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Extended essay cover

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Candidate session number			
Candidate name			
School name			
Examination session (May or November)	MAY	Year	2015

Diploma Programme subject in which this extended essay is registered: ESS

(For an extended essay in the area of languages, state the language and whether it is group 1 or group 2.)

Title of the extended essay: What consequences does human caused eutrophication, in the Baltic Sea, have on the cod fish?

Candidate's declaration

This declaration must be signed by the candidate; otherwise a mark of zero will be issued.

The extended essay I am submitting is my own work (apart from guidance allowed by the International Baccalaureate).

I have acknowledged each use of the words, graphics or ideas of another person, whether written, oral or visual.

I am aware that the word limit for all extended essays is 4000 words and that examiners are not required to read beyond this limit.

This is the final version of my extended essay.

Candidate's signature: _____ Date: 5th March 2015

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The supervisor must complete this report, sign the declaration and then give the final version of the extended essay, with this cover attached, to the Diploma Programme coordinator.

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Please comment, as appropriate, on the candidate's performance, the context in which the candidate undertook the research for the extended essay, any difficulties encountered and how these were overcome (see page 13 of the extended essay guide). The concluding interview (viva voce) may provide useful information. These comments can help the examiner award a level for criterion K (holistic judgment). Do not comment on any adverse personal circumstances that may have affected the candidate. If the amount of time spent with the candidate was zero, you must explain this, in particular how it was then possible to authenticate the essay as the candidate's own work. You may attach an additional sheet if there is insufficient space here.

independently formulated the idea for the essay, and selected relevant sources. She discusses the contents fluently, demonstrating a clear knowledge of the topic.

This declaration must be signed by the supervisor; otherwise a mark of zero will be issued.

I have read the final version of the extended essay that will be submitted to the examiner.

To the best of my knowledge, the extended essay is the authentic work of the candidate.

As per the section entitled "Responsibilities of the Supervisor" in the EE guide, the recommended number of hours spent with candidates is between 3 and 5 hours. Schools will be contacted when the number of hours is left blank, or where 0 hours are stated and there lacks an explanation. Schools will also be contacted in the event that number of hours spent is significantly excessive compared to the recommendation.

I spent [4] hours with the candidate discussing the progress of the extended essay.

Supervisor's signature: _____ Date: 5th March 2015

Assessment form (for examiner use only)

Candidate session number		

Criteria	Achievement level				
	Examiner 1	maximum	Examiner 2	maximum	Examiner 3
A research question	2	2		2	
B introduction	2	2		2	
C investigation	3	4		4	
D knowledge and understanding	3	4		4	
E reasoned argument	3	4		4	
F analysis and evaluation	2	4		4	
G use of subject language	4	4		4	
H conclusion	1	2		2	
I formal presentation	2	4		4	
J abstract	0	2		2	
K holistic judgment	2	4		4	
Total out of 36	24				

Name of examiner 1: _____ Examiner number: _____
(CAPITAL letters)

Name of examiner 2: _____ Examiner number: _____
(CAPITAL letters)

Name of examiner 3: _____ Examiner number: _____
(CAPITAL letters)

IB Assessment Centre use only: **B:** _____

IB Assessment Centre use only: **A:** _____

International Baccalaureate Diploma Program

Extended Essay

Environmental System & Societies

What consequences does human caused eutrophication, in the Baltic Sea, have on the cod fish?

Word count: 3448

Date: 26th September 2014

Abstract

The Baltic Sea, the youngest sea in the world. Due to its unique mixture of salt- and freshwater, the species in the Baltic Sea are as unique as the sea itself. One of these species is *Gadus morhua callarias*, more known as the Baltic Sea cod. This sub-species has adapted to the unique brackish water, and as a top predator in the ecosystem, it is vital for the survival of the entire Baltic sea. Over 100 million inhabitants, in 11 different nations, surround the sea and it has taken its toll. Since the use of commercial fertilization for agriculture began, in the 1950s, the eutrophication in the Baltic Sea has increased massively. The eutrophication has had a devastating effect on the entire ecosystem, ultimately culminating in the cod fish as the top predator. This essay will present the current state of the Baltic Sea; what consequences human caused eutrophication has had on the cod fish; and finally evaluate the current attempts of finding solutions for this vitally important problem. Both primary and secondary sources are being used in this essay. With help from accurate reports on the condition of the Baltic Sea and the Cod fish species and help from the marine-biologist Jonas Fejes this essay contains information appropriate to the topic and applieds to research question.

