Why do jellyfish bloom in Norwegian waters and what can be done to recover the ecosystems in the North Sea and on the Norwegian coast?

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Abstract

The ecosystems with their relationships between fish species and stocks, have been established by evolution for millions of years, but during the last 50 years, the ecosystems in the North Sea and along the Norwegian coast have been changed fundamentally by fisheries. The North Sea mackerel stock has been depleted and its feeding grounds have been invaded by the Western mackerel which spawns west of Ireland. This stock is now very rich in numbers and occupies the North Sea, the Norwegian Sea and the western Barents Sea. If the trend continues, mackerel may outcompete many of the other fish stocks in the area. Traditionally and until the beginning of the 1970s, there was a large stock of sandeel spawning in the North Sea and on the Norwegian coast. Sandeel juveniles was an important food source for a wide range of species, including sea mammals and birds. The fact that this stock has also been overfished, may explain many changes observed in the ecosystem on the west coast of Norway, for example a large reduction in the populations of sea birds. There are several instances where ecosystems shift to sustain jellyfish blooms in response to depletion of forage fish stocks. This was registered in Namibia in the 1990's, where the pilchard stock was decimated and the biomass of jellyfish soon became overwhelming. On the west-coast of Norway, there are now frequent blooms of jellyfish, yet another indication that a controlling factor is missing in the system, in this case sandeel, which is a key species in the transfer of nutrients from zooplankton to higher trophic levels in the area. In this paper, I give a description of the situation and some suggested measures that should be taken in fisheries management.

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1. Introduction.

In July 2013, large densities of jellyfish were observed on the coast of Western Norway (Bergens Tidende (local newspaper) 11/7-13 and own observations). This may be a similar situation to that we observed in Namibia in 1990-1993. In some areas of Namibian waters there was so much jellyfish that it was difficult to take trawl samples of fish registered in our acoustic surveys. The trawl was filled with jellyfish in a short time and busted. Even though we had data that indicated that the most important plankton eater of the Bengal upwelling system, the pilchard, was being decimated by fisheries, nobody then saw a possible connection between the enormous jellyfish production and the all times low pilchard population.

Recently, marine scientists in Namibia have indicated that there may be a connection between the extensive fisheries of plankton feeders in the area and the production of jellyfish (Flynn and others 2012; Roux and others 2013). In this context, information from the surveys of fish stocks on the Namibian coast in the 1990s, performed by the Institute of Marine Research, Bergen, Norway (IMR), may be of interest.

2. The dr. Fritjof Nansen Research Program

When Namibia became independent in 1990, NORAD and FAO made an agreement with the government of the new state to evaluate the size of the fish stocks in their coastal waters. The surveys were called the "Dr. Fritjof Nansen Research program" and IMR was asked to execute the scientific part of the program. The previous Director of IMR, Gunnar Sætersdal, got the responsibility of planning the program and the present author, as the leader of IMR`s department for pelagic fish, was appointed to lead the field work on the forage fish. The results of the surveys are described in FAO reports from the program, of which two are referred to (FAO 1990; FAO 1993).

The bioacoustic measurement methods which were applied in the project had been developed at the IMR in the 1970`s and used as basis for the regulation of capelin fisheries in the Barents Sea (Hamre 1985). When the investigations were started in May 1990, the hydrographical conditions in the Benguela current were well known and the system was described as one of the biologically most productive worldwide. The pilchard was the largest stock of plankton feeders in the ecosystem. There was some information that extensive pilchard fisheries had been performed by Eastern European fishing vessels since the beginning of the 1950`s, but the South African catch statistics were not available at that time. The literature showed, however, that pilchard had a similar life history to Norwegian Spring Spawning herring. The nursery area for yearling pilchard stretched along the whole coast of Namibia, while mature pilchard was caught, mainly in the autumn (April-May), in the Northern area. Some of the older part of the population was also present on the coast of southern Angola (FAO 1989). Based on this information, it was decided that the size and life history of the pilchard population should be the primary goal of the first survey of pelagic fish. The results of the survey are described in (FAO 1990; FAO 1993) and can be summarized as follows:

The pilchard stock in Namibian waters in 1990 was measured to 750 000 metric tons, and most of it was maturing fish on the northern coast. When the measurements were repeated in 1993, the stock was reduced by 50% and was in a state of depletion. On the cruise in 1990 the jellyfish bloom was discovered.

