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Regulation of fisheries bycatch with common-pool output quotas

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ABSTRACT

Many fisheries around the world are plagued with the problem of bycatch—the inadvertent harvesting and discard of non-targeted species. Bycatch occurs when targeted and non-targeted species coincide in the same habitat and gear is imperfectly selective. One of the prevailing methods of controlling bycatch is the common-pool quota system. Under this system, biologists set total allowable catches (TACs) for both the targeted and non-targeted species, and the fishing season is closed when one of these TACs binds. We develop a predictive model of a renewable resource that is regulated with this kind of common-pool quota system. The model demonstrates that the equilibrium will generally be characterized by excessive discards, shortened seasons, and foregone target species harvest. These results occur even with very efficient (low bycatch) fishing gear. We examine the sensitivity of our predictions to changes in technological parameters and degrees of spatial correlation of target and non-target species. Finally, we derive the optimal bycatch penalty function and describe its significance in light of various policy options available to regulators.

"Bycatch and waste are currently the greatest threats to the commercial fishing industry…A fish that is caught and thrown back dead does not add anything to the economy. It does not put food on the table."—Rep. Wayne T. Gilchrest (R-MD).[1]

1. Introduction

The bycatch and discard of non-targeted species is ubiquitous in today's fisheries. The spatial coexistence of marine species, imperfectly selective gear, and incentive-distorting managerial policies cause a significant portion of catch to diverge from the desired species, sex, or size. Some of this bycatch finds its way into (typically low-valued) markets, but the vast majority is returned to the sea as discards. Early estimates placed the volume of discards at 17.9 metric tons a year, approximately 25% of global landings [1], although a recent reassessment [13] places the proportion at around 8%.

The sheer volume of these discards and their mortality, the charismatic nature of some bycatch species (e.g. sea turtles and dolphins), and the spillovers between fisheries has led to a vociferous outcry from conservation organizations, industry groups, and the general public to reduce bycatch mortality. The upshot, particularly in developed countries with command

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[1] Quoted in the Congressional Record v.141, H10238, 10/18/95.

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and control fisheries practices, has been new policies directed at curtailing the bycatch problem.[2] Along with mandated bycatch-averting gears and time and area closures to protect vulnerable aggregations of bycatch species, a common instrument has been the use of industry-wide quotas on both target and bycatch species. These quotas are enforced by seasonal closure of the fishery upon attainment of any of these quotas. In some cases, the quotas are allocated on an individual vessel basis (as for halibut bycatch quota in the Alaska sablefish fishery) and freely transferable across vessels (as in the New Zealand and Iceland individual fishing quota (IFQ) programs). However, it is more often the case that the quotas are allocated to an entire fleet and are thus common-pool resources to many fishermen. This is most notably the case in several valuable North Pacific groundfish fisheries, but similar management institutions exist for a number of fisheries.[3]

In one of the first papers to address the economics of bycatch, Boyce [5] characterized the open access outcome in a two species system with a joint harvesting technology and found that open access leads to excessive entry and a shortened season relative to the optimal static outcome. Writing about the related topic of discards in an IFQ system, Anderson [2], Arnason [3], and Turner [23] conclude that IFQs on landings tend to generate incentives that promote excessive discards of lesser valued grades or species (a practice known as highgrading). This occurs despite Boyce's finding that IFQs (which are based upon catch in his formulation) could generate the static optimal outcome provided none of the species involved possessed a non-market value.[4]

All of this prior research has followed the bioeconomic modus operandi, comparing open access outcomes with first-best optima. By contrast, there has been little research examining what actually is in the real world, as opposed to what might be.[5] This paper is motivated by the desire to understand some common features of real-world fisheries for which bycatch is an important management focus. These fisheries have several characteristics in common, including: (1) high capital costs and other economic barriers to entry; (2) imperfectly selective gear; (3) management with common-pool quotas on both targeted and bycatch species, enforced with season limits; and (4) limited entry programs restricting fleet size. This combination creates the possibility of strategic behavior in the harvest decisions of fishermen.[6] In such cases, fishermen know that regulators will either close or drastically curtail the target fishery when one of the quotas becomes binding. In small numbers settings, fishermen have incentives to consider the impact of their harvest behavior (conditional on the anticipated behavior of their competitors) on the equilibrium season length. Strategic behavior combined with the complexities of joint production yield a rich array of behaviors. Illuminating the connection between regulatory institutions, fishermen's incentives and bycatch outcomes is worthwhile for understanding the status quo and aiding in the development of more effective alternative policies.

To this end, we develop a simple static and deterministic game in which fishermen jointly harvest target and bycatch species in a multiple common-pool quota setting.[7] This stylized model captures a sufficient number of the aspects of actual bycatch regulation to provide a useful "metaphor" for analyzing fishermen's incentives under these programs relative to the first-best situation. The objective in our quota-constrained problem is to maximize industry profits rather than a broader social welfare maximization. Such a perspective is justified for common cases where bycatch quotas for a target fishery can be taken as given and pre-determined by regulators, rather than determined as part of an optimal solution (or, alternatively where bycatch species have little or no non-market value from a social perspective).

2. The model and the quota-constrained optimum

Assume for a particular season there are N vessels operating in the fishery. The vessels and their captains are homogeneous, face no significant stock or congestion externalities and minimally discount intra-seasonal rents so that a static framework can be employed. We also presume that fishermen remain in the fishery and do not alter their gear in the course of a season so that only variable revenues and costs are salient to decision making. At the beginning of the season, captain i makes a choice of the quantity of target species to harvest (h_X) on a daily basis, limited by restrictions of gear, fishing time, and the intrinsic productivity of the grounds so that $0 \leqslant h_X \leqslant \bar{h}$.[8]

[2] For instance, since the re-authorization of the Magnuson-Stevens Act in 1996 the United States' NOAA Fisheries has been under a Congressional mandate to minimize, "to the extent practicable", bycatch and its associated mortality. This mandate was made all the more pressing when in 2002 an environmental NGO demanded that NOAA initiate rulemaking to "count, cap, and control bycatch in the nation's fisheries" [15].

[3] For instance, the Hawaiian longline swordfish fisheries and the New Zealand arrow squid fishery both face common-pool quotas on key bycatch species [8,17].

[4] This summary of the conceptual bycatch literature is necessarily selective. There is also a growing empirical literature relying on multiple output production technologies and advances in the characterization of undesirable outputs to analyze bycatch and discards [9,18,19].

[5] A notable exception is Larson, House and Terry [14], who utilize a clever combination of linear programming and empirical production economic techniques to examine the reallocation of multispecies quotas across target fleets in the Bering Sea pollock fishery.

[6] Herrera [11] and Jensen and Vestergaard [12] consider the problem of strategic interactions between catch-discarding fishermen and a regulator, but their work concerns the moral hazard problem of discards, whereas ours focuses on the intra-seasonal game played amongst fishermen and between fishermen and regulators even when complete and perfect information is available on all sides.

[7] This paper defines bycatch as the catch of non-target species. Our model does not apply to highgrading.

[8] In reality, catch rates are quite variable on a daily basis given the stochastic environment in which fishing often occurs. Our model can be interpreted as determining the *expected* levels of harvest and bycatch chosen by risk-neutral fishermen in industrial fisheries, where expected profit maximization is a reasonable objective.