Introduction

A human-caused extinction of the cod fish species, that is what is happening in the Baltic Sea today. The cod fish in the Baltic Sea is a complete unique creature, adapted to living in the distinctive brackish water in the sea surrounded by 11 different nations and over 100 million people. Unfortunately for the cod fish, these very people are the ones that have set the species on the path to extinction. Because of the selfishness of human beings, emissions of phosphorous and nitrogen have caused eutrophication, over-fertilization, of different macroalgae and algae planktons. When degraded, these organisms consume oxygen causing hypoxia in the water, disrupting the ecosystem and causing life threatening problems for the cod fish and other species in the water.

I live in the one of the countries that is depending on the Baltic Sea, both the usage of the water as for transport and recreation but also to feed on the species living in it. I have been raised by a father who has the occupation as a marine-biologist working for a better water environment on this planet, and throughout the years I have seen him travel all over the world to help other countries with environmental questions and problems. Not only have he worked with countries outside of EU but also the country we live in. He is the one who have had discussions with me about the major importance of the Baltic Sea. He has opened my eyes for the environmental problem. My dad has taught med about the species living in the water where I swim, he has taught me about the environment where I live and the importance it has to us. His interests have become mine. I have because of him raised awareness about the Baltic Sea and the dependence it has on humanity.

I want to investigate about the consequences of what will happen to the cod fish's ecosystem and the affection on the species in it because of eutrophication caused by humanity. Why I chose the cod fish is because the codfish is an important species both in the sea but also above the sea as for feeding us humans. The cod fish is a top predator in the food chain which regulates the fish stock of

plankton feeding species. This means that if there is too few cods in the water, the plankton feeding fishes will eat all the zooplankton which feed on algae plankton. The result will be a lot greener water with much algae plankton due to the lack of grazing zooplankton. The cod is not only important in the water but also for us living around the Sea. Eleven nations are depending in the sea, to transport goods for import and export, for recreations and also to feed on the species that lives underneath the surface.

The Baltic Sea is a much discussed question in the EU and I believe that is very important to enlighten it and do something about it; both for humanity but also for the species living in the water. I am going to put my main focus on the human caused eutrophication in the Baltic Sea and what impact it has underneath the water surface. I will more specifically look at what the effect eutrophication has on the cod fish but also what will happen to the cod fish and its food chain if the cod stock decrease or in a worst scenario: the cod species go extinct. Organizations around the sea are working daily to save the water and the species within it. Not only am I going to find out about what the consequences on the cod fish is because of eutrophication, but also what the base of eutrophication is and if short terms man-made solutions will help save the sea.

Key terms from the book Ecology and Ecosystem Conservation

Ecosystem: A biological system on the basis of the complex species inhabiting a region as well as the chemical and physical attributes of that region.

Ecosystem stability: Capacity of an ecosystem to maintain, or return to normal species abundances or function in the face of disturbance

Food Web: In a food web we find many different species depending on each other.

Food Chain: Feeding linkages or energy flow among major groups of species.

Trophic Cascades: "The enemy of my enemy is my friend" (Holt 2001).

Eutrophication: Overload of nutrients cause increased growth of plants

Baltic Sea

For about 10,000-15,000 years ago large ice masses started to emerge and created the Baltic Sea, this makes the sea the youngest on earth. The Baltic Sea is known because of its unique large body of brackish water, the mixture between saltwater and freshwater. It is only connected to the ocean waters of the North Sea through a very narrow strait between Sweden and Denmark, The Sounds. The Baltic Sea is due to this a semi closed basin, with a high water renewal time estimated to be more than 40 years. Not only is the water unique but also the species living in it since they have to adapt to feed and reproduce in a brackish water.

Where the Baltic Sea is located is not seen as a very good location. It is bounded by eleven nations, with over 100 million inhabitants living in the drainage basin. Due to a long history of heavy human activity in the drainage area the pollution load to the sea has increased way beyond what is acceptable. The increased concentration of pollutants has caused negative effects on the marine ecosystem, and the species living in the water has not only the brackish water as a pressure on survival but now also pollutants as a threat.

Humanity is the biggest threat right now to the Baltic Sea but also the ones who can help it. The future of the Baltic Sea is depending on us.

