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Comment: Marine Reserves: Will They Accomplish More With Management Costs?

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Abstract *Hannesson (*Marine Resource Economics *13(3) 1998) takes a critical approach to marine protected areas (MPAs) using simulations of MPAs combined with open access. His results show the conservation effect of an MPA of an appropriate size being the same as that achieved with optimal quota regulation, but with a smaller catch. We expand this analysis by adding a management cost function and increasing the fishing costs to a more realistic level. It is shown that the use of MPAs of certain sizes can be a more advantageous management tool than traditional quotas; hence, the inclusion of management costs modifies some of the findings of Hannesson (1998). We also illustrate how sensitive the results are to the choice of fishing cost values, making the attractiveness of private property versus marine reserves much less clear than proposed by Hannesson (1998)*.

Key words Hannesson, management costs, marine reserves.

Introduction

In this paper, we comment upon a paper by Hannesson (1998) where he presents a simple and elegant biomass model for a fish stock migrating between two areas, one a protected area, the other not. Hannesson (1998) compares, by simulation, open access (OA) in the entire distribution area of a stock, open access outside a marine protected area (MPA), and optimal fishing throughout the entire area. His results indicate that the benefits from using MPAs in combination with OA in fisheries management are critically dependent on the migration rate of fish from the reserve to the adjacent fishing grounds. He also shows that a marine reserve of an appropriate size relative to the migration rate will achieve the same conservation effect as optimal fishing throughout the area, but with a smaller catch. His main point is an expansion upon an issue presented by Holland and Brazee (1996), where it is argued that as long as there are no limitations on fishing outside the protected area, MPAs themselves will not maximize economic rents in a fishery. This due to the fact that a rise in yield will lead to increased effort eating up any rents in the fishery.

This latter issue is clear and uncontestable. Our main contention with this work is: (1) the choice of harvest cost value, and (2) the disregard for management costs. We show that taking these two issues into account affects the relative results of the

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different management regimes. We find that Hannesson's (1998) results depend critically upon the harvest cost parameter value, which he admits to setting rather low. Furthermore, optimal harvesting strategies normally require substantial research, data collection, and monitoring of effort and catches in the fishery, activities which are costly and should be included in the calculation of optimal stock and harvest levels. Thus, when comparing private property with a marine reserve combined with open access,[1] the former management comes at a cost.[2]

In the few existing works on the modeling of management costs (Sutinen and Andersen 1985; Anderson and Lee 1996; Arnason 1999), it is suggested that these costs somehow are a function of the difference between the catch level, the manager, and industry desire. Although the level of detail included in the models varies greatly, the principal results of these studies are that including management costs will result in an optimal stock level that is lower than in the case when management costs are ignored, but higher than in the open-access case. The effect on profits will depend on the stock effect, price, and how the management cost function is formulated.

We shall assume that management costs increase with an increasing difference in the stock level desired by the manager and that corresponding to open access, which is a modified form of the function suggested by Arnason (1999).[3] The basis for the assumption is that in order to increase the fish stock above the open access level, some form of enforcement must be applied to reduce harvesting, hence invoking costs (Sutinen and Anderson for a formal presentation). The larger the stock is above the open-access level, the greater the enforcement required.

In the next section, we present a model combining Hannesson's (1998) MPA model and the modified version of Arnason's (1999) management cost model. We then compare the different management regimes studied in Hannesson (1998). The Results section shows that, given the inclusion of management costs, a private property regime may not always be the preferable management strategy. We also illustrate that by varying the choice of harvest cost parameter values in Hannesson's (1998) model, we can obtain more or less the same results regarding stock size and harvest for the different management regimes. A discussion of the results concludes the paper.

The Model

The following bioeconomic model is identical to Hannesson's (1998) marine reserves model, with a modified version of Arnason's (1999) management cost model added on. We use these models to study four management regimes: (*i*) Open access (OA); (*ii*) Private property (PP); (*iii*) Private property with management cost (PPC); and (*iv*) Marine reserves with open access (MR).

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[1] In situations where many parties play a role in the choice of fisheries policy, open access could be a way of "selling" a marine reserve to interest groups who would oppose private property management. Nonetheless, it is clear that since private property is possible, private property outside the marine reserve should also be an option. Due to this paper being a comment to Hannesson's (1998) paper, such an expansion is outside the scope of this work.

