Multiple management objectives within a mixed prawn fishery: which win-win-win situations?

Sophie Gourguet[a], Olivier Thébaud[a,b], Sarah Jennings[c], Rich Little[d], Cathy Dichmont[e], Sean Pascoe[e], and Luc Doyen[f]*

[a] *IFREMER,UMR M101, AMURE, Unité d'Economie Maritime, BP 70, 29280 Plouzané, France*
[b] *School of Economics and Finance, Queensland University of Technology, Australia*
[c] *Tasmanian School of Business and Economics, University of Tasmania, Hobart, TAS 7001, Australia*
[d] *CSIRO Oceans and Atmosphere Flagship, PO Box 1538, Hobart, TAS 7001, Australia*
[e] *CSIRO Marine and Atmospheric Research, 41 Boggo Road, Dutton Park, QLD 4102, Australia*
[f] *CNRS, GREThA, University of Bordeaux, avenue Léon Duguit, 33608 Pessac cedex, France*
**Corresponding author: sophie.gourguet@ifremer.fr*

Summary
Fisheries management must address multiple, often conflicting objectives in a highly uncertain context. While the bio-economic performance of trawl fisheries faces high levels of biological and economic uncertainty, the impact of trawling on broader biodiversity is also a major concern for their management. The purpose of this study is to propose a model-based framework to formally assess the trade-offs associated with balancing biological, economic and non-target species conservation objectives in a mixed fishery. This framework is applied to the Australian Northern Prawn Fishery (NPF). We apply a stochastic co-viability framework of analysis to a multi-species bio-economic model of the NPF considering multiple management objectives. In particular, we consider the implications of including a formal non-target species conservation constraint. Results show that, due to the variability in the interactions between the fishery and the ecosystem, current management strategies present biological and economic risks. The trade-offs associated with respecting at each point in time biological, economic and non-target species conservation constraints with high probability and maximizing the net present value of the fishery are quantified.

Introduction
Fishing activities, like trawling, affect not only the target stocks, but also populations of non-target species. In the case of demersal trawling, such as prawn trawling, fishing activities can be particularly damaging to non-target species and habitats. It is therefore important to take these impacts into account when assessing management strategies.
Marine fisheries management is characterized by multiple, often conflicting objectives. As stressed by Cheung and Sumaila (2008), understanding the trade-offs between various objectives is important in evaluating policies to manage ecosystems and fisheries. The stochastic co-viability approach (Doyen and De Lara, 2010; Martinet *et al*, 2010; Gourguet *et al*, 2013) has been proposed as a relevant framework for quantifying the performance of fishery management strategies against multiple management objectives under uncertainty.
The objective of this paper is to propose a model-based framework that characterizes the trade-offs associated with alternative management strategies in a mixed fishery, with specific emphasis on the consequences of pursuing biological, economic and non-target species conservation objectives. The framework is applied to the Australian Northern Prawn Fishery (NPF), where we consider the implications of including a formal non-target species conservation constraint for the co-viability of fishing management strategies.

Materials and methods
The Australian Northern Prawn Fishery (NPF), situated off Australia's northern coast, is a multi-species trawl fishery targeting several tropical prawn species with different dynamics and recruitment

processes. We use a bio-economic model presented in Gourguet *et al*. (2014). NPF operations interact with several groups of threatened, endangered and protected (TEP) species. The amount of by-catch species caught in prawn trawl nets has been significantly reduced since 2000 through the mandatory introduction of Turtle Excluder Devices (TEDs) and By-catch Reduction Devices (BRDs). However, Brewer *et al* (2006) estimate that nets with a combination of TED and BRD reduced the catches of sea snakes (*Hydrophiidae*) by only 5%. Moreover, there has been growing concern over the impact of prawn trawling in the NPF on sea snake populations since their addition to the 'Listed Marine Species' by the Department of Environment and Water Resources in 2000. Based on these concerns, we include trawling impacts on sea snakes in our analysis, and examine the ability of fishing management strategies to meet multiple constraints imposed on the fishery. Management strategies differ in the number of vessels involved across the fishery. The performance of management strategies is evaluated in terms of co-viability probability (CVA) and average net present value (NPV). The co-viability probability measures the capacity of the fishery to respect, at each point in time, constraints related to the objectives of preserving target stocks, maintaining acceptable levels of annual profit, and reducing the impacts of the fishery on non-target species such as sea snakes.

Results and discussion

Results show that while the status quo management strategy appears to be constrained by a fleet size that is more conservative than the one that would maximize NPV, this smaller fleet size does not meet the inter-annual biological and economic constraints. Higher co-viability probabilities can be achieved, but only at the cost of forgoing economic yield in the fishery. Limiting biological and economic risks would indeed require reductions in the fleet size compared to the status quo, which entails lost economic returns. Results also show that reductions in levels of impacts of trawling on sea snakes are likely to depend on the extent to which operators in the fishery accept higher levels of risks. Although co-viability probabilities must be interpreted with caution due to the sensitivity of these results to the constraints and associated threshold values, comparisons between management strategies do not change qualitatively when multiple threshold values are tested. The proposed framework can assist fisheries managers and stakeholders in seeking consensus when assessing management strategies. Promising future developments of this approach involve the incorporation of a broader set of objectives including social dimensions, as well as the integration of ecological interactions, to better address the needs of ecosystem-based approaches to the sustainable harvesting of marine biodiversity.

References

Cheung, W. W. L., and Sumaila U. R. 2008. Trade-offs between conservation and socio-economic objectives in managing a tropical marine ecosystem. Ecological Economics, 66(1):193–210.

Doyen, L., and De Lara, M. 2010. Stochastic viability and dynamic programming. Systems & Control Letters, 59(10):629–634.

Martinet, V., Thébaud, O., and Rapaport, A. 2010. Hare or tortoise? trade-offs in recovering sustainable bioeconomic systems. Environmental Modeling and Assessment, 15(6):503–517.

Gourguet, S., Macher, C., Doyen, L., Thébaud, O., Bertignac, M., and Guyader, O. (2013) Managing mixed fisheries for bio-economic viability. Fisheries Research, 140:46–62.

Gourguet, S., Thébaud, O., Dichmont, C. M., Jennings, S., Little, L. R., Pascoe, S., Deng, R. A., and Doyen, L. 2014. Risk versus economic performance in a mixed fishery. Ecological Economics, 99:110–120.

Brewer, D., Heales, D., Milton, D., Dell, Q., Fry, G., Venables, B., and Jones, P. 2006. The impact of turtle excluder devices and bycatch reduction devices on diverse tropical marine communities in Australia's Northern prawn trawl fishery. Fisheries Research, 81(2):176–188.