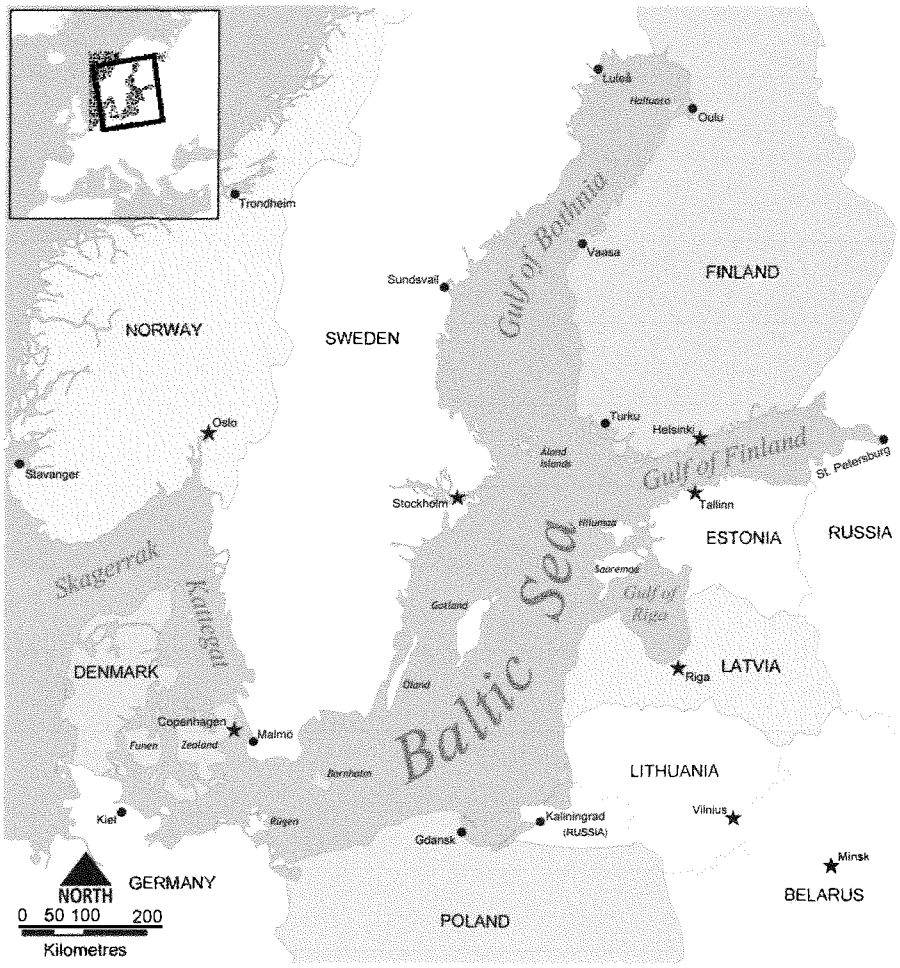

Figure 1.1 *Map over the Baltic Sea and the Nations around it*

Cod Fish

The Baltic Sea cod is a sub-species named *Gadus morhua callarias*. Because of its unique gene this sub-species is the only cod-fish species to be found in The Baltic Sea. The common cod fish lives at a depth of 10-200 m, although in the Baltic Sea the cod lives further down because of the salt level. Saltwater has a higher density than freshwater and therefore is the lower part of the Baltic Sea richer on salinity in the water. Because of the different concentration of salt in the water levels a halocline is created. Halocline is a vertical salinity gradient found in the Baltic Sea, but also

other saline water and oceans. This is important to the cod as the species lays its eggs in the halocline to reproduce.

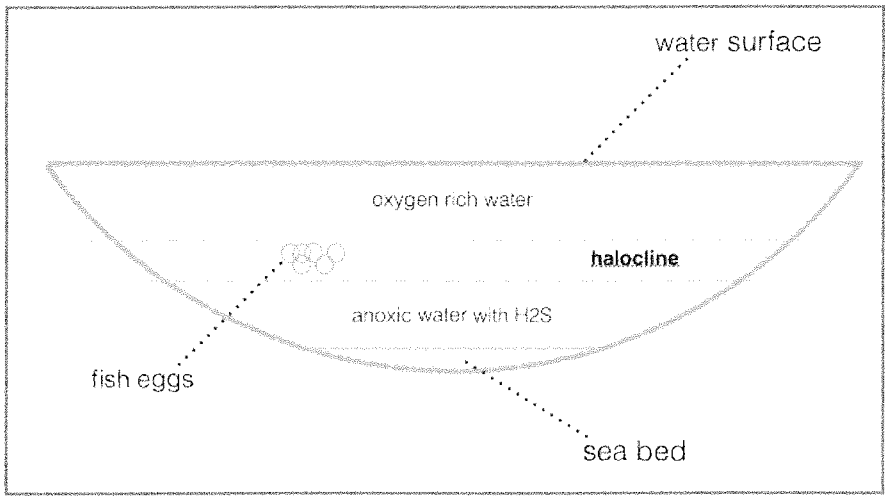

Figure 2.1 *Example of how the reproduction of the codfish looks like, and where exactly the halocline is located.*

Food chain for the Codfish in the Baltic Sea:

- Seals (*Phoca vitulina*), Porpoise (*Phocoenidae*), Humans (Homo sapiens)
- Cod fish (*Gadus morhua callarias*)
- Herring (*Clupea harengus*)Sprat (*Sprattus sprattus*)
- Zooplankton
- Phytoplakton

