Theme Session 1: DYNAMICS OF THE BARENTS SEA ECOSYSTEM

PRINCIPLES OF THE ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT

by
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Introduction

The main body in the management of the fisheries in the Barents Sea is the Joint Russian Norwegian Fisheries Commission (JRNFC). In the later years there has been a changing landscape of fishery management policy and this has been reflected in the work of the commission. In 2001 JRNFC set down an expert group to work out a "Basic document regarding the main principles and criteria for long term sustainable management of living marine resources in the Barents and Norwegian Seas." The main recommendations from that study has been implemented into long term management plans for the Northeast Arctic cod and capelin stocks and a management plan for Northeast Arctic haddock is in progress. The long term management plans, which have been evaluated by ICES to be in accordance with the precautionary approach in fisheries, represent a mayor step forward, moving the aim from the short term view of the quota for next year to a view of a long term harvest and stock development. This long term view makes it possible to ensure a better balance between fishing effort and resource availability.

A new element in this changing landscape of fishery management policy is the "ecosystem approach ". What is the ecosystem approach? Does this represent a completely new direction for the management of fisheries in the Barents Sea? Is the tradition working set up for the JRNFC relevant with regard to the ecosystem approach to fisheries management? Is the commission's latest years emphasis on the long time management plans relevant for incorporating the ecosystem approach in the management of the fisheries of the Barents Sea? The ecosystem approach is variously defined, but principally put emphasis on a management regime that maintains the health of the ecosystem alongside appropriate use of the marine environment, for the benefit of current and future generations (Jennings, 2004).

The question on the ecosystem approach to fisheries management in the Barents Sea has so far not yet been discussed in detail in JRNFC. However, in 2003 a mandate was given to the "Basic Document" expert group to "make a scientific assessment of optimal harvest (maximum sustainable yield) from the most important commercial species in the Barents Sea…The assessments shall include all ecosystem elements available for evaluation, i.e. natural and man-made effects on reproduction, growth and survival." Here JRNFC gives a clear signal that ecosystem parameters should be included in the scientific assessments. This should be regarded as a step towards an ecosystem approach.

The aim of the present contribution is to review the present management status with regard to the ecosystem approach, and to review some aspects which could be considered on the way towards a more extended ecosystem approach in the management of the living marine resources in the Barents Sea.

An example: is there an ecosystem approach to the management of the northeast arctic cod?

In June 2006 ICES released an advice for TAC for Northeast Arctic Cod for 2006 of 471 000 tonnes. This advice will be the basis for discussion at the 34th meeting of JRNFC in November 2005. If this advice is adopted as part of the management of Northeast Arctic cod for 2006 it may be reasonable to ask if JRNFC has introduced an ecosystem approach in the management of the living marine resources.

Some people will argue that this advice has not a basis in the ecosystem approach. This is mainly because the assessment of the cod is made on basis of single stock population model and technique (XSA, VPA). They will argue that before you can have an ecosystem approach the fish stock assessments have to be made on the basis of a large holistic model taking into account as many ecosystem parameters as possible (temperature, plankton, prey and predator species etc).

We feel that this is not a constructive starting point for an implementation of the ecosystem approach to management of living marine resources. We should look at the present TAC advice as a step forward in the way toward an ecosystem approach. It is true that the assessment is made on basis of a single stock population, but the quota is now, unlike previously, chosen on the basis of a long term management plan. In the development of the management plan historical data on stock development and ecosystem data have been an important factor. Further, the management of the cod cannot be seen isolated from other management measurers made by JRNFC. The quota for cod has to bee seen in connection with the quota for the capelin fishery. Here the commission has accepted that the consumption of capelin by cod is taken into account when the TAC for capelin is set. Thus the trophic levels (i.e. ecosystem structure and function) is kept intact. Other management measures have been introduced by the JRNFC such as closing areas of the shrimp and bottom trawl fishery if large amounts of cod fry is recorded in the catches, In addition sorting grids in bottom trawl allowing undersized fish to escape from the trawl have been introduced. These measures reduces the impact on the ecosystem due to the fishing practices.

