12 The Namibian-South African Hake Fishery: Costs of non-cooperative management

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Abstract
The Namibian Exclusive Economic Zone borders South African, Angolan and international waters. Several commercially important species migrate in and out of these different areas. Hake is one such stock which is shared between these countries since it hardly straddles international waters. Despite the literature showing that such shared stocks make cooperative management between the respective states sharing them substantially more profitable than the alternative, at the moment we do not see agreements of this kind between Namibia and its neighbours. In this paper, we apply bioeconomic theory to study the potential for loss of benefits to Namibia and South Africa from not cooperating in the management of the hake fishery. Angola is not included in the analysis because it catches less than 0.5% of the total annual landings of hake.

Introduction

The literature on the management of transboundary fisheries has demonstrated the large potential gains that may be achieved from cooperation between nations exploiting shared stocks[1] (see for instance, Munro, 1979; Armstrong and Flaaten, 1991). In countries with long traditions for industrial

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1 The fishery studied in this paper fits into the definition of shared stocks, as we will be studying a stock that crosses the boundaries of two countries' Exclusive Economic Zones (EEZs) (Munro, 2000). Hence, we will not be discussing so-called highly migratory or straddling stocks, where for the former, tuna is the most prominent example (Duarte etal., 2000), and the latter covers all species that move between EEZs and adjacent high seas (Lindroos and Kaitala, 2000)

fisheries, bilateral agreements are common and historic – a case in point is Norway and Russia in the management of the Northeast Atlantic cod and other stocks in the Barents Sea. In countries where artisanal fisheries are the rule, these types of agreements are not often seen, most likely due to social and political concerns.

A recent Norway FAO Expert consultation on the management of shared fish stocks took place in Bergen, Norway (FAO, 2002; 2003). The main goal of this consultation was to provide information and analysis to foster international understanding of the management of shared fish stocks. Several case studies of the state of shared management of joint stocks of fish from different parts of the world were presented (FAO, 2003). FAO (2002) reports the conclusions of three Working Groups of the Consultation: (i) resolving allocation issues, (ii) achieving coordination of management plans and objectives and research problems, and (iii) ensuring implementation and enforcement of management agreements. These are issues that participants at the Consultation believed needed to be properly addressed to ensure that the world's joint fishery resources are managed sustainably, and in an economically sensible manner.

In the case of Namibia, which historically has been dominated by foreign fleets (Sumaila and Vasconcellos, 2000), cooperation was to a large degree directed towards South Africa, from which Namibia obtained independence in 1990. Despite or perhaps as a result of this, we do not observe specific fisheries agreements between the two countries. Though the political instability in Namibia's second neighbouring country, Angola, has not been a situation that encourages cooperative agreements,[2] the lack of agreements with South Africa shows that a more stable situation in Angola might not be expected to affect this.[3] The question therefore becomes, in a backward-

[2] Since 1994 some Namibian purse seiners have been licensed to fish in Angolan waters. This was originally negotiated due to declining catches of sardine in Namibian waters. In 1995 a large part of the sardine stock moved into the Angolan EEZ and half of the total catch of that year came from Angola. The stock collapsed and since then these vessels have been forced to target sardinella (*Sardinella aurita* and *S. maderensis*) and Angolan horse mackerel (*Trachurus trecae*), neither of which are considered shared stocks. (Dave Boyer, pers. comm.).

[3] In Anon (1999) the problem of stock depletion of transboundary stocks is connected to "lack of collaborative management of shared resources" (Table A1). Yet under suggestions for activities to remedy this, cooperation is limited only to industrial financing, resource assessment, information gathering, and the like. Actual cooperative fisheries management is not mentioned. Sydnes (2002) finds this lack of cooperation at the management level to be common amongst developing countries.

looking perspective, has there been a price paid for not having such cooperative agreements?[4] We will, in the following, concentrate on the hake fishery.

