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IMPACTS OF FISH FARMING ON THE STATE OF ESTONIAN COASTAL SEA

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Abstract. To assess and predict the impacts of fish farms on marine environment, a joint research project was launched in 1987 by the Nordic Council of Ministers.

The state of marine environment is affected by the discharge of nutrients and suspended matter, both organic substances and chemical compounds, into the sea from fish farms. However, fish farms are by no means the greatest sources of sea pollution. In 1994–95 fish farms were responsible for less than 1% of both N and P load in the Baltic Sea. To further decrease the load of pollution in the Baltic Sea fish farming should be developed in harmony with the environment. This calls for the use of environmentally friendly feeds and materials at the marine fish farms, improved feeding methods ensuring efficient utilization of nutrients, and the location of the farms in areas with an appropriate hydrological regime.

Key words: fish farming, coastal sea, pollution load, HELCOM.

TROUT BREEDING IN ESTONIA

The practice of rearing fish goes back well over a century in Estonia. Incubation of trout eggs and breeding of trout at fish farms was introduced in the 1890s. Almost simultaneously carp was transplanted to manor ponds. In 1910, there were more than 25 fish farms in Estonia, and the total area of fish breeding ponds exceeded 30 hectares (Paaver, 1993). During World War I and the Russian revolution, Estonia was cut off from the market of St. Petersburg. This caused a remarkable decline in the number of fish farms in Estonia. In the initial period of the independent Republic of Estonia there were about ten pond-fish farms, where 11–12 tonnes of fish was raised annually. Until 1936, the main field of activity was incubation of fish roe in seven fish hatcheries. Fish were raised only in two state-owned farms – at Antsla and Löwenruh.

Estonian fish farming gained again momentum in the 1970s, when several well-off collective fisheries undertook to promote trout breeding. However, it was possible to arrange fish farming quickly and with small investments only in cages.

The fish were hatched in river and pond water, and then transferred to saltwater cages for commercial production.

The collective fishery Saare Kalur had a fish cage farm at Vätta, Hiiu Kalur in Kirikulahe Bay, Pärnu Kalur in Tõstamaa Bay, Lääne Kalur at the Rohuküla port, Majak in Kolga Bay, and the S. M. Kirov Collective Fishery in Hara Bay. In 1974, the S. M. Kirov Collective Fishery started to build a fish farm at Pärispea, where the fish ponds were located immediately in the coastal zone. At this farm 4.5 m^3 of sea water per second was pumped into the ponds, which ensured the exchange of water 22 times a day. The farm has operated since 1976, and its rated capacity is 300 t of commercial fish annually.

In 1977, Saare Kalur undertook to build a fish farm at Kesknõmme. For that purpose an area of two hectares was isolated from the surrounding area by dams and fences in the coastal zone of Tagalahe Bay. The rated annual capacity of the farm was 150 t, which was achieved in 1993. The amount of the fish produced in sea water in Estonian coastal areas increased steadily, reaching its maximum (506 t) in 1989 (Table 1).

Table 1

Production of marine fish farms, t

Collective fishery	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Kirov	257.5	274.5	265.0	104.6	24.4	122.2	300.1	303.8	319.4	349.4	308.6
Saare Kalur	41.3	51.8	65.0	73.4	83.3	63.7	61.6	85.6	86.1	71.3	65.6
Majak	11.5	20.0	18.0	16.0	28.0	23.1	25.9	43.4	51.5	65.1	62.1
Hiiu Kalur	2.5	4.9	3.0	3.0	2.6	2.6	3.8	3.3	3.2	2.2	3.2
Pärnu Kalur	11.2	10.9	7.0	1.0	–	–	0.6	10.6	11.4	8.8	3.5
Lääne Kalur	11.9	10.4	12.0	10.2	12.1	9.9	10.6	8.9	7.0	8.7	–
Total	335.9	372.5	370.0	208.2	150.4	221.5	402.6	455.6	478.6	505.5	443.0

In 1990, 737 t of commercial trout was produced in fresh- and marine-water farms. Since then the production has been gradually falling. This may be explained both by the rearrangement of ownership relations and the reduction of the eastern market. In 1991, the last marine fish cage farm was closed. As to the sea-water based farms, trout is still raised at Pärispea and Kesknõmme: in 1995, 82 and 150 t, respectively.

As Estonia is a country with long trout breeding traditions, we have every reason to believe that against the background of the general upswing of economy, fish farming will receive a fresh impetus. That is why attention should be focused on the assessment of the potential impact of fish farming on the marine ecosystem.

The responsibility is even greater now, when independent Estonia has joined with the Helsinki Convention. Information on the pollution sources of fish farms and their impact on the environment is urgently needed to direct fish farming activities to suitable areas and to choose right feeds and adequate technologies.

