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ANALYSIS

Investing in natural capital as management strategy in fisheries: The case of the Baltic Sea cod fishery

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ABSTRACT

Many of today's fish stocks are officially managed following the precautionary approach. Yet, different political objectives and uncertainties among fishermen about their economic future make its implementation difficult. Over 75% of all commercially valuable stocks are exploited, overused, or collapsed and in a state of recovery [FAO, 2004. The state of the world fisheries and aquaculture. FAO, Rome. Managing fish stocks with an ecosystem-based approach is likely to stop the divestment of natural capital by combining sustainable use strategies with the preservation of marine ecosystems. Using the example of the Baltic Sea cod fishery, we show that a recovery program is economically and ecologically viable and reduces negative externalities. While policy makers must assist fishermen during the early years of the program, fishermen will experience greater landings and profits in subsequent years.

1. Introduction

Marine ecosystems provide many material goods for human consumption. Stocks of individual species also deliver services to other organisms in the ecosystem. These latter services take various forms ranging from filtering sea water (e.g., mussels) to providing cover from predator fish (e.g., algae, corals). To manage the extraction of material marine resources, decision makers commonly maximize the long-term consumptive yield of individual stocks (especially fish stocks) but neglect their service function. Moreover, in the present state of declining stocks fisheries management is often driven by other objectives, e.g., to keep fishermen in business. As a result, permissible landings too often remain unchanged or are only insufficiently reduced. With 75% of all commercially valuable stocks fully exploited, overused, or collapsed and in a state of recovery (FAO, 2004), these practices are problematic. Contributing to the decreasing fish stocks are low-cost fishing methods that create large negative externalities such as bycatch of juveniles and non-target species, habitat destruction, and devastated ecosystems. Policy makers must therefore move towards a more comprehensive framework of fish stock management that accounts, at least partially, for the complex interactions and services of multiple organisms in the marine environment.

In this paper, we first discuss the interpretation of fish stocks within different theories, focusing on single and multi-species models, natural capital, and the theory of funds. We then identify the management practices that emerge from these perspectives and evaluate their implementation and effectiveness. Current approaches often led to overexploitation of stocks and destruction of habitats, but there also exist examples of successful small scale management schemes that prevent excessive use and minimize externalities. Based on these experiences, we propose a recovery program for Baltic Sea cod that breaks the present policy deadlock between

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fishermen's fear of bankruptcy through reduced quotas and the ecological interest of recovering the cod population and protecting the ecosystem. The Baltic Sea represents an ecologically well understood and geographically manageable area where cod is severely overfished, and hence provides a suitable ecosystem for our analysis. The results show that an investment in natural capital can lead to greater sustainable landings and reduced externalities, and be economically viable.

2. Fish stocks as capital

2.1. *Single and multi-species models in fisheries economics*

Marine ecosystems provide many benefits for humans besides the use of individual fish stocks (e.g., oxygen production). Their complexity, however, makes the valuation of benefits outside the direct consumption of fish stocks difficult. As a result, the potential use of a fish stock has traditionally been assessed isolated from its role in the ecosystem (e.g., Clark and Munro, 1975). Following Fisher (1906) who referred to "all stocks that create a stream of wealth" as capital, fish stocks were often interpreted as a homogeneous capital category. Based on this notion, Clark and Munro (1975) and Clark (1990) do not distinguish between investments in fish stocks and other investment decisions. Fish stocks, they argue, generate a usable amount of fish, and the fish's reproduction rate corresponds approximately to the rate of return on capital. Clark (1990) then assumes a sole owner of the fish stock who searches for the greatest net present value of profits from its landings, constrained only by the population's growth rate.

Because a fish stock does not exist on its own in an ecosystem, but interacts with other species as either prey or predator stock, single stock models have been extended to include multi-species aspects (e.g., May et al., 1979; Flaaten, 1998). These models generally recommend smaller usable amounts than single stock approaches (Ströbele and Wacker, 1995), and can be seen as early attempts to integrate ecosystem functions. However, multi-species models also view fish stocks as capital stocks. Examining multiple instead of only single stocks therefore continues to exclude the species' ecosystem functions and services from the analysis.

2.2. *Fish stocks as natural capital*

Pearce (1988) was the first to distinguish natural capital as a separate category of capital. The idea was not only to define stocks of natural resources (like fish stocks) as 'capital stocks' but to also integrate ecosystem services and functions into the analysis (see also Daly, 1996). Further, the theory of funds proposed by Faber and Manstetten (1998) allows an interpretation of capital beyond the single or multi-species stock approach. Funds are entities that provide material goods, non-material services, or both. Faber and Manstetten (1998) distinguish two groups of funds — living and non-living funds. Living funds have the ability to reproduce, but they also require services from non-living funds for survival (e.g., fish need clean water to live in). Furthermore, over time living funds can increase the stock of non-living funds. The growth of coral reefs over thousands of years illustrates this replenishing effect. Non-living funds, in contrast, are characterized by their services to living funds as well as their potential to be consumed (Fig. 1).

Fish are hence living funds that produce food for humans and other organisms (e.g., prey species are consumed by humans as well as predator fish) and that provide services to the marine environment. The consumable or usable portion of the fish biomass is commonly interpreted as a separate stock that is continuously replenished by living funds, generates a usable flow of goods, and depends on the services of the living and non-living funds from which it is generated. With the exception of a possible extinction through natural causes in the long-term, funds have an indefinite lifespan. Although a fund's individual organisms die over time, their ability to reproduce keeps the fund in balance. In contrast to single stock and multi-species models, the theory of funds incorporates a stock's services and functions to the ecosystem. Because the approach requires a minimum stock size to maintain these functions and services, only the amount above this level is available for consumptive use.