The hake fishery

Namibia's EEZ borders both Angolan and South African waters, and several different species including hake cross these borders. Hake is found in the Benguela Current Large Marine Ecosystem (BCLME), which covers the west coast of South Africa, the entire Namibian coast, and southern Angola depending on the position of the Angola-Benguela front, which moves seasonally between 14 and 17 degrees South.

Three of the most important fisheries in the EEZ are hake, horse mackerel and sardine (Sumaila, 2000). The most economically important ones are sardine, which is found mainly in Namibian, South African and occasionally Angolan waters, and hake, which migrates between South Africa and Namibia (see Namibian and South African hake catches in Figure 1). In the following, we will study the issues connected with this latter shared stock. However, there are actually two species of hake involved,[5] *Merluccius paradoxus* and *Merluccius capensis*, that mix in Namibian waters, increasing the complexity of this fishery. In practical management, this fact is not taken into account, as the hake is treated as a single stock fishery, which we will also do in the following. Hake accounts for around half of the value of Namibia's fish catch, while the strongly fluctuating sardine fishery has contributed much less (Manning, 2000).

The shallow-water Cape hake, *M. capensis*, dominates the Namibian catch, while South Africa catches mostly the deep-water hake, *M. paradoxus*. However, recent data show that the proportion of *M. paradoxus* in Namibia's catch continues to increase. The *M. capensis* is found further inshore than the *M. paradoxus*, and as the fish grow older they tend to migrate into deeper waters, where the older *M. capensis* mix with the younger *M. paradoxus*, leading to predation by the former upon the latter (Hutchings, 1995). However, both *M. paradoxus* and *M. capensis* are transboundary species (Boyer and Hampton, 2001), and the fact that they interact "cannibalistically" brings in further stock-management issues. Hence, the way and manner in which

4 The interesting question of what price may be paid by posterity if such an agreement does not come about, is left for future research to determine. We would like to stress that this paper must be seen as a minor first step in a deeper future analysis of the fishery in question.

5 In fact there are three hake species in Namibian waters, the third being the Benguela hake (*Merluccius polli*), which is mainly found in Angolan waters (Boyer and Hampton, 2001).

Namibia manages *M. capensis* can be expected to affect the South African harvest of *M. paradoxus*, and vice versa.

Figure 1 shows a threefold increase in the Namibian harvest of hake in the last decade. This is due to Namibian conservative harvesting policy immediately after independence following years of mismanagement. This policy resulted in very low post independence harvests, which were allowed to increase over the ten-year period presented. South African harvests, on the other hand, stayed relatively constant.

MODEL

To help manage a given shared fish stock such as hake of the Benguela current ecosystem, a number of equilibrium solutions can be computed from bioeconomic models (Sumaila, 1999):

- sole owner solution;
- open access equilibrium solution;
- non-cooperative solution, and;
- cooperative solution.

A sole owner solution is relevant if the countries sharing the resource were to agree to allow only one of them to exploit the resource under some form of arrangement. Or, if the countries could exploit the resource as if they were a sole owner in all respects, that is, they work in full harmony in terms of their objectives with respect to the use of the shared resource. This is clearly a difficult equilibrium to reach in practice but it can serve as a benchmark for the ideal economic solution that can be achieved. The open access equilibrium is the other end of the story – this solution is arrived at when there is no attempt to manage the exploitation of the resource in any way. Hence,

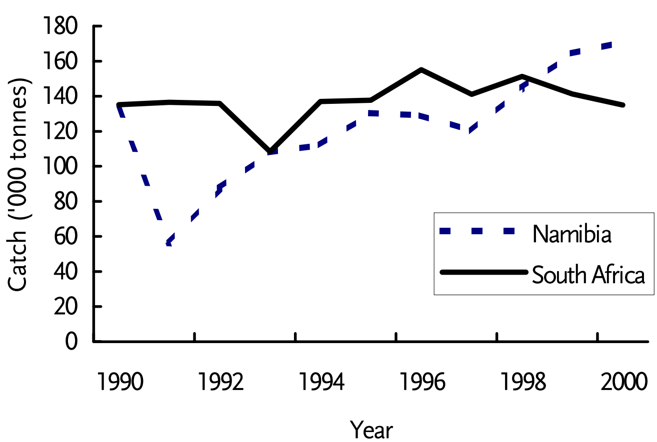

Figure 1. Hake catch by South Africa and Namibia from 1990 to 2000.

