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Analysis

Offsetting Externalities in Estimating MEY in Multispecies Fisheries

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ABSTRACT

The Australian federal fisheries policy identifies maximising net economic returns as the primary objective of fisheries management. This has largely been interpreted as maximising the net economic yield (MEY) in fisheries. More recently, the influence of reducing yields to achieve MEY on prices and the transfer of consumer surplus to producers has been raised as a potential issue. Achieving fishery MEY may result in a reduction in net economic returns in a broader sense if the loss to consumers exceeds the gain to the industry. The transfer of consumer surplus to producers is also potentially undesirable, and may result in a dead weight loss. Similarly, the disutility associated with bycatch in fisheries may also affect our interpretation of "optimal" yields if non-monetary values are considered. These externalities are generally not considered in determining MEY. In this paper, we develop a generic multispecies bioeconomic model that is used to estimate the impact of broadening the consideration of net economic returns to include changes in consumer surplus as well as the inclusion of non-market values associated with bycatch. We find that traditional measures of MEY may not achieve maximum returns to society overall if these externalities exist.

1. Introduction

Fisheries management is often characterised by multiple objectives, generally including a range of environmental, social and economic objectives (Hilborn, 2007). In the federally-managed fisheries of Australia, maximising the net economic returns to the Australian community has become a dominant objective. This has been interpreted as achieving the biomass that, on average, produces maximum economic yield (B_{MEY}) in the Commonwealth Fisheries Harvest Strategy (DAFF, 2007).

While other objectives do indeed exist in Commonwealth fisheries management (Pascoe et al., 2014; Pascoe et al., 2009), these currently do not influence the setting of the biomass target for the fisheries. For example, policies to reduce bycatch rely on spatial and fishing gear restrictions to achieve a reduction rather than influence the main species targets. "Standard" methods for assessing maximum economic yield (MEY) do not account for environmental externalities, particularly in terms of bycatch and discards, which may affect the optimal outcome from a broader societal perspective.

This fishery-centric definition of economic benefits has also been criticized by some for ignoring upstream impacts from fisheries production, such as the impacts on fish processors and retailers who's business are also affected by the quantity landed (Christensen, 2010; Grafton et al., 2012). Although the merits of including these sectors into the estimation of MEY is questionable (Pascoe et al., 2013), a potential issue has been raised by others (e.g. Anderson, 1980; Hannesson, 1993), namely the impact of changes in consumer benefits from moving to a fishery profit maximisation target if this also results in higher prices to consumers. This may result in a net transfer of benefits from consumers to producers, potentially resulting in a deadweight loss in economic benefits overall. In such a case, a broader definition of MEY to include both consumer and producer benefits may be more appropriate when setting target reference points (Anderson, 1980; Grafton et al., 2012; Hannesson, 1993; Squires and Vestergaard, 2016; Vieira and Pascoe, 2013).

Incorporation of these factors into a "MEY" consideration will result in a potentially different optimal level of catch and effort depending on the magnitude of the interactions. The traditional assumption of most bioeconomic models is that prices are invariant with quantity landed, and hence price flexibility (the percentage change in the price of a product due to a 1% change in quantity supplied of that product) is zero. A priori, based on traditional and simple economic supply and demand principles, we would expect that if price flexibility is in fact zero, then marginal revenue (MR) and average revenue (AR) are the same. Maximising fishing profits by equating marginal revenue to marginal cost (MC) is hence optimal from a social perspective (Fig. 1a). However, if price flexibility is less than zero, both MR and AR decline with increasing quantity of catch, with MR declining at a faster rate.

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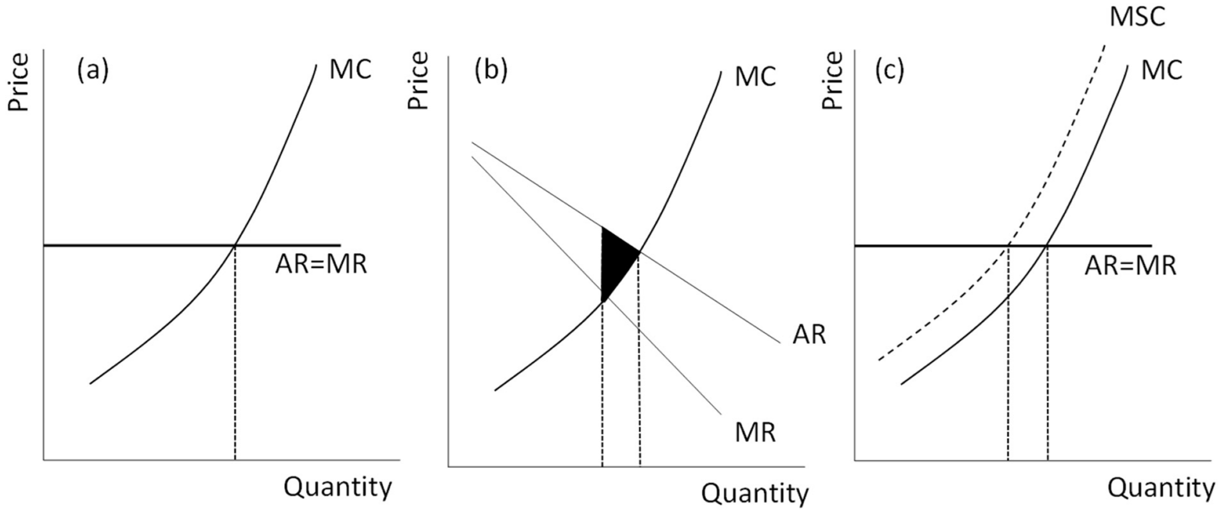

