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Life cycle assessment of the Maine and southwest Nova Scotia lobster industries

John Driscoll*, Catherine Boyd, Peter Tyedmers

School for Resource and Environmental Studies, Dalhousie University, 6100 University Ave, Suite 5010, Halifax, Nova Scotia B3H 4R2, Canada

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ABSTRACT

Commercial fisheries contribute to a number of non-localized environmental and resource depletion problems, such as climate change, through the provision and use of fossil fuels, vessels, gear, refrigeration, and bait, and during post-capture processes. Here, we investigate the degree to which different management regimes may affect two fisheries' contributions to a suite of non-localized environmental concerns. Life cycle assessment (LCA) is used to quantify the contributions made by the 2006 Maine and 2005–2006 southwest Nova Scotia fisheries for American lobster (*Homarus americanus*) to a suite of global environmental problems. The lobster fishery phase was the primary driver of resource and environmental impacts as characterized in the selected impact categories. Direct diesel use by the lobster boat was the primary source of impacts at the fishery phase, but the provision and use of bait was also a substantial contributor, particularly in the Maine fishery. Post-capture transportation of live lobster by air was a major contributor in the LFA 34 model. Lobstermen in both fisheries reported using approximately one liter of fuel per kilogram of lobster landings, but Maine lobstermen reported using three kilograms of bait per kilogram of lobster landings, while LFA 34 lobstermen reported using only one kilogram of bait per kilogram landings. The difference in bait use per unit landings resulted in the Maine lobster fishery having slightly higher global environmental impacts, when measured by the chosen impact categories, than the Nova Scotia fishery. However, the two fisheries' contributions to the selected environmental impact categories were broadly similar, despite their different management regimes, and an obvious influence of management was not identified. The findings for the lobster fisheries are placed into context with other food production systems.

1. Introduction

1.1. Marine capture fisheries and the environment

Relative to the attention paid to issues such as bycatch and habitat impact, little attention has been paid to commercial fishing's contributions to less-localized resource depletion and environmental problems (Pelletier and Tyedmers, 2008). These "global" scale concerns include climate change, depletion of the stratospheric ozone layer, and the depletion of non-renewable resources, among others. For fisheries, fossil fuel use by commercial fishing vessels tends to be the greatest contributor to such global environmental impacts (Hospido and Tyedmers, 2005; Parker and Tyedmers, 2012a; Ziegler et al., 2003). Fisheries may also contribute to global-scale concerns through processes that supply bait, ice, fishing gear, anti-fouling paint, and refrigeration capability, as well as through post-capture transport, storage, and processing of the catch (Hospido and Tyedmers, 2005; Parker and Tyedmers, 2012a; Ziegler et al., 2003).

Since management decisions can alter the scale and types of gear used, the number and characteristics of vessels deployed, and general fishing practices of a fleet, today's management decisions may cause changes in a fleet's fuel use and contribution to global environmental challenges that will be hard to reverse in the future (Driscoll and Tyedmers, 2010). Here, we report on a study that used life cycle assessment (LCA) to quantify the contributions made to a suite of well-known global environmental and resource concerns by the activities associated with the Maine and southwest Nova Scotia fisheries for American lobster (*Homarus americanus*, hereafter referred to as "lobster"), as they were conducted in calendar year 2006 (Maine) and the 2005–2006 fishing

* Corresponding author. Present address: Institute for Resources, Environment, and Sustainability, University of British Columbia, 2202 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada.
E-mail addresses: john.david.driscoll@gmail.com (J. Driscoll), catherineboyd@gmail.com (C. Boyd), peter.tyedmers@dal.ca (P. Tyedmers).

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season (southwest Nova Scotia). We then discuss similarities and differences between the two fisheries, with particular attention paid to potential influences by the different policy and management systems that governed the two fisheries during the specified time periods.

1.2. North american lobster industries

In the year of this study (2006), lobster was the single most commercially lucrative marine species in the United States (NMFS, 2008a) and Canada (DFO, 2008). While lobster landings only accounted for 1% of that year's total US commercial fisheries landings by mass, they represented 10% of the total value of U.S. commercial landings that year (NMFS, 2008a). The economic importance of lobster was even more pronounced in Canada: while lobster landings composed approximately 5% of the mass of all commercial Canadian landings in 2006, they accounted for 34% of the total value of all Canadian fisheries landings (DFO, 2008).

1.2.1. Maine and lobster fishing area 34

Maine and Nova Scotia share extensive coastlines on the Gulf of Maine (Fig. 1), and were the two most important lobster producing jurisdictions in their respective nations in the year of this study, accounting for 34% and 32% of total 2006 North American lobster landings, respectively (NMFS, 2008b, DFO, 2008). For management purposes, waters in Atlantic Canada are divided into Lobster Fishing Areas (LFAs), with the most productive one being LFA 34 (Fig. 1).

