in an overall net increase in environmental impact. This is rarely considered by environmental organisations that lobby for changes across many sectors without considering the trade-offs involved.

Need

This project will kick-start a collaboration that examines production impacts of MPAs and methods for including environmental impacts in fisheries management. These

methods will highlight the importance of fisheries in environmentally friendly food production. Work following on from this project will provide practical guidance for managing fisheries to truly target net environmental outcomes.

Objectives

1 Examine MPA effects on fisheries production

This was considered in some detail providing improvements to a paper co-authored with Colin Buxton, Bob Kearney and Caleb Gardner which will be submitted shortly.

2 Develop a methodology for incorporating environmental impacts (primarily emissions) in fisheries management

This was considered in detail, forming the basis for the paper in objective 4.

3 Submit a Fulbright application for continuing related work

A more ambitious ARC early career research fellowship application was submitted which will provide goal than the original objective of submitting a Fulbright application which will still be pursued).

4 Publish findings in a scientific journal and industry publication

A journal paper has been drafted and will be submitted shortly. An industry publication will be produced about the paper once this has been accepted.

Methods

Klaas Hartmann (KH) visited Paul Armsworth (PA) and his group at the University of Tennessee in Knoxville for two weeks. This time was spent intensively developing theoretical results that consider i) the impact of MPA introduction on fisheries production and ii) methods for incorporating environmental impacts (especially emissions) in fisheries management. Given time constraints greater emphasis ended up being placed on the latter.

The project considered how environmental impacts (in particular emissions) can be incorporated in fisheries management. Current management techniques frequently target MEY (maximum economic yield). However, by externalising many factors relevant to the operation of fisheries, they underestimate the societal costs of fishing. For example, to date we know of no study that explicitly considers fisheries CO2 emissions in the context of global food production. Consequently a level of catch exceeding MEY (or a spatial concentration of catches exceeding spatially disaggregated MEY estimates) may reduce overall emissions from global food production by replacing less efficient agricultural production. This project explored these concepts and considered how fisheries management could incorporate this and how trade-offs between sectors could be made (e.g. to answer questions like whether the introduction of an MPA will provide a net environmental benefit).

Results/Discussion

After visiting PA, KH and PA have continued working to bring developed results through to publication. A prestigious ARC early career researcher fellowship (DECRA) application was submitted which would permit KH to work on this topic almost exclusively for three years. A Fulbright application which will supplement this by providing additional support for KH will also be made in mid 2014.

Benefits and Adoption

This work provided the early foundation for considering total global impact of fisheries management decisions. Work following on from this will provide guidance to fisheries managers that are seeking to minimise environmental impacts of a fishery.

Further Development

I am seeking additional funding (ARC Decra and Fulbright fellowships) to allow me to concentrate further on this research. This would enable me to take this work from a theoretical framework through to practical management advice and tools.

Appendices

An excerpt from the ARC DECRA application is attached on the following page.

Excerpt from Klaas Hartmann's ARC DECRA Application

Title

Modern fisheries management to reduce global environmental impact

Short Summary

New fisheries management approaches are needed for the 21st century challenges of environmental impact, global seafood trade, equity and food security. The project will address these challenges by developing management techniques that utilize modern technology and consider the overall environmental and societal impact.

Summary

Seafood has become the most highly traded global food commodity. This has significant and unexpected implications on global food security and environmental impact, which are rarely considered in fisheries management. I will explore these issues using statistical models coupled with extensive global datasets. New fisheries management strategies will be produced using both traditional management controls and spatial management. Fisheries managers will be able to use these results to consider the complex trade-off between global environmental impacts, food supply, equity and societal benefits. This directly addresses two of the key scientific needs identified in the Australian Government's recent report "Marine Nation 2025".

Details

Internationally, seafood has become the most highly traded food commodity [9]. The significant and unexpected implications of this fact on global food security and environmental impact are rarely considered in fisheries management. New methods are needed to understand these implications and improve management of our seafood resource, particularly in the context of increasing food security concerns. In this project I will build on my existing work [1] to:

- Develop analytical tools for understanding the global implications of local fisheries management decisions on the overall carbon footprint, equity in food security and economic benefit.
- Apply these tools to provide practical insights for managing *individual* fisheries and fish stocks to:
    i. Reduce overall global emissions from food production
    ii. Appropriately allocate the fish stock between competing users (e.g. artisanal/subsistence fishers and factory trawlers)

This project will capitalize on and extend several cutting edge global fisheries datasets and models developed at IMAS. **By developing an understanding of global impacts of fisheries management this project will fill a crucial knowledge gap in fisheries management.**

Project Quality and Innovation

I Does the research address a significant problem?