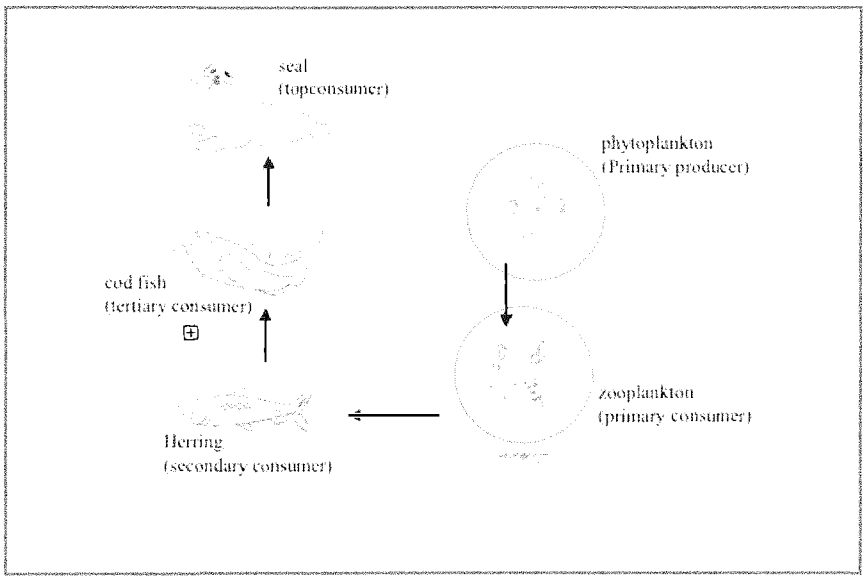

Figure 2.2 *Food chain of the cod fish in the Baltic Se*

Human Caused Eutrophication

The overflow of nutrition, as nitrogen and phosphorus, comes from different sources. Most of it is from the agriculture fertilization, from the cars we drive, the industries, and the non-cleaned drains from households that leads into the sea from all the nations around it.

Around 80 percentage of the impurity (nutrients, persistent organic pollutants, heavy metals) that is found in the Baltic Sea are transferred to the Sea by the streams that are located in the adjacent countries to it. For each year, around 70 000 tons of nitrogen and 30 000 tons of phosphorus are supplemented to the sea and cause an eutrophication of the water body. The nutrient load has been more than doubled during the past 100 years. The amount is although different from year to year but has been too high, which unbalance the nutrients turnover in the sea, since the 1950's. The increased growth of planktonic vegetation (phytoplankton) in the water, which is caused by the overload of nutrients, decreases the biodiversity because of highly competitive species taking over by mass reproduction. This is more commonly know as algae bloom.

You can easily see if waters suffer from eutrophication by the large amount of phytoplankton and macrophytes. Two things happen. Primarily a mass development of phytoplanktons will shade other plants from sunlight which causes a heavy reduction. Secondly, all the organic material from the fast growing planktons will fall down to the bottom. Microorganisms decompose organic matters and for this they need oxygen, so all oxygen will be consumed by the degradation process causing dead bottoms.. When oxygen concentration in the bottom water decrease to zero other organism continues with the decomposition but they use sulfur and by that forming hydrogen sulfide (H_2S) which is toxic and kills the sea bed and the water above it.

Another problem that has revealed itself is the internal load of nutrients that is stocked up in the sea bottom. The seabed sediment stores the load Phosphorous and Nitrogen, and when it dies due to lack of oxygen and is degraded these nutrient are once again released into the water. This

creates a problem, because no matter how much we limit our current emissions, the sea is basically killing itself.

