Fish stocks and enviroment in marine and inland waters

Swedish Assessments 2009

Battle Harbour, Labrador, 1910.

FISKERIVERKET
SWEDISH BOARD
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Introduction

Since 2004 the Swedish Board of Fisheries has issued an annual review in Swedish of the status of fish stocks and the environment in Swedish inland and marine waters. This is an extract in english from the 2009 issue. The review has two major sections: one where the assessment and prognosis for the 80 most important fish- and shellfish stocks are presented and one where the environmental conditions in the major aquatic ecoregions – the Baltic, Skagerrak/Kattegatt and Swedish inland waters – are discussed from an ecosystem perspective.

In this extract just four fish and shellfish species are included as examples: cod, as the most important demersal species for the Swedish fishery, vendace and pike-perch which are important both in the coastal and inland fisheries and Norway lobster, which is the major shellfish species. The Baltic ecoregion is included as an example of the ecosystem analysis.

In addition to those larger, reccuring standing sections the annual review contains chapters on issues of current interest. This is exemplified by a presentation of the marine protected area which has been established in the Kattegatt in Swedish-Danish cooperation. There is also each year a special focus article. For this English extract a new text has been written, discussing the objectives of the Common Fisheries Policy from the point of view of the ongoing reform.

Axel Wenblad och Håkan Westerberg
June 2009

In focus:

The ecosystems approach and the objectives of the Common Fisheries Policy

The objectives of the present CFP as formulated in Council Regulation (EC) No 2371/2002 are: "The Common Fisheries Policy shall ensure exploitation of living aquatic resources that provides sustainable economic, environmental and social conditions."

To ensure this the Common Fisheries Policy shall be guided by the following principles of good governance:

(a) clear definition of responsibilities at the Community, national and local levels;
(b) a decision-making process based on sound scientific advice which delivers timely results;
(c) broad involvement of stakeholders at all stages of the policy from conception to implementation;
(d) consistence with other Community policies, in particular with environmental, social, regional, development, health and consumer protection policies.

In its recent Green Paper the EU Commission finds that those objectives so far have not been reached and that one of the reasons for this is a lack of focus and priority that could provide more concrete guidance or help to measure policy achievements.

The analysis of the Swedish Board of Fisheries is that the fundamental problem with the current objectives is that short- and long-term, social, environmental and economic objectives are mixed without any clear priority. This means that different objectives are often conflicting. When this happens the experience is that short-term economic and social costs usually is prioritized over long-term concern for sustainability and optimal yield of the fish resources.

In practice the fisheries policy is often used as a tool for regional policy. This is counter-productive if the rebuilding of the fish stocks to an optimal level is sacrificed. With the present decimated resources the low economic performance and viability of the fishing sector means that fishing has become uninteresting as an occupation even in communities that used to be strongly dependent on the sector.

The Council regulation of 2004 laying down measures concerning incidental catches of small cetaceans is an example of implementation of the ecosystems approach in fisheries management with a focus on preserving biological diversity. (Harbour porpoise with calf, photo Fjord and Baelt Centre, Denmark.)
Foto: Maria Boström

Zuan Wu is a recreational lake in Nanking which, by optimising use of fish from all ecological niches, also yields 1 500 kg fish/ha yearly. This is an extreme example of ecosystem approach to management with a focus on the producing aspect of the ecosystem.

The ecosystem approach as fundament

The ecosystem approach to management is a paradigm shift and can not be introduced gradually. Either you take the whole ecosystem into account or you don't. To implement the ecosystems approach in fisheries management means creating a process where stakeholders on several levels cooperate – research, management, the fishing sector and other stakeholders – to preserve the common values of the aquatic ecosystem.

Fish has a decisive role in all functions of the aquatic ecosystem, not only as a target for harvesting ecosystem goods but as a participant in all the other life-supporting services of the ecosystem. Fish dominate the roles as prey or predator at several trophic levels in seas and inland waters. By excessively depleting fish at any of those levels an imbalance and a chain of events is started, with often unforeseen consequences. Eutrophication, red tides and mass occurrence of jellyfish have all been traced to disturbances of the role of fish in the ecosystem.

The European Union acts through the Integrated Maritime Policy to ensure that the fisheries policy contributes to the ecosystem based approach,

What is the ecosystem approach?

The ecosystems approach – EA – is a management principle that has been adopted by several countries, including Sweden. The Summit on sustainable development held in Johannesburg 2002 recommended its implementation by the year 2010. EA is a cornerstone in the Convention on Biological Diversity. There is no generally accepted definition of EA however.

A tentative plain-language definition of EA is "By using existing knowledge about how nature works to exploit living natural resources in such a way that the rest of the environment not is harmed and that the resource isn't depleted. The larger the uncertainty about how the system works the more precaution is needed. Management must be continuously evaluated and revised according to its results"

EA is a knowledge-based principle for management, not for science. Knowledge of a complex aquatic ecosystem large uncertainty is compatible with EA but demands application of precaution.

There are two main dimensions of the EA – an intra-sectorial dimension, which for the fishery policy means the reciprocal relation between the fishery and the ecosystem, and a cross-sectorial dimension which concerns the effects of other sectors on the aquatic ecosystem and in this way on the fishery. The cross-sectorial dimension is part of the Marine Strategy of the Community, the intra-sectorial dimension is a question for the CFP.

which is fundamental in the Marine Strategy Framework Directive. The Commission ascertains that applying maximum sustainable yield, MSY, as a management target will improve the resource base for the fishery and this shall be attained by 2015.

The Marine Strategy is the environmental pillar of the Maritime Policy and its Framework Directive shall ensure that all policy areas, including the fishery policy, cooperate and integrate environmental concern in their respective policy.

New objectives and objective hierarchy

A reformed CFP should use the ecosystem approach as a framework and ensure that the structure and function of the fish ecosystem is maintained, supporting all other policies within the Maritime Policy. Additionally the CFP should contribute to the prosperity of the coastal communities in Europe by restoring the fish resources towards a maximum sustainable yield. To achieve the above the objectives must be clearly formulated and prioritized.

Suggested objectives in order of priority:

1. The Common Fisheries Policy shall secure the consumers access to sound food by exploiting the marine ecosystem at close to maximum sustainable yield, without jeopardising biological diversity and the resilience of the ecosystem.

2. The Common Fisheries Policy shall contribute to the Maritime Policy by taking the effects of the fishing sector on the regulating and supporting functions of the ecosystem into account.

3. The Common Fisheries Policy shall contribute to a fishing sector which creates occupation, income, recreation and preserves a cultural heritage. The fishing sector shall give a standard of living which follows that in the rest of society. To achieve that the fishing capacity must be continuously adjusted to the limits set by the recourses.

Their mutual interaction and relation to other policy areas must be made clear. The objectives shall give unambiguous guidance for management decisions. The point of departure in formulating the objectives are the four main ecosystem goods and services – the producing, regulating, supporting and cultural services. The objective with the highest priority for the Fisheries Policy is given to the producing service.

The next objective relates to the supporting and regulating services and the third objective relates to the cultural services.

In addition to the objectives clear guidance is necessary for their application. The objectives should be broken down into measurable components with time-frames. Indicators and principles for decision making are important as well as principles for evaluation of the effects of decisions.

A system of adaptive management should be incorporated in a reformed CFP. The Fisheries Policy must be dynamic and able to adapt both to how its objectives are achieved and to the development in adjacent policy sectors. Evaluation and corrections of decisions should be continuously used tools to control the quality and achievement of the policy.

What is MSY?

The concept maximum sustainable yield, MSY, comes from the simple fact that in a situation with a low fishing pressure the total catch will increase if the fishing capacity is increased. This can continue up to the point where the catch exceeds the natural growth of the fish stock. This is the MSY level.

If the fishing capacity is increased further the total catch will go down, which is the present situation for most fish stocks in EU waters.

Instead of the total catch the economic yield can be looked at in a similar manner. The total catch increases slower and slower when the fishing capacity increases, but the total cost of the fishing operations is directly proportional to the effort. This means that the point of maximum economic yield is at a lower fishing capacity level than MSY. This point is called MEY.

The situation gets more complicated for mixed fisheries. The MSY level will be different for different species and the MEY-level looking at the value of the total catch can be both higher and lower than the MSY-level. In a mixed fishery the reasonable ecosystems approach is that the total fishing capacity of the fleet should be dimensioned by the MSY level of the most vulnerable stock. This is a strong argument for changing from a quota regulating system to a regulation of effort.

The fishery resources

The current status of four fish and shellfish species of significant economic value to the Swedish fishery is presented.

Where available the assessment and advice made by ICES is used. Otherwise the data comes from the experimental fishing and national fishery statistics collected by the Swedish Board of Fisheries.

The maps show the geographic distribution of Swedish catches in 2007 of the species on a one by one minute latitude and longitude minute grid. Red dots show those catch positions with the largest catches that together makes up 75 % of the total catch.

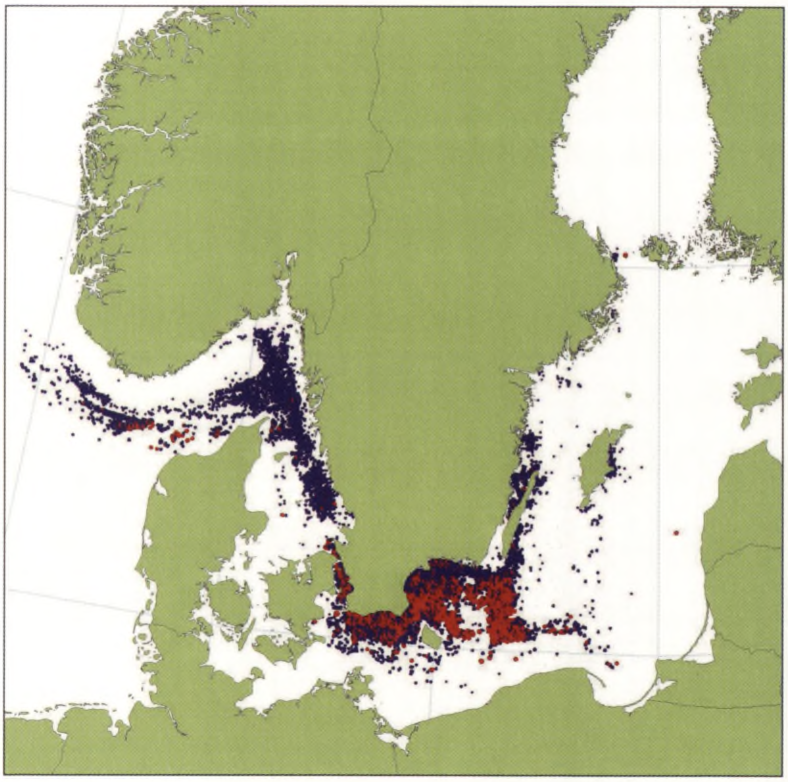
Cod

– GADUS MORHUA

The Swedish cod fishery

Cod is caught both with bottom and pelagic trawls, as well as using gill-net and long-line. Gillnetting has declined during the last years with the diminishing abundance of large sized cod.