3. Management of fish stocks

3.1. *The precautionary approach*

The introduction of the 200-mile Exclusive Economic Zone in 1977 brought nearly all fish stocks under the control of national governments. Fisheries management and resource allocation schemes have thus become national matters. Most countries currently use quota management systems with a total annual allowable catch from a single stock as their main management instrument. In determining the total permissible catch from each stock, many countries follow the precautionary approach.

The underlying notion of the precautionary principle is to manage the fish stock "within safe biological limits." These safety limits are established by fisheries biologists of the International Council for the Exploration of the Sea (ICES) and other organizations through an assessment of the fish stock biomass. For species with less available data, decision makers act conservatively, so that fewer data translate into more restrictive limits.

The approach distinguishes four different thresholds, two on biomass size (B) and two on fishing mortality (F).

- B_{lim} Biomass limit: the biomass level below which the possibility of a total breakdown of the stock is very high and the reproductive capacity reduced; the fish stock size is so low that biologists cannot predict recovery over time.
- B_{pa} Biomass precautionary limit: a stock size level such that a short-term reduction in fishing effort is expected to allow the stock to recover above this limit. Reproductive capacity is not yet reduced. Greater uncertainties regarding a species stock size cause B_{pa} to be set at higher levels and further apart from B_{lim}.
- F_{lim} Mortality limit: the annual fishing level above which the risk of a total breakdown of the stock is extremely high.
- F_{pa} Mortality precautionary limit: the annual fishing level above which the risk that the stock size falls below B_{pa} is high.

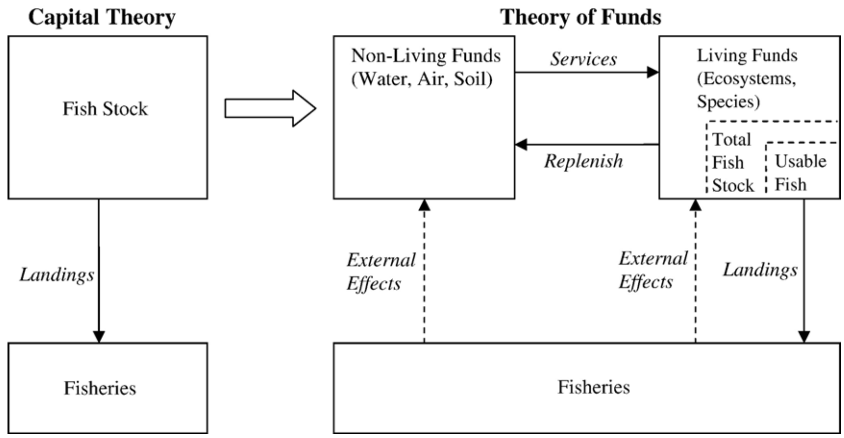

Fig. 1 – Conceptual overview of capital theory and the theory of funds in fisheries.

All limits are entered into an indicator matrix to aid decision makers in allocating catching quotas (Fig. 2). If a fish stock decreases below B_{pa} or if its mortality risk exceeds F_{pa}, fishing effort must be substantially reduced. A further drop of the fish stock below B_{lim} or an increase in mortality risk beyond F_{lim}, mandate a complete stop of fishing of the affected species in order to prevent its commercial extinction and allow for recovery. The precautionary principle hence leads policy makers to hold the fish stock biomass above B_{pa} and the mortality risk below F_{pa} at all times. The approach however has an important drawback. Although maintaining a healthy fish biomass helps preserve the species' functions and services in the marine ecosystem, this is not a distinct objective. The policy focus is almost exclusively on fish stock biomass and does not explicitly incorporate negative externalities and the dependence of living funds (fish stocks) on functions and services of other funds.

A crucial prerequisite for managing fish stocks with the precautionary framework is to determine the total annual allowable catch strictly based on scientific stock assessments and to allocate the permissible amounts appropriately to fisheries. When these dimensions enter into the political debate as has occurred in the U.S., Canada, or the EU, the precautionary approach becomes difficult to implement. The EU represents a particularly good example of a jurisdiction that has accepted the precautionary approach as its official management system, but that subsequently failed in its application. Various conflicts of interest between different member countries have resulted in exceptions for 'special' national circumstances and too generous quotas (Edwards et al., 2004).[1] An analysis by the European Commission estimates that approximately three quarters of the EU's commercially viable fish stocks are overused or fully exploited (European Commission, 2001). The main reason for this depletion is stated in the report as the overcapitalization of the fleet. Fishing capacity and fishing effort continuously exceed the use potential of the stocks. In addition, fishing operations have become more efficient because modern search technology and larger nets allow fishermen to locate and catch fish assemblies more easily.

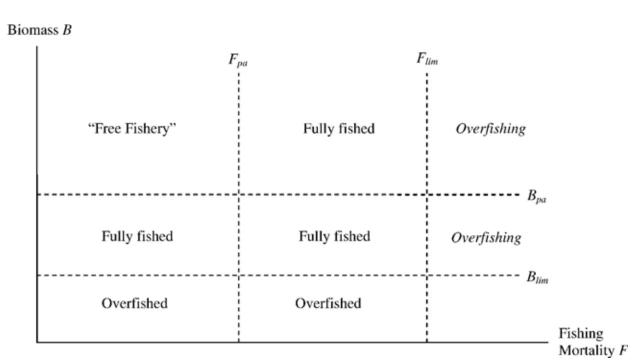

Fig. 2 – Decision matrix and policy implications according to the precautionary approach to fisheries management (Caddy and Mahon, 1995).

