industry, the transition from frozen to live markets for GBR reef fish might be seen as positive development in both economic and ecological terms. On the other hand, the increased prices paid for live fish are likely to have provided at least part of the incentive for real increases in effort seen in the fishery since 1994. Any potential benefits of the live fish industry, such as reduced catch rates, especially of by-product species, that can be sustained by individual fishers due to value adding on the live product, may be offset by overall increases in effort. Prudent management action is advisable, therefore, to control effort adequately and avoid real or perceived stock depletions, either locally in areas close to ports and population centres or more widely, and economic hardship in the fishery.

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An economic analysis of the spawning aggregation function in Komodo National Park, Indonesia

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Abstract

This study provides an economic valuation of the demersal fishery spawning aggregation function in Komodo National Park. A parametric generalised single-period model is developed to assist in modeling and estimating the value of the fishery linkages. For a linear function, the maximum value of the spawning aggregation function is calculated to be USD 629,000 annually at 100% protection of the spawning sites. This is of a similar order of magnitude to the direct recreational values associated with the park.

Introduction

Komodo National Park (KNP) is widely recognised as an exceptional storehouse of both terrestrial and marine biodiversity with global significance. Established in 1980, it is listed as a World Heritage Site and a Man and the Biosphere Reserve. Located between Sumbawa and Flores Islands in eastern Indonesia, the park consists of three main islands, Komodo, Rinca, and Padar and several smaller

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islands. The park contains most of the habitat of the world's largest reptile, the Komodo monitor. While originally established to protect the Komodo dragons, it is now highly valued as a marine reserve as well. About 76 per cent of the area of the park is water; it is considered one of the richest areas for coral species in Indonesia and contains one of the most diverse collections of fishes in the world.

The goal of park authorities is to conserve and sustainably use the biodiversity assets of KNP through establishing a set of mechanisms and systems to help ensure effective long-term park management. International funding support is directed towards implementing a 25-year master plan completed by the government of Indonesia with the assistance of The Nature Conservancy (TNC et al. 2000).

In support of the planning efforts at KNP, a series of economic analyses was conducted. Their scope included economic policy reviews, economic feasibility studies for alternative livelihood development in the park area, and a cost–benefit analysis (CBA) of the conservation initiative. The CBA was intended to look at the overall efficiency of the conservation expenditures, given the likely income from enhanced tourist revenues from diving and dragon watching. In addition, the CBA looked at a number of hitherto neglected benefits of conservation through estimating their potential economic contribution in monetised terms. Valuation of a spawning aggregation function was one of these additional benefits. Its inclusion within the analysis performs an important awareness-building role to the extent that the monetised value can be directly compared to the direct benefit measures associated with tourism.

As readers of this Bulletin are well aware, the potential value of spawning aggregation sites is becoming well acknowledged in the scientific literature (Pet et al. 2001; Pet-Soede et al. 2000; Russell 2001; Sadovy and Eklund 1999; Johannes 1997; Turnbull and Samoilys 1997; Vincent and Sadovy 1997). Within the context of marine protected areas, such sites can also serve an important basis for delineating the protected area system, implementing seasonal closures or instituting similar regulatory measure (Nowlis and Roberts 1999; Roberts 1997, 1998a, 2000). But many policy-makers are unconvinced or unaware of the benefits of protective measures, and the traditional economic analyses of marine protected areas (MPAs) management typically focus on tradeoffs between conservation benefits and fishery catch (see Cartier and Ruitenbeek 1999 for review). More recently, economic analyses have started addressing so-called 'spill-over benefits' from MPAs, whereby MPAs are seen to provide an important function through allowing fishery stocks to recover within no-take zones (Roberts 1998b; Rodwell et al. 2000). In such areas, economic efficiency may be improved through (i) higher yields; (ii) lower fishing effort and cost to realise these yields; or (iii) lower regulatory costs because of easier monitoring of the fishing fleet. But the role and value of spawning aggregations in such spill-over analyses is not addressed.

In the case of KNP, ongoing monitoring studies have revealed the importance and the complexity of spawning aggregation sites within the park boundaries (Pet 1999; Pet et al. 1999; Pet and Muljadi 2001). Upon the advice and request of TNC, economic analyses were conducted to draw attention to the potential economic significance of this function. The purpose of this article is to present the simplified model and estimates for KNP.