fishers of both countries pursue their fishing interest unilaterally. This equilibrium solution can also serve as a benchmark for the worst equilibrium that can be reached. A non-cooperative equilibrium will be used to depict the situation in which each country manages the fishery alone under the assumption that the fish is not a shared resource. Thus, the non-cooperative solution (Clark, 1980) lies between the open access and sole owner solution. This solution we believe captures the current management situation for hake. Finally, a cooperative solution is one in which the two countries work together to maximize their joint benefits from fishing after taking into account their different preferences (Munro, 1979).

We begin by developing the sole owner and open access solutions in the case of the shared hake stocks. We then compute and compare the solutions from these management scenarios with the outcome obtained given the current management regimes in the two countries. Finally, we develop and compute a simple cooperative solution in which the two countries differ only in the prices their fishers receive per unit weight of fish. It should be noted that the models presented are simple 'first cut' models that should lead to more detailed models in our future research. A detailed model will, for example, relate and discuss the different equilibrium solutions to the particularities of the fishery more rigorously.

The biological model

On the biological side of the model, a logistic growth function is applied. We assume, in similar fashion to that of biologists working on Namibian hake, that the two main hake stocks found in the ecosystem are similar enough ecologically to be considered as one and the same for modelling purposes. Hence, growth is described by the single species logistic function:

$$F(x) = rx(1 - \frac{x}{K}), \tag{1}$$

where x is the stock biomass, r is the intrinsic growth rate and K is the carrying capacity of the environment. It is assumed that in equilibrium harvest equals growth, i.e. $h(\text{t})=F(x)$, hence equation (1) gives the equilibrium harvest.

The sole owner model

The sole owner is assumed to maximise the following objective function:

$$PV = \int e^{-\delta t}(p - c(x))h(t)dt, \tag{2}$$

where PV is present value, p, is the unit price of harvest $h(t)$, and $c(x)$ is the unit cost of harvesting, as a function of the stock biomass x, while δ is the discount rate. The variables x and h must satisfy the non-negativity constraints.

The solution to the above problem is (Clark, 1990):

$$F'(x) - \frac{c'(x)F(x)}{p - c(x)} = \delta \tag{3}$$

The left side of equation (3) describes the stocks' own rate of economic rent creation, which under optimal conditions must equal society's rate of discount. This equation implicitly gives the optimal stock size, economic rent, etc.

The open access model

According to Gordon's theory of the open access fishery, fishing effort expands to a level E_∞ at which revenues exactly equal opportunity costs (Gordon, 1954). In terms of our logistic model, the equilibrium effort level is given by (Clark, 1990):

$$E_\infty = \frac{r}{q}\left(1 - \frac{c}{pqK}\right), \tag{4}$$

given that $c(x)=c/qx$, where c is the unit cost of effort, q is the catchability coefficient and K is the carrying capacity of the stock. The corresponding stock level $x = x_\infty$ is:

$$x_\infty = \frac{c}{pq} \tag{5}$$

Hence, in open access the optimal stock size is determined only by the cost, price and catchability data.

The cooperative model

In Munro's 1979 paper on transboundary fishery management, a bioeconomic model of two states managing a single transboundary fish species is presented. The two countries are modelled as having different costs, discount rates or consumer tastes. In this work we apply Munro's transboundary management model to the hake fishery in order to determine whether there is anything to gain from cooperative interaction between South Africa and Namibia in the management of this species. We will, however, limit this study by assuming that the key difference between the two countries is the prices they receive per unit weight of hake they land.

It is demonstrated in Clark (1980) and also in Levhari and Mirman (1980) that the outcome to the fishing nations of non-cooperation is, as would be expected, of unquestionable undesirability. In developing a cooperative management analysis, Munro (1979) combined the standard economic model of the fishery with cooperative game theory. In the following, we redefine this model to suit our game of two players harvesting the same fish stock while facing different prices in the marketplace. It is assumed that there is potential for a binding agreement under cooperation.