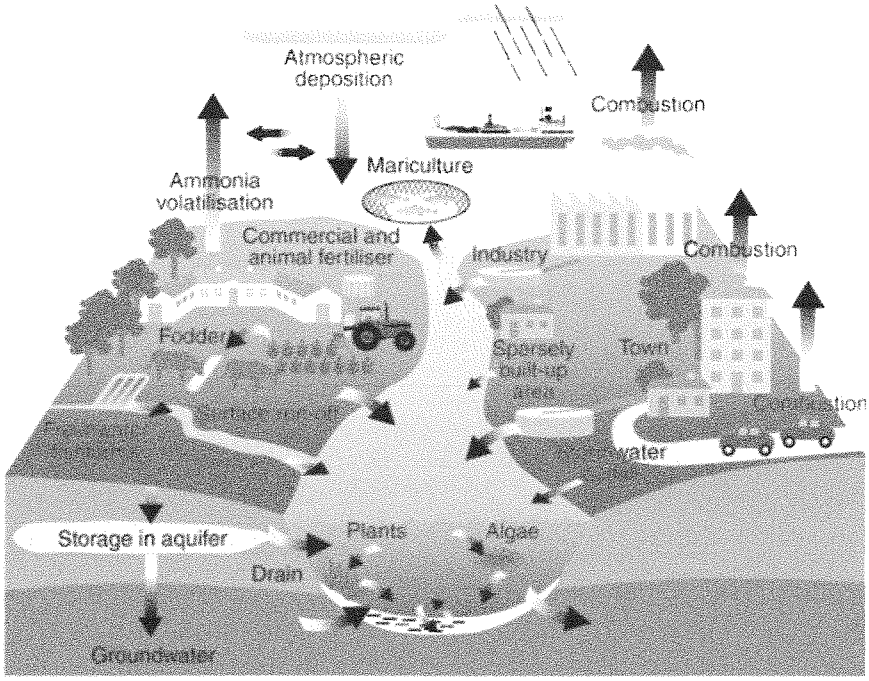

Figure 3.1 *This gives a clear picture over how humans contribute to the eutrophication in the water with emissions that goes both straight into the the water but also up in the air the results in atmospheric deposition.*

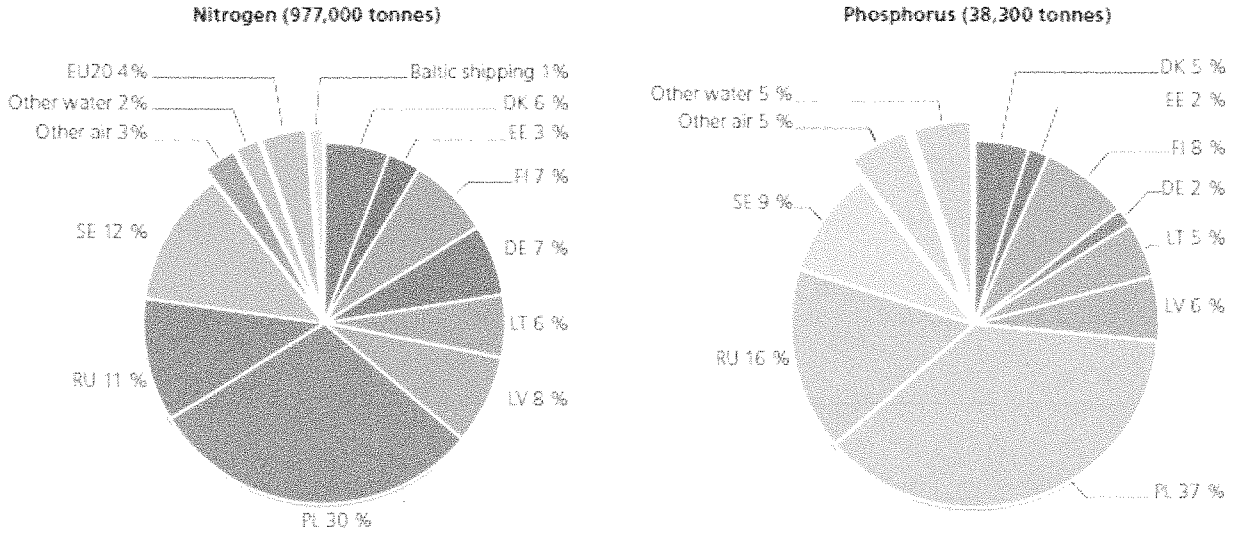

Figure 3.2 *This is a graph published 2010 in a publication by the organization HELCOM. The graphs shows the emissions of Nitrogen and Phosphorus in percentage by the nations around the Baltic Sea (Note that it is only the counties that are members in HELCOM)*

History: What started the eutrophication in the Baltic Sea?

Before 1940: The Baltic Sea ecosystem was balanced and resilient. This state is what we want to establish again. In principle, we need to reduce the annual total emissions to the Baltic Sea down to the amounts transferred annually in the 1940s.

1950: Agriculture started to use commercial fertilizes with nitrogen and phosphorus, the urbanization accelerated and the amount of untreated wastewater increased, we started to use phosphate in detergents. This increases nutrient input which lead to more nutrients in the water and therefore an increase of the biomass of all species living in it.

Consequences on the Cod fish

Figure 4.1 *A sick cod-fish found close to the sea bed of the Baltic Sea video-recorded by the organization "Save our Baltic Sea"*

Studies made by International Union for Conservation of Nature and Natural Resources (IUCN) on the cod fish population in the eastern Baltic Sea have shown a decrease on the species. In the beginning of the 1980's the cod stock population was the heights measured with an amount of twice as much as there is today. In the 21st century the cod populations was close to a collapse from human caused eutrophication, but also from over fishing. Today is the species listed as 'vulnerable',

according to the organizations Baltic Marine Environment Protection Commission (HELCOM) and IUCN, because of the climate change and eutrophication. In recent finding the cod population has been found to be in a bad state with a 20 percent stock decrease during the past two years. At first it was thought that the primary source to the cause of a decreased population was because of lack of herring and sprat which the cod fish feed on, but now new researches shows that it is not related to the decrease of the cod's pray. The new results show that the decrease is caused by the spread of hypoxic sea beds, which is a result of eutrophication. Because of the increased area with hypoxic sea beds in the Baltic Sea the competition of space for food make the cod stock to decrease.

