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A continuous involvement of stakeholders promotes the Ecosystem Approach to Fisheries in the 8-fjords area on the Swedish west coast

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Abstract

The coastal marine environment in the 8-fjords area on the Swedish west coast has been subjected to various stakeholder co-management initiatives since 1999. Stakeholders and authorities have acted by supporting and implementing gradually stricter fishing restrictions following the collapse in the 1970s of several demersal fish stocks and their apparent lack of recovery. Moreover, concerns have been raised regarding a locally sharp depletion of eelgrass meadows, in addition to an apparent increase in the number of seals and cormorants. The present 8-fjords initiative applies a cross-sector approach to environmental management and thus also addresses various types of environmental pollution. This study has compared the environmental work around the 8-fjords to 15 principles regarding the ecosystem approach to fisheries (EAF). The main strength that has been identified among the EAF principles is the continuous involvement of stakeholders. Among weaknesses in the EAF is the scarcity of suitable indicators that are necessary for appropriate monitoring, especially biomasses of functional groups as well as economic and social indicators. Many environmental problems in the fjords remain and it is possible that improved adherence to EAF principles will facilitate solving some problems and alleviating others. Moreover, the application of the EAF in practice in the 8-fjords can serve as a guiding example for co-managing other aquatic ecosystems towards ecological, economic and social sustainability. The experiences from the 8-fjords initiative, including its

extensive stakeholder involvement, may serve as a practical EAF example to be studied by researchers and managers globally.

Introduction

The Ecosystem Approach to Fisheries

Overfishing and degradation of coastal habitats have prompted extensive theoretical work on how an ecosystem approach to fisheries (EAF) can be applied. The EAF has been put forward as a more sustainable way to manage fisheries and ecosystems than traditional management approaches (Pikitch et al., 2004; Zhou et al., 2010; Fogarty, 2014). Difficulties in predicting changes in the ecosystems and complex relationships and interactions have contributed to some of the shortcomings in traditional management, which has typically focused on one species at a time and on fisheries as the only societal sector (CFEPTAP, 2006; Fogarty, 2014). Hitherto, ecology, sociology and economics have only played a limited role in the management of ecosystems (Marasco et al., 2007). The EAF is instead a way to attain ecologically, socially and economically sustainable fisheries by taking whole ecosystems into account (Cochrane, 2002; FAO, 2003a, b; Pikitch et al., 2004; Zhou et al., 2010; Fogarty, 2014; Fulton et al., 2014).

EAF principles

There are different definitions of the EAF. The present study uses 15 main principles for the EAF as determined by Long et al. (2015) from 13 selected key EAF references (e. g., FAO, 2003b; NOAA, 2007; CBD, 2000; Table 1).

Table 1. The 15 principles for the Ecosystem Approach to Fisheries used in this study. These principles were found in a majority of 13 key references according to Long et al. (2015).

Principle number	Principle name	In number of key references
i	Consider ecosystem connections	11
ii	Account for dynamic nature of ecosystems	8
iii	Acknowledge uncertainty	8
iv	Appropriate spatial and temporal scales	10
v	Distinct boundaries	8
vi	Adaptive management	9
vii	Integrated management	8
viii	Interdisciplinarity	8
ix	Recognise coupled social-ecological systems	8
x	Use of scientific knowledge	8
xi	Sustainability	8
xii	Stakeholder involvement	8
xiii	Decisions reflect societal choice	8
xiv	Ecologic integrity and biodiversity	8
xv	Appropriate monitoring	8

(i) An ecosystem usually consists of fauna, flora, microorganisms and non-living components that interact in a way that they form a functional unit (Tansley, 1935; World Resources Institute, 2005). Considering ecosystems connections means that focus should not primarily be on target species in commercial fisheries, but on all components and processes in the ecosystems (Pikitch et al., 2004); e. g., other fish species, trophic relationships over the life-cycles, what regulates food availability, and constraints in fish reproduction.

(ii) Ecosystems have dynamic properties due to the fact that many ecosystem features vary over time and space and in many cases they display a non-linear response to external changes (Håkanson et al., 2010; Large et al., 2013).

(iii) Acknowledging uncertainty that arises from measurement error, and assuring that the uncertainty in modelling how ecosystems respond to different types of management is quantified and communicated (Håkanson et al., 2010; Large et al., 2013).

(iv) To establish a practical limitation of the work and thereby substantiating the EAF, appropriate temporal and spatial scales should be used.

(v) Delineation should be made with distinct boundaries. The choice of scale is affected by site-specific ecological and societal conditions (Long et al., 2015). The spatial delineation may, for example, need to be adapted to the geographical extent of fish habitats and to administrative borders and multi-scale monitoring may be necessary in order to capture all relevant ecological processes (Lewis et al., 1996) as well as economic and social processes (Leslie and McLeod, 2007).

(iv) Adaptive management is based on environmental monitoring, is evidence based and aims towards a process-based learning that adjusts management to new knowledge, changing conditions and towards decreasing uncertainty in measurements, predictions, and decisions (Engle et al., 2011; Westgate et al., 2013).

(vii) Integrated management means that management has a long-term perspective and is holistic, i.e., takes into account a wide range of knowledge from different disciplines, such as hydrology, ecology, biology, economics, sociology and oceanography. Integrated management also incorporates the interaction between land and coastal waters, and between coastal waters and the sea (Engle et al., 2011; Vallega, 2013).

(viii) Integrated management thus requires interdisciplinarity.

(ix) Connections between social and ecological systems have to be recognised. Ecosystems are continuously affected by human activities, while ecosystem services such as food production or provision of recreational opportunities affect society (World Resources Institute, 2005; Liquete et al., 2013).