Thus several elements have been introduced by JRNFC that point toward an ecosystem approach in management of the living marine resources. We feel that the correct approach in the way towards a more fully ecosystem approach would be an extension and systematization of these elements, and a gradual introduction of other elements. Some of these elements are discussed in the chapters below.

Scientific assessment and prognoses

Within the field of modelling, assessments and prognoses a move towards ecosystem approach can take place within the following:
- More extensive use of ecosystem information in the population parameters applied in assessment
- Expansion of the multi-species models from the capelin-cod connection already in use

Ecosystem information in population parameters, assessment models and prognoses

The following principles should be taken into account in this work:
  1. A principle of the ecosystem likelihood at the assessment of the stocks status;
  2. A principle of the ecosystem correspondence at the fisheries prediction
  3. A principle of the ecosystem stability at the calculation of TAC and substantiation of the fishery strategy
  4. A principle of minimization of attendant ecosystem disturbances during fishery.

1) We understand the principle of the ecosystem likelihood as the usage of the ecosystem characteristics for determination of the reliability of the obtained stock estimates and population parameters of the commercial species. For example, high growth rate of cod in the Barents Sea should correspond to the heightened heat content of waters or to a higher biomass of the capelin stock. High estimates of capelin abundance should be proved the same way by the increased content of this species in the stomachs of the predators. A situation cannot be realistic when the calculated consumption of a species by a predator exceeds the existing estimates of this species population biomass.

Realization of a principle of the ecosystem likelihood suggests in the practice of the fisheries investigations two approaches to the introduction of ecosystem data into the process of the stock status assessment: either to use directly the ecosystem characteristics in the assessment models as the input data at the determination of its parameters or to consider them as a criterion of reliability of the obtained estimates of the stock status.

Quite a many models have been developed for assessment of a stock size with the use of some elements of the ecosystem approach, trophic relations mainly. The example is a method of multi-species virtual/population analysis, on the basis of which the multi-species models are developed for the North, Baltic and Barents Seas. Elements of a relationship predator-prey are included either into various production models. Such models are developed in particular for shrimp biomass assessment in the Barents Sea and in Icelandic waters accounting data on consumption of shrimp by cod. There are also the other examples. However, the multi-species approach is not widely used at the stock assessments, since the modern models are imperfect, and they have a high demand to an input data, that is often difficult to realize at practice.

Using ecosystem parameters as a criterion of reliability of the obtained estimates of the stock status, it is necessary to be guided by the following ideas:

  - Interrelations of all elements of the ecosystem;
  - Uncertainty in estimates of populations and ecosystem parameters:
  - Flexibility of the ecosystem relationships;
  - Relativity of our knowledge of both the functioning of the ecosystem and a role of the discussed species in it;

The simplest way of analysis of the ecosystem correspondence between the available data on stock status is the expert assessment. The application of the formalized approach for such a kind of analysis requires the development of the corresponding models.

2) A principle of the ecosystem correspondence at the prediction of the stock dynamics should be understood as conformity of the projected of the stock status with the expected changes of the ecosystem parameters, basing on the existing of knowledge of the interrelation between the ecosystem characteristics and population parameters of the fishing species. This principle is intuitively evident; nevertheless proper attention is not always paid to it. The objective reason for that is the absence or unreliability in many cases of the projected estimates of the expected dynamics of the ecosystem parameters. The example of realisation of the principle for the Barents Sea is the usage at the latest ICES Arctic Fisheries Working Group of the results of analysis of the projected ecosystem situation for the assessment of expected conditions of growth and feeding, natural mortality of recruitment of cod and capelin stocks in the Barents Sea.

3) Under the principle of the ecosystem stability at the substantiation of the fisheries strategy we understand the conservation of the balanced correlation of the populations of commercial species connected between each other by trophic relationships. Breaking of the formed trophic relations in connection with the sudden increase of the predator abundance or reduction of abundance of its main food object is quite usual for the boreal ecosystems, however, it is always a destabilizing factor for the ecosystem structure and function, especially if it concerns the dominating species.