[2] The assumption of zero management costs for marine reserves may seem somewhat strong, as it is clear that control of the reserve area may involve some cost. However, with the possibility of satellite tracking, these costs may be presumed to be minimal as compared to the costs involved in controlling output.

[3] The modification of Arnason's (1999) model consists of using stock level as a variable instead of harvest.

We will start by defining the model for the marine reserve (MR). Here, S_o is defined as the density of fish in the fishable area, while S_m is the equivalent in the reserve. The size of the reserve is m, leaving the area outside the reserve to be $(1 - m)$. The rate with which the fish move is defined as z.

The rate of change in the density of fish in the fishable area is thus:

$$\frac{dS_o}{dt} = rS_o(1 - S_o) + zm(S_m - S_o) - Y. \tag{1}$$

The first term on the right-hand side of equation (1) describes the growth in the fishable area, while the second term expresses the net migration to the fishable area, and Y is the harvest. The net migration expression is determined as follows. The probability of fish migrating out of the fishable area is m, and the moving fish in this area is $z(1 - m)S_o$. Hence, the total migration out of the fishable area is $mz(1 - m)S_o$. In order to keep to our density measures, we divide by the size of the fishable area $(1 - m)$, and the density of the fish migrating out of the fishable area becomes mzS_o, which is the negative expression in the second term in equation (1). The equivalent is calculated for the density of fish migrating out of the reserve into the fishable area.

Assuming p is the unit price and c/S_o is the unit cost of harvest, we obtain the objective function:

$$H(S_o, S_m) = \left[rS_o(1 - S_o) + zm(S_m - S_o)\right]\left(p - \frac{c}{S_o}\right). \tag{2}$$

The open access (OA) and private property cases (PP and PPC) can be modeled as follows. The density of the stock is here defined as S, while the other parameters are as for the MR case. This gives us the objective function for the PPC case:

$$H(S) = rS(1 - S)\left(p - \frac{c}{S}\right) - \beta(S - S^{O.A.}) \tag{3}$$

where the last term describes management costs. The management costs are a function of the difference between the total stock size, S, and the open-access stock size, $S^{O.A.}$, with β being a positive constant. Arnason (1999) suggests that management costs be formulated as a positive function of the absolute difference in the level of harvest desired by the sole manager ($Y(S)$) and the harvest resulting from open access [$Y(S^{O.A.})$]. We use the corresponding stock levels for simplicity. In the PP case, β is set equal to zero. For the OA regime, we observe that the last term in equation (3) equals zero, and the stock size becomes equal to c for a unit price.

Hannesson (1999) finds management costs in Iceland, Norway, and Newfoundland ranging from approximately 2.5% (Iceland) to more than 25% (Newfoundland) of catch value in the period 1989–96. Arnason (1999) claims that fisheries management costs lie between 5 and 30% of the landed value. OECD (2000) shows that in 1997, management costs in OECD countries varied from 2 to 90% of the value of the catch of marine fisheries. Management costs here include administration, research, and monitoring. Based on the above, we have calculated a maximum β value of 0.048 for our model (see the appendix).

By using a $c = 0.15$, Hannesson (1998) obtains a unit profit of almost 75% percent of the price for the PP case.[4] This seems unreasonably high for most fisheries.[5] We have increased the costs to $c = 0.6$. This still gives a unit profit of 25%, which is probably still high compared to the reality of many fisheries. This markedly changes some of Hannesson's most central results.

Results

In the following, we present the results of several simulations using the different management regimes.[6] Introducing management costs when the harvest cost is kept at the original low level ($c = 0.15$) has little effect on the results obtained by Hannesson (1998). The inclusion of management costs resulted in only a slight reduction in optimal stock level and an increase in catch compared to the PP case (figures 1 and 2). Given that it is desirable to have a large optimal stock and harvest, the PPC case, therefore, yields better results than the MR case for most reserve sizes (m) and migration rates (z), as long as c is low, since we observe both higher optimal stock size and larger harvests.

In figure 3, we study the effects of varying the rate of migration, z, when the harvesting cost parameter, c, is increased to 0.6. In this case, the PPC strategy gives a higher stock level than the MR strategy only when the migration rate is higher than about 0.3. Also, the PPC stock size is approximately 10% greater than for the MR case, at most. The catch and the exploitation rate (Y/S) in the MR case is lower than that of the PPC case for all values of z and m less than approximately 0.4 and 0.35, respectively. However, the differences are not great. Note that the OA strategy gives the highest harvest, at the cost of the stock level.