(x) Basing management on science ensures that the best available knowledge is integrated into decisions. Science promotes an increase in knowledge in a systematic way and lays the ground for new insights, methods, and technologies which are essential to meet societal and environmental challenges (UN, 2014). Science also increases the knowledge and understanding of interactions between society and nature, and may guide societal influence on nature in a sustainable direction (Kates et al., 2001; Miller et al., 2014).

(xi) Sustainability has been defined as development which meets the needs of today without jeopardising the ability of future generations to meet their needs (UN, 1987).

(xii) Cooperation between stakeholders and scientists has been suggested as the most effective way to manage fisheries and ecosystems (Mackinson et al., 2011; Burger and Niles, 2013). Including stakeholders into fisheries management is therefore on the rise globally (Sandström et al., 2015).

(xiii) Such inclusion can improve the way that decisions reflect society's choice (Mackinson et al., 2011). Involving stakeholders in management and balancing their different interests regarding coastal environmental issues can even be considered a feature of democracy (Buanes et al., 2004).

(xiv) Ecological integrity and biodiversity together form one of the principles.To safeguard ecologic integrity means protecting and promoting the ability of ecosystems to self-organise through their inherent processes and structures (Burkhard et al., 2011). Biodiversity consists both of a structural diversity of molecules, genes, species and habitats, and of a functional diversity of processes and interactions within the ecosystems. Humans assign monetary and other values to biodiversity (Spash et al., 2009), in addition to that biodiversity also shapes the structure and function of ecosystems (Cardinale et al., 2012b).

(xv) Appropriate monitoring requires indicators that can be monitored (Schmitt and Osenberg, 1996). Indicators are thereby crucial for the practical success of an EAF (Jennings, 2005; Stelzenmüller et al., 2013; Fay et al., 2013; Vinueza et al., 2014; Fulton et al., 2014; Levin and Möllmann, 2015). Indicators provide information that describes states and changes in ecosystems and their interaction with society (Hall and Mainprize, 2004). Ideally, there should be ecological, economic and social indicators (Leslie and McLeod, 2007). Examples of ecological indicators are the proportion of habitat coverage, the biomass of fish species (Fulton et al., 2014), the number of species, the species composition in the ecosystem (Vinueza et al., 2014), the mean length of species and their slope size spectrum (Link, 2005). For discussions on optimal quantitative indicators for the impact of fisheries on ecosystems, see e. g. Link (2005) and Methratta and Link (2006).

The 8-fjords area

There is a need to demonstrate how EAF policies may be applied in practice (Long et al., 2015; Patrick and Link, 2015). The inshore area between the islands Tjörn and Orust and the Swedish mainland, in the province of Bohuslän on the Swedish west coast, is called the 8-fjords area, as it consists of the eight fjords: By, Havsten, Halse, Askerö, Kalvö, Stig, Hake and Älgö (fig. 1). Since 1999, these fjords have been subjected to various stakeholder co-management initiatives, and five municipalities have made a joint effort to create the so-called 8-fjords initiative focusing on managing fisheries and ecosystems in the fjords. Lately, attempts have been made to include additional fjords such as the Koljö fjord north of the Orust island as well as coastal waters south of the Älgö fjord down to River Nordre Älv (57°48'N, 11°49'E) in the joint management (Johansson, 2015). One of the main aims within the 8-fjords initiative has been to enable a recovery of collapsed local demersal fish stocks (Degerman, 1983; Svedäng et al., 2001; Svedäng, 2003; Bartolino et al., 2012; Cardinale et al., 2012a), primarily through implementation of rigorous fishery restrictions. A second concern has been a drastic decline in seagrass cover in parts of the 8-fjords, partly since seagrass beds are essential for recruitment of many fish species (Nyqvist et al., 2009; Baden et al., 2012). Related management goals are productive and fishable demersal stocks and beneficial conditions for seagrass beds to recover. Predation from seal and cormorant populations is a third concern that has been suggested to prevent demersal fish stock recovery. Regarding seals and cormorants, no management goals have been set and improved data collection is considered to have first priority at present. Furthermore, the 8-fjords initiative works with several additional marine environmental issues such as eutrophication and marine litter (Johansson, 2015).

Objective of the study

The objective of this study is to assess how the management of the 8-fjords conforms to EAF principles. The criteria for EAF used are the 15 principles outlined by Long et al. (2015). Furthermore, we intend to provide a background description of the 8-fjords initiative and to address the environmental issues that are at stake. The Swedish Agency of Marine and Water Management (SWaM) and researchers have selected the 8-fjords area as a suitable pilot study area for EAF work in Sweden. This study intends to benefit the 8-fjords initiative by making its work better known and by pointing out strengths and weaknesses of its achievements in an EAF perspective. Moreover, the study could provide helpful and constructive ideas regarding how the EAF can be applied in practice.

