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Are marine reserves and harvest control rules substitutes or complements for rebuilding fisheries?

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ABSTRACT

Harvest control rules and no-take marine reserves are two management approaches increasingly advocated as effective means of rebuilding depleted fish stocks and averting the collapse of fisheries. We incorporate the two approaches into a bioeconomic model and evaluate how they act as substitutes and/or complements when used together in fisheries stock recovery plans. Simulations of the model with estimated parameters from an actual fishery show that the cost of adopting a harvest strategy of slow stock rebuilding can be offset or substituted by a no-take reserve. For each of the harvest strategies explored, we find there is a range of reserve sizes that can act as a complement in a stock recovery plan such that a no-take reserve improves both the profitability of fishers and average annual harvest during stock rebuilding. We demonstrate that a stock recovery plan that incorporates both harvest control rules and no-take reserves can simultaneously contribute to conservation, economic and socio-economic objectives of fisheries management.

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1. Introduction

The importance of rebuilding already depleted fish stocks and the need to prevent further collapse of fisheries worldwide is uncontentious (Worm et al., 2009; OECD, 2010). Recent studies demonstrate the biological and economic benefits of stock rebuilding and averting fisheries collapse (Arnason et al., 2009; Sumaila et al., 2012; Costello et al., 2012). Despite the potential payoffs, according to the Food and Agricultural Organization of the United Nations, about 30% of assessed fish stocks are overexploited and need rebuilding (FAO, 2012) and overfishing remains a threat to marine species and ecosystems (Halpern et al., 2008).

Stock recovery plans have been implemented in many fisheries around the world to reduce fishing mortality, but with mixed success (Caddy and Agnew, 2004; Rosenberg et al., 2006; Murawski, 2010). Factors found to be associated with the successful recovery plans include the deployment of measures that effectively control fishing mortality and, in addition, a legal and stakeholder mandate for fisheries managers to give priority to long-term biological, ecosystem and economic benefits over shorter term and socio-economic outcomes (Murawski, 2010).

There are a number of management approaches available to reduce fishing mortality rates, including rules to directly control harvest levels (Gooday et al., 2010; Froese et al., 2011; Costello et al., 2012) and the establishment of no-take marine reserves in which harvesting is prohibited (Roberts et al., 2005; Gaines et al., 2010). Harvest control rules that are underpinned by monitoring and assessment of the status of the target stock provide a scientific basis for setting catch limits (Smith et al., 2008; Punt, 2010). Harvest control rules also provide a necessary condition for the implementation of rights-based catch shares that can enhance fisheries sustainability (Grafton et al., 2006a) and decrease the chance of fisheries collapse (Costello et al., 2008). Likewise, the establishment of no-take marine reserves has been promoted in many countries as a way to control fishing mortality, thereby restoring depleted fish stocks as well as enhancing the sustainability of fisheries (Roberts et al., 2005). There is evidence that the implementation of no-take reserves can increase fish biomass, individual fish size, and species richness within reserve boundaries (Lester et al., 2009).

No-take marine reserves are frequently presented as an alternative management approach to harvest control rules in the recovery of declining fisheries. In part this is because marine reserves, relative to harvest control rules, have been shown to help to mitigate irreducible management error and environmental uncertainty (Lauck et al., 1998; Mangel, 2000) that, in turn, decreases the chance of fishery collapse (Grafton et al., 2009). Nevertheless, the enforcement of a no-take reserve alone is insufficient to achieve conservation goals (Allison et al., 1998). This is because the efficacy of reserves as a fisheries management tool critically depends, among other things, on management of the fishery outside the reserve, including harvest control rules (Hilborn et al., 2004, 2006; Armstrong and Skonhoft, 2006; Sumaila and Armstrong, 2006; White and Costello, 2010; Costello and Kaffine, 2010; Rassweiler et al., 2012; Yamazaki et al., 2012).

In this paper we explore how harvest control rules and no-take reserves perform when used jointly in fisheries stock recovery plans. Previous studies have provided the conditions under which the two management approaches separately contribute to successful rebuilding outcomes (Larkin et al., 2006; Gooday et al., 2010; Costello et al., 2012). Researchers have also examined the effects of reserve establishment when the fishery is managed in conjunction with an economically optimal harvest strategy (Neubert, 2003; Schnier, 2005; Grafton et al., 2006b, 2009; Sanchirico et al., 2006, 2010; Little et al., 2010b; Yamazaki et al., 2010). To date, however, there has been no study that has quantitatively modeled and evaluated how the two approaches are substitutes and/or complements in rebuilding fisheries. To this end, we assess the performance of alternative stock recovery plans to quantitatively explore: one, whether harvest control rules and no-take marine reserves are substitutes in hastening the speed of recovery of a fishery; and two, whether no-take reserves and harvest control rules are complementary in terms of their effects on the speed of stock rebuilding, the net present value of the fishery and average annual harvest during the rebuilding phase; and three, how the two management approaches interact when used jointly to affect the tradeoffs between potentially conflicting fisheries objectives.

The rest of the paper is structured as follows. Section 2 develops a bioeconomic model of a fishery that allows for the implementation by a management authority of a stock recovery plan aimed at