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In the beginning of the 1960`s, the power block was introduced into the purse seine fisheries on pilchard on the coast of Namibia, centered in Walvis bay, where the catches were delivered for fish meal production. This led to dramatically increased catches and after a period of 10 years, the stock had more or less collapsed (Figure 1), similarly to what happened to Norwegian Spring Spawning herring when the power block was introduced in the Norwegian purse seine fisheries in 1962.

A connection between the pilchard fisheries and the jellyfish bloom seems logical, as the decimation of key populations of plankton feeding fish may stop the transfer of biomass from plankton to higher trophic levels. The uneaten zooplankton biomass may die, sink to the bottom and thus constitute a nutrient supply for jellyfish polyps or zooplankton may directly be eaten by the jellyfish. There are many examples of jellyfish blooms worldwide, although they have not been coupled directly to overfishing of forage fish (Gershwin 2013). One of the most severe examples is the jellyfish blooms in the Black Sea, where *Mnemiopsis* bloomed to up to 500 specimen per m^2. Its population was estimated to more than 1 billion tons, more than the world's total annual landings of fish (Gershwin 2013; Ivanov and others 2000). Several hypotheses have been put forward to explain the jellyfish bloom in the Black Sea of which one is overfishing of anchovy (Gershwin 2013). The description of the fish landings by Gershwin (2013) shows very clearly that several fish stocks had been overfished before the jellyfish bloom started. Furthermore, forage fish had been overfished in the Caspian sea prior to a jellyfish invasion there (Ivanov and others 2000). A similar mechanism may be causing the jellyfish bloom on the coast of Western Norway, indicating that some important plankton eating fish species have been overfished.

3. The most important plankton eating fish in Norwegian waters

The key species of plankton eating fish on the Norwegian coast are Norwegian Spring Spawning herring, sandeels and mackerel (Hamre 1994). They can affect the balance of ecosystems in different ways.

0-group herring and 0-group sandeel are the most important converters of plankton to catchable fish in the Norwegian coastal current during the spring and summer. The main spawning of herring occurs near Stadt (62ºN) in spring and larvae and juveniles drift northwards in the coastal current during summer and autumn where they are fed upon by different species of fish, seabirds and mammals. The spawning stock of herring was almost depleted by fisheries at the end of the 1960`s and 0-group herring in the coastal current disappeared. There was no bloom of jellyfish in response to the collapse in the herring stock, but the reason for this may be that the population of sandeel was large enough to keep the zooplankton at a sufficiently low level to prevent a jellyfish bloom.

In the 1950`s the population of 0-group sandeel on the coast of Western Norway was very large. The author studied the biology of Atlantic Bluefin Tuna at the time and followed it`s migration southwards along the coast after it arrived at Stadt in June. It migrated southwards, but stopped when it met the enormous amounts of sandeel juveniles outside Hordaland and Sogn og Fjordane (60 to 62ºN). The tuna also fed on herring, but sandeel was probably the most important prey. In July-August, most of the herring juveniles were distributed further to the north, while 0-group sandeel was distributed on the west coast and was the most important prey for animals at higher trophic levels. It seems that the sandeel population had developed a strategy for survival by offering part of its juvenile production to protect the spawning areas from invading predators. This strategy undoubtedly protected the spawning stock of sandeel from predation by tuna in the 1950`s. In later years mackerel has invaded the areas where adult sandeel is caught. Mackerel eat sandeel, and the invasion of mackerel on the sandeel spawning grounds may also indicate that the amount of 0-group sandeel is reduced and that the spawning stock therefore is less protected.