Capelin stock reduction in the Barents Sea as the main food object of cod leads both to the slowing down of cod maturation and to the increase of cannibalism (Ozhigin et al.,1996; Dolgov, 1999). Under the deficiency of the food cod migrate far to the east of the sea, where they feed on polar cod, the important food object of birds and sea mammals (Marine colonial birds…, 1995; Nilssen et al.,1997). Under the reduction of the capelin stock, food migrations of harp seal vary also, and this species predation press on Gadidae increases (Invasion of …, 1998).

Large-scale breaks in the ecosystem cause the fisheries crisis. According to the existing opinions, during the previous century there twice at least was a situation in the Barents Sea, which caused a crisis of fishery (Giske et al., 1998). It was mentioned for the first time in the end of the 19th – early 20th centuries. At that time fishing for cod was reduced. Catches were low, and small fish with low fatness predominated in catches. Besides, a mass invasion of seals to the coast of Norway was observed, and a big number of dead birds were registered. In the 1980's the events have happened similar to those in the end of the 19th-early 20th centuries. A collapse of the capelin stock took place, and stocks of cod, haddock and saithe decreased. From 1977 to 1990, a total year catch in the Barents Sea reduced from 4 mill. t to 0.5 mill. t (Nakken, 1998). A mass invasion of seals was observed off the coast of Norway, a high mortality of sea birds was registered in the Spitsbergen and in the Norway (Vader et al., 1990; Skjoldal, 1990, Blindheim, Skjoldal, 1993).

Therefore, the main task of the ecosystem approach to the management of the stock exploitation should be a development of the fisheries strategy providing a possibility to reduce maximally a probability of arising of the ecosystem large-scale breaks that can result in the decrease of fish productivity.

The main factors destabilizing the marine boreal ecosystems status are the large-scale oceanographic processes independent on the human control. In the Barents Sea, the increase of the influence of the warm Atlantic waters favours as a rule the inflow of zooplankton, increase of the fish growth rate and appearance of their abundant year classes (Dalpadado et al., 2002). A cold period vice versa is characterized by the decrease of the primary bioproduction of the Barents Sea and appearance of poor year classes of commercial fish species.

In the process of the evolution the marine ecosystems existing under the dynamic conditions have acquired an adaptive resistance to the destabilizing influence of the external natural factors. That is why the varying oceanographic conditions are not themselves a reason of crises in the ecosystem, although they change the level of the ecosystem total productivity and fish productivity in particular. The inadequate fishing pressure, which does not consider the dynamics of relationships on the background of climate change, is able in a greater measure to stimulate or accelerate the transference of the ecosystem to the crisis. At the same time, the regulated fishery can play a role of a stabilizing factor for the ecosystem functioning, if it promotes the support of a ratio between the population sizes of predators and their prey species or food competitors within a certain range.

A principle of the ecosystem stability suggested for the management of the exploitation of the marine bioresources contain the two basic ideas:

> - For the commercial species connected between each other by the trophic relations there is the optimal ratio of sizes of their populations at which the total catch in the long-term aspect will be maximal;
> - For the inter-dependent species dominating in the ecosystem there are limits in the ratio of sizes of their populations, overrun of which is connected with a high measure of risk of crises arising in the ecosystem functioning that can result in a sharp decrease of its productivity.

The first of the items can be considered as a reference point for the multi-species fishery. The second is more significant, since it promotes conditions of the long-term stable exploitation of marine bioresources . Realization of this idea in practical management suggests nor only the account of food requirements of predators in the calculation of TAC, but the regulation of the abundance of the inter-dependent species within the established limits as well. And all species engaged in the fisheries, both the forage species and predators of the high trophic levels, can be objected to the directed regulation of abundance from the ecosystem stability point of view.

Multispecies models as an element of ecosystem approach to fisheries management in the Barents Sea

Multi-species modeling should be treated as an element of the ecosystem approach to the management of living marine resources. It is believed that the first multi-species model based on trophic interactions between species and designed for sea fish stocks assessment and projection was suggested by Riffenburgh in 1969 (Ursin, 1982). The model developed by him combined three species on the Pacific coast of North America: hake, anchovy and sardine. Agger and Nielsen in 1972 adapted this model for the North Sea that is regarded as the first experience of the use of a multi-species model for description of commercial species in the European seas (Ursin, 1982).