The management of cod is separated on several stocks. The Swedish fishery targets four stocks, where the eastern Baltic stock is the most important and the Kattegatt stock the most vulnerable.



Facts

GEOGRAPHIC RANGE: Cod is found in all seas surrounding Sweden, but is relatively rare in the Bothnian Bay.
SPAWNING: On the west coast spawning takes place in January to April. In the southern Baltic ripe cod are found the whole year. In the waters east of Bornholm and further north in the Baltic cods spawn in basins with depths of 70–250 m, with high salinity bottom water. Spawning occurs near the surface and the eggs and larvae are pelagic.
MIGRATION: Different cod stocks make different spawning and foraging migrations.
AGE AT MATURIT: 2–6 years.
MAXIMUM AGE AND SIZE: The cod can become 40 years old, but this has not been observed in Swedish waters.
Specimens larger than 150 cm weighting more than 50 kg have been caught.
BIOLOGY: The typical depth range of cod is 10–200 meters but cods can be found even in very shallow water. In the Baltic cods prefer deep water due to salinity conditions. Shoals form only in connection to spawning. Young cod are benthic feeders and adults also prey on small pelagics.
The cod is cannibalistic.

Cod

Development of catch and stock parameters for the Eastern Baltic Cod

Eastern Baltic Cod

Approximately 90 % of the Swedish catch comes from this stock. Poland and Sweden are the nations that have the largest share of the quota. During the three last years ICES estimates that just 65 % of the landings have been reported.

Status of Stock

ICES has not been able to assess the stock size in relation to reference levels as the levels used earlier are regarded as not adequate any longer. The stock has increased since 2005 but is still at a historically low level. Fishing mortality 2007 was compatible with a sustainable exploitation. Recruitment has been low since the late 1980-ies. The year-classes 2003 and 2005 are expected to become larger than earlier classes.

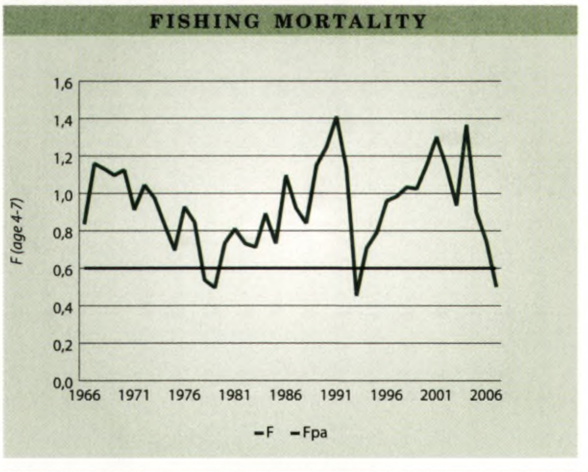
ICES Advice for 2009

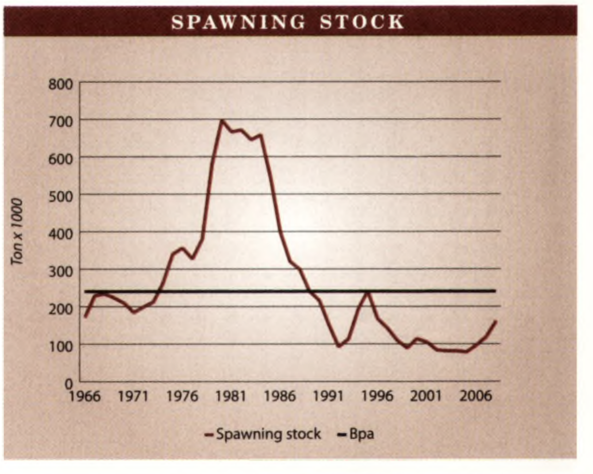
According to the EU-management plan for this stock the TAC becomes 48 600 ton and the expected discard 1 400 ton. Evaluation of the plan has not been possible but ICES recommends following the management plan during 2009.

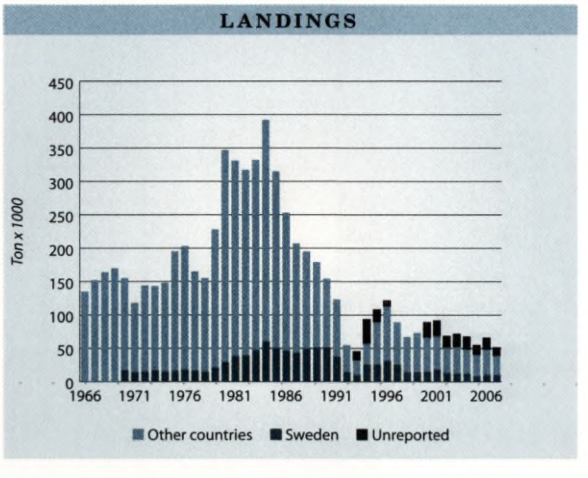
Underreporting of catches has occurred since 2000. Estimates are uncertain but ICES has in the assessment decided to include data available from sources within the fishery and control agencies selectively. During the last years the minimum estimate of under reporting is 35-45 %.

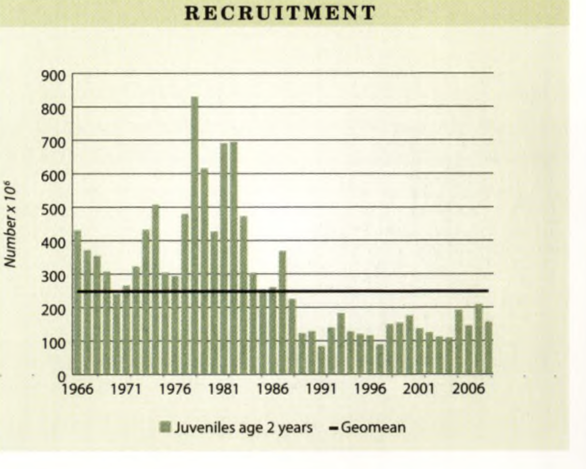
EU Regulation for 2009

Total TAC 44 580 tons, the Swedish quota is 10 375 tons.









Cod

Development of catch and stock
parameters for the Kattegatt Cod

Kattegatt Cod

Cod is caught by Swedish and Danish fishermen using bottom trawl, gillnets and Danish seine. This is a mixed fishery which in addition to cod targets other gadoids, flatfish and Norway lobster. The Swedish share of the cod catch is approximately 30 %. Discard is not included in the assessment.

Status of Stock

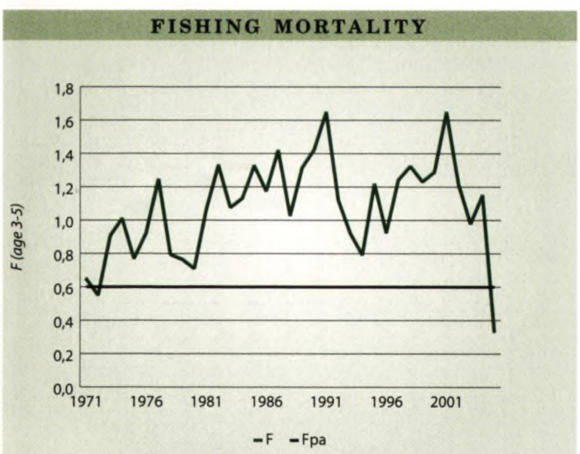
ICES regard the catch statistics as too unreliable for a stock assessment and just look at trends of the stock. The spawning stock is diminishing and near a historic minimum. Fishing mortality can not be estimated reliably. Recruitment has decreased since the 1970-ies and reached its lowest level the last years.

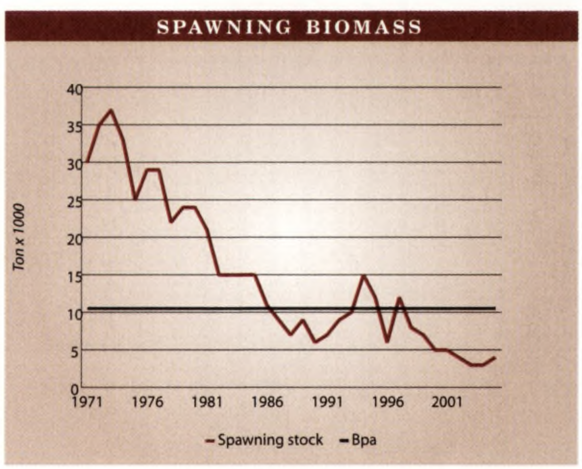
ICES Advice 2009

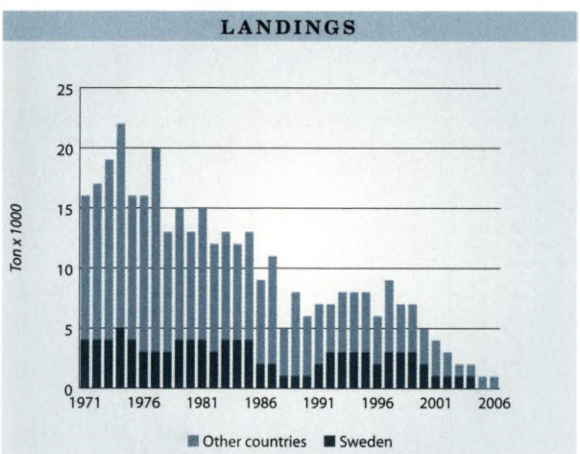
No catch of cod.

EU Regulation for 2009

Total TAC 505 tons, the Swedish quota is 147 tons.







Norway lobster

- NEPHROPS NORVEGICUS

Kattegatt, Skagerrak

Mainly fished using bottom-trawl, but there is also a pot fishery for Norway lobsters. The Swedish catch is approximately 25 % of the total in the area.