A widely held gold standard in fisheries management is to manage individual fisheries for maximum profit (net present value), ostensibly to maximise the public benefit from a public resource. Environmental and societal costs are usually traded off against the value of the fishery to achieve a balance between food production, economic benefit and environmental and community concerns.

However due to extensive international seafood trade, a decision made in one fishery can influence demand and production in a (possibly poorly managed) fishery on the other side of the planet. Consequently a well-intentioned management decision aiming to reduce environmental impact from one fishery may result in a worse overall outcome at a global scale. Likewise adhering to strict economic outcomes can result in inequitable outcomes; this is particularly pronounced where artisanal (possibly subsistence) fishers are working alongside factory trawlers.

This project will provide new insights into these problems and develop valuable tools for fisheries managers and governments in both developed and developing countries. These will enable them to consider the global implications of their decisions and make informed decisions that actually target their desired goals. As well as providing methods for improving contemporary management rules, I will develop cutting edge spatial management strategies, which will be of increasing importance over the next decade.

II Is the conceptual/theoretical framework innovative and original?

Understanding the food security and environmental implications of international trade will fill a critical knowledge gap for managing fisheries at a fisheries management and international policy level. The resulting tools will be applied to answer three questions.

Question 1: How should a fishery be managed to reduce net global environmental impacts such as carbon emissions?

The societal costs of carbon emissions are rarely considered in a fishery (e.g. fisheries are exempt from the Australian carbon tax). Consequently managing fisheries to maximise profit will generally result in excessive carbon emission, as emissions costs are not paid by industry (instead they are paid by all of society at a later date through climate change impacts).

To address this problem, the carbon footprint of several fisheries has been calculated (i.e. carbon dioxide emissions per kg of fish) and some fisheries are now actively being managed to reduce their carbon footprint [10]. This is a step in the right direction, however my previous research has demonstrated that managing an individual fishery to minimize its carbon footprint can also unintentionally result in a global food production footprint increase [1]. This is because a change in supply of one seafood product will affect the consumption of other products, some with substantially higher carbon footprints. Consequently the current push to reduce carbon footprints in individual fisheries could end up being counterproductive.

I will extend my theoretical proof of concept model [1] to make it applicable to real fisheries and datasets. This will be applied to case studies to provide management advice specific to those fisheries and establish general guidelines for all fisheries. In order to answer the above question I will address the following task:

1.1 *Develop a mathematical framework to explore optimal management of a fishery for reducing global environmental impact.* This will extend on my early work in [1] and include a spatially explicit fisheries model coupled with a market substitution model. This framework will permit results from existing stock assessment models (e.g. the Tasmanian rock lobster fishery [11]) to be used directly by this model. Alternatively simple fisheries dynamics will be used for data poor fisheries. The models will be Bayesian and parameterised using Markov chain Monte Carlo (MCMC) methods in AD Model builder (ADMB), OpenBUGS and/or PyMC, depending on their complexity and application. (e.g. OpenBUGS is excellent for demonstrating techniques and simple models to a broader audience but can lack the flexibility and efficiency for complicated models).

1.2 Global implications of a local fisheries management decision depend on the international trade of that seafood product, on consumer substitution between products and on the environmental impacts of the substitutes. I will *characterize these aspects for key seafood categories corresponding to the case studies in 1.3*. Different valued products have very different dynamics and target markets and these case studies span the spectrum from low cost to luxury commodities. This analysis will utilize i) existing global trade [5], fishing and fuel consumption datasets developed at IMAS and ii) existing market studies (e.g. [12]).

1.3 *Apply the model to several case studies* including i) Australian small pelagic fishery (which has recently received much media coverage in relation to the super trawler Margiris [13]) ii) Tasmanian abalone, and iii) rock lobster [11]). These case studies will offer the opportunity to consider very different substitution regimes and model dynamics. For example, rock lobster is a luxury commodity valued over $60/kg and the substituted products could include non-food commodities. In contrast low value seafood may be substituted for with protein sources from intensive terrestrial agriculture or even by environmentally more damaging wild harvests. For each case study, the best management strategy will be explored alongside current management decisions. Results will be used to develop guidelines that can readily be applied by fisheries managers in other fisheries to estimate the overall impact of their decisions on global emissions.

Question 2: How should a fish stock be managed for fishers from different economic settings?