SPECIFIC POLLUTION LOAD FROM FISH FARMING

The pollution load from fish farming may be evaluated by monitoring or calculations based on the amount of the feed used and the quantity of fish produced. Table 2 presents initial data suggested in the literature for assessing the pollution load.

The table shows that the pollution load is highly variable. It depends on the quality of feed, feeding technology, and ambient conditions. Although ambient conditions have markedly improved in recent years, the variation between single measured pollution loads is still considerable. As Table 3 shows the total pollution load has increased due to the marked increase in fish production (Mäkinen, 1991).

Table 2

Initial pollution load data according to Mäkinen (1991)

Type of pollution	Pollution load	
	g/kg feed	g/kg fish
Solid substances	80–280	110–520
BHT_7	100–370	145–720
Nitrogen	7–149(43)	12–305(77)
Phosphorus	2–22(7)	4–36(13)

Table 3

Total production of farmed fish and the resulting pollution load to the Baltic Sea (from Mäkinen, 1991)

	1980	1985	1990
Production of fish, t	6 700	18 100	45 800
P load, t	87	235	595
(%)	(0.17)	(0.47)	(1.19)
N load, t	536	448	3 664
(%)	(0.05)	(0.14)	(0.37)

According to Ackefors & Enell (1990), in 1989 fish farming accounted for 1.5 and 0.04% of the total phosphorus and nitrogen load, respectively, in the Baltic Sea. Therefore, it may be maintained with certainty that fish farming is not of decisive importance in the perishment of ecosystems in the Baltic Sea. Adverse effects appear locally.

The overall trend in the load can be estimated from data on the production, the average feed coefficient, and the average nutrient content of the feeds used. In evaluating the specific load, it seems most reasonable to base on the amount of the fish produced.

The methods presented in the HELCOM Recommendations (1994) for evaluating the pollution load from fish farming are based on the amount of the feeds used and the fish produced. The pollution load can be described with the following equation:

$$L = 0.01\ (IC_i - GC_f)\ , \tag{1}$$

where L P or N load to the water body, kg/a;
I amount of feed used for feeding fish, kg/a;
C_i P or N content in fish, %;
G growth of fish, kg/a;
C_f P or N content in fish, %.

The content of nutrients (P, N) in feed depends on the quality of the feed. In fish the content of nutrients varies with the species and age of fish. Therefore, according to the method recommended, the nutrient content both in feed and farmed fish should be measured. If there are no relevant data available, the following values presented in the HELCOM Recommendations (1994) can be used:

	P content, %	N content, %
Fish	0.4	2.5
Dry feed	1.0	7.5
Semimoist feed	0.8	5.0
Moist (fresh) feed	0.45	2.5

In the following, the methods recommended by HELCOM to assess the pollution loading from the marine fish farms in Estonia are applied. The 1995 data served as a basis. At the Kesknõmme and Pärispea fish farms the combined amount of feed used was 370 t (dry feed 330 t, wet feed 40 t), the amount of fish produced was 180 t. Using equation (1), the following nutrient loads were obtained: P 2.7 t and N 21.2 t. These values were added to the total loading from Estonia (Table 4).

Table 4

Total pollution load from Estonia to the Baltic Sea in 1995, t

Region	BHT_7	Suspended matter	N_{tot}	P_{tot}
Gulf of Finland	3912.4	6884.9	3217.8	264.7
Väinameri	154.7	119.2	63.5	11.9
Gulf of Riga	280.3	382.2	175.5	36.5
Baltic Proper	7.0	3.0	4.1	0.9
Estonian and Latvian rivers	6.0	6.2	3.7	0.8
Total	4360.4	7395.5	3464.6	314.8
Fish farms	–	–	21.2	2.7
Total	4360.4	7395.5	3485.8	317.5

The data presented in Table 4 allow us to estimate the contribution of fish farms to the total pollution load from Estonia. The calculations show that it is 0.61% for N and and 0.96% for P.

In most cases, the assessment of the pollution load from fish farming on the basis of monitoring has not given unambiguous results. As an illustration serve the water analysis data of the Pärispea fish farm. Water samples were taken and analysed from the input and output of the fish farm four times a year (Table 5).

Table 5

Pollution load determined on the basis of the water analysis results in the Pärispea fish farm in 1993–94, mg/l

Date	N_{tot}			P_{tot}			BHT_7			Suspended matter		
	In-flow	Out-flow	Diffe-rence*	In-flow	Out-flow	Diffe-rence*	In-flow	Out-flow	Diffe-rence*	In-flow	Out-flow	Diffe-rence*
10.02.93	5.2	5.3	+0.1	0.6	0.65	+0.05	0.1	0.2	+0.1	10	13	+3
15.06.93	1.5	2.0	+0.5	0.1	0.11	+0.01	0.5	0.8	+0.3	12	13	+1
21.09.93	7.2	7.5	+0.3	0.4	0.45	+0.05	1.0	1.3	+0.3	12	13	+1
8.12.93	7.2	7.5	+0.3	2.8	2.4	–0.4	1.1	1.3	+0.2	12	13	+1
23.05.94	5.6	5.6	0	0.03	0.03	0	1.5	1.6	+0.1	2	2.5	+0.5
20.07.94	1.7	1.4	–0.3	0.02	0.06	+0.04	3.0	3.5	+0.5	4.3	2.3	–2.0
14.09.94	2.0	2.2	+0.2	0.28	0.32	+0.04	4.0	4.3	+0.3	5	4.6	–0.4

* + designates higher pollution load in the outflowing water and – in the inflowing water.

