Marine Policy 40 (2013) 41–52

Contents lists available at SciVerse ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

From low- to high-value fisheries: Is it possible to quantify the trade-off between management cost, risk and catch?

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ARTICLE INFO

Article history:
Received 24 April 2012
Received in revised form
6 December 2012
Accepted 6 December 2012
Available online 30 January 2013

Keywords:
Fishery risk
Management costs
Trade-off
Statistical model

ABSTRACT

Fishery managers are faced with the challenge of maintaining sustainable fisheries at the lowest possible cost while conforming to international and national obligations. Given that fisheries range from low to high value, there is a real need to understand how to trade ecological and economic risks, and the various costs associated with their management, against the benefits from catch. Key to this is an understanding of (a) the costs corresponding to a given level of acceptable risk, or conversely, (b) the change in risk given a change in cost investment. This paper first defines biological, economic and ecosystem risk at a whole-of-fishery level, and then develops a simple model to quantify the trade-offs between risk, cost and catch. Using as case studies Australia's federally managed fisheries that range from data-rich to data-poor, risk was quantified for target species in terms of both their limit and target reference points (defined as "biological risk" and "economic risk", respectively), and for ecosystems in terms of overall ecological impact (defined as "ecosystem risk"). A statistical linear model was used to quantify the risk–cost–catch frontier for each of the three forms of risk. The most parsimonious models were statistically significant for each. However, the management and research costs were mostly positively correlated with risk, indicating that these tended to be reactive to risk, as opposed to risk decreasing in response to increased costs. The only model where this was not the case was for the ecosystem risk, which is probably because these risks have only recently been assessed and the management response to these risks across all the fisheries has so far been limited. For target species risks, it was not possible to develop a model for proactive use. However, the method itself has merit and, if the costs were defined to a greater level of resolution, and/or a time-dynamic modelling approach considered, these issues could potentially be addressed.

1. Introduction

The management of renewable resources such as fisheries can be costly, with much of the cost arising from the need to understand and mitigate the risk of damage to the long-term sustainability of the resources and their related ecosystems. Given that fisheries range in value from relatively low to very high, there is a need to understand how to trade ecological and economic risk and costs associated with management against the benefits, represented by the catch. This relationship is known as the risk–cost–catch frontier [1]. Catch can be defined in terms of both its mean and variability [1]. As fishing pressure increases, the overall mean catch may increase, at least in the short term, but so too may its inter-annual variability. Management costs here are defined broadly in terms of the costs of (1) the information needed to assess and manage the fishery, (2) the management decision process, (3) research and (4) compliance. Finally, risk is used in the context of change and undesirable consequences to the target species and the broader ecosystem as well as to the economics of the fishery. The current study considers risk as having three components: biological risk, pertaining to the target species of the fishery, economic risk in terms of the target species, and ecosystem risk, pertaining to all species and habitats with which the fishery interacts. These are defined in detail in Section 3.

Although the directions of the three-way trade-offs between risk, cost and catch are well understood conceptually (Fig. 1), this frontier is only theoretically defined. Fishery managers need to

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0308-597X/$ - see front matter
http://dx.doi.org/10.1016/j.marpol.2012.12.009

assess this trade-off both within and across fisheries. That is, for a given level of risk, what are the associated costs (management costs) and benefits (catches)? Conversely, if costs or catches are adjusted, what will be the effect on risk?

Many fisheries are data-poor [2,3–5] and little is known about their stock status or broader ecological impacts. An important component of the risk–cost–catch frontier is uncertainty [6,1]. As the level of uncertainty increases, the precautionary approach [7] tends to move managers to reduce risk, usually by reducing catch, and/or increasing management costs to better assess and manage risk.

The two-way risk–catch or risk–cost trade-offs have often been examined for individual fisheries using Management Strategy Evaluation (MSE), either for target species [8–11,6,12,13] or for ecosystems [14,15]. These studies, have, in general, supported the need for greater precaution when uncertainty increases, and have shown the value of, for example, fishery independent surveys or multiple sources of data. Despite these MSE approaches, they have almost always been applied at a fishery level rather than across all the ranges of fisheries being managed by a fisheries authority.

Ecological risk, embracing all the species with which a fishery interacts, has become increasingly important. The mandate of fishery management extends beyond target species to comply with, in Australia, principles of ecologically sustainable development, addressed by the Environment Protection and Biodiversity Conservation (EPBC) Act [16] and, more globally, adoption of ecosystem based fishery management [17] via, for example, the FAO Technical Guidelines for Responsible Fisheries [7]. Mitigating against ecological risk further stretches the cost of management in terms of information needs, but also management actions and compliance costs. Such additional costs will be particularly challenging for small scale, data-poor and/or low value fisheries – meaning that it is difficult to determine risk, let alone have resources available to improve the understanding and management of these fisheries.