Most fish stocks are shared between multiple competing extractive users e.g. commercial, recreational and artisanal fishers. These competing uses create a resource allocation problem for fishery managers. Existing work has focused on exploring this issue within a single jurisdiction and most methods (e.g. contingent valuation [14]) fail to address equity and are complicated. As such, decisions are usually made through a political process, often resulting in poor outcomes. In particular a brute force application of the prevailing fisheries management aim of maximising economic yield could have disastrous consequences in many developing countries [15, 16]. To address this question this project will:

2.1 *Extend the mathematical framework in Q1.1. to consider multiple users of a single stock from very different economic settings* (e.g. artisanal fisheries operating alongside factory trawlers). This will deal with several factors including the different biomass targets that would be optimal for each fishing fleet and the food security implications for one group (e.g. subsistence fishers).

2.2 *Incorporate a social welfare function into the framework*, which will quantify equity – both in economic benefit and food security. This model will be used to explore several concepts regarding the value of artisanal fisheries that have been proposed, such as their value as a buffer in the highly uncertain economic conditions present in many developing countries [15, 16].

2.*3 Apply the resulting model to several case studies, particularly in developing countries*. A key case study is Ghana with competing subsistence, artisanal and international fleets accessing the same fishery resource. The optimal management decisions corresponding to a range of assumptions about the value of equity and food security will be explored alongside the decisions that have already been made. This will both highlight how fisheries could optimally be managed as well as revealing the implications and implicit value judgements behind historical fisheries management decisions.

Question 3: How can modern spatial technologies be used to address global food security and environmental impacts?

Most fisheries are managed on large spatial scales (e.g. a single set of rules for an entire state). Whilst this may be appropriate for some highly mobile species, historically this has largely been due to the complication and costs of managing the distribution of fishing effort at smaller spatial scales in a meaningful fashion. The advent of cheap electronics (notably GPS loggers and water proof smart phones/tablets) has enabled fisheries data collection and management at a much finer spatial and temporal scale. Some fisheries have already embraced this. For example the Australian east coast longline fishery alters the fishing ground on a fortnightly basis to avoid bycatch, using a method I developed [7]. Also the Tasmanian abalone fishery (a ~2000t dive fishery) is now collecting near complete GPS data as part of a project I am co-investigating. Small artisanal fisheries are also heading towards better informed spatial management including the Torres Strait traditional inhabitant finfish fishery. In this fishery a project I am leading will use innovations such as smart phone applications to collect fisheries data.

Management strategies utilizing this capacity are in their infancy and there is now great potential for influencing the approaches that will be adopted over coming decades. My current research suggests that the best spatial management strategy can be highly dependent on the interaction with other fisheries through global seafood trade [1]. This makes it the ideal time to develop spatial management strategies that correctly target their intended goals. To address this question this project will:

3.1 *Extend the model developed in 1.1 and 2.1 to be highly spatially explicit and include a fleet dynamics component*. Optimal spatial management strategies will be explored using this model. These methods will combat 'race to fish' traits that occur for high

catch-per-unit-effort (CPUE) periods within otherwise well managed fisheries and address environmental impacts that can't be accounted for with existing economic instruments.

3.2 *Apply the model to the Tasmanian abalone and rock lobster fisheries*. The abalone fishery is managed at a high spatial resolution, focusing on maximizing production (not considering environmental impacts) whereas the rock lobster fishery has no spatial management. The optimal management regimes for these contrasting fisheries will be compared with actual management.

III Will the aims, concepts, methods and results advance knowledge?

Each of the three research questions that comprise this project will extend existing mathematical methods and reveal new fisheries management dynamics. This will provide valuable guidance to fisheries managers and government policy makers for reducing the global footprint of food production whilst ensuring food security.

Question 1 will explore the dynamics of interactions between geographically separated fisheries that are linked by global food trade. This interaction has received limited attention in fisheries management and is becoming of increasing importance as international and national climate change policies are being introduced with the aim of reducing global environmental impacts, using measures such as the carbon tax.

Fisheries in different countries also interact where they fish the same stock. This project will consider the food security and economic implications of this effect (Question 2) which can be particularly important if one country has substantially poorer economic conditions. The developed framework will provide a quantitative method for evaluating the impacts of management decisions in this context.

Modern technology is providing new opportunities for both collecting high resolution spatial fisheries data and managing fisheries at a finer spatial resolution. This project (Question 3) will develop fisheries management strategies that utilize this whilst addressing the previous concerns about global fisheries impacts. Importantly, the scale and nature of environmental and social impacts of fishing currently ignored in management models differs from the spatial scale and nature of impacts on fish stocks that existing management policies are designed to address. Therefore, more spatially resolved management methods will likely be required in order to incorporate these missed environmental impacts in policies and management strategies.