The investments in larger fishing vessels and particularly in modern technology were initially made possible by EU subsidies, which were based on the belief that oceans contained substantially more fish. Fisheries used the newly gained capacity and efficiency to increase their landings outside EU territory. After the declaration of Exclusive Economic Zones, the EU began to buy fishing rights to maintain access to world fish stocks. The basic strategy was to decrease production costs and increase landings in the short-term. As fish stocks declined, the political pressure to maintain high (and unsustainable) total catches increased, because the oversized EU fleet required rather large minimum landings to prevent its financial collapse. EU policy has therefore not preserved fish stocks as mandated by the precautionary framework, but instead resulted in low stocks by giving fishermen the ability to fish more at lower costs.

3.2. *Rights-based fisheries management and the ecosystem approach*

Although oversized fleets are the main contributor to the decline of world fish stocks, their effect is amplified by the

[1] The EU uses a two-step system, where the Council of Ministers sets member country quotas based on predetermined shares and where each country then uses its own approach to allocate these further to individual fisheries (e.g., Sweden: open access for Baltic cod; Denmark, Germany: individual non-transferable quotas for Baltic cod). The failure of the precautionary approach is therefore primarily caused by an excessive total EU quota.

Table 1 – External effects of different fishing methods in Baltic Sea fisheries (Döring et al., 2005)

Fishing gear	Bycatch of			Negative consequences for overall ecosystem
	Undersized specimens of target species	Non-target species	Birds and marine mammals	
Gill net	Low	Low, for carefully selected fishing areas	Partially high, use of pinger (i.e., sound device) hardly successful	Low, because used in open water
Trap net	Low, but greater than with gill nets	No real problem because bycatch survives	Traps must be covered, little information about bycatch of marine mammals	Low, because of fixed position
Longlines	Low	Low, in most cases	Problematic in some fisheries	Low
Pelagic trawl	Depends on mesh sizes, low survival rate of escaped fish	Problematic in some areas, e.g., cod bycatch in the Baltic Sea	Low	Low
Bottom trawl	High, because escape windows or mesh sizes are inadequate to avoid bycatch	High, because all fish in front of the ground rope are caught (up to 95%)	Low	High, destruction of seabed, plowing of ocean floors, leveling of structural elementsm, etc.

extreme short-term perspective of many countries' management policies. In the EU, for example, fishermen have few economic incentives to preserve the fish stock (Hatcher and Gordon, 2005). Their fishing rights are neither rights on the total fish stock, but only on a share that varies from year to year, nor on specific fishing areas. Fishermen's uncertainty regarding future landings therefore remains high. This situation encourages overexploitation of resources in the short-term and discourages investments in natural capital (i.e., fish stocks) in the long-term, as individual fishermen are unable to reap the benefits of any conservation commitments.

Recognizing the lack of economic incentives, some countries such as New Zealand and Iceland, have introduced individual transferable quotas (ITQs) in order to complement the precautionary approach (New Zealand: Newell et al., 2003; Iceland: Gudmundsson, 2004). These individual property rights, which are initially often distributed according to fishermen's historical allocations, guarantee fishermen fixed shares of the total allowable catch each year. Because the rights are transferable, higher cost producers will sell their shares to lower cost producers, thereby reducing overcapacity and improving economic efficiency of the aggregate fleet (Anderson, 1997).[2] To attain continuing economic and ecological viability, the ITQ system further requires policy makers to prevent excessive concentration of ITQs and to place restrictions of the permissible fishing method. Without gear restrictions fisheries tend to use the cheapest methods, which generally are also the most destructive (Armstrong and Sumaila, 2001). This effect is clearly visible in the German Baltic cod fishery where the use of trawls instead of longlines prevails in today's overuse situation (Table 1). For the future, however, supporters of the ITQ approach predict that the remaining fishermen who have accumulated the quotas will work together cooperatively to manage the stock in an ecologically responsible way and that government regulation can be reduced (see Dietz et al., 2004, for an example in New Zealand).

The intended long-term structure of an ITQ system, i.e., the cooperative management of fish stocks, is similar to community-based management systems practiced for centuries by many small scale fisheries throughout the world (Berkes et al., 2001; Dolsak and Ostrom, 2003). Communities in this context consist of small numbers of fishermen managing certain areas and fisheries themselves. Community-based management systems cooperatively determine the type of permissible fishing gear and the total allowable catch, which is then allocated to individual fishermen according to specific community-developed rules. These management frameworks rely on the notion that communities have an inherent interest in maintaining and protecting the ecosystems their livelihood depends on.

Management approaches that actively incorporate the objective of reducing disruption of ecosystems through fisheries are also referred to ecosystem-based management systems. They are based on the notion that less interference with the natural ecosystem translates into better living environments for fish, and if part of the ecosystem is damaged, either through overfishing or negative external effects, landings and other uses will also decline (Collie et al., 1997; Kaiser and de Groot, 2000). Ecosystem-based management approaches therefore focus not only on maintaining strong stock levels of the target species but also on protecting biological diversity. The U.S. National Research Council defines such ecosystem-based management approaches as taking "… major ecosystem components and services – both structural and functional – into account in managing fisheries… They value habitats, embrace a multi-species perspective, and are committed to understanding ecosystem processes … Their goal is to rebuild and sustain populations, species, biological communities and marine ecosystems at high levels of productivity and biological diversity so as to not to jeopardize a wide range of goods and services from marine ecosystems which provide food, revenues, and recreation for humans" (US National Research Council, 1998). The ecosystem-based approach hence extends beyond the precautionary approach to fish stock management as it incorporates the species' interactions with other components of the ecosystem.