The mackerel population has increased dramatically, both in numbers and distribution area during the last 50 years. Investigations of egg distribution (Iversen 1973) and results from tagging experiments (Hamre 1978) have shown that there were two populations of mackerel in the North Sea and west of Shetland as late as in 1973, one which spawned in the central North Sea and one that spawned west of Ireland. After the North Sea mackerel was depleted by exploitation in the first half of the 1970`s, the Irish mackerel took over its feeding grounds, but returned to Irish water for spawning. From then on, the mackerel was managed by ICES as one stock, called western mackerel, with spawning in the Atlantic Ocean. It is this stock which during the feeding migration invades the North Sea, large parts of the Norwegian Sea and the southern part of the Barents Sea. The western stock continues to spawn in the Atlantic Ocean, but some 5% of the total mackerel stock did spawn in the North Sea in 2011 (ICES 2012). This means that the North Sea mackerel stock still exists and could be restorable if the western mackerel is removed from the North Sea. The increased access to food by taking over the feeding grounds in the North Sea and Norwegian coastal waters is probably the reason for the large increase in the western mackerel population since the start of this millennium.

Due to high swimming speed, the mackerel is an effective plankton feeder, but also an effective predator on all smaller and slower moving fish, such as capelin, sandeel and juvenile herring. The large increase in the western mackerel stock may also be the reason of the dramatically decreased recruitment of European eel since the 1970s. This can be shown, for example, by the lowered catches of glass-eel in the river Imsa in western Norway. In 1978, 121 000 glass-eel were caught, while in 2007 this was reduced to 100, e.g. a decrease of 99.9% (Røed 2013).

Mackerel is not a preferred prey by other predators because of the high cost of energy to catch them. The mackerel is therefore inferior to other forage fish for transfer of biomass to higher trophic levels. The mackerel also uses an ample amount of energy to support its speed, and since biomass and energy are equivalents (Hamre and others 2014), mackerel is probably less efficient than the other forage fish in retaining biomass from food. In the context of multispecies management, the population of mackerel should therefore be held at a relatively low level to obtain a maximum sustainable yield from the ecosystem to which it belongs.

4. Conclusion

Everyone who knows the Norwegian coast will have perceived that the populations of sea birds, especially seagull and tern, are strongly reduced. In the area west of Bergen, only small flocks of sea birds have survived. The number and nesting success (size of litters) of seabirds have been regarded as a good indicator of the availability of food from pelagic fish (NRK (Norwegian broadcasting) 22.10.13, Ut I Naturen). The observations listed above indicate that depletion of North Sea mackerel and sandeel are the main reasons for the reduction in the seabird populations on the parts of the Norwegian coast facing

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the North Sea. Unfortunately, the data series on reproduction of seabirds on the west-coast goes back only to 2008 when SEAPOP was started (www.seapop.no).

The statistics for the catch of North Sea sandeel (Figure 2) show that the catches increased dramatically from 1970, and indicate, although no assessment has been done, an almost total collapse of the population after 2002. According to an assessment of the stock from 1983 to 2006 (Figure 3) the stock became gradually reduced, and already at the end of the 1990`s there was an effect on the seabirds in Nordland (NRK, 27.08.13, Ut i Naturen). The depletion of the sandeel stock seems to have been most disadvantageous for fish and birds at the west coast of Norway, and occurred concomitant with the bloom of jellyfish in western Norway. The jellyfish blooms in Norway may thus be a parallel to what happened in the Benguela current after overfishing the small pelagic fish, especially the pilchard stock.

5. Suggested measures

The marine ecosystem on the west coast of Norway may now face a historical crisis. The main triggers are overfishing of sandeel and North Sea mackerel, but the crisis is accentuated by changes in the ocean climate which favors migration of western mackerel. The ecosystem with its relationships between fish species and stocks has been established by evolution for millions of years, but only during the last 50 years, it has been changed fundamentally by fisheries. Western mackerel has now become a threat to recruitment of sandeel, herring, European eel and perhaps also capelin. As part of the fisheries management system, we cannot do anything about the temperature, but we can regulate the fisheries. We can stop sandeel fisheries and increase the fisheries of western mackerel. This means that:

- All fisheries of adult sandeel should halt for the time being and should not be opened before the stock is rebuilt to a size similar to that prior to 1990 (anticipated, but may be estimated approximately with VPA). The number and nesting success of seabirds may also be used as an indicator of a rebuilt sandeel stock.
- The fishing on the western mackerel stock should be intensified, especially the part of the stock which now invades the areas for spawning sandeel. Instead of protecting this mackerel with extra management measures, as is the case now, the stock should be reduced using extraordinary efforts. Fisheries of western mackerel in the spawning areas off the coast of Ireland – Shetland during the spawning time should be strongly intensified, in order to rehabilitate the stock inherent to the North Sea.
- One should establish research to investigate mackerel predation on other forage fish, using samples of stomach contents. The similar program for Barents Sea cod can be used as a template for this investigation.

The two first measures will clearly be debated nationally and internationally, because they are based on circumstantial evidence. However, in this case the indications are so strong that they should be accepted as a basis for the suggested fishery regulations.

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Figure captions

Figure 1. Catch and biomass of the pilchard stock in the Benguela current, west of Namibia.

Figure 2. Catches of sandeel from 1952 until 2010 in Fisken og havet, særnummer 1-2010, page 152.

Figure 3. Assessment of spawning stock and numbers of 0-group sandeel in the North Sea, 1983-2006. Fisken og havet, særnummer 1-2007, page 132.

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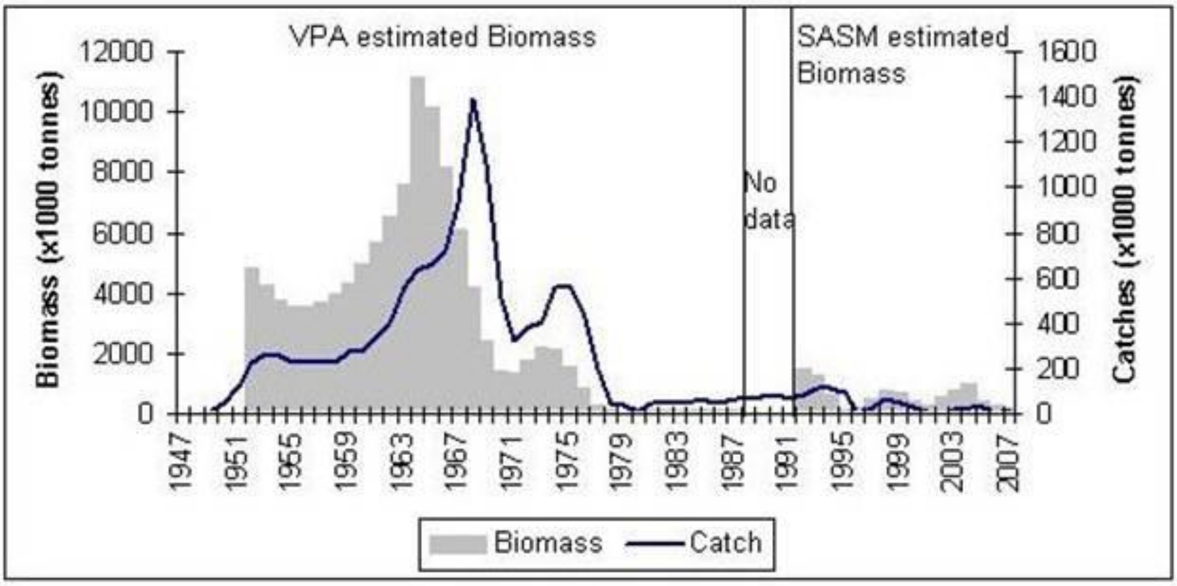