For the Barents Sea, purposeful activity towards development of multi-species models destined for optimization of fisheries management has been pursued since late 1980's. In the Bergen Institute of Marine Research (IMR) a MULTSPEC model was developed to describe stock dynamics and trophic interactions in the Barents Sea between cod, capelin, herring, harp seal and Minke whale (Tjelmeland and Bogstad, 1998a). Estimations in the model are done with the time step of 1 month. According to the scheme of areas used in the model, the Barents Sea was divided into 7 areas.

Later on, based on the MULTSPEC model, a model AGGMULT was developed, which was distinguished, first of all, by aggregation of data (Tjelmeland and Bogstad, -1998b). The AGGMULT is spatially non-aggregated model with the time step of 1 quarter. As distinct from the MULTSPEC, the AGGMULT model includes only three species: cod, herring and capelin.

The MULTSPEC and AGGMULT models were designed as analytical instruments for analysis of multi-species fisheries strategies in the Barents Sea. For practical application of the multi-species approach to the estimation of total allowable catch of capelin in the Barents Sea, a simplified version of the multi-species model called Bifrost was developed (Gjøsæter et al., 2002). This model does not use the spatial structure of the Barents Sea and includes only two species: capelin as an object of fishery and cod as predator of capelin. Since 1998 ICES with the use of this model and based on acoustic survey data has been estimating annually the total allowable catch (TAC) of the Barents Sea capelin taking into account food requirements of cod (Gjøsæter et al., 2002).

Interaction between capelin and Norwegian spring-spawning herring is also a simulation object in the Barents Sea. The Norwegian spring-spawning herring are drifted to the Barents Sea at their early life stages and dwell there for 3-4 years until the maturity. It is reckoned that immature herring in the Barents Sea are able to consume larval capelin largely, thereby affecting adversely the capelin stock (Huse and Toresen, 1995). This, in its turn, has an effect on cod feeding conditions, growth and maturity rates as well as on cannibalism level. To simulate these interactions a model SYSTMOD was designed – a system model of fisheries in the Norwegian and Barents seas (Hamre and Hatlebakk, 1998). In this model there is no division of the Barents Sea into areas. Parameters of recruitment and growth of herring, capelin and cod are related to climate changes. Warm period favors good recruitment and growth of all the species but the appearance in the Barents Sea of rich herring year classes entails massive mortality of larval capelin.

At PINRO, works on multi-species modeling at the first stage were confined to adjustment of MSVPA model to the conditions of the Barents Sea as this model was primarily designed for the North and Baltic seas. In early 1990's, the two-species models, "cod-capelin" and "cod-shrimp" were developed at PINRO (Berenboim et al., 1992; Ushakov, Korzhev, Tretyak, 1992). Further improvement of the model resulted in the eight-species MSVPA model for the Barents Sea designed in the second half of 1990's. In addition to capelin and shrimp, arctic cod, herring and haddock as food items of cod and harp seal and Minke whale as supplementary predators were incorporated in the model (Korzhev, Dolgov, 1999; Multi-species analysis…, 2001). Time step used in the MSVPA model for the Barents Sea is one quarter. The model is not structured spatially, i.e. does not include details of the simulated processes by areas.

Since 1996, PINRO carries out works towards development of a multi-species model based on the use of algorithms formalizing cause-and-effect relations in growth, feeding, maturation, migration, mortality and recruitment in fisheries populations (Filin et al., 2003). The core element of the model being developed is cod as the most extensively studied species of crucial importance not only for fisheries but also for the Barents Sea ecosystem. The model simulates intra-population and inter-species relations of cod and is destined for optimization of multi-species fisheries management in the Barents Sea.