The definition of ecosystem-based management reflects well the theory of funds, demanding not only the sustainable

[2] The transferability feature of quotas increases the efficiency of resource use as higher cost producers transfer quotas to lower cost producers. Transferable quotas have also been used, for example, to allocate emission rights for sulfur dioxide (SO_2) in the U.S. and carbon dioxide (CO_2) in the EU.

use of fish stocks but also protecting the aquatic environment by requiring the use of non- or low-impact fishing gear. Under this approach, a fish stock recovery program must therefore consist not only of investments in natural capital through reduced catches but also of investments in natural capital through switching to less destructive fishing methods even if production costs as opposed to social costs increase. The externality cost savings associated with adopting a different fish stock management scheme can then be expressed as the aggregate (*PV*) of all discounted non-market amenity values $\alpha(t)$,

$$PV = \int_0^\infty \alpha(t)e^{-it}dt, \quad (1)$$

where *i* denotes the discount rate and *t* the time variable (Eq. (1)) (Hampicke, 2001), and be measured by the consumers' willingness to pay for ecolabeled fish (Wessells et al., 1999). Moreover, the recovery program should allow fishermen to benefit from conservation efforts, i.e., reduce uncertainty regarding future landings, to ensure their support. In the following section we propose a management scheme for Baltic Sea cod that meets these requirements and show that the program is economically and ecologically viable and decreases negative externalities on other funds.

4. The Baltic Sea cod fishery

4.1. *Baltic Sea cod*

The Baltic Sea is a brackish water semi-enclosed sea with only few fish species (cod, herring, sprat and flatfish species). The small number of species makes the interactions between living and non-living funds less complex, which has allowed marine biologists to gain a sound understanding of the funds' relationships in the ecosystem and to develop reliable fish stock models (Köster et al., 2001; STORE, 2002). Therefore, the Baltic Sea provides a well suited domain to analyze whether an investment in natural capital via an ecosystem-based recovery and management program for cod is economically and ecologically viable.

Due to unfavourable environmental conditions (low salinity and oxygen content) in the spawning areas, cod reproduction rates have remained low throughout the Baltic Sea since the early 1980's. Annual fishing limits however, were consistently set at levels above those recommended by ICES as ministers feared bankruptcies of their fishermen (Sterner and Svedäng, 2005).[3] Although Denmark, Germany, and Sweden implemented extensive decommissioning programs at the beginning of the 1990s, the impact of their fleet reductions was not large enough to prevent a further decline of the cod stock as not all nations participated (e.g., Poland, Lithuania, Latvia, and Estonia only started decommissioning vessels after joining the EU in 2004). Moreover, most Baltic cod fishermen used trawl nets causing significant bycatch which has affected other living funds (Table 1). The low spawning rates and excessive catches have caused cod stocks to decrease substantially over the past 25 years. Currently the stocks remain significantly below the precautionary limit B_{pa} (Fig. 3). Overfishing has also reduced the cod's service function to the Baltic's marine ecosystem. Fewer cods have caused an increase in sprat stocks (prey species) who feed on zooplankton. Higher predation on zooplankton however leads to greater algae growth, one of the main reasons for the declining oxygen content in deeper layers. These vital ecological dependencies between living and non-living funds and the cod's economic importance in the Baltic Sea make its recuperation imperative.

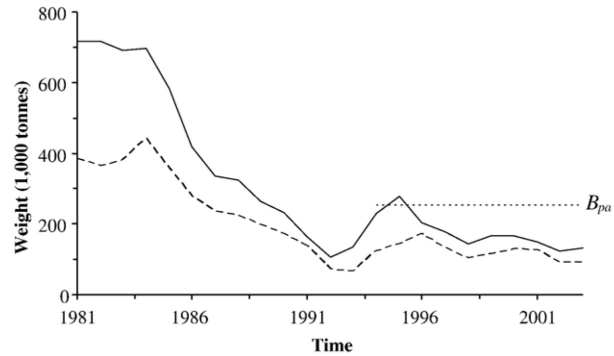

Fig. 3 – Cod spawning stock biomass (solid line) and total landings (dashed line) in the Baltic Sea from 1981 to 2003 and precautionary biomass limit B_{pa} (WGBFAS, 2004).

Yet, cod fishery affects the Baltic's marine environment well beyond reduced fish stocks. Bottom trawl, as the presently dominating fishing method, has been shown to damage flora and megafauna in various fishing regions across the world, severely impacting bottom-living fish, invertebrates, algae populations, and predator prey relationships (Jennings and Kaiser, 1998; Thrush and Dayton, 2002). Although less studied, similar affects can be expected for the Baltic Sea. Seabed protection thus becomes a mandatory task to prevent further loss of Baltic bottom habitats. Other harmful affects of trawling include the bycatch of non-target fish species and marine mammals. While habit destruction and bycatch are negative externalities, their extent depends on the type of fishing gear used (Table 1). For example, in the Baltic Sea a switch away from trawls to longlines will greatly decrease the impact of cod fisheries on its ecosystem.

4.2. *Management program*

Starting with the present situation, how can policy makers design a viable recovery program? The first step is a shift away from the current system of setting politically manipulable quotas to permanently fixing the number of fishing licences, and thus allowing fishermen to directly benefit from future increases in the fish stock. The second task involves an investment in natural capital (i.e., the cod stock) by introducing an adjustment period during which the cod stock can recover, which will be followed by a switch to ecologically less compromising fishing gear as the final measure.