Figure 4 shows the effect of introducing management costs when varying the size of the reserve, m, given that the harvest cost parameter is increased to 0.6. The MR case gives a higher stock level and conservation effect for all reserve sizes above approximately $m = 0.55$, while catch level is lower than for the PPC case for all reserve sizes above approximately $m = 0.5$. The PP case yields better results than the MR case for most values of m and z, irrespective of the value of the harvest cost parameter c. The OA case, again, gives the highest harvest at the cost of the stock level. It can be shown that as the value of β is reduced, the PPC case naturally becomes more and more similar to the PP case. Still, reducing the value of β to 0.032 in the high-cost case (corresponding to management costs equal to 20% of the catch value), does not make it necessary to reject the idea of using MPAs in the management. In this case, the PPC and the MR cases will generate equal results when m and z take on the values of approximately 0.6 and 0.2, respectively.

Another feature that may be observed when changing c, is that a conclusion regarding optimal management strategy in the area where PPC and MR yield similar results, is more sensitive to changes in the values of m and z when c is kept at a low level. This point is readily observed if one compares figure 1 to figure 4 and figure 3 to figure 2. Small changes in m or z in the low-cost case (figures 1 and 2) cause large changes in the relative stock and harvest levels; whereas, the corresponding changes in the high-cost case (figures 3 and 4) result in smaller differences. This feature is strengthened as either harvesting or management costs increase.

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[4] Hannesson (1998) did present variations in c, but uses these observations mainly to discuss the effects of low values of c.

[5] For instance, in one of the more efficient fisheries in the world, the Norwegian cod trawl fishery, Armstrong and Flaaten (1991) obtain a unit profit of 50% in an optimal fishery.

[6] The software package Excel was used for the simulations.

