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Managing fisheries for environmental performance: the effects of marine resource decision-making on the footprint of seafood

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ABSTRACT

The concept of seafood sustainability does not typically include the energetic or material demands of the capture or supply chain processes, despite the significant impacts they generate. We used life cycle assessment (LCA) to measure the environmental footprint of the supply of Tasmanian southern rock lobster, *Jasus edwardsii* (TSRL). International airfreight of live lobsters was the major contributor to global warming potential (GWP) and cumulative energy demand (CED) indicators, while the fishing stage accounted for the majority of impacts to eutrophication potential (EP), water use and marine aquatic ecotoxicity. The environmental footprint of the TSRL in our scenarios was responsive to marine resource management decisions made inside and outside the fishery. Targeting maximum economic yield rather than maximum sustainable yield decreased the carbon footprint by 80% or 10 kg CO_2e kg^{-1} of lobster at capture. Limiting access to the fishery by increasing the coverage of marine protected areas increased the fishery's carbon footprint by 23% or 3 kg CO_2e kg^{-1} of lobster at capture. The unintended consequences of management changes suggest that in a future of increased carbon emission regulation, marine resource decision making should not be made in isolation of broader environmental impacts.

1. Introduction

Improving the environmental sustainability of seafood supply is typically associated with protecting the target species (Worm et al., 2009), non-target species (Hilborn, 2007a) and reducing ecosystem impacts (Pelletier and Tyedmers, 2008), as fisheries management evolves towards an ecosystem-based fisheries management (EBFM) approach (Zhou et al., 2010). However, the broader environmental impacts generated by fisheries, in particular the use of fossil fuel in vessels (Tyedmers et al., 2005; Tyedmers and Parker, 2012; Ziegler and Hansson, 2003; Thrane, 2004a) and the transportation of landings (Andersen, 2002; Winther et al., 2009; Karlsen and Angelfoss, 2000), have largely been excluded from the ecosystem approach, despite their substantial impact (Pelletier et al., 2007).

The implications of improving our understanding and management of the wider impacts of seafood production are significant given the scale of global seafood production. In 2011 approximately 154 million tonnes of seafood was produced globally from capture fisheries (marine and inland) and aquaculture (FAO, 2012), accounting for approximately 16% of the world population's intake of animal protein and 7% of all protein consumed (FAO, 2010). Food production is expected to increase due to growing demand (FAO, 2009), with demand for animal protein in particular influenced by the growth in affluence of emerging economies (Speedy, 2002).

Marine capture fisheries contributed 51% of the total seafood produced in 2011 (FAO, 2012) and at the same time were accountable for about 1.2% of global oil consumption and the emission of more than 130 million t of CO_2 into the atmosphere (Tyedmers et al., 2005). Additional emissions are generated by processes occurring beyond the capture phase in marine fisheries, in particular from transport, as seafood is the most highly traded food product (Smith et al., 2010). Over 5% of the world annual seafood catch is transported by air freight and this figure will likely increase with growing demand for fresh fish (FAO, 2005).

Abbreviations: CED, cumulative energy demand; CPUE, catch per unit effort; EBFM, ecosystem-based fisheries management; FUI, fuel use intensity; GWP, global warming potential; LCA, life cycle assessment; MEY, maximum economic yield; MPA, marine protected area; MSY, maximum sustainable yield; TSRL, Tasmanian southern rock lobster; TAC, total allowable catch.

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Fisheries are managed for a range of objectives, encompassing biological, economic, social and political goals (Hilborn, 2007b). Harvests can be controlled by many methods, broadly grouped as either input or output (catch) controls (Beddington et al., 2007). Output controls directly limit the amount of fish which can be taken from the water each period with a Total Allowable Catch (TAC). Input controls indirectly control the catch through restrictions on fishing, such as limits on the number of licences, capacity of boats, and gear restrictions.

A common historic goal for sustainable harvest in fisheries is Maximum Sustainable Yield (MSY) (Worm et al., 2009), where ongoing biological yield, or food production, is maximised (Fig. 1). This objective can be implemented by applying the level of fishing effort that produces the maximum yield, without affecting long-term productivity (Sparre and Venema, 1998). MSY has been incorporated into the 1982 United Nations Convention on the Law of the Sea, thereby facilitating its integration into national fisheries acts and laws in several countries (Mace, 2001). While MSY provides maximum sustainable biological production, it does not necessarily maximise other common objectives such as employment, ecosystem preservation or economic profitability (Hilborn, 2007b; Larkin, 1977; Punt et al., 2001; Mardle et al., 2002).