The main problem for the cod fish, caused by eutrophication, is the poor reproduction. The cod is reproducing by laying their eggs in the halocline, in the deeper areas in the Baltic sea, as shown in figure 2.1. When caused eutrophication, anoxic water with H_2S is right above the sea bed which kills the eggs. In this way the reproduction of the cod fish decreases. This is where the bottom water needs to get oxygenated. If not the cod fish will not be able to make a sustainable reproduction. With a low oxygen level in the water the cod habitat areas decline.

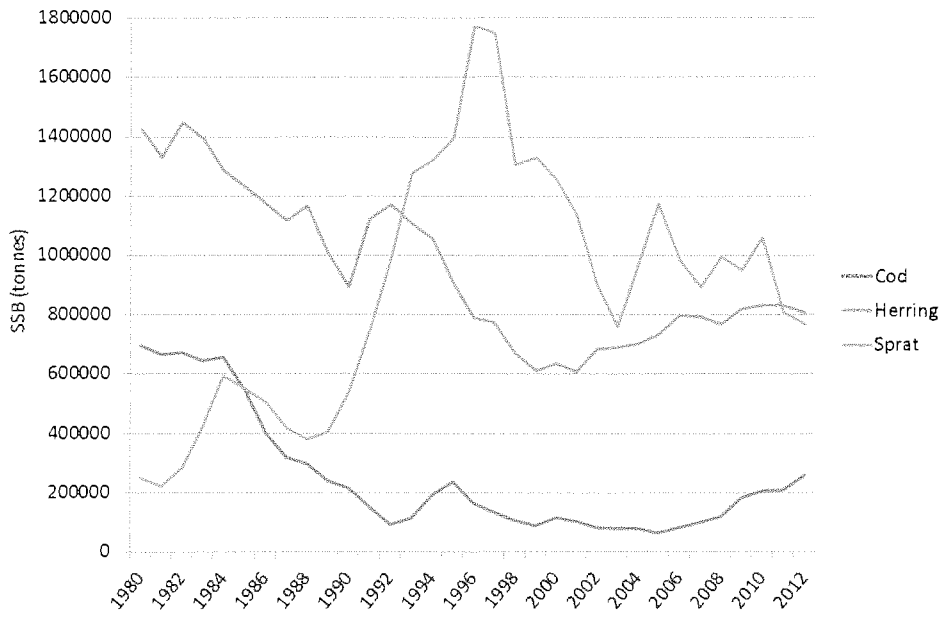

Figure 4.2 *SSB (Spawning Stock Biomass) of the species Cod, Herring and Sprat*

Problems due to loss of cod fish

The ecosystem of the Baltic Sea has changed over the year because lack of cod fish in the water. The decrease of the cod has also resulted in a decrease of zooplankton, which the prey of the codfish, the herring, lives of. When zooplankton decreases phytoplankton, the zooplanktons' main food source, increase which also lead to algae blooms. Large biomass volume of phytoplankton uses a large amount of oxygen when degraded and that in turn lead to dead sea beds. The more cod fish that will disappear from the sea the greater areas with dead seabed will there be.

With less cod in the Baltic Sea there will also be an acceleration of the eutrophication. Oxygen free sea beds are leaking phosphorus to the water above. Sediments, that in oxygen rich conditions is a trap for phosphorus, will under oxygen free conditions be a source of phosphorus. This internal load of phosphorus will enhance the eutrophication and the growth of more biomass, which will increase the oxygen deficit when degraded. This will cause even more cod eggs to die, and by this way the negative spiral will continue.

The eutrophication caused by humans is not the only factor that puts pressure on the Baltic Sea. Over fishing is increasing the pressure on both cod population and the eutrophication. With other words, it is hard for the codfish to reproduce but also the over fishing by human decrease the number of cod fish in the sea.

When an decrease of a species occur in a specific area there will be an increase of the species it feeds on and that will also affect both the consumer and the prey. This is when a trophic cascade occurs. The competition among the species will get aggressive. If the cod fish were to disappear due to the pressure of human activity (eutrophication and overfishing) it would affect all the species in its food chain and food web. The herring would increase and the zooplankton will decrease, and the phytoplankton will then increase. The top consumer will not have as much prey as before the increase and therefore decrease in stock.