Throughout this project the theoretical research will be applied to several case studies to provide suggestions for management improvements in those fisheries, whilst ensuring that the research remains relevant and provides insights valuable to fisheries in general.

Research Environment

Is there a supportive and collaborative research environment for the project?

Fisheries science is part of the recently formed Institute for Marine and Antarctic Studies (IMAS). IMAS has drawn together leading scientists from a range of related disciplines. In the "Excellence in Research for Australia 2012" the University of Tasmania (UTAS) ranked equal highest in the country for fisheries science (rating 4) and Oceanography

received the highest ranking (rating 5). IMAS provides a stimulating academic environment that encourages inter-disciplinary collaboration. For example I am co-supervising a PhD student with an IMAS oceanographer and have recently coauthored a paper with IMAS government policy researchers. UTAS is a research provider to the Australian Seafood CRC through which I have built strong collaborations and developed four research projects.

In the fisheries science group, seafood food security and global seafood supply has become a focal topic. A series of recent successful grants have been building this interest with IMAS staff Dr. Reg Watson, Dr. Caleb Gardner, Dr. Bridget Green and Dr. Sean Tracey making substantial contributions in this area. In addition to this four PhD students are working on related topics. The IMAS fisheries group has been building its international reputation with regular visits from eminent fisheries scientists including Prof. Ray Hilborn (University of Washington, USA) and Andre Punt (University of Washington, USA) who are among the world's leading fisheries scientists. **There is no better research environment for this project.**

The local research environment will be enhanced by strategic interactions with four close inter-disciplinary collaborations. **Paul Armsworth** (University of Tennessee and the USA National Science Foundation's National Institute for Mathematical and Biological Synthesis) is a leading mathematical ecologist whose closely related work on spatial fisheries management and conservation economics has appeared in *PNAS* and *Trends in Ecology and Evolution*. **Eleanor (EJ) Milner-Gulland** (Imperial College, UK) is an expert in ecology and human behaviour. Her closely related work on food markets in developing countries and fisheries has appeared in journals including *Frontiers in Ecology and the Environment* and *Fisheries Research*. **Christophe Béné** (Vulnerability and Poverty Reduction group, Institute of Development Studies, UK) is a socio-economist whose work on the role of artisanal fisheries has appeared in *Fish and Fisheries* and *Ecological Economics*. **Ray Hilborn** (University of Washington) is a leading fisheries scientist whose work on global fisheries dynamics has appeared thirteen times in *Nature* and *Science*. This project will be further supported through related Discovery and DORA applications that were submitted earlier in 2013 (I am a co-investigator on the Discovery application).

Will the project provide the DECRA Candidate with the capacity and opportunity to develop an independent record of innovative, high quality research?

This project will fill a crucial knowledge gap in fisheries management that will be of increasing importance over coming years. It draws on my existing expertise in areas where I have already built a strong publication record, whilst drawing on the strengths of my inter-disciplinary expertise. The resulting theoretical work will be publishable in leading applied mathematics, theoretical fisheries and ecological economics journals. Applications to global datasets (which have already been produced and are held by IMAS and collaborators) provide a clear pathway to publishing in high impact journals. This is the approach that led to my *Nature* publication [17] and has provided collaborators Watson and Hilborn with a dozen *Nature* and *Science* publications each.

Are the necessary facilities available to complete the Project?

This study involves sophisticated model formulation and application to key case studies. Essential datasets are already held at IMAS and access to others has been secured with potential fall-back case studies already identified. Ongoing meetings with collaborators are scheduled to provide additional guidance on aspects of the project in which they are world experts. I have extensive experience working with geographically spread teams (e.g. the five authors on my recent Nature publication were spread across four countries).

The modeling in this project will require only **moderate computing power**. From past experience IMAS' 48 core dedicated machine (I am the primary user) will suffice. Additional UTAS High Performance Computing facilities are also available if required.

Are there adequate strategies to encourage dissemination, commercialisation (if appropriate) and promotion of research outcomes?