Sustainable Maximum Economic Yield (MEY) has recently been implemented as an alternative fisheries management target (Grafton et al., 2010) including in many fisheries in Australia and the United States. Under a MEY harvest target, economic yield is maintained sustainably over the long run at the biomass or effort level where the difference between the costs of harvesting the fish and the revenues obtained from the catch is greatest (Fig. 1) (Norman-López and Pascoe, 2011). Compared to a MSY-managed fishery, a target of MEY tends to be more conservative and will generally result in reduced fishing mortality (or catch) and higher biomass (Kompas et al., 2011). This occurs because economic yield is affected by the cost of fishing, which is reduced when biomass or stock abundance is higher.

Objectives related to sustainability of the marine environment are also targeted directly through management systems, for example, Marine Protected Areas (MPAs), which aim to protect biodiversity (Browman and Stergiou, 2004). MPAs can affect commercial fisheries and assessments of the impacts of closing areas to fishing typically account for effects on catch and profit in the fishery, but not the effects on the broad environmental impacts of fishing.

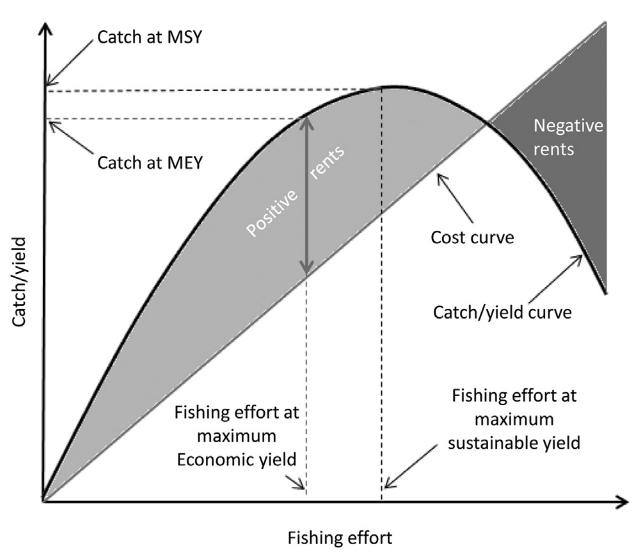

Fig. 1. Relationship between Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY), based on the original Schaefer model as presented by World Bank and FAO (2008).

We used life cycle assessment (LCA) to examine the unintended, and generally unacknowledged, environmental consequences of commonly applied fishery management policies and a competing marine resource use on the footprint of supplying Tasmanian southern rock lobster (TSRL) for export. LCA is a tool endorsed by the United Nations to promote sustainable patterns of production and consumption, and to increase the eco-efficiency of products and services (Hertwich, 2005). This research illustrates how incorporating LCA considerations into fisheries management can provide information required to enhance the sustainability of seafood supply.

1.1. *Study fishery: Tasmanian southern rock lobster (TSRL)*

Southern rock lobster (*Jasus edwardsii*) was selected as a case study as it is representative of the growing trade in airfreighted seafood and is a single species fishery that experiences a range of management strategies across the 13 jurisdictions where it occurs. The Tasmanian fishery is managed as one stock and commercial catch is taken from areas all around the state. The catch is mainly exported live and marketed to China's growing middle class (ABARE, 2009). The TSRL fishery is an inshore coastal fishery, ranging from zero to 200 m depth, where 80% of traps are set at less than 50 m. In the 2010/11 season 236 licensed vessels reported catches of rock lobster (Hartmann et al., 2012). Commercial harvests of TSRL are controlled with a quota management system plus size limits, season and gear restrictions (Gardner et al., 2011). Fishers use baited traps with approximately equal parts Tasmanian caught Australian salmon (*Arripis trutta*) and jack mackerel (*Trachurus declivis*), and barracouta (*Thyrsites atun*) imported from New Zealand.

2. Methods

2.1. *Life cycle assessment*

Life cycle assessment (LCA) provides a holistic framework for comparing products, production methods or changes made along the supply chain using methods standardised through the International Organization for Standardization (ISO, 2006a, 2006b). The functional unit of comparison used here was 1 kg of live lobster at the point of arrival in the main export market of Beijing, China. The life cycle includes capture, storage, packaging and transport of live lobsters to market [refer to van Putten et al., 2013]. The supply chain was included to determine the relative importance of the fishery stage to the environmental footprint under different fishery management scenarios. All processes during capture and export of TSRL were included, however capital goods such as fishing boats, vehicles and buildings, were excluded as they are generally of minor importance (Ellingsen and Pedersen, 2004; Thrane, 2004b; Ellingsen and Aanondsen, 2006; Hospido and Tyedmers, 2005). By-catch and discards in rock lobster fisheries are low (Gardner et al., 2011; Brock et al., 2007), including for TSRL juveniles which can exit through mandatory escape gaps in traps, and so we considered the fishery a single species fishery. While processors occasionally handle other species from other fisheries, the volume of these species is small and does not alter the functioning of the processing facility.

2.2. *Software and impact assessment methods specific to Australia*

Impact categories, or indicators, were selected from the Australian Indicator set (v2) for their relevance to Australia as well