Organizations

Nations around the Baltic Sea are cooperating towards a healthy sea. HELCOM (Baltic Marine Environment Protection Commission - Helsinki Commission) is a non-political organization created by the nations. The organization was established approximately 40 years ago to protect the marine life and the environment of the Baltic Sea from eutrophication caused by humans. European Union (EU) has several tools for the environmental recovery of the Baltic Sea and its drainage basin. For example there are the EU Marine Strategy Framework Directive and the EU Strategy for the Baltic Sea region. Both of them include goals and tools for the work with the improvement of the Baltic Sea environment. EU also has several funds for research and development, funding scientists and organizations dedicated to improve the quality and resilience of the Baltic Sea ecosystem.

The question about how to save the Baltic Sea is constantly discussed in EU, but it is the action to put the plans and laws in that takes time. Although we have to have in mind that we cannot expect the sea to be healthy in one week or a month, it will take years. Since it takes more than 40 years with the naturally inflow of water change all the water in the Baltic Sea, for the process to happen naturally it is bound to takes centuries.

Possible solutions

Solutions to help save the Baltic Sea and the species in it are many. There are both long term solutions and short term solutions. One specific way to help the seabed gain oxygen the artificial way is by help from the so called 'Wave Energized Baltic Aeration Pump' (WEBAP). The pump is the closest thing to a solution mankind have come up with so far when transporting oxygen rich surface water to the dead sea bed. This project is coordinated by the Swedish research institute IVL and has been since it started in 2010. The operation is conducted near the Swedish coastline. The

project is sponsored economically by EU and IVL, but also by the local municipality where the project took place in Sweden. The total budget of the project was 1.178.606 € and had a project time of two years and nine months. Although the project is still ongoing whereas the results were positive for the Baltic Sea. This is a short term solution to help the sea bed gain oxygen and in that way decrease the eutrophication which will lead to a better habitat for the codfish.

This is how the pump works:

1. Waves force oxygen-rich water into a reservoir inside the oxygen pump
2. Because of higher water lever inside the reservoir than the surrounding sea lever a vertical flow is induced
3. This flow implies that the oxygen-saturated water from the reservoir flows vertically through the tube to oxygen-depleted deep water layers. This causes an increase of the oxygen content in these lacers a well as a mixing of existing stratification.

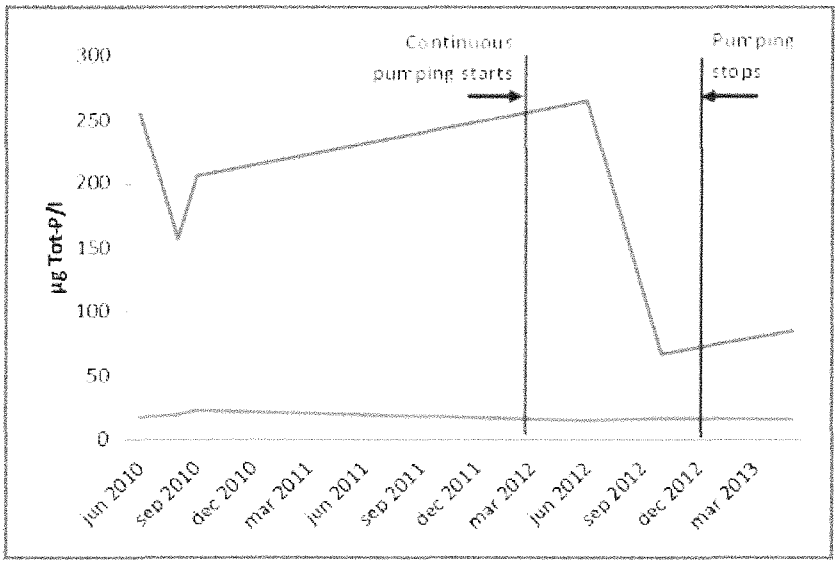

Figure 5.1 *Graph showing the results of the WEBAP done in the bottom water of 100 meter depth in Kanholmsfjärden.*

Results of the WEBAP:

As we can see in figure 5.1 it is an small increase of oxygen concentration in the bottom water within months. This can take nature up to year to occur naturally. With help from the pump

the bottom water gets oxygenated. The results showed that here was an increase of oxygen levels in the water. This draw the conclusions to that the improved oxygen level in the water happens because of the natural inflow of oxygen-rich water. But what cannot be excluded is that the pump also did have a positive impact.