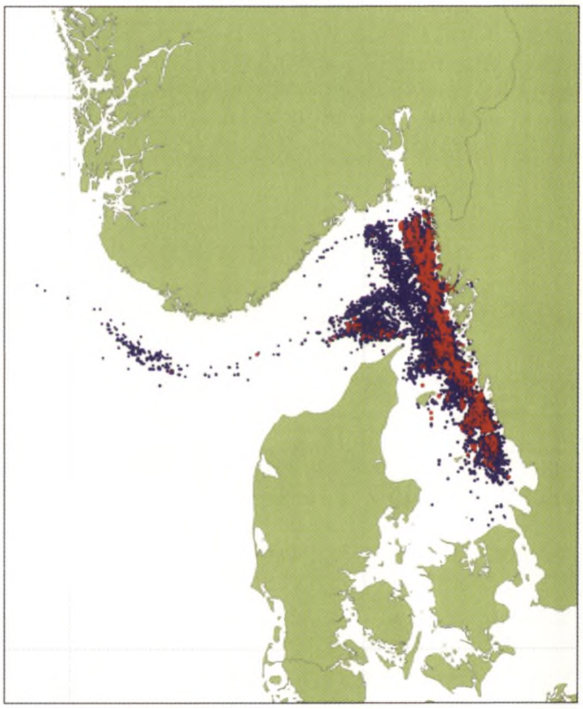
With the presently used trawl gear by-catch of benthic fish is large. This by-catch can be considerably reduced using a sorting grid. Use of sorting grid is now mandatory for trawling in designated trawling areas inside the general Swedish trawling limit. Large quantities of undersized Norway lobster are still discarded however.

State of Stock

The status relative precautionary exploitation boundaries can not be assessed. Commercial fishery indices (landings per unit effort) suggest that the stocks in Skagerrak/Kattegatt are exploited at a sustainable level.

Advice

Due to uncertainty in the available data ICES is not able to reliably forecast catch. The recommendation is not to exceed the current levels of exploitation. Measures to ensure species selection (sorting grids) should be used to minimise the by-catch of cod and other benthic fish species.



Catchlimit for 2009

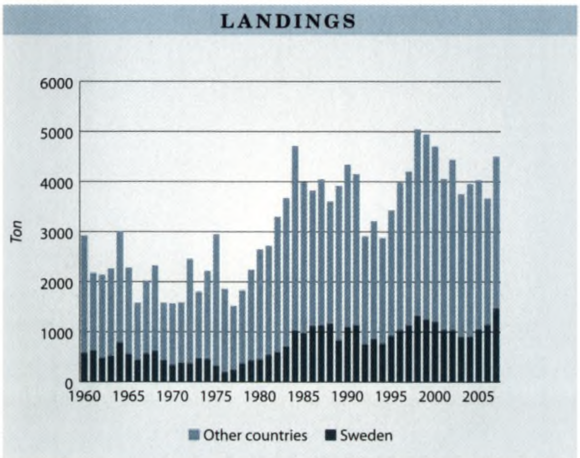
The Skagerrak/Kattegatt TAC is 5 170 ton, the Swedish share 1 359 ton. The limits on number of fishing days to reduce cod catches in the North Sea, Skagerrak and Kattegatt don't apply to vessels using sorting grid.

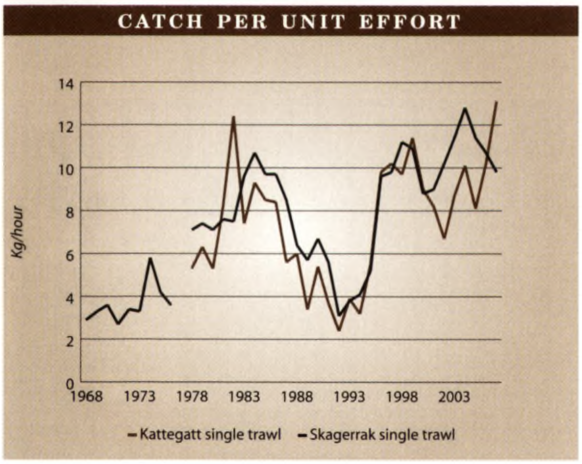
Facts

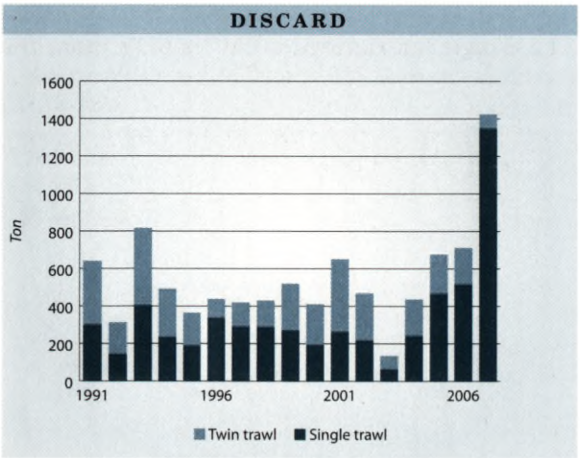
GEOGRAPHIC RANGE: The North Sea, Skagerrak and Kattegatt
SPAWNING: Females spawn every second year in March–November. The eggs are fertilised during deposition and are carried 8–9 moths before hatching. The larvae are pelagic.
MIGRATION: Stationary.
AGE AT MATURIT: 3–5 years.
MAXIMUM AGE AND SIZE: Unknown.
BIOLOGY: Lives on soft bottoms with silt or clay where the animal burrows into holes. The depth distribution is between 40 and 250 meters. During the night the Norway lobster forages on brittle stars and small benthic invertebrates.

Norway lobster

Development of catch and discard of
Norwegian lobster in Skagerrak and Kattegatt







Fisherman demonstrating the Swedish Nephrops sorting grid.

Pike-perch/Zander

- SANDER LUCIOPERCA

Baltic proper and the Åland Sea

Baltic proper and the Åland Sea are the main fishing areas of brackish water pike-perch. The fishery is mainly gill-netting. After a deep decline in the 1990-ies commercial catches increased in the early 2000. The catch in 2008, 27 ton, was the lowest since the beginning of data collection in 1994. The catch in the northern Baltic proper has decreased from 43 to 8 tons during this period. The Åland Sea is now the most important fishing area with a steady increase since the year 2000, but with a downturn in 2008.

Pike-perch is favoured by the recent warm summers. This effect is counteracted by an increased fishing pressure, demonstrated by data from experimental fishing at the Uppland coast. In experimental fishing individuals of >40 cm length have decreased by 98 % since 1995. The total numbers of individuals increase, but the large individuals are rapidly eliminated by the fishery.

Status of Stock

The stationary pike-perch is strongly influenced by local conditions. A high fishing pressure gives a high mortality on large individuals and the stocks in the Åland Sea will continue its decline unless the fishing mortality is decreased. The status in the rest of the Baltic is unclear.

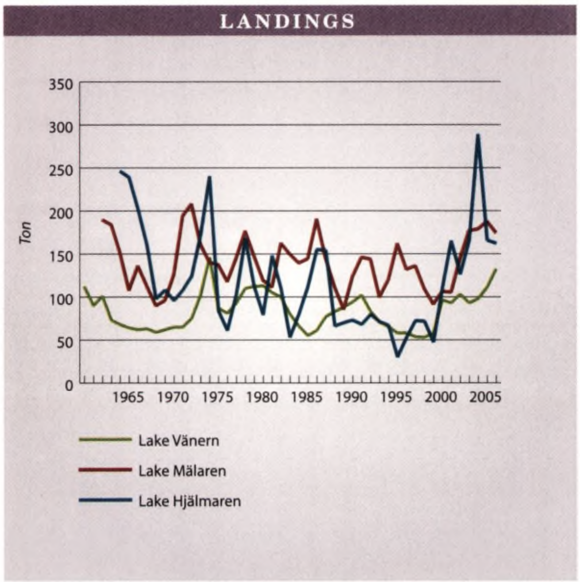
Biological advice

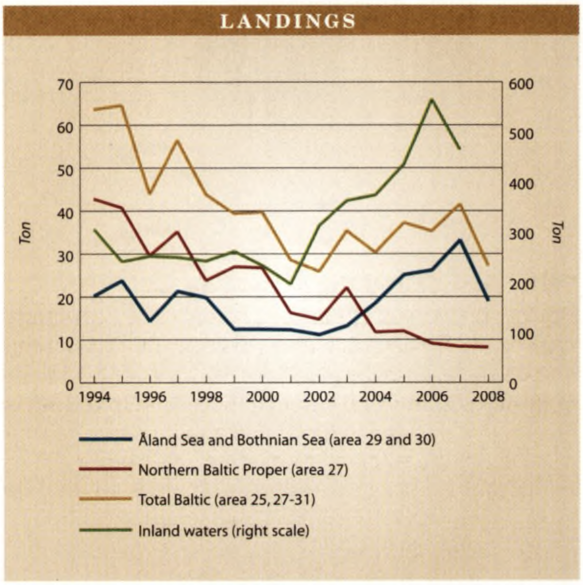
The management should take the local conditions of growth areas into account. Fishing pressure should be decreased in the Åland Sea.

Facts

GEOGRAPHIC RANGE: Pike-perch is common in the lakes Vänern, Hjälmaren, Mälaren and their drainage areas. In the Baltic it is common along the coast of Uppland, in the Stockholm archipelago and in Bråviken. It can be found along the whole Baltic coast.
SPAWNING: Spawning takes place from April to June in one to three meters depth on varying sediment substrate. Spawning can also occur in streams. The roe is placed in shallow excavations where it adheres to the substrate. The male protects the roe for some days.
MIGRATION: The pike-perch is stationary with range of movements in coastal water less than 10 km.
AGE AT MATURIT: The male matures at 2-4 years and the female at 3–5 years of age.
MAXIMUM AGE AND SIZE: Maximum recorded age 23 years. Specimens of 130 cm length and 15 kg weight have been caught in freshwater.
BIOLOGY: Pike-perch prefers large and turbid lakes and brackish archipelagos or streams with weak currents. Summertime the activity is in the night, otherwise during dawn and dusk. Young pike-perch prey on crustaceans and fish fry, adults are exclusively fish predators.

Pike-perch/Zander





Lake Vänern, Vättern, Mälaren and Hjälmaren
The pike-perch fishery in the Great Lakes uses pound-nets and fish-traps during the summer and bottom set gillnets the rest of the year. There is no pike-perch fishery in Lake Vättern.