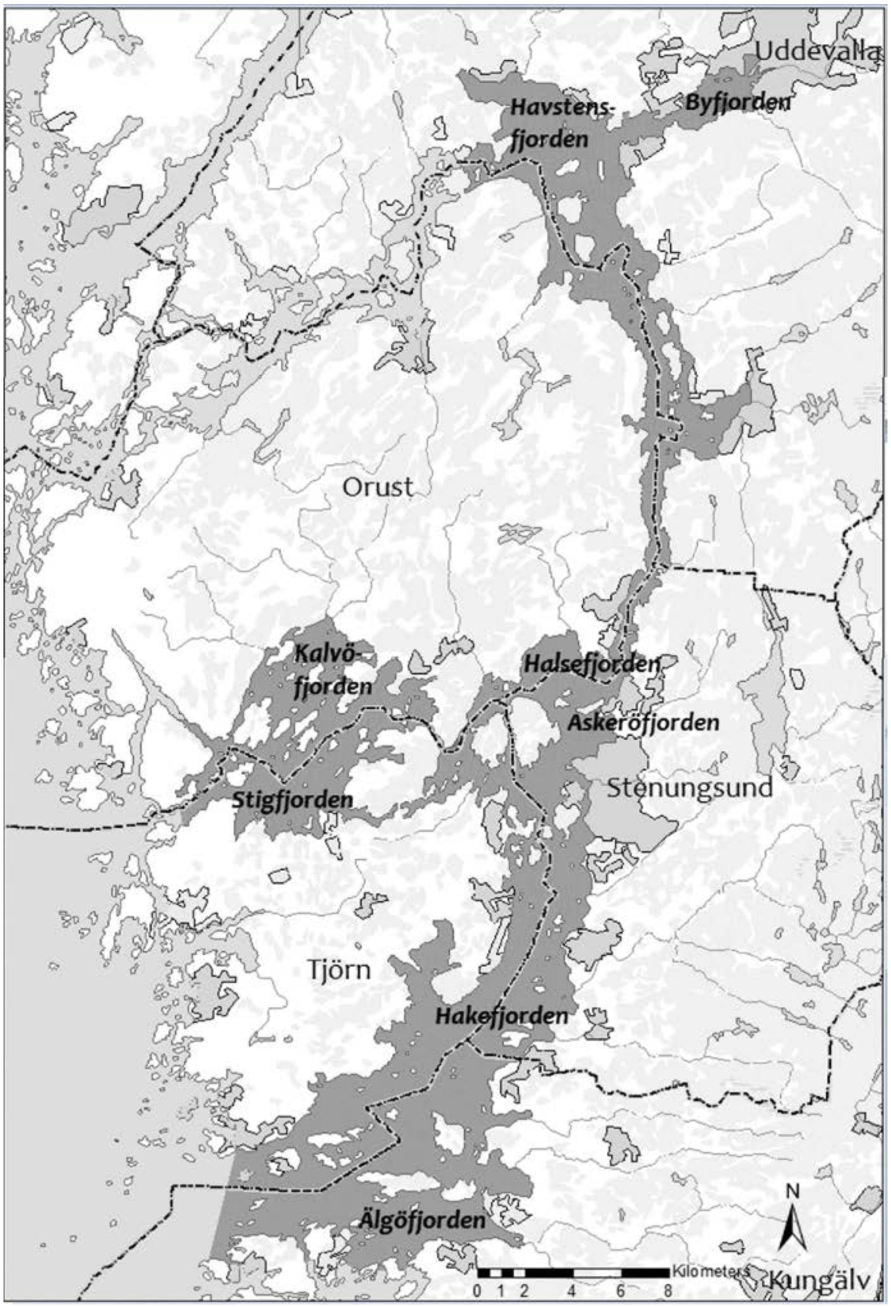

Figure 1. The original 8-fjords area (darker grey colour) inside or between the islands Tjörn and Orust. Dashed lines denote municipality borders. Background data from Lantmäteriet (open map data).

The 8-fjords initiative as a response to three environmental concerns

The 8-fjords have historically been very productive and have probably been fished ever since hunters-fishers-gatherers first settled in the area towards the end of the Weichselian ice age. During the 19th century, stock declines are believed to have forced local fishermen to gradually search for more remote fishing grounds in and far beyond the North Sea (Cardinale et al., 2014). An even more dramatic fisheries driven change occurred around the end of the 1970s, when stocks of cod and other demersal fish collapsed, particularly in the 8-fjords area, but also in nearby waters (Degerman, 1983; Svedäng et al., 2001; Svedäng, 2003; Svedäng and Bardon, 2003; Bartolino et al., 2012; Cardinale et al., 2012a). The absence of fishable stocks of cod, pollack and plaice in the 8-fjords area has thereby been disastrous to the local fishery and has profoundly changed its preconditions (Table 2). These stocks show no signs of recovery; however, recent investigations in 2013 and 2014 have shown abundance of cod eggs in early life stages (2-6 days old; Henrik Svedäng, pers. obs.) and mature cod, indicating that cod reproduction still occurs in the area, albeit to a very limited extent (Sköld et al., 2008; 2011).

Table 2 also shows that while demersal fish catches have decreased dramatically, commercial catches of the pelagic species sprat and herring have increased. This increase could be related to higher local abundance of these pelagic species, possibly gaining from the coastal zone cod protection regulations (Swedish Board of Fisheries, 2009). The higher catches of the pelagic species might also be due to a higher fishing effort, as coastal herring and sprat are relatively important for Swedish coastal fishing since both species still occur abundantly in sheltered waters and are also of a better quality. In other words, the rather small-scale fishery on herring and sprat is still viable and profitably due to local circumstances. Sprat in the fjords may comprise local stocks, as their morphology, growth and reproductive effort differ from those of sprat in waters outside of the islands Tjörn and Orust (Molander, 1952; Vitale et al., 2015). Similarly, the herring stocks along the Skagerrak coast also appear to be local and genetically differentiated (Ruzzante et al. 2006).

The most recent example of more rigorous fishing restrictions is from 2010 when the Swedish Board of Fisheries and the 8-fjords initiative agreed to implement a no-take zone and a zone where only manual gear is allowed half of the year in the Havsten fjord (fig. 2). The 8-fjords initiative stressed at the time that public support for the restrictions would be key to their success. In addition, in a larger zone covering the fjords Koljö, Havsten, By, Halse, Askerö, Kalvö and Stig, fishing for cod, pollack and haddock (*Melanogrammus aeglefinus*) is prohibited except when using manual gear or crustacean pots.

Table 2. Changes in commercial fish catch between 1962 och 2004-2008 in Koljöfjorden, Havstensfjorden, Byfjorden, Halsefjorden, Askeröfjorden, Kalvöfjorden, Stigfjorden, and Hakefjorden. Data from Hannerz (1970) and the Swedish Board of Fisheries statistics (nowadays the Swedish Agency of Marine and Water Management).