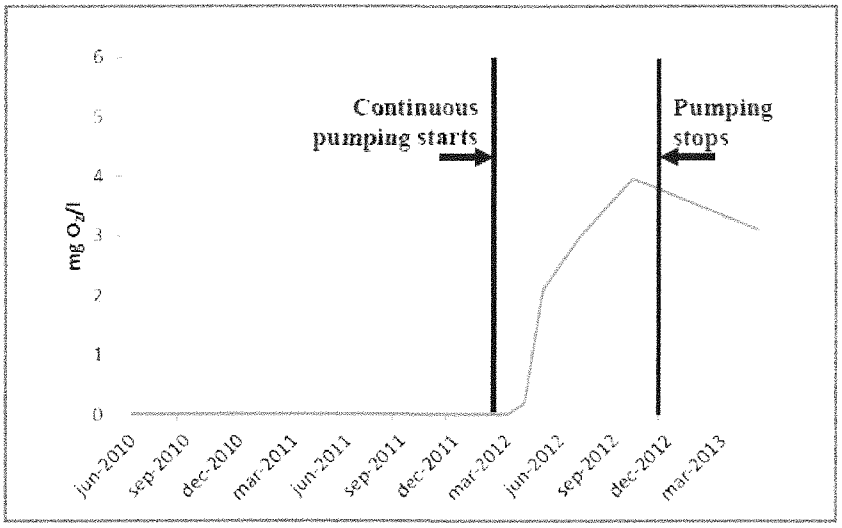

Figure 5.2 *Total amount of phosphorus (mg/l) in the bottom water (red) and surface water (blue) measured in Kanholmsfjärden.*

Measurements were also done on the phosphorus level in the same area. In figure 5.2 there is a radical decrease of phosphorus in the bottom water. It indicates that right after the oxygen level in the water increase phosphorus concentrations decreases. What is interesting here is that the change of phosphorus concentration was not observed in the surface during this time, also shown in the figure by the blue vertical line. One theory is that the oxygenation disturbs the existing stratifications which will lead to an increased level of phosphorus in the surface water but also as a result of a phosphorus-rich bottom water that could move to the surface. The aim is now to get oxygenation to decrease the phosphorus concentrations in the surface waters too, it will result in a reduced primary production in the photic zone

Conclusion

An intensive use of nutrients in our society during the last 60 years has, through discharge and leakage to our water bodies, caused an over fertilization, or eutrophication, that the nature has never seen before. Normally nature has mechanisms to handle excessive nutrients, however semi-closed basins like the Baltic Sea has less potential due to long water renewal time to recover from a long term intensive overload of nutrients. The human induced discharge of nutrients to our waters has therefore caused a dramatic change in the Baltic Sea ecosystem. For example the oxygen free sea bed areas and its bottom water have increased every year.

One of the top predators in the Baltic Sea ecosystem is the cod. The cod stock is under strong pressure from poor reproduction conditions due to the eutrophication induced oxygen-free bottom water. If this continue the cod species in Baltic Sea will be extinct, and without one of the most important top predators it will endanger the whole ecosystem balance in the Baltic Sea. A total ecosystem collapse is around the corner if nothing is done. This situation will influence a lot of services we are used to get from the Sea; for example recreation and food.

Several organizations are working to improve the situation in the Baltic Sea. HELCOM and EU are the most powerful. During the last 20 years has the focus been to decrease the load of nutrients from point sources and agriculture. The eutrophication of the Baltic Sea has started an internal load of nutrients, which will continue support the eutrophication process, even though the external load has decreased to acceptable levels. The water renewal time is more than 40 years in the Baltic Sea, which gives an extremely long recovery time. To speed up the process we need to oxygenate the bottom water artificially to help the Baltic Sea to recover from the self-induced eutrophication. The WEBAP project is one successful attempt to transport oxygen rich surface water down to the dead sea beds. But it will be very costly to save the Baltic Sea and its cod stock by this artificial way. My conclusion is that if we want to save the Baltic Sea we need to work on many different actions at the same time since it is shown that it can not happen naturally. The

solution presented in the essay is only one example of how humanity can help the recovery of the Baltic Sea. It is important to continue the decrease load of nutrients to the sea to gain a sustainable ecosystem.

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2.1 & 2.2 drawn by author of the essay Hanna Fejes

3.1: "NUTRIENT INPUTS TO THE BALTIC SEA." *Inputs of Nutrients*. HELCOM. Web. 12 aug 2014. <http://helcom.fi/baltic-sea-trends/eutrophication/inputs-of-nutrients/>.

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4.1: Rydén, Folke. "Save Our Baltic Sea." *Save Our Baltic Sea*. BalticSea2020, 1 Jan. 2009. Web. 8 May 2014. <http://www.saveourbalticsea.com>.

4.2: "Marine-Species." *Marine Species*. HELCOM. Web. 26 Sept. 2014. <http://helcom.fi/action-areas/species-and-habitats/fish-communities/marine-species>.

5.1 & 5.2: "Final Report of WEBAP." IVL Swedish Environmental Research Institute Ltd. Web. 26 Sept. 2014. <http://webap.ivl.se/download/18.6cf6943a14637f76eab20de/1402406624337/C26 - WEBAP - Final Report (public version).pdf>.