The objective functions that players 1 and 2 wish to maximise are assumed to be:

$$PV_1 = \int e^{-\delta t}(p_1 - c(x))\alpha(t)h(t)dt, \tag{6a}$$

$$PV_2 = \int e^{-\delta t}(p_2 - c(x))(1-\alpha(t))h(t)dt \tag{6b}$$

where $0 \leq \alpha(t) \leq 1$, is player 1's share of the harvest, p is the unit price of harvest $h(t)$, and $c(x)$ is the unit cost of harvesting, as a function of the stock biomass x, while δ is the discount rate.

Given the above objectives, a potential cooperative agreement can be characterised by:

$$\max PV = \beta PV_1 + (1-\beta)PV_2 \tag{7}$$

Where β, a constant that can take values from 0 to 1, is a bargaining parameter and a measure of the weight given to 1's management preferences.

By solving the above maximisation problem for each possible β ($0 \leq \beta \leq 1$),[6] we determine the Pareto efficient frontier in the space of realised payoffs. By choosing a cooperative game solution option, β can then be determined for this. Assuming that only prices differ for the two countries, the optimal biomass time path is given by the following modified golden rule equation (Munro, 1979):

$$F'(x^*) - \frac{[(\alpha\beta + (1-\alpha)(1-\beta))c'(x^*)]F(x^*)}{\alpha\beta p_1 + (1-\alpha)(1-\beta)p_2 - [\alpha\beta + (1-\alpha)(1-\beta)]c(x^*)} = \delta \tag{8}$$

For the cooperative regime, we assume that there is a binding agreement between the two countries, that the harvest shares are constant, and that no side payments are allowed.

In solving (8) for x^*, we obtain the optimal stock level as a function of β, which can be applied to equations (6a and 6b), in order to obtain the two countries' optimal present values (again as functions of β). By varying the bargaining parameter β between 0 and 1, we find the payoff possibility fron-

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6 For $\beta = 0$ or $\beta = 1$, the optimal harvest program reduces to that of single owner (country 2 if $\beta = 0$; country 1 if $\beta = 1$).

tier. The optimal β can be determined by using the Nash bargaining solution, (Munro, 1979).[7]

Discrete versions of the models described above are run for the last decade, that is from 1990 to 2000.

DATA

Namibia exports almost all of its hake harvests, while South Africa has exported approximately 45% of its hake harvests (Anon, undated)[8]. The reasons for this difference between the two countries are different technology, quality of production, as well as market opportunities. This results in different first-hand prices in the two countries. We have calculated the average first-hand value of hake in 1997 to be 3,852 and 5,140 N$/tonne for South Africa and Namibia respectively (data from Anon, 2000). The prices are applied to the cooperative solution studied. In the sole owner case we apply the higher price, as we are interested in the overall optimal solution, the optimum optimorum (Munro, 1979). Since many of the same companies participate in the hake fisheries both in Namibia and in South Africa, we assume that the costs are the same for the two countries. Costs per unit harvest are assumed to be approximately half of the price per unit harvest (Aina Ulenga, MFMR, pers. comm.). Following Backeberg (1997), a discount rate of 10% is used. With regards to biological data, we assume that the intrinsic growth rate r is 0.344 (Punt, 1994), and the carrying capacity K is 4.4 million tonnes, which is twice that reported for the hake stock outside South Africa in the beginning of the twentieth century (Hampton *et al.*, 1999). The stock size prior to the analysis is assumed to be 0.9 million tonnes (Hampton *et al.*, 1999).[9]

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7 For a review of bargaining schemes, see Kaitala (1985). In this paper we will only study the so-called dictator solutions, that is, β equals 0 or 1, as with the data given below this will be sufficient to show that a cooperative solution will not differ substantially from the sole owner solution.