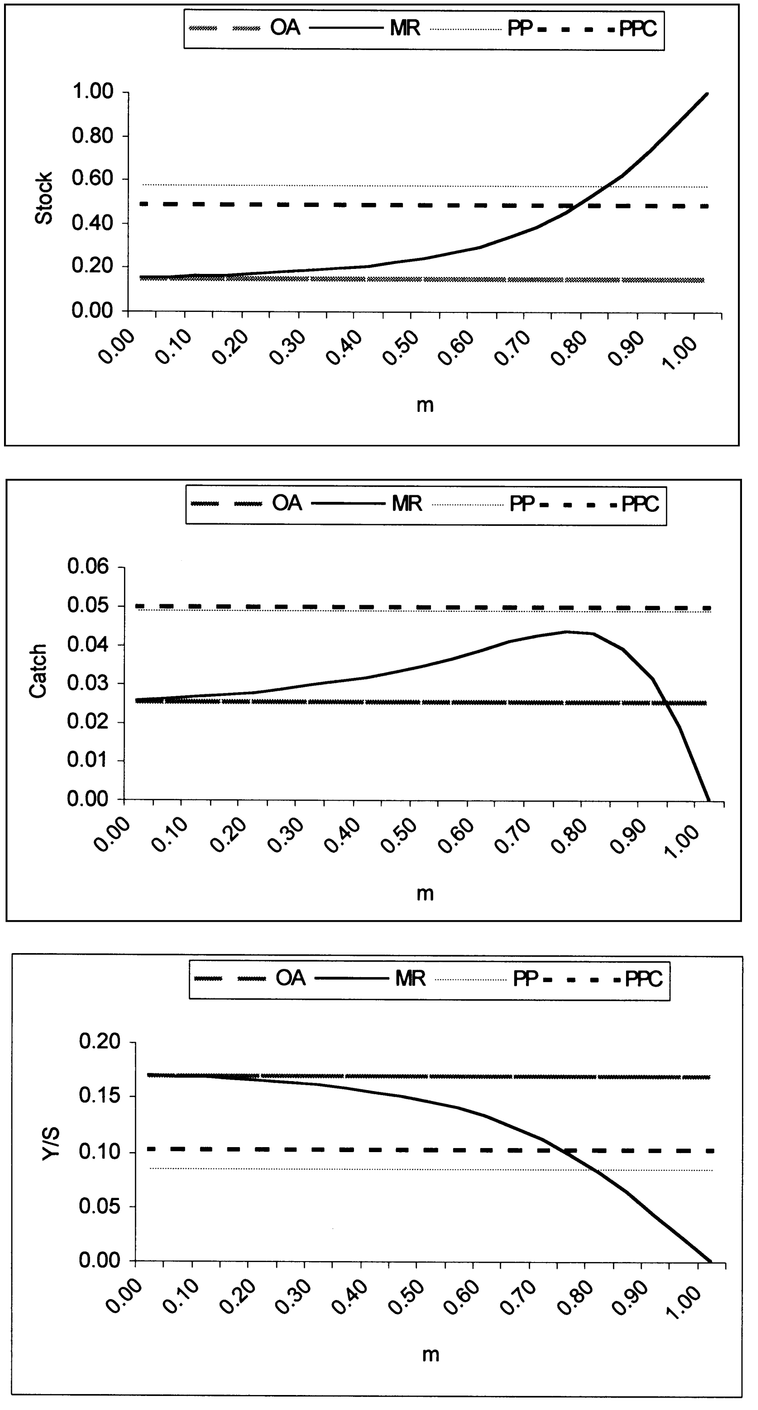

Figure 1. Effects of Varying Rates of Reserve Size *m*
(c = 0.15; z = 0.5; r = 0,2; β = 0.035)

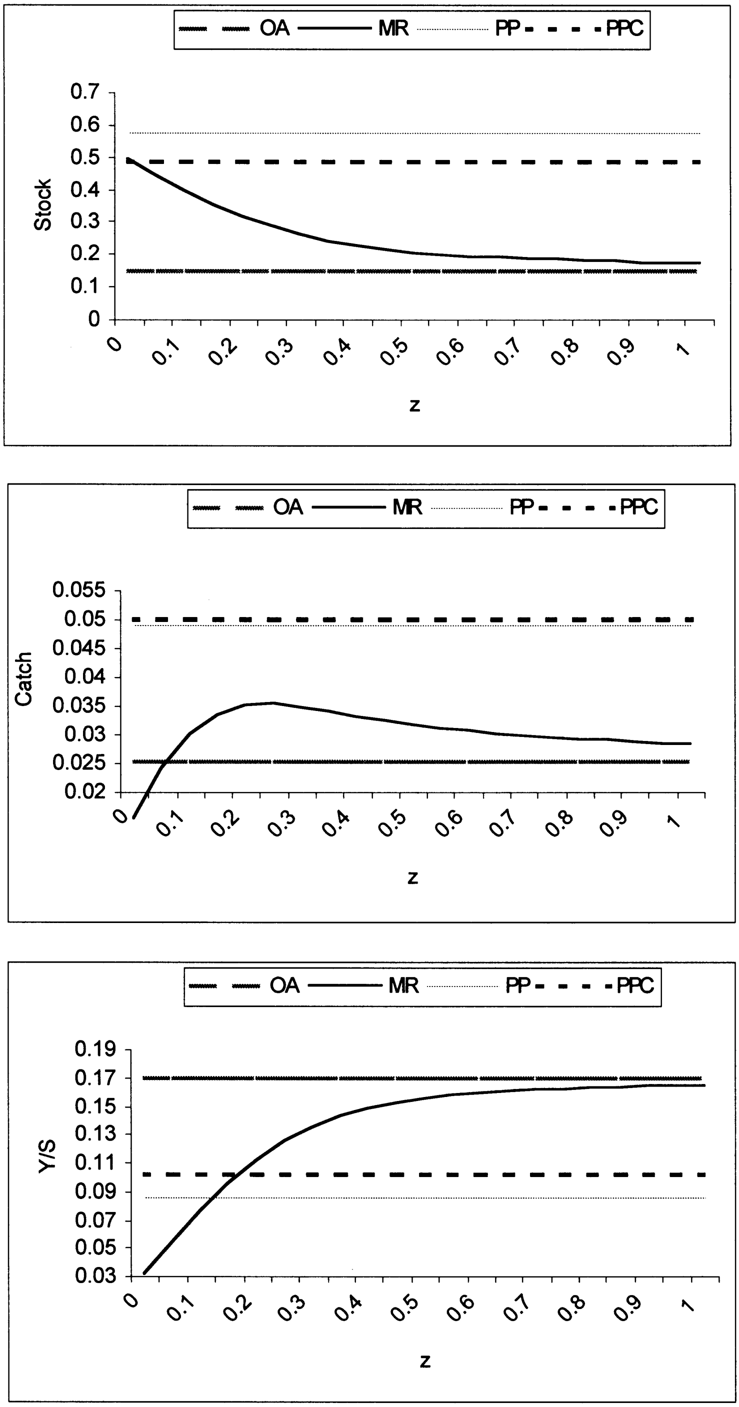

Figure 2. Effects of Varying Rates of Migration *z*
(c = 0.15; m = 0.4; r = 0.2; β = 0.035)