The catches in Lake Vänern fluctuate between 150 ton (1976) and 50 ton (2000). The recent catches have increased gradually and were 132 tons in 2008. In Lake Mälaren the historic catches varies between 100 and 200 tons. Due to strong year-classes 1999 and 2001 the catches increased to 174 tons in 2008.

The pike-perch is favoured by increasing nutrient concentrations and in the mid 1960-ies when Lake Hjälmaren and Mälaren were highly euthrophic a total of 465 tons were caught in the three lakes. Reduction of nutrient load and high fishing pressure gave lower catches, with a minimum of 196 ton in 2001.

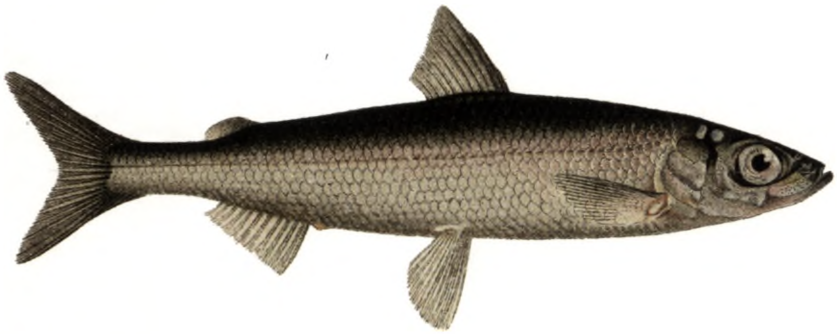
Since then warmer climate and positive management measures (increased minimum landing size and mesh width) has improved the catches to 565 ton in the year 2006. The catch in 2008 was 469 ton.

Status of Stock
The pike-perch stock is very strong in Lake Hjälmaren and increasing in Lakes Vänern and Mälaren. Strong year-classes are 1997, 1999 and 2001. Recruitment in 2005 and 2006 appears to have been strong. Pike-perch is the most important species for Swedish commercial inland fishery.

Biological advice
The number of licensed fishermen has increased in the three lakes and no additional licenses should be granted during some years. The minimum landing size should be increased from 40 to 45 cm in Lake Mälaren to optimize yield.

Vendace

- COREGONUS ALBULA



Bothnian Bay

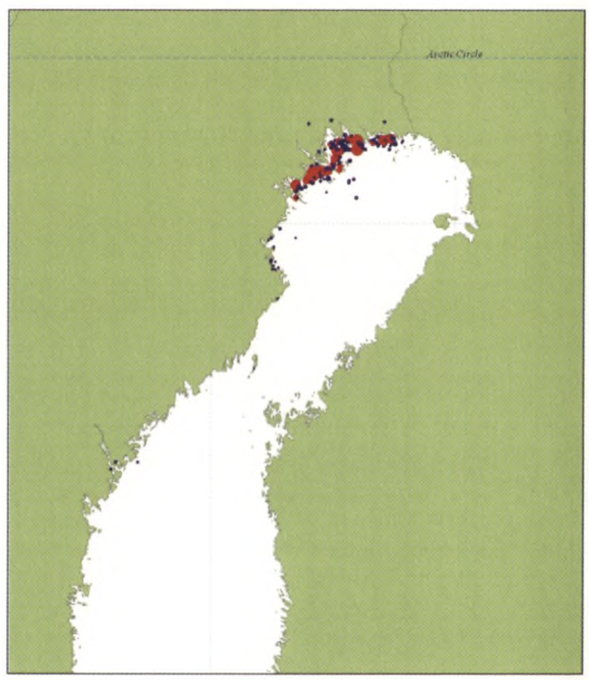
The vendace fishery in the Bothnian Bay is for the roe and the main catch is taken with trawl during late autumn. From 2009 the use of a sorting grid is mandatory to select out juvenile vendace. The catches declined and were very low at the end of the 1990-ies. Catches has since increased until 2004 but has declined again since then. The stock also increased until 2004, mainly due to the very strong year-classes 2001-2003. Recruitment depends partly on the spawning stock size, but is also strongly dependent on temperature conditions.

The recent year-classes have been small or medium, which has led to a decrease of the stock. As the catch mainly targets one or two year old fish the decline is noticed rapidly in the fishery and the catch per unit effort has decreased.

The low proportion of older fish indicates a high fishing pressure. Given the same fishing pressure and continued low recruitment the catches will decline further.

Status of Stock

The Bothnian Bay stock has recovered from the depletion in the early 1990-ies, mainly thanks to the strong year-classes 2001-2003. Since 2004 the stock has declined and can be expected to continue to decline. The low proportion older fish and variable recruitment makes the stock vulnerable to exploitation.



Biological advide

Fishing effort should not increase.

Lakes Vänern, Vättern, Mälaren and Hjälmaren

Lake Hjälmaren is to shallow and warm for vendace. Historically the fishery in Lake Vättern was large with a catch of 68 ton in 1957.

Facts

GEOGRAPHIC RANGE: Vendace is found in deep inland lakes all over Sweden and is common in the Bothnian Bay. Present in the coastal water of Medelpad and Ångermanland near the large river estuaries.
SPAWNING: From October to December on sand or gravel at varying depths.
MIGRATION: Summer distributed is over most of the Bothnian Bay with a spawning migration to the north-westerly coast in autumn.
AGE AT MATURIT: One year
MAXIMUM AGE AND SIZE: 10 years. In freshwater specimens of up to 45 cm and 1 kg have been caught.
BIOLOGY: The vendace lives pelagically in shoals. Food is pelagic crustaceans and insect larvae. Growth varies geographically. Vendace usually grows to 15-20 cm, seldom to more than 30 cm in length. Reproduction is strongly influenced by climatic factors and varies much.

Vendace

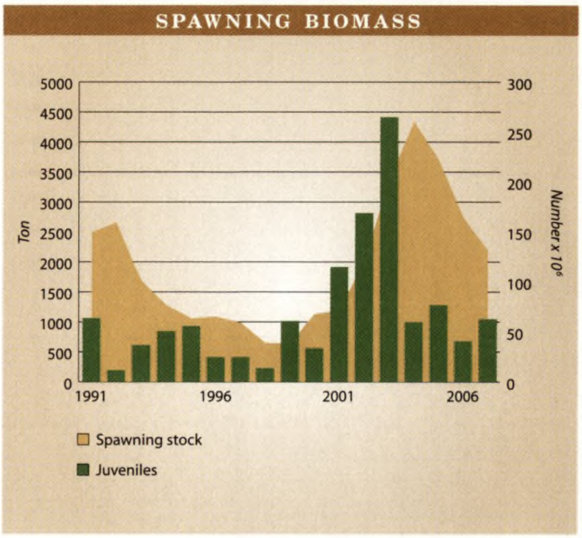
A fishery for roe was developed in Lake Mälaren in the 1960-ies. The development of a vendace fishery came later in Lake Vänern, peaking in 1996 at 576 ton. Since then the catch has declined and was approximately 210 ton during 2007 and 2008. One reason is large diatom blooms during the autumn which has hampered the fishery.

At present the Vättern fishery yields less than 1 ton. Large year classes 1977 and 1992 probably made the stock crash due to starvation. In Lake Mälaren catches were high until 1990, when the fishery crashed. At this time no young vendace were seen and the catches have remained low since then. A small increase has been noted during the last years and the catch was approximately 10 tons in 2008.

Status of Stock

Freshwater stocks of vendace declined drastically in the whole European range in the mid 1980-ies. Lack of winter ice is regarded a probable cause in the area east of the Baltic. A similar connection between the duration of ice-cover and recruitment has been found in Lake Mälaren.

The status of all freshwater vendace stocks in Sweden is weak. Recruitment was very low during 2007 in both Lake Vänern and Vättern.



Development of stock and catch in in the northern Bothnian Bay. Young fish in numbers.

The aquatic enviroment

In this section trends in the environmental conditions of special importance for the development of the fish resources are discussed. Fish and shellfish stocks depend on environmental conditions in several ways, e.g. by the temperature and salinity during larval development, directly by physiological effects and indirectly by the effect on food availability.

The Baltic Sea

Summary

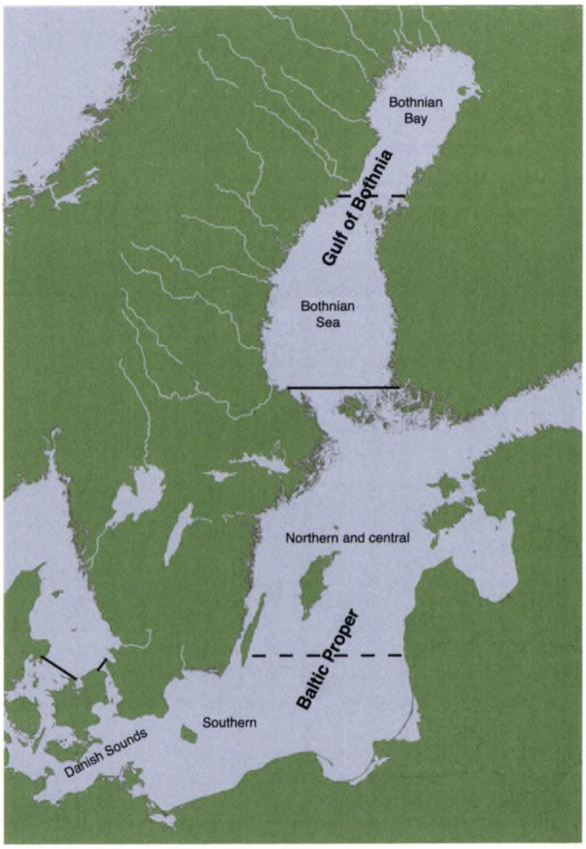
Changes in temperature, dissolved oxygen and salinity are important for the function of all parts of the Baltic ecosystem. Those parameters are regulated by the inflow of saline water through the Danish Sounds and by long-term climate changes including the runoff.

Sea surface temperature increases in the Baltic Proper, whereas the temperature in the Gulf of Bothnia shows an increasing variability between years but no clear trend. Salinity decreases in the whole Baltic. A major inflow of saline water occurred during the winter 2007, but the strength was less than the inflow of 2003.