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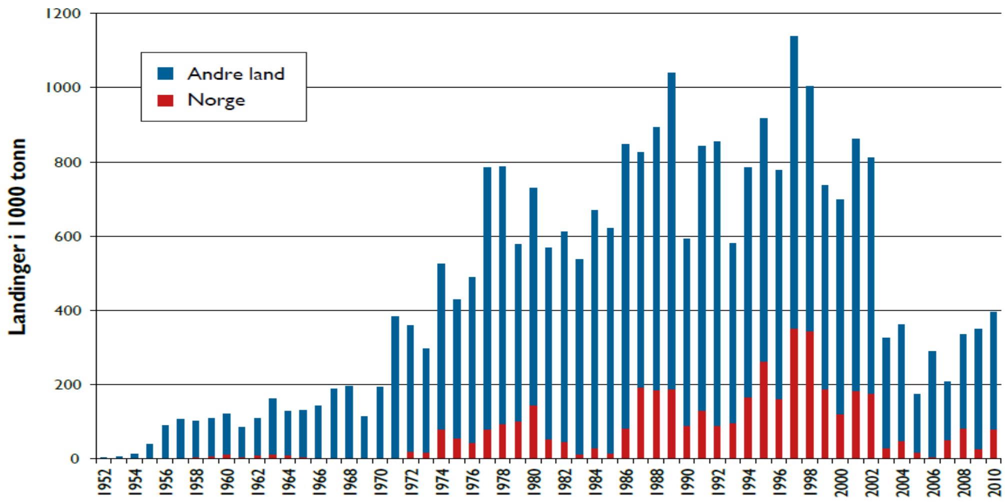
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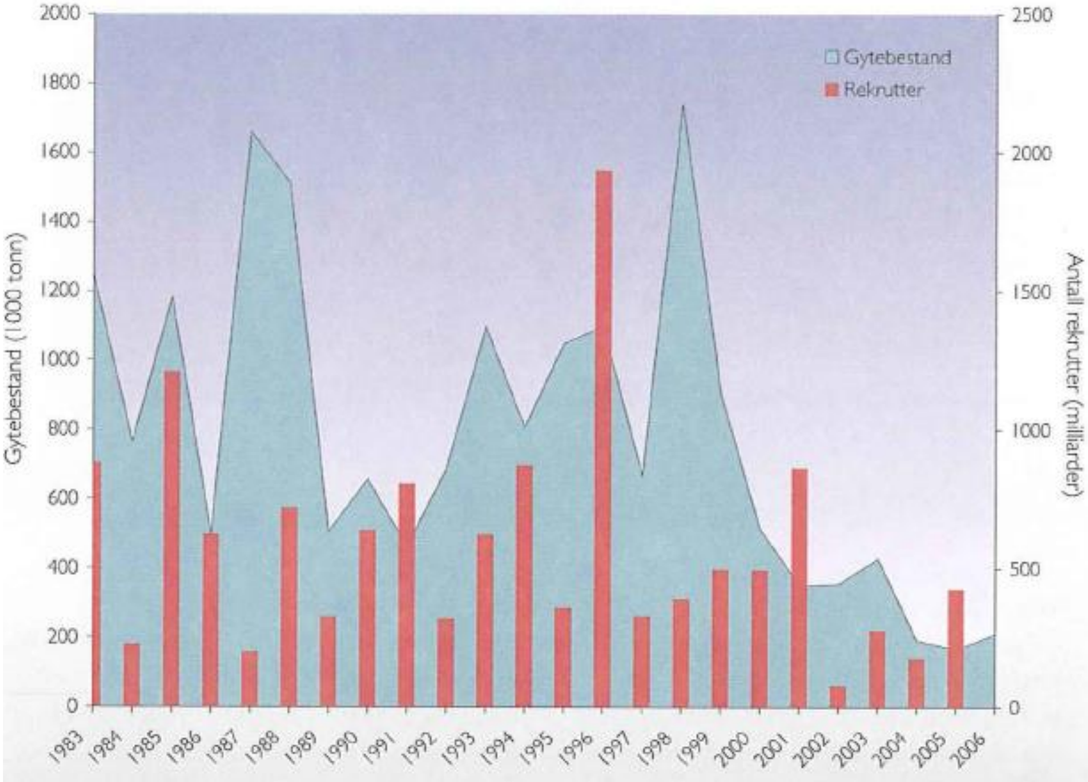
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Figure 3

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