Although similar with respect to gear type and deployment, target species, and physical environment, the lobster fisheries in Maine and LFA 34 differed considerably in their respective policy and management schemes at the time of this study (Table 1).

2. Methods

LCA is an internationally standardized biophysical accounting framework (ISO, 2006) that has been used to evaluate the environmental impacts of various foodstuffs (Andersson, 2000), agricultural systems (Haas et al., 2001; Heller and Keoleian, 2003; Hospido et al., 2003), and seafood production systems (Ayer and Tyedmers, 2009; Ellingsen and Aanondsen, 2006; Hornborg et al., 2012; Hospido and Tyedmers, 2005; Papatryphon et al., 2004; Parker and Tyedmers, 2012a; Pelletier and Tyedmers, 2007; Pelletier et al., 2009; Ramos et al., 2011, Thrane, 2006; Ziegler et al., 2003). LCAs include four components: goal and scope definition, life cycle inventory analysis, life cycle impact assessment, and interpretation (Avadi and Freon, 2013; ISO, 2006).

Table 1
Summary of commercial lobster fishing regulations in 2006 for Maine and LFA 34.

Restriction	Maine	LFA 34
Season	Year-round[a]	Last Monday in November–May 31
Trap limit	800 in water[b]	375 until March 31, 400 thereafter
Vessel length	No limit	<45'
Carapace length (minimum)	82.5 mm	82.5 mm
Identify (V-Notch) Egg-Bearing females	Mandatory	Not mandatory
Possession of V-Notched females	Illegal	Illegal
Number of licenses (2006)	5,764[c]	967[d]
Limited entry	Yes	Yes
License retirement	Yes	No

[a] Except for season (December 1–June 30) in Monhegan Island Lobster Conservation Area.
[b] Except for 600 trap limit in Monhegan Island Lobster Conservation Area.
[c] Sum of all LC 1, 2, and 3 in zones A–G (DMR, 2008).
[d] 937 licenses are full-time, 30 licenses are Commercial Communal (First Nations; DFO, 2006).

2.1. Goal, scope, functional unit, and system boundaries

This study was designed to quantify the contributions made by the Maine and LFA 34 lobster fisheries to a range of environmental concerns. The systems of study were the 2006 Maine and 2005–2006 LFA 34 lobster fisheries, and associated processes. The functional unit for the Maine study was one metric ton of live lobster, caught in calendar year 2006, delivered to a live storage facility in Boston, Massachusetts, and stored for 72 h. For the Nova Scotia study, the functional unit was one metric ton of live lobster caught in the 2005–2006 fishing season (last Monday in November, 2005, through May 31, 2006; Table 1) and delivered to Las Vegas, Nevada. The boundaries of the analyses encompassed those processes required for the provision and/or use of the vessel, gear, bait, fuel, and post-capture storage and transport of live lobster (Fig. 2). The models of post-capture transport reflected common distribution networks for lobster caught in the Maine and LFA 34 fisheries (e.g., regional distribution for Maine lobster, and distribution to distant U.S. markets for LFA 34 lobster).

2.2. Allocation

Lobstermen use the post-processing remnants ("racks") of several fish species for bait. The environmental burdens associated with the fishery phase for each of these species were allocated between racks and fillets by mass (Ayer et al., 2007; Pelletier and Tyedmers, 2011). For the Maine LCA, the impact of this allocation decision was evaluated as part of a sensitivity analysis (see Sections 2.5 and 3.3 for description and results, respectively, of this sensitivity analysis).

2.3. Life cycle inventory

2.3.1. Data collection

For the Maine LCA, data related to fishing effort, trap use, vessel characteristics, anti-fouling paint application, fuel and bait use, and lobster landings for the 2006 fishing season were collected via a one-page mail-out survey, sent with a stamped return envelope to 4000 randomly-selected Maine lobster license holders between April and August, 2007. Inputs to trap and vessel construction, bait storage and processing, and post-capture transport and storage of lobster (except for electricity use at the storage stage) were determined from interviews with representative businesses. Fuel use data for bait fisheries were obtained from the Northeast Fisheries Science Center's Fisheries Sampling Branch (for Atlantic herring fisheries) and the literature (Tyedmers, 2004). Electricity use for live lobster storage was calculated based on a model of the electrical requirements of water pumping and chilling (Lobster Institute, 2001; SeaFish.org, 1990).

A questionnaire was developed and administered to 250 of the 979 licensed lobstermen to determine the typical style of fishing carried out in LFA 34. Particular effort was made to ensure lobstermen from a variety of communities and who fished different distances from shore were surveyed. The questionnaire was designed to elicit detailed data on average annual fuel use, bait use (quantity and species), bycatch (quantity and species), and boat and gear characteristics. Representatives from the fisheries that catch fish destined for bait were contacted for data on fuel inputs to fishing. Electricity data for bait freezing and storage were collected through an on-site visit with a large bait supplier and follow up e-mail communication. Data regarding operational energy inputs to tank houses and drip system operations were collected from