The deep water of the Baltic is still stagnant and areas with anoxic bottoms are increasing. During 2008 the total anoxic area reached a historic maximum. The combination of salinity and oxygen at mid-water depth is critical for the survival of cod egg and larvae. The reproduction volume for cod increased in 2008 compared to earlier years but remains below that of 2003 and the conditions in the 1980-ies.

Increasing temperature and decreasing salinity in the Baltic Proper is expected to change the food web, especially the abundance and species composition of zooplankton. Lack of food means higher larval mortality and a lower growth of adult fish. There is a lack of monitoring data of zooplankton.

The ecosystem analysis and biological advice should be improved by a more comprehensive sampling program for zooplankton and a better knowledge of the food preferences of fish.



It is increasingly evident that the abundance of zooplankton in the Baltic Proper at present is limited by fish predation. When the large fish predators become fewer they are not able to keep the plankton-eating small pelagics down. The spread and increasing abundance of comb jellies is also a risk as they are efficient zooplankton predators. A lower fishing mortality on large predatory fish is likely to improve the situation and increase the resilience of the Baltic ecosystem.

The coastal fish community in the Baltic have several freshwater species that depends on river mouths or isolated bays for reproduction. The identification, restoration and protection of such habitats are important to maintain the presence of large predatory fish in the coastal zone. The populations of the three species of seal are all increasing in the Baltic. The role of the seals in the Baltic ecosystem needs to be better understood. Improving the knowledge about food choice and better ecosystem models are necessary. There is also a direct conflict between seals and the fishery. Damage to gear and catch is a serious threat to the small-scale fishery with passive gear.

Trends in the commercial catch show a diminishing catch during the last decade, especially for the demersal species in the Baltic Proper. In the Gulf of Bothnia there is a decline especially in the catches of freshwater species.

Oceanography

The Baltic is one of the largest brackish water bodies in the world. The total area is 390 000 km^2. On the Swedish side the Baltic Sea is divided into the Baltic Proper – from the Danish Sounds to the Åland Archipelago – and north of that the Gulf of Bothnia, which in turn is divided into a southern part called the Bothnian Sea and north of that the Bothnian Bay. The Baltic is shallow with a mean depth of 56 meter.

Salinity decreases gradually from approximately 12 PSU in the southern, most marine parts, to 1-2 PSU in the innermost parts of the Bothnian Bay. The water is also stratified, with colder and more saline deep water layers.

The salinity in the deepest basins in the south can rise to more than 20 PSU during inflows from Kattegatt. In the Baltic Proper the water is stratified permanently. In the Bothnian Bay the stratification breaks up during the winter mixing.

The surface salinity in the Baltic Proper is 8-9 PSU at the outlet through the Sound and approximately 6 PSU in the northern area. In the south the permanent halocline is found around 40 meters depth, in the central and northern deep basins at approximately 80 meter. There is a series of deep basins separated by shallow thresholds. The thresholds limit the water exchange between the basins which influences the hydrographical and ecological characteristics. In the south, with direct contact with the Danish Belts, is the Arkona basin with depth of 45 meter. The northern threshold is between Bornholm and Sweden, leading to the Bornholm basin east of Bornholm with a depth of 105 meter.

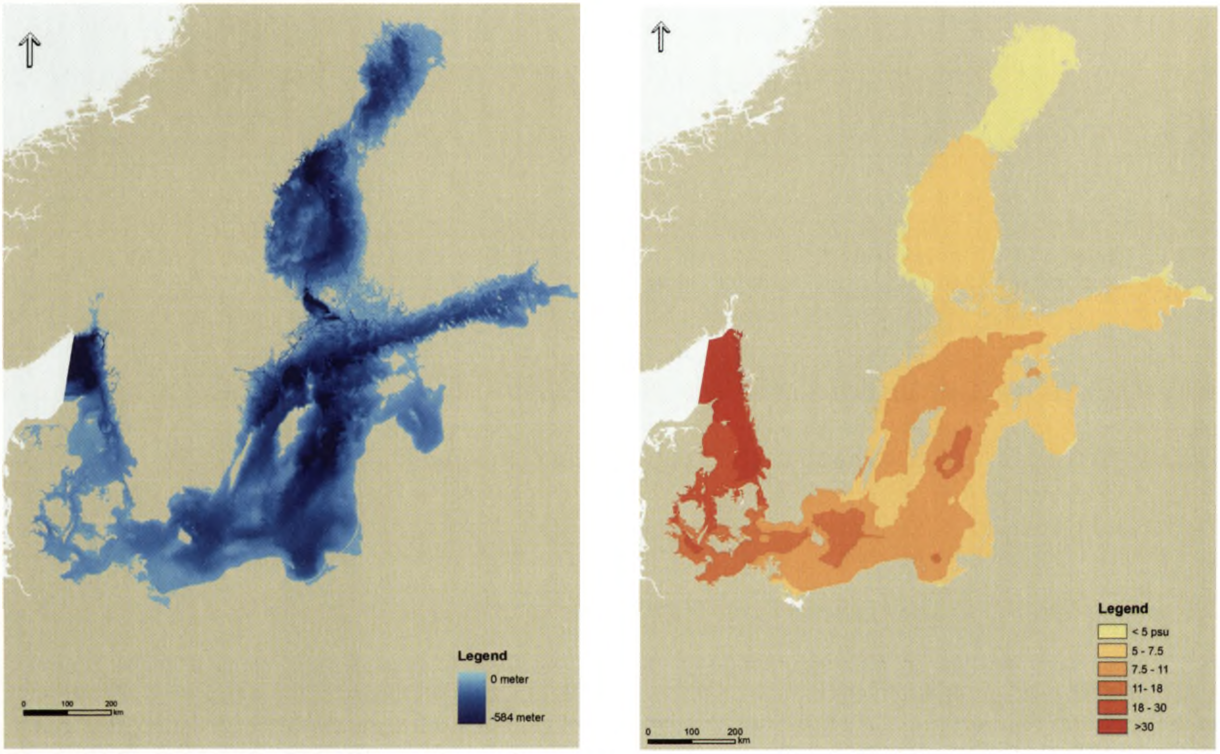
The connection to the northern basins in the central Baltic is called the Stolpe trench. Three basins are found east, north and west of Gotland. The eastern Gotland basin has a maximum depth of 249 meter. The northern basin has a rough bathymetry and contains the deepest part of the Baltic – the Landsort deep at 459 meter. The maximum depth in the western Gotland Basin is 205 meter.

This basin is separated from the Bornholm basin in the south by the shallow Hoburg Bank and Midsjöbankarna. To reach the western Gotland basin the deep water has to move counter clockwise around the island, this can take several years. The deep water in the Gotland basins is often stationary and anoxic with hydrogen sulphide during long periods.

The conditions in the Gulf of Bothnia differ from that in the Baltic Proper. In the Bothnian Sea the surface salinity is around 6 PSU in the south and less than 5 PSU in the north. The deep water is slightly more saline. The halocline is weak and is found at 50-60 meters depth. The maximum depth is 200 meter. The Bothnian Bay is almost limnic in the north, where salinity drops to less than 2 PSU. The stratification is weak and the water is vertically homogenous during the winter.

Salinity inflows

The Baltic hydrography is strongly influenced by sporadic inflows of salt water from the Kattegatt. Since the end of the 1980-ies episodes with massive inflows have been rare; 1993 and 2003 being the most recent ones. The frequency of inflows is connected to the North Atlantic Oscillation – the NAO climate cycle with 8-10 years periodicity – which also has an impact on ice-conditions. To be regarded as a massive inflow the total volume of saline, oxygen rich water should exceed 100 km^3. Each year there are a number of minor inflow events, usually



The marine landscape of the Baltic has been charted in the EU project BALANCE.
Charts from Zyad Al-Hamdani and Johnny Reker (eds.). 2007. Towards marine landscapes in the Baltic Sea. BALANCE interim report #10, see http://balance-eu.org/

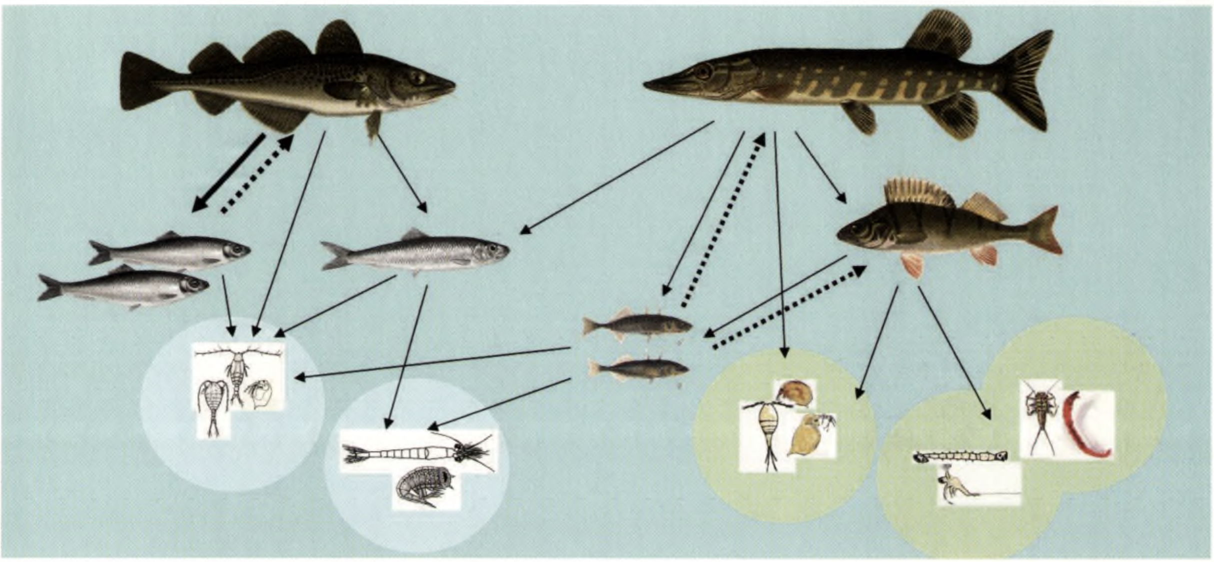
through the Sound, that has some impact on the deep water of the Arkona and Bornholm basins. Those inflows mix and continue as intermediate water layers in the northern basins. To replace the deep water in the Gotland basins massive inflows are needed, preferably during the winter period when the dissolved oxygen concentration is high in the cold water.