Common name	Scientific name	1962 (tonnes/year)	2004-2008 (tonnes/year)	Percentual change
European lobster	*Homarus gammarus*	0.98	0.31	-69
Pollack	*Pollachius pollachius*	4.68	0.01	-100
Atlantic mackerel	*Scomber scombrus*	4.41	0.94	-79
Garfish	*Belone belone*	23.16	-	-100
Turbots	*Scophtalmus sp.*	1.10	-	-100
European plaice	*Pleuronectes platessa*	33.31	0.02	-100
Common dab	*Limanda limanda*	1.17	-	-100
Atlantic herring	*Clupea harengus*	16.83	203.13	+1107
European sprat	*Sprattus sprattus*	193.93	486.72	+151
European flounder	*Platichthys flesus*	8.53	-	-100
Atlantic cod	*Gadus morhua*	69.09	0.13	-100
Whiting	*Merlangius merlangus*	0.55	0.01	-98
Common sole	*Solea solea*	0.57	0.01	-99
Sea trout	*Salmo trutta*	2.35	0.01	-100

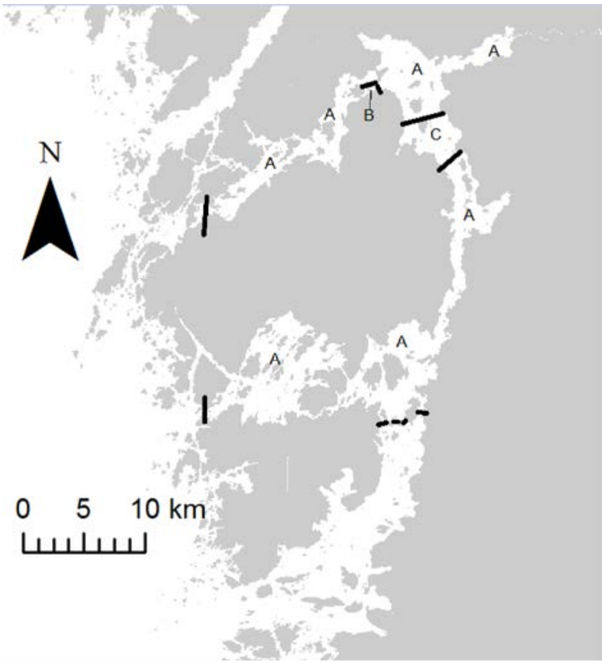

Figure 2. Fishing restrictions in the 8-fjord area. A: Fishing ban for cod, pollack and haddock. Fishing for other species with manual gear, crustacean pots and mussel scrapers are legal gears. B: All fishing is prohibited. C: Fishing with manual gear is allowed half of the year from Orust Island (see fig. 1) and the mainland. All other fishing is prohibited.

A second concern of the 8-fjords initiative has been the locally drastic decline of eelgrass (*Zostera marina*) beds (Nyqvist et al., 2009; Baden et al., 2012). Eelgrass is the dominating seagrass in the northern hemisphere, and is the only seagrass species in the 8-fjords (Nyqvist et al., 2009). Eelgrass beds form three-dimensional habitats that are essential for many species and are therefore particularly essential to protect. Fry and juvenile fish can use eelgrass beds as feeding grounds and as protection against predators. Eelgrass beds can thus widen the bottleneck for survival that the fry and juvenile stages and their exposure to food constraints and predators comprise (Obaza et al., 2015). Moreover, epibenthos that feed on epiphytic algae on eelgrass serve as a food source for many fish species in different stages. Thus, the extent of eelgrass cover may in many ways be a limiting factor for the production of fish and for marine food production for humans (Baden et al., 2012). In addition, eelgrass meadows prevent sediment erosion or resuspension by waves and thereby allow storage of substantial amounts of carbon and nutrients (Cole and Moksnes, 2016). Between the 1980s and 2000, eelgrass cover decreased by about 60 percent in the Swedish Skagerrak area. Geographical variations were, however, substantial. Investigations in the 8-fjords have discerned a notable difference in eelgrass reduction between the three areas Stenungsund, Uddevalla, and Kungälv (fig. 3;

Nyqvist et al., 2009). The cause of the reduction may have been a combination of eutrophication and trophic cascades following selective fishing of demersal fish such as cod. Such trophic cascades may have occurred in the Skagerrak around 1990 (Baden et al., 2012). The eelgrass meadows have not shown apparent signs of recovery, although an update of their state would benefit the analysis (Susanne Baden, pers. comm). Attempts have been made to artificially transplant eelgrass to depleted areas, albeit with limited success, possibly because trophic cascades resulting in low grazer abundance have not been reversed and turbid waters persist (SWaM, 2016; Niclas Åberg, pers. comm.).

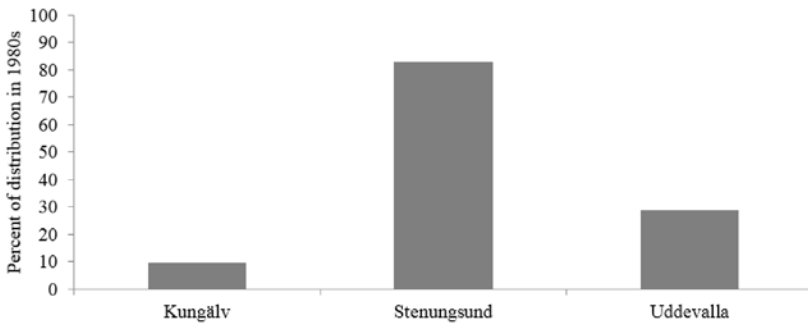

Figure 4. Distribution of eelgrass beds at monitoring stations in three areas of the 8-fjords in year 2000 compared to the 1980s. Data as mean values from Nyqvist et al. (2009).