In accordance with the adopted scheme, the model is constructed stage by stage, through creation of separate structural units able to function both as an element within one single model and as an independent model. The first model constructed on the basis of such approach was a CONCOD (CONsumption of COD) model meant for quantitative assessment of feeding and growth of cod in the Barents Sea using data on food supply, temperature and abundance of the cod population as the base (Filin, Gavrilik, 2001). The CONCOD model was further developed into the STRAFICOD (STRAtegy Fishery of COD) model describing implications of different fishing strategies for the cod stock with regard to trophic links between cod and capelin.

In 2001, the first version of a STOCOBAR (STOck of COD in the BARents Sea) was constructed. This model comprised CONCOD and STRAFICOD models. The STOCOBAR model includes seven species as prey to cod such as capelin, shrimp, arctic cod, herring, euphausiids, juvenile haddock and cod. The model is not structured spatially. Time step in the model may be set equal to one year or half a year.

Thus, Russian and Norwegian scientists have accumulated a wealth of experience in constructing multispecies models for commercial species in the Barents Sea. Unfortunately, the majority of the models have not been put to practical use as analytical instruments for stock assessment, projection or TAC estimation. The cause of that may be both shortcomings in the existing models and insufficient opportunities to provide them in full measure with necessary input data.

Elements related to the ecosystem approach that are not traditionally discussed by JRNFC

So far in the present contribution we have discussed how to incorporate ecosystem information in assessment models and how to interrelate several species, thus enabling the mangers to take ecosystem information into account when deciding upon catch quotas. The mandate to the scientists on this field is given in JRNFC 2003 decision on an assessment of optimal harvest including ecosystem information.

However, in implementing the ecosystem approach, JRNFC can expand the traditional field of discussion to also evaluate other elements. A common thought on the ecosystem approach is a transition from traditionally maintaining fish stocks at a healthy to maintaining ecosystem health. This on the background of increased activities in the Barents Sea of shipping, waste disposal and oil and gas exploration. Further, use of certain fishing can have an impact on the environment. It is a world wide growing concern that the fishing operations should allow for the maintenance of the structure, productivity and diversity of the ecosystem on which the fishery depends Two elements, that traditionally have not be dealt with have been pointed out as indicators for ecosystem health and are relevant to the management of fisheries are the following:
  • Biodiversity
  • Pollution

The ocean floor is increasingly recognized as an important reservoir of marine biodiversity. There are at present planned joint Norwegian /Russian investigations on benthos habitat and species structure in the Barents Sea. The use of certain fishing gears or practise can have a disproportionately harmful ecological impact on species and habitats in some areas. As discussed in the introduction of this contribution there is at present area/time restrictions for certain fisheries in the Barents Sea in order to protect young individuals of commercial fish species. This current measures could easily be expanded to benthos species, and the discussion could also be expanded to included eventual marine protected areas (MPA). MPA can be a useful tool on the way towards an ecosystem approach. The following elements are relevant (Bowman and Stergiou, 2004).

  • Rebuilding overexploited fish stocks
  • Preserving habitat and biodiversity
  • Maintaining ecosystem structure
  • Buffering against the effects of environmental variability
  • Serving as a control area (population parameters on exploited groups in some areas can be compared).

The fishing industry in the Barents Sea is dependent on a non-polluted Barents Sea when selling the products. At present the Barents Sea is defined as clean. However, on a background of increased activities in the Barents Sea of shipping, waste disposal and oil and gas exploration it is important the development of pollution state is investigated and monitored so a non-polluted state of the Barents Sea can be documented. The competence and responsibility in this field has traditionally been within environmental bodies, but it is important that the monitoring is coordinated with the fisheries management body.

Conclusions

There is no single way to implement the "Ecosystem approach", it depends on historical practices and national, regional and global conditions. We feel that JRNFC has taken important steps on a way to implement an ecological approach when managing the living marine resources of the Barents Sea. Incorporation of ecosystem information and multi-species models in assessments will continue the next years.

A further implementation will probably need extension of the traditional field of discussion from the health and state of commercial fish stocks to the health and state of the Barents Sea ecosystem (of which the commercial stocks represent one element). Pollution and biodiversity could be actual candidates for further analysis with regard to the ecosystem approach. The implementation should be a gradual process where much of the foundations for the theoretical work, investigations and surveys are already set.

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