Biologists of the Federal Research Center for Fisheries (BFAFI) in Germany predict that using more selective trawl

[3] Hammer and Zimmermann (2004) estimate that annual fishing limits exceeded ICES recommendations on average by about 20%.

nets with special exit windows for smaller-sized cod allows stocks to increase in as early as three years (Ernst et al., 2000; Bethke, 2006). Bethke's (2006) estimates, for example, are based on Shepherd's (1982) model of sustainable yield curves to describe the relationship between the spawning stock biomass and recruitment, and on Beverton and Holt's (1957) yield-per-recruit model which uses a knife-edge selection function and assumes constant mortality during the forecast period to describe fish yield as a function of technical measures. His approach reduces the uncertainty regarding future fish stock biomass by increasing the average age of the fish landed. This increase permits younger and smaller fish to spawn before being caught and hence ensures an average reproduction rate within the stock that exceeds mortality from fishing efforts. Specifically, Bethke (2006) shows that by raising the minimum age from 2.7 to 3.4 years (through increased mesh size), the same annual tonnage can be landed while catching less specimens. Furthermore, spawning stock biomass will double within two years because the cod can spawn at least once before being caught. Continuing this program for five or more years expands the age distribution of the spawning stock to include sufficient mature specimens such that fishery no longer depends on the recruitment of a single year class. This expanded distribution of spawning stock over various age groups hence ensures an average spawning success (i.e., reduced spawning variability) as spawning rates are no longer determined by only one age group (Bethke, 2006). The initial delay in recovery is due to the composition of the current spawning stock, which is dominated by 3–4 year-old specimens (approximately 35 cm in size). The current situation is displayed in Fig. 3, where the spawning stock biomass is only modestly greater than total annual landings (which depend on the yearly recruitment of 3–4 year old cod).

Following the initial recovery period, the stock management program must then incorporate any negative affects of cod fishery on the stock itself and on other species in the ecosystem to reduce the impact on the species' complex interactions. Hall (1999), for example, report low negative externalities for longlines. Minimum hook and bait sizes only target cod above a particular size, bycatch of non-target species and other marine animals is low, and negative consequences for the overall Baltic Sea ecosystem are limited (see also Döring et al., 2005, Table 1). Thus, after the initial reduction of cod landings and with an ecosystem-based management approach, fishermen can expect to catch more fish and to report increased profits.

4.3. Analysis

The subsequent assessment, which relies on very conservative assumptions, shows that such recovery and management program can indeed be viable and not only lead to increased landings but also to fewer negative affects on the Baltic's ecosystem. The analysis is based on data from the cohort model by Ernst et al. (2000), a biological growth model for cod fish in the Baltic Sea, as well as forecasts by Bethke (2006). Their models incorporate various biological and environmental uncertainties such as recruitment, natural and fishing mortality, and environmental conditions in the spawning grounds. Only their most conservative biological growth predictions are used here. Assuming a 50-year time horizon, we evaluate four alternative scenarios:

1) Status quo — Baltic Sea fisheries continue to catch cod at present rates of 50,000 tonnes per year using trawl nets with current mesh sizes.
2) Recovery program I — Reduction to 25,000 tonnes per year during the first 5 years by using trawl nets with greater mesh sizes and escape window, 50,000 tonnes in year 6, 5000 tonnes per year increases for the next 20 years, and 150,000 tonnes per year thereafter. In year 25, switch to longlines only.
3) Recovery program II — Reduction to 25,000 tonnes per year during the first 5 years by using trawl nets with greater mesh sizes and escape window, 50,000 tonnes in year 6, 10,000 tonnes per year increases for the next 10 years, and 150,000 tonnes thereafter. In year 15, switch to longlines only.
4) A hypothesized sustainable catch of 150,000 tonnes per year by using longlines only.

In scenarios 2 and 3, 5 years of reduced catches at the beginning of the recovery period are followed by 45 years of greater landings. These landings are always below the possible landings predicted by Ernst et al. (2000) and Bethke (2006), and thus a conservative assumption. Scenario 4 presumes that a long-term annual catch of 150,000 tonnes is already feasible (for example, through an earlier conservation program). Using the above annual catches $h(t)$, the net present value (NPV) of future profits is computed as

$$\mathrm{NPV} = \sum_{t=1}^{50} e^{-\delta t}\{p - c[N(t)]\}h(t), \tag{2}$$

where δ denotes the fishermen's discount rate and $N(t)$ the fish stock biomass. The fishing costs $c(.)$ are reported in Table 2 and based on a fixed number of fishing licenses that reflect the 2004 decommissioning programs of the new EU member states. Our analysis is hence based on an already reduced fleet size, and assumes no further cuts beyond this target level. The average cod price is set at $p=1500$ Euro/tonne (average in 2004 season), the lowest real price recorded for Baltic Sea cod between 1990 and 2006. Because future white fish prices are expected to rise due to increased demand (e.g., Delgado et al., 2003) this price level also represents a very cautious approach.

4.4. Results

The results in Table 3 show that scenarios 2–4 substantially outperform the status quo (scenario 1) for real discount rates similar to those of other industrial and agricultural sectors.