The increasing numbers of harbour seals (*Phoca vitulina*) and great cormorants (*Phalacrocorax carbo sinensis*) have raised growing concern for potentially being additional threats to the recovery of demersal fish in the area. Seals and cormorants may even benefit from no-take zones and there are other examples in which top predators have been shown to prevent fish stock recovery (Boncoeur et al., 2002; Fanshawe et al., 2003; Middlemas et al.; 2006, Trzcinski et al., 2006; O'Boyle and Sinclair, 2012; Bromaghin et al., 2013). From having been extinct in Swedish waters in the early 1900s, great cormorant colonies re-established on the Swedish east coast in the mid-1900s and on the Swedish west coast in the 1990s where approximately 3,000 breeding pairs were counted in 2012 (Engström and Wirdheim, 2014; Swedish Environmental Protection Agency, 2013). Harbour seals off the Swedish west coast have recovered after having been decimated by hunting, diseases and environmental toxins, with numbers increasing from about 3,000 animals in the mid-1900s to historically high levels in the 2000s (Heide-Jørgensen and Härkönen 1988; Olsen et al., 2010). In the annual moult count, between 4,000 and 6,000 harbour seals have been counted in the Skagerrak during the last five years, with an annual increase of 7 % (Bäcklin et al. 2016). Preliminary investigations suggest that a similar development in abundance of seals and cormorants could also have occurred in the 8-fjords area (Karl Lundström and assistants, pers. obs.). However, the rise in top predator abundance which was recorded in the 2000s occurred after the decline in demersal fish in the 1970s. Thus, seals or cormorants are not a likely cause of the demersal fish decline.

Seal and cormorant hunting remains a controversial issue in Sweden and elsewhere. In the 8-fjords area, while some want hunting for harbour seals and great cormorants to be banned, there are also proponents of increased hunting. Included in the seal and cormorant controversy are the size and growth rate of the population as well as the diet of these predators. No systematic census or diet analysis has been performed in the 8-fjords area, so details about current numbers and prey choice of seals and cormorants in the area are lacking. However, the 8-fjords initiative has in cooperation with scientists performed a small-scale pilot study which showed that monitoring of abundance and diet of seals and cormorants in the area would indeed be possible. Further investigations of top predator abundance and diet could address whether seals or cormorants may prevent a recovery of demersal fish stocks. A conceptual Miradi model (Schwarz et al., 2012) elaborating on how fishing and top predators may affect fish fauna and fish habitat is given in fig. 5.

In addition, the 8-fjords initiative has focused on a large number of other environmental and societal issues with more or less strong connections to fish communities and the coastal ecosystems, such as marine litter, nutrient inputs and eutrophication, other seabirds than cormorants, the distribution of blue mussel (*Mytilus edulis*) banks, artificial reef construction, mussel farming, tourism, recreational facilities, and trout (*Salmo trutta*) habitat restoration in the tributaries to the fjords (Johansson, 2015). The initiative has also been involved in artificial deepwater oxygenation of the By fjord which has been described in detail by Stigebrandt et al. (2015).