8 Recent price increases in the Spanish market have, however, increased this share to 65% (AllAfrica, 2002).

9 This is an average of survey data from South Africa and Namibia, and an estimate from an age-structured production model (Hampton *et al.*, 1999). The two numbers differed by about 100,000 tonnes. The survey estimate for 1990 was, however, uncharacteristically high as compared with the closest years, but nonetheless fit well with the data in the age-structured production model.

RESULTS

When studying the cooperative solution with different prices, we find that the outer limits as regards the payoff possibility frontier, that is β equals 1 and 0, result in optimal stock sizes that hardly differ (1,871,491 and 1,780,404 tonnes, respectively). Hence, weighting of management preferences to the advantage of either of the countries hardly affects the optimal harvesting strategies, this despite the South African price being only 75% of the Namibian price. Hence, even greater differences in the parameters involved are needed in order to obtain more significant effects of cooperative management.[10] In the following, we will derive results under sole ownership management and open access, and compare this with the computed rent from the actual harvest profile in the 1990s.

Using the data presented earlier, we calculated the economic rent, biomass and catch levels obtainable under the various equilibrium solutions presented above. The results show that under sole ownership the equilibrium stock size is about 1.9 million tonnes (see Figure 2); the equilibrium

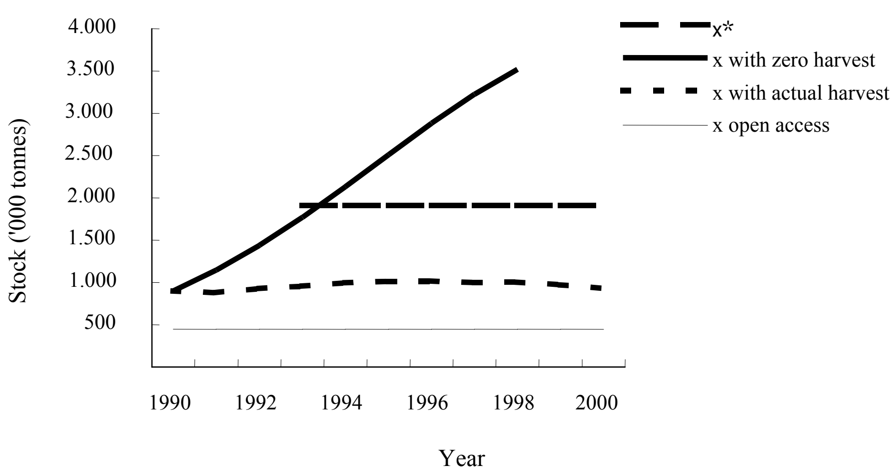

Figure 2. Stock size from 1990 to 2000 using the presented model.

[10] This lack of big difference may well be due to the fact that our single species biological model does not capture the natural interaction between juvenile and adult hake, and the interaction between the fishing gears employed to exploit the resource in the two countries.

harvest is about 370 thousand tonnes (see Figure 3), and the total economic rent over the 11-year period of 1990 to 2000 is about N$8.6 billion[11]. The equivalent numbers for the open access equilibrium are just under 0.5 million tonnes; 138 thousand tonnes; and zero N$.[12] These numbers depict the potential bioeconomic loss when hake is exploited under pure open access. The numbers show that while as much as N$8.6 billion of economic rent is dissipated under open access compared with what is obtainable under sole ownership, the stock size is also much lower, at about only a quarter of the biomass under sole ownership.

We know that hake is not exploited under pure open access, since Namibia and South Africa both have elaborate management arrangements for hake. However, the stocks are currently non-cooperatively managed because even though hake is a shared stock, it is not managed cooperatively. We allow the actual catch profiles of the two countries to help us depict the non-cooperative solution for this fishery. The justification for this is that the actual management has been one of non-cooperation between the two countries involved, hence both parties can be expected to have acted in expectation of the other maximizing own interests. Our calculations indicate that the economic rent from hake harvested in both countries is about 70% of the