Table 2 – Fishing cost estimates for Baltic Sea cod fisheries based on the 2004 EU target fleet size (Döring et al., 2005)

Fishing gear	Annual landings (tonnes)	Fishing costs (Euros per tonne)
Bottom trawl	25,000	1700
	50,000	1200
	150,000	850
Lonlines	150,000	1000

Table 3 – Net present values of profits from alternative fishing scenarios over a 50 year time horizon and different real discount rates

Discount rate (%)	Net present value (million euros)			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
0.0	750	2768	3077	3750
2.0	469	1503	1737	2347
4.0	318	857	1036	1589
13.4	105	105	155	679

Their net present values exceed those in scenario 1 when applying discount rates of 0%, 2%, and 4%. In these cases, Baltic cod fishermen economically benefit from an investment in natural capital. Only for real discount rates of 13.4% and greater, do efforts to recover cod stocks begin to become less profitable as indicated by equal net present values in scenario 2 and the status quo (105 million Euros). Evidence from Ireland, where the cod stock management system is similar to the one currently employed in the Baltic, however, shows that such large discount rates are rather typical for fishermen (Hillis and Wheelan, 1994). These rates, combined with high per tonne costs and fear of economic losses in the initial years of any adjustment period, prevent them from implementing measures that would increase cod stocks and catches in the long-term (Rowse, 2004). Hillis and Wheelan (1994) also find that the large magnitudes of fishermen's discount rates (rates range from 25% to 40%) are mainly due to the great uncertainty perceived about future landings. Therefore, if this uncertainty is reduced, discount rates will drop to levels comparable to those of other sectors in the economy (i.e., the risk-adjusted interest rate, see also Sumaila and Walters, 2005).

Table 3 also shows that the long-term benefits of a cod recovery program in the Baltic Sea extend beyond greater sustainable fishing quotas. More cod and larger individual fish increase the feasibility of longlines, a fishing method that – in contrast to trawl nets – keeps the Baltic's floor environment in its natural state and reduces bycatch of juveniles and non-target species. Döring et al. (2005) estimate that longline costs decrease to approximately 1000 Euros/tonne when cod stocks reach levels that sustain annual landings of 150,000 tonnes or more. These costs are only slightly greater than the 850 Euros/tonne estimated for trawl nets (Table 2).

Following the Faustmann–Hartman approach commonly used in forestry economics (Hampicke, 2001), the program's externality cost savings (Eq. (1)) can be incorporated into Eq. (2), resulting in

$$\mathrm{NPV} = \sum_{t=1}^{50} e^{-\delta t}\{p - c[N(t)]\}h(t) + \sum_{t=1}^{50} \alpha(t)e^{-\delta t}. \quad (3)$$

As indicated, these cost savings (e.g., intact seabed ecosystems, fewer bycatch of endangered fish species and marine mammals) can be measured by the price premium buyers are willing to pay for ecolabeled fish (Wessells et al., 1999). The computation of the net present value of future profits in Eq. (3) thus differs from Clark (1990) in two important dimensions. First, the variable estimates entering the model are obtained using the recovery and ecosystem-based management program and hence integrate ecosystem functions. Second, the expression explicitly captures the externality cost savings associated with switching to lower impact fishing gear, an aspect not considered by Clark (1990).

Although obtaining cod specific data to conduct the above calculations is beyond the scope of this study, Döring and Wichtmann (2007) provide some preliminary figures. Their recent survey of consumers of Baltic Sea fish, including cod, shows a possible eco-premium of 0.40–0.45 Euro/kg. Assuming conservatively that only half of this premium is actually passed on to fishermen, the resulting extra revenue of 200 Euros/tonne more than offsets the moderately higher costs of using longlines (1000–200 = 800 Euros/tonne) versus trawl nets (850 Euros/tonne) (Table 2). These results show that the use of more selective fishing methods can substantially lessen the impact of cod fisheries on the stock and the overall ecosystem without loss of economic viability.

4.5. *Discussion*

Despite its simplicity, the above model incorporates various biological and environmental uncertainties and uses very conservative assumptions of landings, fishing costs, cod price, and long-term fleet size. Moreover, as relatively few species and factors influence cod stock development in the Baltic, catching fewer and only large individuals during the early years of the proposed program has a great probability of at least recovering the cod biomass. Nevertheless, in case of ongoing low recruitment a further reduction in the number of fishing vessels will be necessary.

The investment in natural capital in form of a growing cod stock does not only occur during the recovery phase. The subsequent switch of fishing methods from trawl nets to more selective longlines as prescribed by the ecosystem-based management approach also constitutes a continuing investment in natural capital as more mature individuals are caught. Longlines further reduce the impact on other species and habitats and thus integrate the notion of preserving ecological functions and services. Jointly, these approaches will lead to a stable long-term balance between cod stock size and fishing effort, preserve the Baltic's ecosystem, and avoid closure of additional fisheries. The proposed management program is hence in contrast to prior approaches by Clark (1990) and others, which do not demand a switch to ecologically less compromising fishing methods.

Two important policy implications follow directly from the above. First, if Baltic fishermen shall reduce their landings substantially during a recovery period, they need incentives to do that. Potential alternatives include direct payments, governmental loan guarantees, and other measures designed to reduce fishermen's financial hardship during that initial period. In the example above (scenarios 2 and 3), which requires a conservative 5-year reduction of cod landings by 50% (50,000 tonnes to 25,000 tonnes), direct payments of Baltic countries would total at most 187.5 million Euros (real discount rate of 0%) to compensate for lost profits. This amount is small when compared to the economic and ecological values created by such an investment in natural capital through the proposed recovery program. But even without any cash payments and only loan guarantees, conservation efforts remain economically viable as reported in Table 3 (NPV of future profits from scenarios 2 and 3 exceed those of scenario 1 for real discount rates less than 13.4%). These results are consistent with Rechlin (1999) who shows that a more careful use of cod stocks in the late 80's and early 90's would have resulted in greater biomass and lower social costs in subsequent years. If, for example, annual catches of 150,000 tonnes were already feasible today, fishermen's profits would be substantially greater (scenario 4 versus scenario 1 in Table 3).