Fig. 1. The relationship between price and quantity showing expected marginal cost (MC), average revenue (AR) and marginal revenue (MR) curves and the dead weight loss (shaded area). The marginal social costs (MSC) are also shown in panel (c).

Maximising profits to producers (MR = MC) may lead to a transfer of benefits from consumers to producers, with a consequent overall loss of both consumer and producer surplus (i.e. deadweight loss) seen as the shaded area in Fig. 1b.

Traditional models and analyses also do not generally consider the non-market costs associated with fisheries production, such as habitat damage and bycatch, with an overwhelming reliance on technical measures (e.g. regulated hook types or bycatch reduction devices) or spatial closures to limit bycatch and habitat damage (Hall and Mainprize, 2005). However, Beaumont et al. (2008) found that marine biodiversity does indeed have considerable value to the broader community, and reductions of such result in a loss of benefits to society as a whole. Squires and Vestergaard (2016) also developed a theoretical model demonstrating that taking into consideration non-market benefits associated with ecosystem services generated within fisheries systems resulted in a higher "optimal" stock level than if these benefits were ignored. Armstrong et al. (2017) included such non-use values associated with habitat damage from fishing into a single species bioeconomic model and found this affected the "optimal" size of the harvested stock, compared with the case in which these costs are ignored. If such externalities exist more broadly, such that the marginal social cost (MSC) is greater than the marginal (fishery) cost, maximising fisheries profits (MR = MC) may result in too much fishing activity from a societal perspective (which is optimised at MR = MSC) (Fig. 1c).

With the exception of Armstrong et al. (2017), most previous studies have not attempted to derive empirical estimates of maximum economic yield per se in the presence of these environmental externalities, but generally recognised that a socially optimal yield would be different if such externalities were considered. Several studies have considered management instruments that may result in moving the fishery towards a more socially optimal outcome. For example, some studies have considered the effect of a bycatch (Boyce, 1996) or habitat (Holland and Schnier, 2006) quotas on optimal production from a social planner perspective. Innes et al. (2015) and Pascoe et al. (2010) proposed a bycatch tax as a possible management mechanism to reduce bycatch to socially acceptable levels, while Herrera (2005) found that a tax on bycatch is more likely to achieve a social optimum than quotas.

While the direction of the likely effects can be estimated based on these simple theoretical models, most fisheries are substantially more complex. In multispecies fisheries, optimal output levels depend not only on biological and economic characteristics of a particular species, but the characteristics of the species that are generally caught with it. Hence, the extent to which maximising fishery profits is equivalent to maximising economic returns to society as a whole will depend on the characteristics of the fishery, including the economic and biological characteristics of the set of species caught as well as the strength of any price-quantity relationship and the "importance" of bycatch or other externalities.

The aim of this study is to examine how the consideration of consumers and environmental impacts affects the measure of "net economic benefits" and how this compares to a "traditional" view of MEY as the effort/catch/biomass combination that maximises fisheries profits. The study uses a generic multispecies bioeconomic that includes realistic parameter values (based on existing multispecies fisheries) but does not relate to any fishery in particular. The generic model is used to estimate traditional measures of MEY, and compare these with measures which also include consumer surplus and negative externalities. The model is run stochastically with a range of potential interactions to derive a distribution of potential outcomes.

2. Model Specification

Two types of biological growth models are commonly applied in bioeconomic models based on different assumptions: the Schaefer model assuming an underlying logistical growth (Schaefer, 1954; Schaefer, 1957); and the exponential model developed by Fox (1970) based on a Gompertz growth function. Although the logistic model is commonly employed due to its simplicity, the exponential growth model has been found to be more broadly applicable to a wider range of fisheries (Halls et al., 2006; Silliman, 1971).

In this study we apply the equilibrium model based on Fox (1970) which has the form:

$$C_i = q_i K_i E \exp(-q_i E/r_i) \tag{1}$$

where C_i is the catch of species i, r_i is the instantaneous growth rate of species i, K_i is the carrying capacity of species i, q_i is the catchability coefficient of species i and E is the level of effort applied to the fishery as a whole. A single fleet is assumed (which produce the level of effort, E), and only technical interactions between species is also assumed (i.e. no predator-prey interactions).

The model is solved as a non-linear optimisation problem with the base case objective function as:

$$\underset{E}{Max} \quad \Pi = \sum_i p_i C_i - cE \tag{2}$$

where Π is total fishery profits, p_i is the price of species i, and c is the cost per unit of fishing effort. The model estimate the steady state level of fishing effort (E^*) that maximises profits, and the resulting