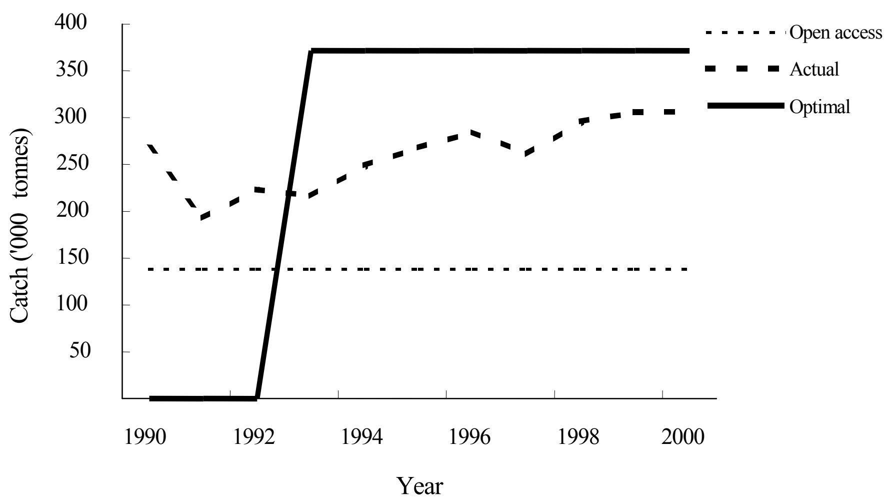

Figure 3. Catch in tonnes from 1990-2000.

11 The economic rent is calculated for the 11-year period and discounted back to 1990. In the case of optimal harvests, the harvesting commences in 1993, when the build-up phase to optimal stock size is over. Hence economic rent in the optimal scenario is calculated for the years 1993-2000.

12 We disregard rent from the "fished-down" phase.

N$8.6 billion computed when sole ownership is assumed. The current estimated biomass is just less than 1 million tonnes; hence, it is approximately half of the sole ownership equilibrium biomass. The results, however, show that just over two thirds of the potential rent from the hake stocks is actually realized under current management regimes. Thus, our estimate of the potential cost of non-cooperation is about N$3.6 billion over the 11-year period being studied. This implies an average annual loss of about N$327 million or 31% of the total achievable rent under joint management. The low estimated stock level compared with the optimal case is an indication of potentially greater losses in the future.

CONCLUSION

We have presented a simple model for the hake fisheries of Namibia and South Africa, and used it to estimate the potential cost of non-cooperative management of this shared stock. Because of the simple nature of the model, our results can only be taken as indicative of this cost. More detailed modelling of both the biological and economic aspects of the fishery is required before something definitive can be said about the potential gains from cooperative management.

With respect to biology, detailed modelling that takes into account the natural interactions between the different stocks of hake, between juvenile and adult hake through cannibalism, and between hake and other species in the ecosystem is required. On the economic side, we need to incorporate more on preferences and differences between Namibia and South Africa into the model to be able to make more categorical statements about the cost of non-cooperation. Also, how the two countries negotiate and decide on the sharing of benefits from cooperation is left to future work.

Having said the above, the current results demonstrate that the potential losses due to non-cooperation can be quite high. Thus, there is a need for the development of cooperative agreements between Namibia and South Africa for the management of the hake stocks of the Benguela current ecosystem, if the full benefit from the resource is to be extracted. It must be added that this potential loss notwithstanding, Namibia retains, relative to other countries, a significant amount of rent from its management of the hake fishery. Still, there are further gains to be made from cooperative management between Namibia and South Africa.

REFERENCES

AllAfrica (2002): Export Needs Cause Local Hake Shortage. *allAfrica.com*, Aug. 16; *http://allafrica.com*.

Anon (1999): Transboundary Diagnostic Analysis (TDA) UNDP Windhoek, Namibia. *http://www.ioinst.org/bclme/resources/index.htm*, *http://www.ioinst.org/bclme/resources/table_a1.htm*.

Anon (2000): *Fishing Industry Handbook South Africa, Namibia and Mocambique 2000*. Exbury Publications, South Africa.