The Baltic ecosystem

The Baltic has a unique mix of marine and freshwater organisms that interact. The species composition changes from south to north due to diminishing salinity and a colder climate. The fraction of marine species decreases and the freshwater species increases north along the Swedish coast. The salinity gradient means that the marine species experience an increasing osmotic stress and decreasing growth rate going north. Some marine species have adapted genetically to a lower salinity.

The Baltic ecosystem is relatively simple with few dominating species. In the experimental fishery with static gear conducted by the Board of Fishery the last two years 67 species were found on the west-coast, 46 in the Baltic Proper and 24 in the Bothnian Bay. Trawl surveys gave 63 species in Skagerrak, 53 in Kattegatt, 24 in the southern and 16 in the northern Baltic Proper.

The commercial marine fish species with the northernmost distribution range are cod, flounder, herring and sprat. Among the non-commercial are eelpout, sand goby, the smaller sand eel and pipefish. The coastal water in the Baltic is dominated by freshwater species as perch, pike and roach. Both marine and freshwater species move between inner coastal water and the open sea for spawning and foraging. The migration is often seasonal, but can differ between different life stages. Migrating freshwater species reproduce in rivers but spend the



Schematic food web of a Baltic fish community. At the top exemplified by cod and pike preying on plankton eating herring, stickleback and bottom-feeders as perch.

adult life in the sea, as for example salmon and whitefish. The distribution is primarily a function of salinity and temperature tolerance, but the fish community is also affected by anthropogenic factors as eutrophication and fishery.

Stock structure

The brackish environment in the Baltic is a challenge for both marine and freshwater species and gives an advantage to local stocks that have adapted to the low salinity.

Flounders have two ways of coping with the loss of buoyancy of the eggs at low salinity. In the southern Baltic spawning takes place in deep water where the eggs can float at the halocline. In the northern Baltic the eggs are smaller and with a thick shell and can develop at the bottom. The northern and southern flounder are genetically separate and should be managed as different stocks.

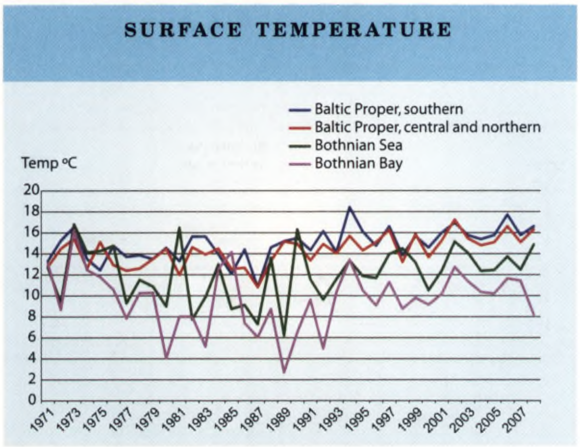
Many species tend to return to their place of birth to spawn. Such species usually have a well developed stock structure and large genetic differences between stocks. Salmon and trout are examples of this. Management of those species must take special precautions to avoid unsustainable fishing mortality on small local stocks when the different stocks mix at sea.

Some species lack clear differentiation into different stocks, instead there is a gradual decrease of genetic exchange with distance along the coast. Examples of this are perch and pike. In this case the management unit can be determined from a maximum distance along the coast with strong genetic similarity. For Baltic perch and pike this is distance is 100-150 km.

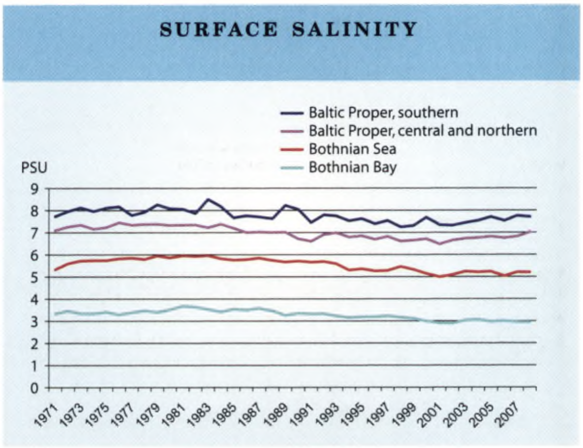
The hydrographical year 2008

Freshwater inflow to the Baltic Proper was approximately normal during the beginning of the year, except for a peak around the turn of January-February. Inflow was above average during the summer and normal during the rest of the year. To the Gulf of Bothnia the freshwater inflow was normal during most of the year, except for May when the flow was twice the average. A number of small saltwater inflows with oxygen rich water from Kattegatt occurred in January, February and June as well as in October, November and December. The effect could be seen in the Arkona basin but the inflows did not change the conditions in the Bornholm basin. Due to a larger inflow during the late 2007 the oxygen conditions in the deep water of the Bornholm basin was favourable in the early 2008.

Sea surface temperatures were normal in the southern Baltic Proper most of the year, except for



Mean surface water temperature during June-August in the Baltic.



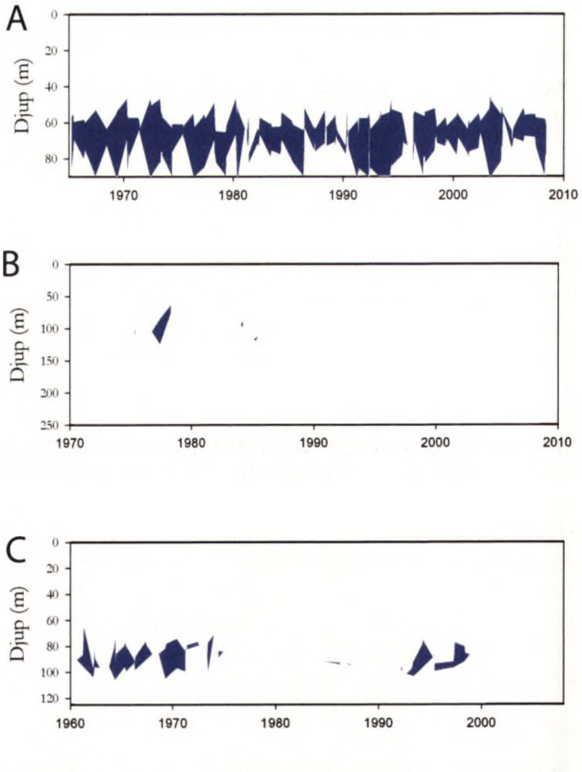
Yearly mean salinity in the surface 10 meters.

a warmer than normal period in June and July. The nutrients phosphorus and silica were above normal most of the year, but inorganic nitrogen was normal. The spring bloom came in March-April and after that the nitrogen concentration was below the detection limit until October.

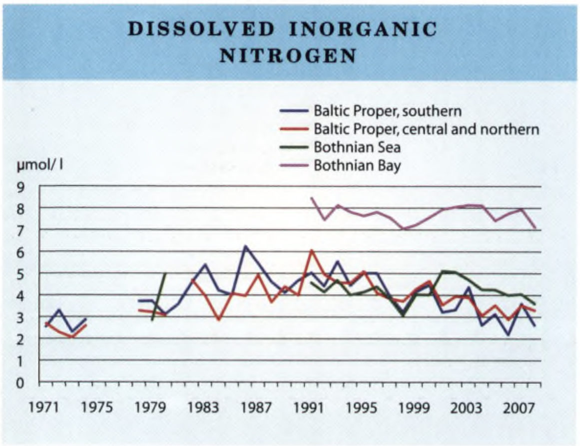
In the central and northern Baltic Proper the surface temperature had a similar development as in the south. The concentration of inorganic nitrogen was normal the whole year. Silica was slightly high during the summer in the central region.

Phosphorus has during the last couple of years been much above normal. In 2008 it decreased to near normal levels, except for during the beginning and end of the year, when concentrations were high. The spring bloom came in April and nitrogen fell rapidly to below the detection limit.

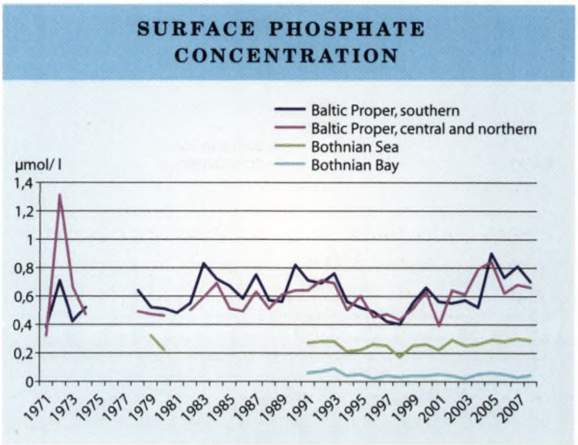
At several Baltic stations a potentially poisonous phytoplankton species, *Chrysochromulina polylepis*, which caused a large fish-kill on the west-coast in 1988, dominated the spring bloom. The bloom in the Baltic peaked between March and April. Diatoms usually dominate the spring bloom depleting the pool of silica, but this year high concentrations of silica was found in May. There was a second bloom of *C. polylepis* in September.



The development of the reproduction volume of cod after 1980, measured at stations in the Bornholm, (A), Gotland (B), and Gdansk (C) basins.



The level of available nitrogen (DIN) is decreasing in the Baltic Proper. The highest DIN concentrations are found in the Bothnian Bay, where primary production is limited by phosphate.



The phosphate concentration (DIP) has increased in the Baltic Proper during the last decade. The level in the Gulf of Bothnia is considerably lower due to the freshwater influence.

The yearly bloom of cyanobacteria took place in July in the Baltic Proper and in August in the Bothnian Sea. During the end of July large areas of the Baltic surface was covered with mats of floating cyanobacteria. The Stockholm archipelago was worst affected, whereas the beaches of Öland and Gotland had less problem. The bloom in 2008 was short but intense.

Trends in temperature and salinity

Large-scale climate change with increasing air temperature and precipitation during the last decades is reflected in the Baltic water temperature. A prognosis made by the Swedish Meteorological and Hydrographical Institute in 2007 indicates that the water temperature will rise by 2-4 degrees and the ice cover decrease by 50-80 % by 2100 compared to the present situation. The surface temperature is increasing in the Baltic Proper but temperatures in the Gulf of Bothnia are more variable. During the period 1971 to 2008 the coldest years in the Gulf of Bothnia were in the end of the 1980-ies. Surface salinity decreases in the whole Baltic.