This paper addresses the question of whether it is possible to define a general risk–cost–catch frontier that can be applied to any given fishery within a management agency's portfolio. Other than conceptually in policy [1] this has not been defined quantitatively, especially not across a management agency's total portfolio of fisheries. Thus managers are unable to explicitly resolve questions such as, (a) for a specified acceptable level of risk, what would be the corresponding management, research and compliance costs; (b) conversely, given a change in management cost or catch, what would be the change in risk, and is this risk acceptable; and (c) what are the minimum data requirements for, in particular, a new fishery?

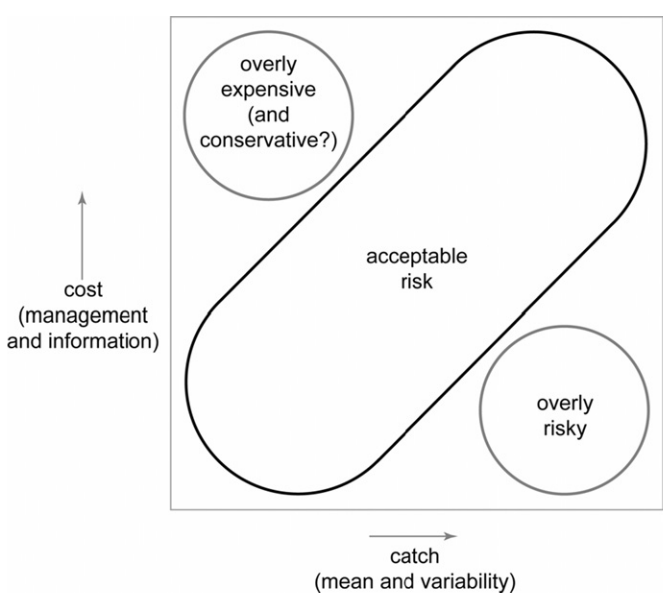

Fig. 1. Schematic from Sainsbury (2005) cost and catch combinations showing regions that are likely to acceptable and unacceptable.

Australian Commonwealth managed fisheries are used to explore these questions, given the availability of data from fishery status reports (e.g. [18]) and ecological risk assessments [19], as well as AFMA data on management costs. Data from these fisheries, ranging from data-rich (e.g. the Northern Prawn Fishery) to data-poor (e.g. the Coral Sea hand collectable fishery), were used first to define biological, economic and ecosystem risk at a whole of fishery level. A quantitative trade-off frontier of risk, cost and catch across the Australian portfolio was then developed.

2. Categorising risk

Three measures of risk were considered – (a) biological risk to target species, (b) economic risk to target species, and (c) ecosystem risk. "Risk" here is related to the failure to meet fishery environmental and economic objectives, where the former was categorised as risk to the target species (hereafter called "biological risk") and to the ecosystem as a whole ("ecosystem risk"). Risk is typically defined in terms of both likelihood and consequence; here the focus was on a composite of the two.

The economic and biological risk definitions were based on target and limit reference points respectively, as defined in Australia's Commonwealth Harvest Strategy Policy (HSP) [20]. The HSP defines the target reference point in terms of Maximum Economic Yield (MEY). The limit reference point is defined, as 0.5 of the biomass at maximum sustainable yield (B_{MSY}), or proxy.

For each component of risk, a single value or index was determined for each fishery as a whole. In the case of biological and economic risk, this involved aggregating risk values or indices across the target species. Ecosystem risk was defined as the proportion of "high risk" species relative to all the species with which the fishery interacts. The specific approach taken for each form of risk and full details of the derivation of each definition are presented below.

2.1. Biological and economic risk of target species

2.1.1. Biological risk

Risk in terms of the target species was assumed to relate to the limit and target reference points specified in the Commonwealth HSP. Although the proxy for limit reference point is generally defined as 20% of B_0, the unfished biomass [20], its aim is a threshold below which the stock of any species should not fall – a state of being overfished.[1] Therefore target species biological risk was defined as the risk of not meeting the Commonwealth Harvest Strategy requirement of being above the limit reference point. An exploitation rate that will results in the limit reference point being reached is known as overfishing.

To inform the biological risk definition, the 2008 status of each fishery as cited in the Bureau of Rural Science's (BRS's) Status Report [18] was used. The overfished and overfishing categorisations specified by species were considered, and by numerically

[1] It is acknowledged that, while this proxy is widely embraced as a proxy limit reference point, it may not be realistic for some species, given their population dynamics. For example, it may be overly conservative for fast-maturing species, and vice versa.