The second crucial policy task is to reduce fishermen's long-term uncertainty by guaranteeing specific shares of total future landings. Regulators must therefore restrict the number of cod fishing licences in the Baltic to ensure that fishermen will indeed benefit from greater subsequent catches. Because this measure reduces uncertainty, fishermen's discount rates will decrease. Future landings could, for example, be allocated among the existing cod fishermen using an ITQ-type system where the initial shares correspond to the fishermen's current percentages of total landings. This method ensures fixed quotas of annual allowable catches. Another, sometimes additional, alternative would be to implement a community-based management approach where fishermen receive rights for particular fishing areas, especially in coastal waters. Both ITQs and community-based management as parts of the proposed ecosystem-based approach have the common objective of providing incentives to invest into natural capital.

Overall, our analysis shows that the proposed cod recovery program is economically and ecologically viable and meets the main objectives of an ecosystem-based management approach, stocks above critical levels and preservation of ecological functions and services. Fleet reductions beyond the current target level may therefore not be necessary. While policy makers must assist and educate fishermen during the early years of the program, fishermen will experience greater landings and profits in subsequent years.

5. Conclusion

In this paper, we argue that the precautionary approach as a single-stock management scheme is insufficient for fisheries management, because it only inadequately incorporates negative externalities. The experience of the EU shows that conflicting interests make the precautionary framework difficult to implement. Moreover, the scheme does not account for the complex interactions and the species' functions and services in the marine environment. Therefore, we argue in favour of a more comprehensive approach that explicitly accounts for those dimensions and that overcomes the existing impasse between economic and ecological interests. Using the example of the Baltic Sea cod fishery, we demonstrate how the reduced fleet (after the current decommissioning programs of the new EU member countries are completed) together with the use of a fishing method that depends on stock size for its success (longlines instead of trawls) can lead to a balance between stock size and fishing effort. The program predicts increasing cod landings and profits after an initial period of lower catches. Moreover, the use of longlines reduces fisheries' impact on species and habitats, incorporating the objective of preserving ecological functions and services.

Although appealing, the recommended transition to ecosystem-based management practices requires the assistance of policy makers. Measures must be directed at restricting the number of licenses and permissible fishing methods as well as at reducing fishermen's uncertainty. Potential programs should therefore focus on lessening fishermen's financial hardship during the initial recovery period and assure specific shares of cod landings thereafter. We encourage future researchers to further investigate the factors that influence fishermen's discount rates. This information is important to help design future conservation and recovery programs and to craft policies that generate fishermen's support for these measures. Hillis and Wheelan (1994), for example, only focus on fishermen in a conventional quota management system, but reliable data on discount rates from community-based fisheries are lacking.

REFERENCES

Anderson, L., 1997. Efficiency and distribution issues during the transition to an ITQ program. In: Pikitch, E.K., Huppert, D.D., Sissenwine, M.P. (Eds.), Global Trends: Fisheries Management. American Fisheries Society, Bethesda, pp. 213–224.

Armstrong, C.W., Sumaila, U.R., 2001. Optimal allocation of TAC and the implications of implementing an ITQ management system for the North-East Arctic cod. Land Economics 77, 350–359.

Berkes, F., Mahon, R., McConnez, P., Pollnac, R., Pomeroy, R., 2001. Managing Small-scale Fisheries — Alternative Directions and Methods. Development Research Centre, Ottawa.

Bethke, E., 2006. Limitation of fishery effort or increase of minimum mesh opening? A comparison for maximization of profit of the Baltic Cod fishery. Informationen aus der Fischereiforschung 53, 13–22.

Beverton, R.J.H., Holt, S.J., 1957. On the dynamics of exploited fish populations. London, Fisheries Investment Ser. 2, 19, 19.

Caddy, J.F., Mahon, R., 1995. Reference points for fisheries management. Fish. Tec. Pap., vol. 347. FAO, Rome.

Clark, C.W., 1990. Mathematical Bioeconomics. J. Wiley & Sons, New York.

Clark, C.W., Munro, G.R., 1975. The economics of fishing and modern capital theory: a simplified approach. Journal of Environmental Economics and Management 2, 92–106.

Collie, J.S., Escanero, G.A., Valentine, P.C., 1997. Effects of bottom fishing on the benthic megafauna of Georges Bank. Marine Ecology. Progress Series 155, 159–172.

Daly, H.E., 1996. Beyond Growth. Beacon, Boston.

Delgado, C.L., Wada, N., Rosegrant, M.W., Mijer, S., Ahmed, W., 2003. Outlook for Fish to 2020: Meeting Global Demand. World Fish Center, Penang.

Dietz, T., Ostrom, E., Stern, P.C., 2004. The struggle to govern the commons. Science 302, 1907–1912.

Dolsak, N., Ostrom, E., 2003. The Commons in the New Millennium: Challenges and Adaptations. MIT Press, Cambridge.

Döring, R., Wichtmann, W., 2007. Chances of an eco-labelling for fisheries products for the German fishing industry. Report for the German Ministry for Food, Agriculture and Consumer Protection. BMELV Bonn.

Döring, R., Bender, S., Brosda, K., Kraus, G., Kube, J., Laforet, I., Schaber, M., Sordyl, H., Schulz, N., 2005. Die Ostsee als Beispiel für eine neue natur-und ökosystemverträgliche Fischerei. Final report for the Federal Agency for Nature Conservation. BfN, Bonn.

Edwards, S.F., Link, J.S., Rountree, B.P., 2004. Portfolio management of wild fish stocks. Ecological Economics 49, 317–329.