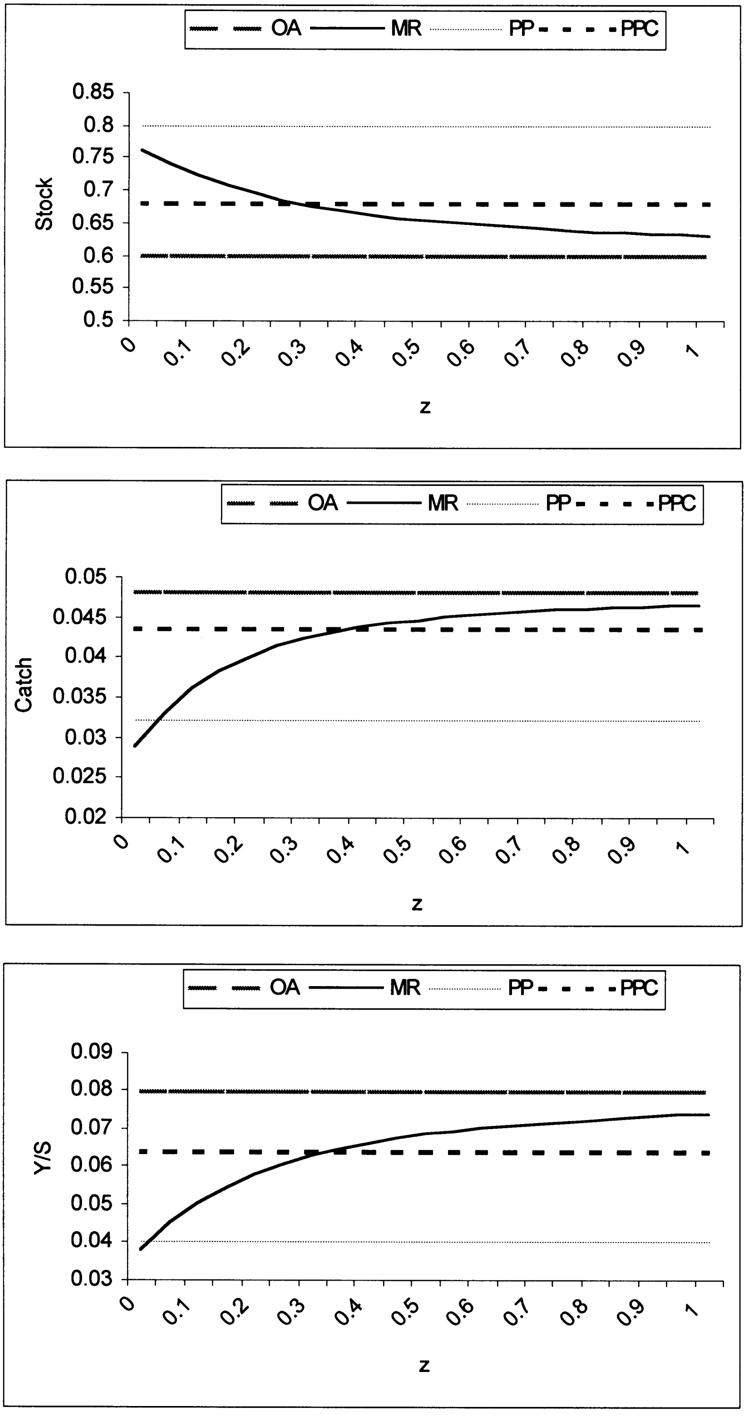

Figure 3. Effects of Varying Rates of Migration z
(c = 0.6; m = 0.4; r = 0.2; β = 0.048)