Model

At this time, little is known about the complex dynamics of spawning aggregations in Komodo. Moreover, no economic analyses of the value of this function have been conducted elsewhere; hence no formal methodology has been developed for treating this potentially important value. To address the issue, a generalised model was developed that could be used in any setting. The model requires some considerable simplification of the relationships, yet it provides enough scope and flexibility to permit value estimates to be generated that are of similar reliability to those associated with other costs and benefits (e.g. recreation benefits) typically incorporated into a CBA at the feasibility analysis stage.

A simple single-period model is used that reflects a parametric density function for the demersal fishery in the park area. The model has a general form as follows:

x = Presumed area of spawning aggregation sites
X = Presumed influence area
P = Total protected area (no-take zone) ($P \leq X$)
a = Degree of protection given to spawning area ($0\% \leq a \leq 100\%$)
D_o = Fishery density in absence of disturbances
$D = D(ax,b)$ = Generalised fishery density, such that $D = a^b D_o$
$H(a,b,X,P) = D * (X - P)$ = Harvest value

The annual value of the spawning function is taken as the difference between $H(a=0,b)$ and $H(a=1,b)$ for any particular site. This general model is very flexible as it can accommodate all extremes of the usual management assumptions. At one extreme we have the typical assumption that spawning aggregation is not important (b=0) and that the density function is thus not a function of protection efforts. In such a scenario, protecting some area simply reduces fishery harvest because of the no-take zone. We can also specify a linear dependence (b=1) between spawning aggregation site protection and density; at b=1, a 50% protection would place the density throughout the region at 50% of D; even so, harvest value would be less than 50% of the total fishery because of the influence of the no take zone. One can also model non-linear effects (b>1) to demonstrate strong linkages between spawning aggregation site and regional density. In general, the value of the spawning aggregation function will depend on the ratio of the no-take area to the influence area (P/X), the ratio of the spawning area to the no-take area (x/P), the protection level of the spawning area (a), and the linkage parameter (b).

Data and assumptions for KNP

Information for KNP was derived from the management plan (TNC et al. 2000) and from official government fishery statistics for the demersal fisheries in the region (BPS 2000; Dinas Perikanan Kabupaten Bima 2000). We caution that one of the most important values of this function is the Benchmark Density (D_o), which is based on secondary sources through local Fishery Department landing data — these data in Indonesia are known for their unreliability and the final result must therefore be regarded as an order-of-magnitude estimate.

In the case of Komodo Park, we place a maximum value on the spawning aggregation function based on the following assumptions:

- Total area of influence X = 3,142,000 ha (~100 km radius; excludes land)
- Total area of spawning aggregation sites x = 1700 ha (reef area in KNP)
- Total protected area (no-take zone) = 132,000 ha (area of KNP Marine component)
- Benchmark density (D_o)= USD 0.209 · ha^{-1} (based on local demersal fishery statistics)

Results and discussion

For a linear function (b=1) the maximum benefit value of the spawning aggregation function is calculated to be USD 629,000 annually at 100% protection of the spawning sites. In a traditional economic analysis that excluded this function (i.e. b=0), the impact of the MPA would be to impose a *cost* to the fishery sector of USD 27,600 (corresponding to the lost value of the fishery density within the no-take zone of 132,000 ha).

The benefit value is considerable in relation to other benefits associated with the park. In present value terms (using a 10% discount rate) the benefit corresponds to USD 6.3 million. To place these figures in perspective, TNC estimates annual operating costs for KNP to be of the order of USD 1.5 million to USD 2.0 million. The park currently generates about USD 60,000 annually in direct gate revenues from diving and dragon-watching tourists, although this 'recreation benefit' will likely increase substantially as the number of visitors increase and as gate fees are increased to match those in marine parks elsewhere in the region.

The implications of these results for management authorities are significant. First, they provide an economic rationale for aggressively protecting known and potential spawning aggregation sites. Second, at KNP, the value of such aggregation sites is equal in economic significance to the recreational value of the park as a whole. Finally, overall protection efforts are consistent with protecting a regional demersal fishery on which many households living outside of the park depend.

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