Ernst, P., Müller, H., Dahm, E., Gabriel, O., 2000. Konzept für eine bestandsschonende Nutzung der Dorschvorkommen in der westlichen Ostsee. Informationen für die Fischwirtschaft 47 (1), 19–24.

European Commission, 2001. Green Paper — The Common Fisheries Policy after 2002. European Commission, Luxemburg.

Faber, M., Manstetten, R., 1998. Produktion, Konsum und Dienste in der Natur — Eine Theorie der Fonds (Production, Consumption and Services in Nature — A theory of funds). In: Schweitzer, F., Silverberg, G. (Eds.), Selbstorganisation. Jahrbuch für Komplexität in den Natur-, Sozial-und Geisteswissenschaften Band, vol. 9. Duncker & Humblot, pp. 209–236.

FAO, 2004. The State of the World Fisheries and Aquaculture. FAO, Rome.

Fisher, I., 1906. The Nature of Capital and Income. Macmillan, New York.

Flaaten, O., 1998. The Economics of Multispecies Harvesting: Theory and Application to the Barents Sea Fisheries. Springer, Berlin.

Gudmundsson, E., 2004. Capacity reduction in the icelandic trawler fishery. Proceedings of the XVIth Annual Conference of the European Association of Fisheries Economists. FAO, Rome. CD-Rom.

Hall, S., 1999. Fish Biology and Aquatic Resources Series 1: The Effects of Fishing on Marine Ecosystems and Communities. Blackwell Science, Oxford.

Hammer, N., Zimmermann, C., 2004. Einfluss der Umsetzung der ICES-Fangempfehlungen auf den Zustand der Fischbestände seit Einführung des Vorsorgeansatzes. Informationen aus der Fischereiforschung 50, 91–97.

Hampicke, U., 2001. Remunerating nature conservation in central European forests: scope and limits of the Faustmann–Hartman approach. Forest Policy and Economics 2, 117–131.

Hatcher, A., Gordon, D., 2005. Compliance with U.K. fishing quotas. Land Economics 81, 71–86.

Hillis, J.P., Wheelan, B.J., 1994. Fisherman's time discounting rates and other factors to be taken into account in planning rehabilitation of depleted fisheries. In: Antona, M., Catanzano, J., Sutinen, J.G. (Eds.), Proceedings of the sixth Conference of the International Institute of Fisheries Economics and Trade, IIFET-Secretariat, Paris, pp. 657–670.

Kaiser, M.J., de Groot, S.J., 2000. Effects of fishing on non-target species and habitats. Biological, Conservation and Socio-economic Issues. Blackwell, Oxford.

Köster, F.W., Hinrichsen, H.-H., St. John, M.A., Schnack, D., MacKenzie, B.R., Tomkiewicz, J., Plikchs, M., 2001. Developing Baltic cod recruitmen models. II. Incorporation of environmental variability and species interactions. Canadian Journal of Fisheries and Aquatic Sciences 58, 1534–1556.

Jennings, S., Kaiser, M.J., 1998. The effects of fishing on marine ecosystems. Advances in Marine Biology 34, 201–352.

May, R.M., Beddington, J.R., Clark, C.W., Holt, S.J., Laws, R.M., 1979. Management of multispecies fisheries. Science 205, 267–277.

Newell, R., Sanchirico, J.N., Kerr, S., 2003. An empirical analysis of New Zealand's ITQ markets. In: Shallard, B. (Ed.), Proceedings of the 12th Biannual Conference of the International Institute of Fisheries Economics and Trade. Bruce Shallard & Associates, Wellington.

Pearce, D., 1988. Economics, equity and sustainable development. Futures 20, 598–605.

Rechlin, O., 1999. Fischbestände der Ostsee, ihre Entwicklung in den Jahren seit 1970 und Schlußfolgerungen für ihre fischereiliche Nutzung — Teil 1: Dorsch. Informationen für die Fischwirtschaft 46 (2), 10–15.

Rowse, J., 2004. Using the wrong discount rate to allocate marine resources. Marine Resource Economics 19, 243–264.

Shepherd, J.G., 1982. A versatile new stock-recruitment relationship for fisheries, and the construction of sustainable yield curves. Journal du Conseil - Conseil International pour l'exploration de la mer 40, 67–75.

Sterner, T., Svedäng, H., 2005. A net loss: policy instruments for commercial cod fishing in Sweden. Ambio 34, 84–90.

STORE, 2002. Environmental and fisheries influence on fish stock recruitment in the Baltic Sea (Stock Recruitment in the Baltic). Final Consolidated Report to the EU-Commission, FAIR CT 98 3959.

Ströbele, W.J., Wacker, H., 1995. The economics of harvesting predator–prey systems. Journal of Economics 61, 65–81.

Sumaila, U.R., Walters, C., 2005. Intergenerational discounting: a new intuitive approach. Ecological Economics 52, 135–142.

Thrush, S.F., Dayton, P.K., 2002. Disturbance to marine benthic habitats by trawling and dredging. Annual Review of Ecology and Systematics 33, 449–473.

US National Research Council, 1998. Sustaining marine fisheries. A Report of the Committee on Ecosystem Management for Sustainable Fisheries. Ocean Studies Board, Commission on Geosciences, Environment and Resources, National Research Council. National Academy Press, Washington, D.C.

Wessells, C.R., Johnston, R.J., Donath, H., 1999. Assessing consumer preferences for ecolabeled seafood: the influence of species, certifier, and household attributes. American Journal of Agricultural Economics 81, 1084–1089.

WGBFAS, 2004. Baltic Sea Fisheries Assessment Working Group Annual Report. International Council for the Exploration of the Sea, Copenhagen.