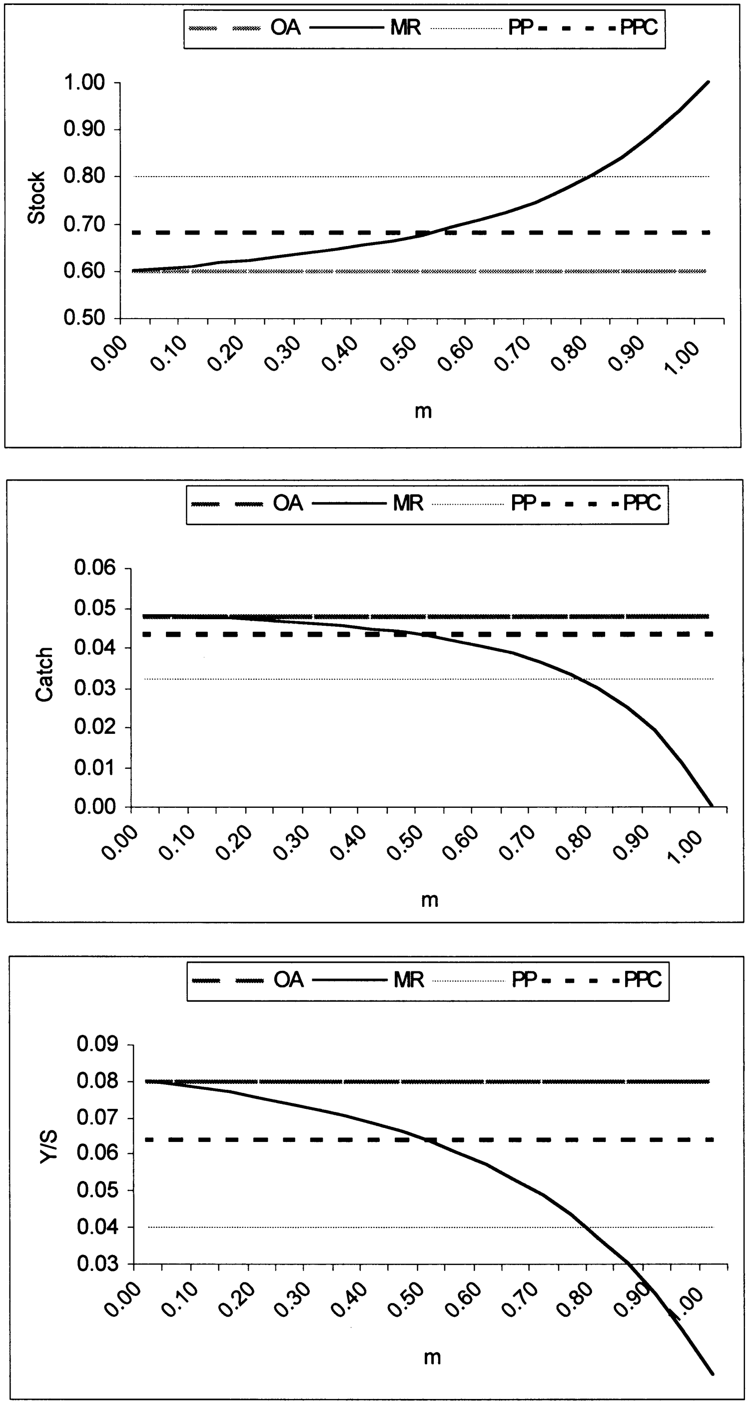

Figure 4. Effects of Varying Reserve Size *m*
(c = 0.6; z = 0.5; r = 0.2; β = 0.048)

Discussion

One of Hannesson's (1998) main points is that marine reserves combined with open-access management do not differ much from a pure open-access management in that both regimes give low catches, have a low degree of efficiency (Y/S), and have low stock levels. We show that these results depend critically on the choice of harvest cost. Hannesson (1998) runs simulations with low costs (c = 0.15) relative to price (p = 1), and obtains the above results. In our simulations, we use a higher, more realistic (we believe) cost (c = 0.6), and obtain the result that the private property (PP) stock size is seldom more than 25% larger than the marine reserve (MR) stock size. However, Hannesson (1998) obtains a PP stock that is, at most, more than three times as large as the MR stock. The relative difference in the catch is also much reduced in our case compared to Hannesson (1998).

We show that for varying reserve size m, the choice of higher harvesting costs results in the PP regime yielding lower harvests than all other regimes, except for a marine reserve greater than 80% of the fishable area, or with a migration rate lower than approximately 0.07.