Oxygen conditions

Random inflows of high salinity water are important both for the salinity and oxygen conditions

The extent of anoxic bottoms in the Baltic during 2008. Areas with an oxygen concentration less than 2 ml/l are grey, presence of hydrogen sulphide shown as black.

in the Baltic deep water. The inflows determine the volume available for successful cod reproduction. This so called reproduction volume is defined as water with salinity above 11 PSU and an oxygen concentration of more than 2 ml/l, which are the conditions necessary for fertilisation and survival of cod eggs. Those conditions are at present found mainly in the Bornholm basin. After several bad years relatively good oxygen conditions existed in the Bornholm basin due to the inflow in late 2007.

The reproductive volume was however not as large as after the major inflow 2003.

In general oxygen conditions were bad in 2008. Anoxic bottoms have been widespread during the whole 2000-ies and the area affected 2008 was record high. Approximately 19 % of the area of the Baltic Proper was anoxic and 33 % had an acute lack of oxygen.

Nutrients

Eutrophication has developed into a major problem in the Baltic during the last 50 years. The sewage treatment at many point sources have improved but diffuse sources and complex biogeochemical processes influences the situation. The national environmental objective is to eliminate eutrophication by 2020, but progress is slow and difficult to reach due to the large-scale and international character of the problem.In the Baltic Proper inorganic nitrogen in the surface water increased until 1991 and the concentration has since then decreased. Earlier data are sporadic from the Gulf of Bothnia and there is no clear trend after 1991.

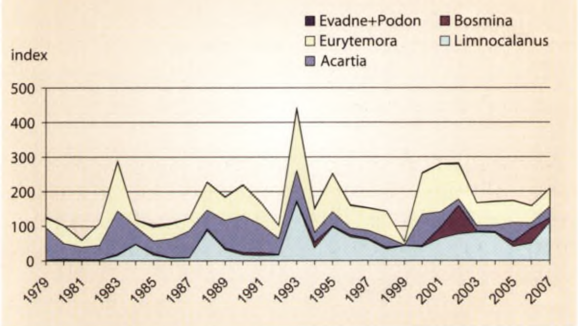
The concentration of phosphate shows no significant change since 1991 but there is a certain increase during the last ten years in all parts of the Baltic except in the Bothnian Bay.

Zooplankton

Copepods of the genus *Acartia*, *Temora* and *Pseudocalanus* are common in the Baltic Proper. The relative composition has changed with time. *Pseudocalanus* dominated until the end of 1980-ies while *Acartia* and *Temora* have been dominant since then. The change is most evident during the peak in zooplankton abundance during the spring. The transition can in part be explained by the lower salinity, but is also caused by increased predation from zooplankton feeders, in particular sprat.

In addition to the copepods cladocerans of the genus *Evadne*, *Podon* and *Bosmina*, as well as rotifers are an increasingly important part of the zooplankton in coastal water and the Gulf of Bothnia. In the Bothnian Sea there has been a change of dominance with *Bosmina* and *Limnocalanus* increasing and *Pseudocalanus* and *Acartia* decreasing.

ZOOPLANKTON ABUNDANCE IN THE BOTHNIAN SEA



The species composition of zooplankton varies with time. The diagram shows the development in the Bothnian Sea, where *Limnocalanus* och *Bosmina* show an increasing trend, while the total amount of zooplankton has no significant change. Data from Finnish Institute for Marine Research.

The abundance of zooplankton is an important factor for fish growth. What regulates the abundance varies. Hydrographic factors are important and there is a strong connection between hydrography, zooplankton and the growth of herring in a situation where the abundance of large predatory fish is high. With few large predators the grazing pressure on the zooplankton keeps their abundance low independent of the hydrography. The result is a permanent slow growth of herring which is the present situation in the Baltic. This started when the sprat stock increased dramatically after the cod crisis in the late 1980-ies.

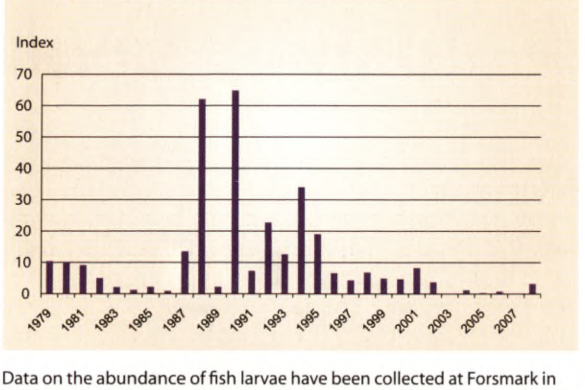
Recruitment

The recruitment success varies between years both in coastal and open sea conditions. The survival of egg and larvae depends on external factors. Temperature, salinity, oxygen concentration and food are particularly important for the strength of a year-class. Along the coast protected bays and freshwater outflows are important spawning and growth area for juveniles of perch and pike. Such areas become warm early in spring and offers high abundance of zooplankton. Those habitats are extensively exploited for harbours, housing and other development however. To secure fish recruitment it is important to protect and, where possible, restore this kind of habitats.

The Swedish Board of Fisheries is engaged in a series of pilot studies of restoration in the coastal areas of the Baltic Proper. The project runs until 2010 and the objective is to demonstrate examples of working restoration methods.

Large-scale processes can also influence the reproduction. Survival of pike and perch has during several years been low in certain regions of the Baltic. This is most pronounced in the outer archipelago, whereas the inner, more protected, archipelago has a higher survival. This indicates that the causal factor is connected to processes in the open sea.

RECRUITMENT INDEX PERCH

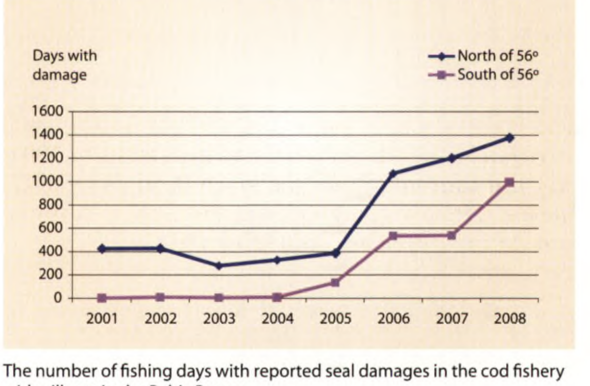


Data on the abundance of fish larvae have been collected at Forsmark in the Bothnian Sea regularly since 1979. The variation between years is large and there is an extended decline during the last decade.

Top predators

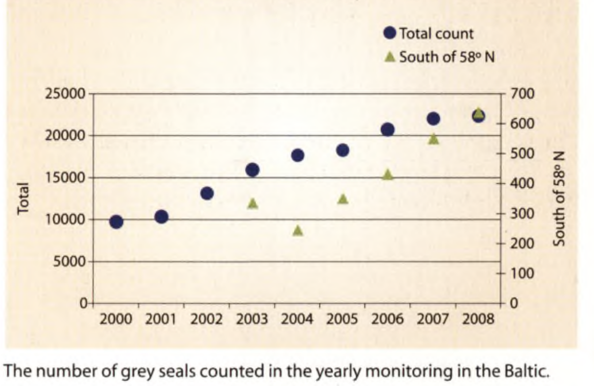
Together with the large predatory fishes seal and fish-eating birds are the important top predators in the Baltic. Three species of seals live in the Baltic. Grey seal is distributed over the whole Baltic, with a declining abundance towards the southern part. Ringed seal are found in the Bothnian Bay and in the Gulf of Riga. Harbour seal has just an isolated population in the Kalmar Sound between Öland and the mainland. Among the birds in the Baltic cormorant are rapidly increasing and is considered to have an impact as fish predator.

SEAL DAMAGES IN THE COD FISHERY



The number of fishing days with reported seal damages in the cod fishery with gillnets in the Baltic Proper.

COUNTED GREY SEALS

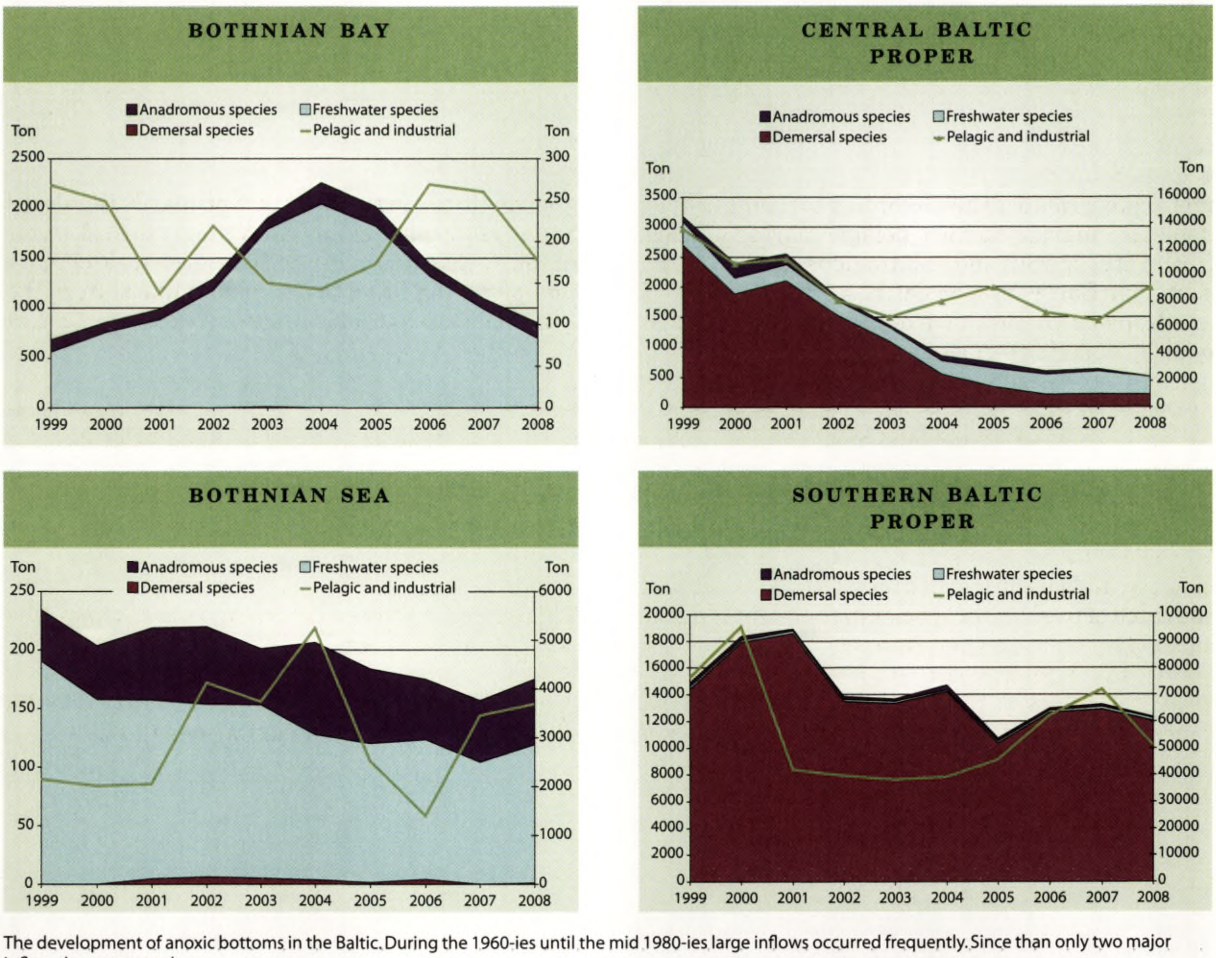


The number of grey seals counted in the yearly monitoring in the Baltic.