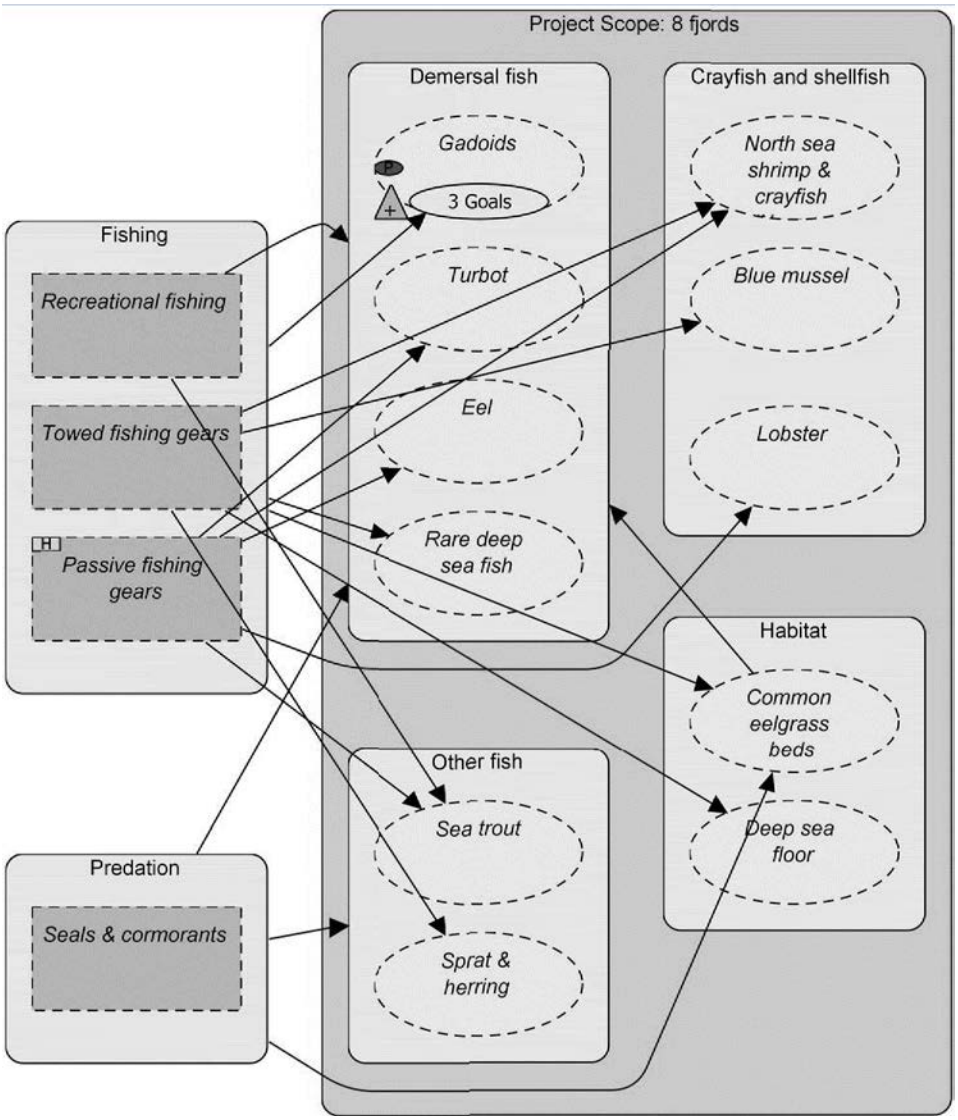

Figure 4. A Miradi model version 2.4.2. (Schwarz et al., 2012) displaying the possible impact of fishing and top predators (seals and cormorants) on fish fauna and habitats. The diet and abundance of top predators has yet to be investigated.

The 8-fjords initiative

Towards the end of the 1990s, an increasing number of people contacted the municipalities around the 8-fjords with concerns about the state of environment of the fjords. As mentioned, the primary concern was the depletion of fish stocks, in particular, of Atlantic cod. Discussions were initiated in 1999 about cooperation within the local communities which ended up in three working groups being formed: the fisheries group, the business group and the environmental group. The groups were coordinated by project leaders, who were eventually hired in 2008, and later on by a steering group (fig. 5). The fisheries group contains representatives for commercial fishermen, different organisations of recreational fishers, the County Administrative Board, and the SwAM, and this group primarily discusses fisheries issues. The business group consists of local entrepreneurs and discusses how better opportunities for nature and culture tourism could be created, and in addition, how crustaceans (e. g., mussels and lobsters) can be cultivated or caught. The environment group includes representatives of environmental organisations, organisations for recreational fishers, municipalities and the County Administrative Board and it has had a major focus on the nutrient loading to the fjords (Johansson, 2015).

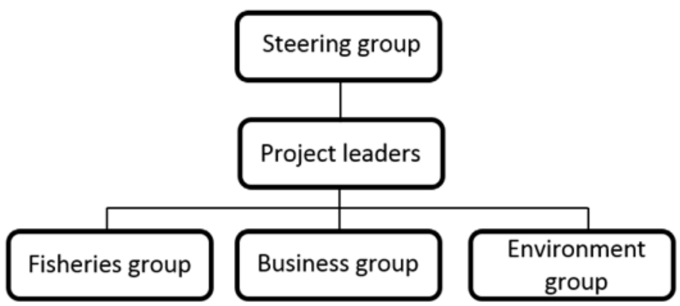

Figure 5. The structure of the 8-fjords initiative. Modified from Johansson (2015).

The work of the 8-fjords initiative is ongoing, and new work depends on what is agreed between government agencies and other stakeholders. According to the project leader and the environmental advisor of the initiative, there has been a widespread acceptance of the no-take zone and other fishing restrictions and this is possibly due to the great extent of stakeholder involvement. In addition, the initiative has put in place artificial reefs to promote lobster and fish aggregation, information campaigns have been launched, elvers (juvenile European eels; *Anguilla anguilla*) have been stocked, and various biotopes have been managed and protected, i.e. rather conventional conservation measures. The initiative has worked with decreasing the number of ghost-fishing nets and with opening up narrow straits in order to allow boat passage and increase the water circulation. Fishermen of various kinds have been encouraged to keep and report catch diaries. The lack of information about the effects of fish predation by seals and cormorants has been the focus of a pilot study for monitoring these predators. Spawning grounds for cod and blue mussel (*Mytilus edulis*) banks have been mapped, as well as the distribution of the white-tailed eagle (*Haliaeetus albicilla*; Johansson, 2015).

Since 2008, there have been about 1-2 annual stakeholder meetings open to the general public with 100-200 participants per meeting. Meetings including smaller groups of stakeholders (e. g., recreational fishermen or business owners) have been held about once or twice per week. During both of these types of meetings, accomplishments have been discussed as well as how to proceed in collaboration with the management; e.g., how legal and financial constraints to desired changes should be handled. The management aims for the 8-fjords initiative have been the following (according to the project leader and the environmental advisor):

(1) get the piscivorous fish back,

(2) seas in balance,

(3) thriving coast and archipelago,

(4) a good sediment environment,

(5) extensive cooperation and co-management, and

(6), ecological and economic sustainability, including viable conditions for local business enterprises.

As earlier mentioned, this vision also includes recreating favourable conditions for eelgrass by means of points 1-6 above. However, there is no specific strategy relating to pollutants, seals or cormorants. In 2016, the fishing restrictions described above are being evaluated, and spawning habitats for trout in tributaries are continuously being improved, and these are currently the main task of the 8-fjords initiative.

How the EAF principles are addressed around the 8-fjords

To determine how the environmental work around the 8-fjords conforms to the EAF, the practical work will be compared to the 15 main EAF principles in Long et al. (2015), as described in the Introduction (Table 1).

Ecosystem connections (i) are largely considered; the 8-fjords initiative does not only work with fisheries, as has been described above, but also with nutrient loading and organic contaminants, and with eelgrass, mussel banks and other parts of the ecosystems, recognising that they are interconnected. The spatial management scale and its boundaries (iv, v) have resulted from the stakeholder initiative. The fjords inside the islands Tjörn and Orust form have many similarities in terms of ecology, but also in terms of traditions and societal aspects by being substantially affected by fishing, tourism and shipping. The managed waters are, however, slowly and in a controlled manner, expanding from the original 8-fjords area to additional fjords and other coastal waters (fig. 1). This is mainly occurring as an explicit wish from residents in nearby areas to be a part of the 8-fjords initiative, which has a reputation of being beneficial for local protection of coastal ecosystems in the area. Temporal scales and their boundaries (iv, v) are applied in various manners. The depletion of demersal fish stocks is not expected to change in the near future as it may take several decades for a recovery, given that the stocks will eventually recover. However, shorter timeframes may be applied when implementing various measures such as artificial reef constructions, nutrient abatement, beach cleaning, culling of seals and cormorants, or deciding about new fishing restrictions.

