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Cyclical harvesting in fisheries with bycatch

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ABSTRACT

Bycatch is often a concern in sustainable fisheries management due to its contribution to overfishing problems. This paper examines bycatch in a multi-sector fishery in which the gear of one sector is imperfectly selective while in the other it is perfectly selective. In the model, the two stocks are biologically independent so the fisheries are only linked through the nonselective harvest externality. An important difference between this paper and prior work is that the bycatch problem and its solution are examined in a dynamic context. In an application to a commercial-recreational fishery, the two-sector harvest policy that maximizes social welfare is found to be cyclical rather than steady-state.

1. Introduction

Bycatch is often a concern in sustainable fisheries management due to its contribution to overfishing problems. Bycatch occurs when fishing gear is nonselective, so that both targeted and non-targeted species are caught from the same effort. It is common for bycatch to be discarded, often with a substantial mortality rate, and it is estimated that over one-quarter of all globally harvested weight is lost in this manner (Alverson et al., 1994). Indeed, in some fisheries more biomass is discarded than kept (Harrington et al., 2005). The contribution of bycatch to overfishing is severe enough that it is considered one of the greatest threats to marine species (Kappel, 2005).

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The global extent of the bycatch problem has attracted a substantial amount of economic research (Pascoe et al., 2010). Much of this work is motivated by problems in which the stock subjected to bycatch is itself valuable and targeted commercially (e.g. Anderson, 1994; Boyce, 1996; Herrera, 2005) or caught recreationally (e.g. Ward, 1994) in multi-sector fisheries, or even enjoyed through existence values (e.g. Hoagland and Jin, 1997). In general, managing fisheries with bycatch using traditional harvest quota policies will be inefficient (Androkovich and Stollery, 1994; Abbott and Wilen, 2009; Holland, 2000).

The existing literature on multi-sector fisheries experiencing bycatch offers insights into the use of various regulatory instruments, including total allowable catches (TACs), individual quotas, taxes and bycatch reduction devices. However, only a few of these papers have examined these mechanisms using dynamic bioeconomic models (Ward, 1994; Androkovich and Stollery, 1994; Herrera, 2005; Skonhoft et al., 2012). Otherwise, there is presently little research that accounts for the role that stock dynamics play in managing a fishery with bycatch. Prior work also assumes or suggests that the optimal equilibrium management regime will be a steady state—that is, constant through time (e.g. Ward, 1994; Androkovich and Stollery, 1994; Reithe, 2006).[1] Outside the context of multi-sector bycatch problems, though, it is widely recognized that optimal fisheries management policies can be cyclical rather than steady-state, particularly for multispecies systems (Fenichel et al., 2010) and when harvesting is nonselective (Tahvonen, 2009).

This paper presents a bioeconomic model of bycatch in a joint commercial-recreational fishery. That is, it analyzes a multispecies system in which the commercial and recreational sectors harvest from two biologically independent fish stocks. The commercial sector's effort is nonselective and produces bycatch while the recreational harvest is selective. Managers use a quota system to regulate effort in the commercial and recreational sectors in order to maximize the net present value of the fisheries.

The analysis presented below offers several contributions to the economics of multispecies harvesting generally and bycatch management in particular. First, the solution to the dynamic multi-sector harvesting problem is derived analytically. Second, the paper builds on the existing bycatch literature by numerically examining the transition path to the long-run equilibrium. Third, the analysis shows that the optimal equilibrium harvesting policy tends to be cyclical, transitioning between states of intensive and relaxed exploitation on the parts of the two harvesting sectors. This result is closely related to prior research on the role of physical and biological capital in renewable resource extraction problems (Wirl, 1992; Liski et al., 2001; Horan et al., 2008). During the cycle a corner solution may be reached, which involves temporarily shutting down one or both harvesting sectors. This characteristic is consistent with a pattern of pulse fishing although it has not yet been identified in a model of separate harvesting sectors exploiting a multispecies system.

This investigation is motivated by a bycatch problem observed in the Great Lakes (Johnson et al., 2004a). Although smaller in scope—boat crews tend to include between one and three people—freshwater fisheries, like marine fisheries, are known to use nonselective gear, such as gill or trap nets (Raby et al., 2011). In the Great Lakes, these methods are used by commercial fishers to harvest lake whitefish (*Coregonus clupeaformis*) but result in the incidental catch of lake trout (*Salvelinus namaycush*), a species targeted by an active and valuable recreational fishing sector. Thus, the nonselective harvesting gear of commercial fishers imposes a potentially significant technological externality on recreational anglers.

2. Model

First, we develop a model of harvesting from a two-species system. The following assumptions are consistent with numerous multispecies fishery problems although they are adopted specifically to fit the motivating case study. Ecologically, the biomass of these species, denoted by s (lake trout) and w (lake whitefish), do not interact. The species s is susceptible to bycatch. There are two harvesting sectors: one is commercial and the other is recreational. The commercial sector uses a non-selective

[1] Skonhoft et al. (2012) is an exception here in that they do analytically verify that the equilibrium is a steady state, although in their paper bycatch is associated with the exploitation of an age-structured population rather than two different species.