In the case of high harvesting costs, an inclusion of management costs reduces the attractiveness of a PP regime versus an MR regime even further, as smaller marine reserves are required in order for the two regimes to give similar results. When c was set at a low level, and with a migration rate, z, of 0.5, the marine reserve had to be as large as 80–90% of the entire fishing area in order for the MR case to yield the same results as the PPC case (figure 1). For a marine reserve with a size of 0.4, the MR case is less attractive than the PPC case in terms of catch and stock levels for all values of z (figure 2). When the harvesting cost parameter is increased to 0.6, the PPC and MR cases yield similar results when the reserve size, m, and the migration rate, z, are approximately 0.55 and 0.35, respectively (figures 3 and 4). When comparing the PPC and the MR cases, increasing the value of c also makes any conclusions regarding optimal management strategy less sensitive to changes in the values of m and z.

The inclusion of management costs, combined with more realistic harvest costs, reduces the unattractiveness of marine reserves combined with open access compared to private property, as presented by Hannesson (1998). Relatively small reserves can be combined with open-access harvesting outside the reserve, without resulting in sacrificed harvest and stock size, as compared with the PP case. Thus, the possibility of the acceptance of marine reserves as a management tool among both managers and users seems more probable.

In this study, the issue of rents has not been discussed, other than to state the fact that private property has the potential to create rent, while marine reserves combined with open access dissipate rent. This is in line with Hannesson's (1998) analysis, where objectives such as conservation and harvest amount are held up as a way to compare the two management options. In the light of experiences from the management of fisheries, this is not an unacceptable approach. In fisheries where efficiency-ensuring measures have been implemented, such as ITQ policies in Iceland, Australia, and New Zealand, political acceptance has often required that the full rents from the fisheries not be extracted from the users. Hence, the rents in the fishery remain, to a large degree, amongst the users, making the difference between a managed and an open-access fishery from a manager's point of view, consist of the potential harvest amount and the stock size or health. Nonetheless, work that explicitly takes into account objectives other than rent are clearly important future studies.[7]

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[7] See Skonhoft and Johannesen (2000) for a model where stock size is explicitly defined as an objective.

In many developing country fisheries, management costs are currently nonexistent. In some fisheries, efficient management is difficult to imagine due to the large number of fishers and landing sites. The “more or less” open-access aspect of the fishery may also have important social functions, in the shape of employment and habitation, which may to some degree compensate for the loss in rents. The implementation of management regimes, such as private property, would presumably require extensive monitoring and the introduction of management costs. In some such fisheries, an MPA may be a better alternative. These issues also relate to industrial fisheries. It is also clear that the use of MPAs as a hedge against shocks or natural fluctuations may increase the viability of the fisheries (Sumaila 1998). This, and the issue of combining marine reserves with management regimes other than open access, is something the authors plan to follow up in future work.

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Appendix

The management costs levels found by Arnason (1999), Hannesson (1999), and the OECD (2000) are, of course, given the respective management regimes, stock levels, and harvesting rates. Hence, it is not obvious for which levels of the two latter variables their findings are applicable to in this setting. We have, therefore, calculated the value of β both for the low ($c = 0.15$) and high ($c = 0.6$) cost case when the management cost term in equation (3) is assumed to be 10, 20, or 30% of the corresponding harvest value. In table A1, we show the values of m and z for which the PPC and the MR cases generate similar results for the given β values.

Table A1

Different Values of β and the Corresponding Values of *m* and *z* for which the PPC and MR Cases Yield Similar Results

			PPC ≈ MR					
			Stock		Harvest		Yield Per Recruit	
c	Management Costs as % of Harvest Value	β	*m* [a]	*z* [b]	*m* [a]	*z* [b]	*m* [a]	*z* [b]
0.15	10	0.012	0.85	-	-	-	0.8	0.15
	20	0.023	0.85	-	-	-	0.8	0.15
	30	0.035	0.8	0	-	-	0.75	0.2
0.6	10	0.016	0.75	0	0.7	0.1	0.75	0.1
	20	0.032	0.65	0.15	0.6	0.25	0.65	0.2
	30	0.048	0.55	0.3	0.5	0.4	0.5	0.35

Note: Cells marked "-" indicate that the PPC case always yields better results than the MR case.
[a] Given that $z = 0.5$
[b] Given that $m = 0.4$