Decisions are taken based on scientific knowledge (x), as the initiative has tight cooperation with researchers from, e. g., the University of Gothenburg, the Swedish University of Agricultural Sciences, and the Royal Institute of Technology. These researchers come from various disciplines such as biology, oceanography, ecology, economics and sociology. Interdisciplinary (viii) and integrated management (vii) are also promoted. Östberg et al. (2010; 2012; 2013) are examples of interdisciplinary studies and have a large focus on environmental economics. Among the findings is that the willingness to pay for better water quality is greater than for stricter regulations concerning noise and litter (Östberg et al., 2012). The coupling of social and ecological systems (ix) is acknowledged and highlighted by the initiative; e. g., the value of fishing for fishermen and society, and the value of well-functioning ecosystems for providing ecosystem services to society, including the local tourism industry, and the effects of various human pressures, such as fishing, agriculture and industrialisation, on ecosystem functions.

Stakeholder involvement (xii) is a cornerstone of the 8-fjords initiative, and this involvement also improves the way in which decisions reflect the societal choice (xiii). By letting stakeholders participate in discussions and influence decision making, there has, as mentioned above, become a wide acceptance of fishing restrictions and other environmental measures. However, management decisions in terms of regulations are ultimately taken by SWaM while measures with fewer legal constraints such as restoration of spawning habitat for trout are undertaken by the 8-fjords initiative and its associated municipalities. Stakeholders and the general public are to a large degree concerned about the state of the fish stocks. Some are also very concerned about the number of seals which is perceived as much larger than before. Others worry more about marine litter, or about a possible dumping of sand

and silt in the vicinities of eelgrass meadows. The dynamic nature (ii) and uncertainty (iii) of ecosystems are accounted for; for instance, the recovery of collapsed demersal fish stocks is acknowledged as being quite unpredictable even though extensive fishing restrictions have been implemented. Biodiversity and ecological integrity (xiv) are considered as important goals with management; although there seems to be particularly large concerns about demersal fish, sea trout, mussels and eelgrass.

The principles adaptive management (vi) and suitable monitoring (xv) are addressed to a certain degree (see Discussion) because both are difficult to attain without a certain number of relevant indicators. There is widespread uneasiness among stakeholders regarding the scarcity of relevant data. There are some indicators regarding the 8-fjords that can be considered operational today, such as eelgrass distribution, dissolved oxygen concentration, and catch in kilograms per trawling hour of cod, turbot, plaice and whiting. Catch-per-unit-effort of eel in fyke nets in Stenungsund (ICES, 2016) is also an operational indicator. Catch-per-unit-effort of medium trophic level fish during 2012 is available from Bergström et al. (2016). Nutrient and chlorophyll concentrations are available from a nationwide database. There are, however, no operational economic and social indicators available. Implementing indicators that also include economic and social aspects as well as whole-ecosystem aspects, would advance these two principles to a greater degree. Moreover, those indicators that can be considered operational to some extent would benefit from more frequent monitoring.

Sustainability (xi) guides the work of the 8-fjords initiative considering that the aims of its work is to make sure that present human pressures do not jeopardise the needs of future generations. However, sustainability cannot be considered to prevail to a large degree because of the poor state of demersal fish stocks and the depleted state of eelgrass meadows. Management of the 8-fjords in the past did neither meet the needs of present generations nor those of future ones.

Discussion

This study shows that the 15 major EAF principles in Long et al. (2015) can be used to assess how the EAF is applied in practice in a case study. Although there are overlaps among certain principles, e. g., between principles iv (appropriate scales) and v (distinct boundaries), and between principles vi (adaptive management) and xv (appropriate monitoring), we still believe that it is suitable to consider all of these 15 principles because as a whole they provide a diverse, specified and fathomable picture of what the EAF is.

Moreover, it appears that the 8-fjords initiative has implemented EAF principles without being aware of it. Our findings can be useful for the 8-fjords initiative by highlighting the strengths and weaknesses of its work in an EAF perspective, which may guide its future work. In addition, this paper can attract increasing interest by researchers, managers, policymakers and the general public to the work of the 8-fjords initiative. The findings do not however, imply that all or even most management goals regarding, e. g., demersal fish stock productivity and beneficial conditions for eelgrass meadows to recover have been reached. The EAF can be seen as an adaptive and robust management process which aims at continuous improvement (Cochrane, 2002). Thus, it is possible that additional measures will be necessary in order to strengthen demersal fish stocks and eelgrass meadows, or that managers and a wide range of stakeholders should be made aware of a possibly slow natural recovery process. The demersal fish depletion as indicated by table 2 is conspicuous even in an international perspective and it is unclear if, how and when these stocks can recover (Svedäng 2003, Svedäng and Bardon, 2003, Thurstan and Roberts, 2010, Rose et al., 2011; Bartolino et al., 2012). By advancing the EAF principles, e. g., by introducing more useful indicators (Link, 2005; Methratta and Link, 2006; Fay et al., 2013), it is possible that the demersal fish stocks and the eelgrass meadows may recover more rapidly and extensively, although this has yet to be demonstrated. Still, to the best of our knowledge, no previously published study on European waters has showed as extensive abidance by EAF principles as the 8-fjords initiative as described in this study. Examples which have been put forward (e.g., de Juan et al., 2012; Gascuel et al., 2012; Möllmann et al., 2014) do not address all principles in table 1. For instance, involvement of stakeholders is lacking or has not been described. Instead, these studies have provided modelling results and other important tools for the EAF. Nevertheless, the ambition to apply the EAF in all European Union waters is well-established in the Common Fisheries Policy (Anon, 2013; Ramírez-Monsalve et al., 2016).