Anon (undated): The Economic and Sectoral Study (ESS) of the South African fishing industry. *http://www.envirofishafrica.co.za/ess/ESS2000WEBSITE/essindex.htm*.

Armstrong, C. and Flaaten, O. (1991): The optimal management of a transboundary resource: The Arcto-Norwegian cod stock. In: *Essays on the Economics of Migratory Fish Stocks*. (R. Arnason and T. Bjørndal, eds.), pp. 137-152. Springer-Verlag, Berlin.

Backeberg, G. (1997): Water institutions, markets and decentralised management: prospects for innovative policy reforms in irrigated agriculture. Presidential address, 35th Annual Conference of the Agricultural Economics Association of South Africa, East London.

Boyer, D.C. and Hampton, I. (2001): An overview of the living marine resources of Namibia. *South African Journal of Marine Science* 23: 5-35.

Clark, C.W. (1980): Restricted access to common-property fishery resources: a game theoretic analysis. In: *Dynamic Optimisation and Mathematical Economics*. (P.Liu, ed.), Plenum Press, New York.

Clark, C.W. (1990): *Mathematical Bioeconomics. Optimal Management of Renewable Resources*. Wiley and Sons, Toronto, New York.

Duarte, C.C., Brasao, A. and Pontassilgo, P. (2000): The application of C-Games. *Marine Resource Economics* 15(1): 21-36.

FAO (2003): Papers presented at the Norway-FAO Expert Consultation on the Management of Shared Fish Stocks, Bergen, Norway, 7-10 October 2002. FAO Fisheries Report No. 695 Supplement.

FAO (2002): Report of the Norway-FAO Expert Consultation on the Management of Shared Fish Stocks, Bergen, Norway, 7-10 October 2002. FAO Fisheries Report No. 695.

Gordon, H.S. (1954): Economic theory of a common property-resource: the fishery. *Journal of Political Economy* 62: 124-142.

Hampton, I., Boyer, D.C., Penney, A.J., Pereira, A.F. and Sardinha, M. (1999): Integrated overview of fisheries of the Benguela Current region. Thematic report for the Benguela Current Large Marine Ecosystem Programme. Windhoek: United Nations Development Programme.

Hutchings, L. (1995): An overview of South African hake fisheries research. In: *The Benguela Current and Comparable Eastern Boundary Upwelling Ecosystems*. (M.J. O'Toole, ed.), Ministry of Fisheries and Marine Resources, Swakopmund, Namibia.

Kaitala, V.T. (1985): Game Theory Models in Fisheries Management: A Survey. In: *Dynamic Games and Applications in Economics*. (T. Basar, ed.), Springer Verlag, Berlin.

Levhari, D. and Mirman, L.J. (1980): The great fish war: An example using dynamic Cournot-Nash solution. *Bell*

Journal of Economics 11: 322-334.

Lindroos, M. and V. Kaitala (2000): Coalition Game of Herring. *Marine Resource Economics* 15(4): 321-340.

Manning, P. (2000): Review of the distributive aspects of Namibia's fisheries policy. NEPRU Research Report no. 21.

Munro, G.R. (1979): The optimal management of transboundary renewable resources. *Canadian Journal of Economics* 12: 355-376.

Munro, G.R. (2000): The UN fish stocks Agreement of 1995. *Marine Resource Economics*, 15(4): 265-280.

Punt, A.E. (1994): Assessment of the stocks of cape hakes off South Africa. *South African Journal of Marine Science* 14: 159-186.

Sumaila, U.R. (1999): A review of game theoretic models of fishing. *Marine Policy* 23(1): 1-10.

Sumaila, U.R. (2000): Fish as vehicle for economic development in Namibia, 2000. *Forum for Development Studies* 2: 295-315.

Sumaila, U.R. and Vasconcellos, M. (2000): Simulation of ecological and economic impacts of distant water fleets on Namibian fisheries. *Ecological Economics* 32: 457-464.

Sydnes, A.K. (2002): Regional fishery organisations in developing regions: adapting to changes in international fisheries law. *Marine Policy* 26: 373-381.