Since 2000 synchronous counts of grey seals have been made by Finland, Estonia and Sweden. During this period the number of counted seals has increased by on average 11.7 %/year. At present the grey seal population is increasing most rapidly on the Swedish side of the Baltic Proper.

Statistics on seal damages in the coastal fishery has earlier been collected from selected fishermen who have kept detailed journals on catch and damages. At present information comes from voluntary reporting in the mandatory fisheries logbook or monthly journal kept by all fishermen.

For a long time seal damages have been most severe in the salmon and whitefish fishery with traps in the Gulf of Bothnia. Recently there is a rapidly increasing conflict with the important gillnet fishery in the Baltic Proper. During 2008 seal damage was reported in approximately half of all fishing days with cod nets north of latitude 56 N. South of this latitude 20 % of the fishing days showed seal damages. In this southern area no damages occurred a few years ago. Seal damages is an imminent threat to the Baltic gillnet fishery. Protective hunting can give some mitigation, but there are several restrictions for protective hunting of seals which in



The development of anoxic bottoms in the Baltic. During the 1960-ies until the mid 1980-ies large inflows occurred frequently. Since than only two major inflows have occurred.

practise limit the possibilities to use it. An alternative is the development of alternative passive gears that are seal-safe. This has been successful for the salmon fishery in the Gulf of Bothnia.

The Swedish Board of Fishery works on the development of cod traps, but if this can become an economically viable alternative for the coastal fishery will take time to evaluate.

Trends in the fishery

Trawl is the dominating gear in all Swedish marine areas except for the central Baltic Proper and north of that, where passive gear as gillnets, fykes and traps are more important. The catch volume using trawl, traps and fykes have been relatively constant during the twenty-first century, but gillnetting has decreased, possibly caused by the seal conflict.

The catch composition can be separated into four main categories of fishes according to their lifestyle: demersal marine species, pelagic marine species, freshwater species and anadromous species. In the southern Baltic Proper catches of demersal and anadromous species have declined during the last decade. Pelagic catches have been stable and the catch of freshwater species increased. Freshwater and anadromous species comprise a small part of the total catch however. In the central Baltic Proper catches have decreased for all categories except that of freshwater species which has been constant.

In the Bothnian Sea and Bay there are no clear changes during the last decade except a decrease of the catch of freshwater species in the Bothnian Sea. In the Bothnian Bay freshwater and anadromous species catch had a maximum around 2004 but has since fallen back to the level at the start of the decade. The changes in catch depend on a mixture of factors, mainly changes in fish stocks, market prices and demand and fishery regulations.

Development of the Baltic fish ecosystem

The preceding sections have described the trends in different aspects of the ecosystem that determine the development of the fish ecosystem and the fishery. Such analysis is important to detect large-scale changes and to adapt management measures to the prevailing conditions. By combining observations of several environmental factors it is possible to identify points where they interact and causes large and rapid changes in the ecosystem. Such events are what have been called regime shifts. Historically regime shifts can be found in all parts of the Baltic. Recently the most dramatic regime shift occurred in the late 1980-ies. Before this the fish community in the Baltic Proper was dominated by a high biomass of cod and herring and a high abundance of certain zooplankton. After the shift the dominant biomass is that of sprat and the abundance and composition of zooplankton has changed.

The conditions in the Baltic are primarily regulated by the frequency of saline inflows and the freshwater runoff, which in turn depends on large scale climate changes. In addition to this the regime shift of the late 1980-ies was brought on by an excessive fishing mortality, which reduced the spawning biomass of cod to an unsustainable level. The sprat stock increased due to favourable spawning conditions and a reduced predation pressure. The herring biomass has declined mainly due to a reduced growth rate. This probably depends on the change in the species composition of zooplankton and an increased food competition with sprat.

This example shows in a clear way the importance of an ecosystem perspective in management. An ecosystem approach in an adaptive management is necessary to secure a fishery which can give an ecologically optimal yield in the long term.

A new marine protected area in the Kattegatt

Each generation uses its own experience of fish abundance as a reference when relating the present situation to what is regarded as a natural level. When the fish stocks change gradually over time the human perception of the state of the fish community becomes misleading.

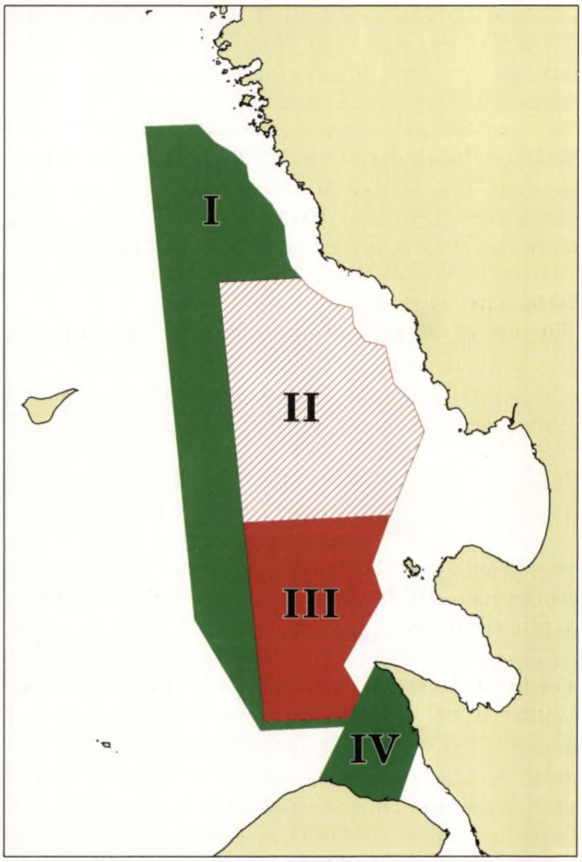
This phenomenon is called a shifting baseline. To avoid this misconception it is important to quantify the historic levels of the stocks, particularly before and after the introduction of the industrial fishery in our waters.

Using historic data we can readily show large changes both in abundance and size distribution of the fish stocks since the 1920-ies. The major stocks are depleted, especially of larger adult individuals. Several local stocks have disappeared completely resulting in a decreased overall reproductive capacity.

To reach the Swedish environmental objectives and a sustainable fishery new management tools are necessary. For the large, straddling marine stocks this must be done in an international cooperation. The cod in the Kattegatt, which used to be a conglomerate of several local breeding groups, has been overexploited for a long time, several of the breeding groups are extinct and the stock is drastically depleted.

Since the year 2000 the recurrent assessment by ICES has been that the fishing mortality is much too high and that the stock is outside safe biological limits. The advice has been to stop all fishing of cod, which so far not have been followed by EU.

During the TAC negotiations 2007 Sweden proposed a ban of targeted cod fishery or alternatively a permanent protection of the core spawning area. Following decision by the Council of Minister bilateral negotiations continued with Denmark during 2008. This led to an agreement about a marine protected area covering the main remaining Kattegatt cod spawning area. The new regulations came into force 2009.



Area I: Closed for fishing 1 January–31 March, with exception for gear that doesn't catch cod.
Area II: Closed the whole year. Between 1 April and 31 December with exception for gear that doesn't catch cod. From 1 January to 31 March crab, lobster and Norway lobster pots are allowed.
Area III: Closed the whole year for all fishing.
Area IV: Closed for fishing 1 February–31 March, with exception for gear that doesn't catch cod.

Regulations

The protected area is divided in four zones with different degree of regulation of the fishery. The map shows the limits of the different zones. Green zones are closed part of the year and red zones are closed the whole year. In certain zones and periods derogation is made for fishery using gear that doesn't catch cod, e.g. Nephrops trawl with selection grid, pelagic herring trawl, crab, Norway lobster or lobster pots and gillnet for lumpsucker with a mesh-size larger than 220 mm.

The eastern limit of the protected area coincides with the Swedish national zone where trawling not is permitted. In this area fishing for cod, haddock and pollack is banned from 1 January to 31 March, a regulation which has been in force since 2004.

Consequences
The aim of the protection is that the permanently closed core area together with the larger closure during the spawning period of the cod shall reduce the fishing mortality on the Kattegatt cod stock and make a rebuilding of the stock possible. In addition to the local Kattegatt cod juvenile cod from the North Sea stocks migrate into Kattegatt. The expectation is that the Kattegatt stock is more concentrated in the protected area and that the cod fishery will be directed on the less vulnerable northern stock.

The protected area is not expected to affect the possibility to utilize the TAC for cod, Norway lobster or any other commercial species as those are available outside the protected area or during a time of year without fishery restrictions. A research cooperation between Denmark and Sweden is ongoing to further develop selective fishing gear to protect the cod.

It is still important to reduce the total fishing effort in the Kattegatt. In the mixed fishery there is an unwanted discard of cod when the TAC is reached. In addition to the Swedish ban on high-grading the amount of cod which a fishing vessel is allowed to land free is maximized to 150 kg/day in Kattegatt. If this is exceeded there is a charge on 80 % of the excess.

The Swedish Board of Fisheries is the government authority responsible for the management of Swedish fish resourses. We have also responsibility for aquaculture and fishery control.

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