Southern Australia, including Tasmania (Fulton et al., 2014) and the Galápagos Islands (Castrejón and Charles, 2013; Vinueza et al., 2014) may be considered two of the first well-documented examples of the EAF in practice globally. These initiatives have been using a wide range of ecological, economic and social indicators, in contrast to the 8-fjords initiative, which only has some indicators and thereby a limited monitoring. New Zeeland applies a first step within the EAF, which includes single-species management of target species in fisheries, with bycatch and habitat factors taken into consideration (Cryer et al., 2016). The EAF is applied on smaller scales in parts of Indonesia, the Philippines and Tanzania as well as on the Solomon Islands (Eriksson et al., 2016). Substantial progress towards an EAF has also been made in Antarctic waters (Watters et al., 2013), in the vicinity of the Benguela current outside southern Africa (Shannon et al., 2010; Smith et al., 2015) and in the northwest Atlantic (Link et al., 2011). Other similar initiatives are on-going in many parts of the world (Pitcher et al., 2009; Pomeroy et al., 2015; see also other articles in this journal issue).

The continuous stakeholder involvement is the backbone of the EAF work around the 8-fjords. Knowledge on marine environmental issues is being strengthened and the experience of a wide range of inhabitants and visitors of the fjord is being shared, which is likely to improve the decision making. Moreover, by including stakeholders in discussions and by letting them influence decisions, it is likely that the acceptance has improved regarding fishing restrictions and other environmental measures. Burger and Niles (2013) found similar acceptance when stakeholders participated in all phases of a process leading to a beach at Brigantine, New Jersey being periodically closed for public access for environmental protection reasons. During the larger meetings 1-2 times per year, the “interested public” (cf. Soomai et al., 2013) around the 8-fjords has probably been reached and may in turn have collected and shared information in their social networks regarding the state of the environment as well as environmental actions and other desired changes. It is essential to keep and develop the continuous network of stakeholders around the fjords to ensure that EAF principles are maintained (Mackinson et al., 2011; Sandström et al., 2015).

The main weakness of the management of the 8-fjords in relation to the principles in table 1 is the scarcity of suitable key indicators for management of coastal ecosystems. Indicators are crucial in monitoring (xv) and adaptive management (vi; Schmitt and Osenberg, 1996; Ehler, 2003; Stelzenmüller et al., 2013) and have been put forward as central (Link, 2005; Methratta and Link, 2006; Large et al., 2013), and even necessary (Jennings, 2005; Fay et al., 2013) for the EAF. Without ecological indicators, it is difficult to quantify human impacts on ecosystems (Methratta and Link, 2006; Leslie and McLeod, 2007), ecological trends and thresholds (Large et al., 2013) as well as the the degree of progress towards reaching management goals (Link, 2005; Large et al., 2013). Some key indicators for the impact of fisheries on ecosystems (see Link, 2005; Methratta and Link, 2006; Fay et al., 2013) such as the biomass of functional groups of fish species are not available for the 8-fjords, although some other indicators have been mentioned in the previous section. Indicators that describe other important aspects of ecosystem structure and function, such as water transparency, nutrient and toxin loads and concentrations (Håkanson and Blenckner, 2008; Fleming-Lehtinen et al., 2015; Lang et al., 2015), are available to some extent. Economic and social indicators are wanted while being of comparable importance as ecological ones (Leslie and McLeod, 2007; Fulton et al., 2014; Vinueza et al., 2014). It is possible that relevant economic and social indicators are already extractable from statistics collected by the municipalities surrounding the fjords, and merit further investigations. Economic and social indicators could highlight the importance of reconstructed demersal fish stocks to inhabitants and tourists around the fjords and assign monetary values to the benefits that improved environmental conditions may bring. Moreover, it is desirable to establish additional ecological indicators, e.g., that more extensively describe variations in the fish community (Link, 2005; Methratta and Link, 2006), the extent of eelgrass cover (Carstensen et al., 2016) or nitrogen isotopes in eelgrass (Schubert et al., 2013), and the diet and abundance of seals and cormorants (Härkönen et al., 2013; Conn et al., 2013). Additional indicators should be developed in close cooperation between the 8-fjords initiative, responsible government agencies, and the research community.

A lack of data as well as of predictive ecological models should not be regarded as hindrances to applying the EAF (Patrick and Link, 2015). However, principles xv (appropriate monitoring) and vi (adaptive management) would be strengthened in the 8-fjords by bridging crucial knowledge gaps. For instance, identifying locally spawning demersal fish stocks in the fjords and mapping their habitats should be performed and provide the basis for future management measures. Studying the number and diet of seals and cormorants could determine the degree to which these top predators pose a threat to demersal fish stock recovery. Additional surveys of eelgrass can provide insights into recent development and how eelgrass recovery could be attained. What kind of ecosystem services are most important to residents and tourists should also be investigated, in addition to the range of goals that stakeholders have regarding the marine environmental work.

To conclude, the 8-fjords initiative and its achievements is in a social aspect a successful and locally popular example of EAF work in practice, although the ecosystems of the fjords, particularly demersal fish and eelgrass, are still in poor condition. This study has possibly demonstrated the first example of the EAF in practice in Europe and could therefore serve as an important contribution to EAF and stakeholder related science and management worldwide. Thus, although much remains to be done with respect to research and management goals, the 8-fjords initiative and what it has accomplished can provide useful guidelines towards practical implication of EAF principles in other parts of Europe and elsewhere.

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