I am passionate about developing theoretical frameworks *and* seeing these through to their application to real management decisions. Moreover, because I maintain exceptionally strong links with public agencies and fishery stakeholders throughout my research program, I am unusually well-positioned to realise the potential applications of my research results. For example, I have provided the model based advice used to make substantial changes to several large fisheries, including a stock rebuilding and profit maximizing strategy in the Tasmanian rock lobster fishery and a current proposal for spatial management in the same fishery. The strategies I will apply to this project are:

1. Communicate results in high impact journals. The global nature of the problems explored in this project combined with Reg Watson and Ray Hilborn's expertise and my track record make this readily achievable. Results from this project will also be communicated to peers at scientific conferences including the World Fisheries Congress, Australian Agricultural and Resource Economics Society (AARES) conference and the Australian Marine Sciences Association (AMSA) conference.
2. I have been invited to guest lecture at the *United Nations University*. This will give me the opportunity to present my research to upcoming fisheries and marine managers from a broad range of countries.
3. I will communicate my results to fisheries managers and policy makers at a national and international scale. This will be achieved through collaborations that are part of this study, publications in accessible trade magazines and presentations at fisheries management meetings. I have had extensive success in achieving this at a state level with numerous articles in trade and recreational fishing magazines and through presenting my work at dozens of industry and public meetings each year.
4. This project will involve at least two PhD students (one student recently commenced and one will be explicitly recruited for this project). These students will be ideally suited for extending this research and applying it beyond the life of this project.

Feasibility and benefit

Are the design of the project and the expertise of the participants sufficient to ensure the project can be completed with the proposed budget and timeframe?

Although this project sets ambitious goals there are four factors that will ensure they are completed in three years.

1. Key datasets for this project including global fishing patterns and comprehensive assessments of several case study species are already completed and available immediately. The data for developed country case studies is held by IMAS (rock lobster and abalone) and is updated on an ongoing basis. The required data for developing countries is freely available.

2. I have extensive experience in the core aspects of the project -- fisheries modeling at the stock level (e.g. [7, 11]), global level (e.g. [5]), biodiversity management at a global scale (e.g.[3, 17]) and spatial fisheries management (e.g. [2, 7]). Furthermore my collaborators -- world experts in their fields -- will enhance relevant aspects of the project. Paul Armsworth (University of Tennessee) and I have developed spatially explicit fisheries models for a range of purposes ([1, 2]) and will continue our collaboration throughout the project. Inter-disciplinary aspects of the project will be explored in collaboration with leaders in each of the fields: Reg Watson, Ray Hilborn (global fisheries analyses), E.J. Milner Gulland (ecology and human behaviour) and Christophe Béné (poverty and fisheries in developing countries).

3. To explore these questions more comprehensively, a PhD student will be recruited. Based on my current supervisory experience I expect the student will be able to contribute substantially to this project. I currently supervise three PhD students with another to commence shortly. One of my PhD students (commenced mid 2012) is conducting closely related work on fuel usage across Australian fisheries.

4. I have extensive experience communicating my scientific work to fisheries managers and stakeholders. My work has consequently underpinned large management decisions particularly in the $60 million revenue Tasmanian rock lobster fishery. This experience will ensure that the results from this project translate into management changes.

Will the completed project produce innovative economic, environmental, social and/or cultural benefit to Australian and international community?

This project addresses the national research priority "An Environmentally Sustainable Australia". It strongly targets two of the research goals: "Sustainable use of Australia's biodiversity" and "Responding to climate change and variability". In the marine context this project directly addresses two of the six national challenges identified in the recent Australian Government's Marine Nation 2025 report [18]– "food security" and "optimal resource allocation". As such it is clearly aligned with the government's priorities for scientific support of our "Blue Economy".

This project will fill a crucial knowledge gap in fisheries management. This will enable fisheries managers and governments to better target economic and environmental goals. The methods developed in Q1 will improve the trade-offs that are made between the

economic benefit from a fishery and the **global environmental impact**. This will be enhanced by Q3, using novel spatial management techniques. The large value of fisheries, their environmental impact and the broad applicability of this research project, mean that this work will provide significant economic and environmental benefits in Australia and internationally. This is supported by the significant changes that my existing fisheries research has provided.

Most fisheries management focuses on maximizing the overall value of the fishery – not how this is distributed among stakeholders or what benefits are accrued by the public. This project will develop new methods for including issues of equity, poverty and food security in fisheries management. This provides **social** and **cultural** benefit by enabling fisheries management to target social and cultural aims as well as economic and environmental, particularly for artisanal fisheries.

Will the proposed research be value for money?

This project will produce cutting edge research, high profile publications and at least two PhD graduates. The proposed collaborations will bring acclaimed international expertise into the IMAS fisheries program. I will strive to inform policy and management decisions - in fisheries this can provide substantial economic benefit from improved management. For example the Tasmanian abalone fishery (one of the case studies) has revenue exceeding $100 million per annum. If (as intended) this project provides even a small improvement in the management of this fishery, this benefit alone would exceed the value of this project. In addition to the case study fisheries, this project aims to directly have an impact on fisheries management globally through dissemination of the methods.

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