The table shows that the pollution load tends to rise, although in terms of some indices the water running out from fish ponds is sometimes cleaner than the inflowing water. The data presented in the table do not enable one to determine the direct relationship between the amount of fish bred and the pollution load. By autumn, the fish have grown in size and weight, their biomass at the farm is 2–3 times as high as in spring, and, therefore, much more feed is needed. However, this is not reflected in the spring and autumn water sample analysis data.

If the pollution load is evaluated on the basis of monitoring data, then unified methods are needed both for the sampling and determination of polluting substances. It is evident that the samples taken immediately during or after feeding contain much more organic substances, particularly when wet feeds are used.

In Estonia, different feeds have been used at trout farms. In the 1970s, when the trout farming received a fresh impetus in the republic, mainly frozen or fresh fish and semimoist feeds were used. The use of semimoist feed has some disadvantages, because about one third of it gets dispersed in the water, contributing to the contamination of the environment. The situation improved when Estonia began to receive feed from the Dnepropetrovsk Concentrated Feed Producing Plant in the Ukraine, which used Japanese technology. With the use of the feeds produced at that plant, the feed coefficient was 2–3 and the pollution load from fish farming decreased considerably.

In 1991, it became difficult to get dry feed from the Ukraine, and therefore wet feed was again widely used besides granulated feeds. This caused a certain rise in the feed coefficient. In 1992, the fish farms started to import dry feeds from Denmark and Finland. In 1992 and 1993, Baltic sprat and herring served as the main feed at the Estonian marine fish farms. In 1994, only dry feed was used. Owing to the use of Danish dry feed, the average feed coefficient at the Pärispea farm was 1.8. The feeds produced in Denmark meet the requirements of the HELCOM Recommendations, i.e. their P content does not exceed 1% and their N content is less than 7.5%. Thus, it may be stated that since 1994 the pollution loading from Estonia's fish farming has been in accordance with the requirements of HELCOM.

LOCAL IMPACT OF FISH FARMING

The local environmental load from fish farming is caused by the high nutrient concentration in water, sludge which deposits under fish cages, and the take-up of chemical compounds in hydrobionts. The local effects may be managed by carefully choosing sites for fish farms and adjusting the amount of the fish bred to the sensitivity of the site to nutrient loading. The load from a fish farm can be markedly reduced by using appropriate feeds and feeding technology.

Nutrients

Nutrients cause eutrophication of the body of water. The amount of nutrients depends on the feed type, feeding technology, and requirements of the fish. Factors like the composition and physical properties of the feed and the amount of the feed used are of great significance. The local loading is smaller in the case of dry feed. Although fish can utilize protein very effectively, they still need feed with a high protein content. The use of protein as an energy source falls if the relation between digestible energy and protein content is optimal.

The phosphorus load can be reduced through optimization of feeding. It is easier to reduce the phosphorus load than the nitrogen load, because the requirement of the fish for phosphorus is much smaller than the demand for nitrogen.

The phosphorus load can be described with the following equation:

$$Y = 10 \times f_c \times P - z, \tag{2}$$

where Y phosphorus load, kg/t fish produced;
f_c feed coefficient;
P phosphorus content in the feed, % of wet weight;
z phosphorus content in the fish bred, kg/t wet weight.

Today, the feed used at trout farms contains less than 1% of phosphorus and 6.8–7% of nitrogen (Braaten, 1991). If high-quality feed is used and the feed coefficient is 1.0–1.5, the phosphorus load is 9.5 kg and the nitrogen load 80 kg per a tonne of rainbow trout weight gain (Kangur, 1994).

Sludge

Sludge is formed on the sea floor in the area of fish farms from unused feed and faeces, which consist mostly of organic carbon and several nitrogen compounds. It has been established that some 75% of the carbon used in feeding reaches the environment, of which 97% accumulates in sediments, and 3% remains in the water (Braaten, 1991). The amount of sludge that is deposited under fish cages is at least by an order higher than in the whole area under fish farming impact (Kangur, 1993). Studies have shown that 1.65 g of O_2 is needed for the decomposition of 1 g of standard fish feed (Braaten, 1991).

O_2 is also needed for the decomposition of plants growing on the account of released nutrients. Studies at Finnish fish farms have shown that the amount of solid residue is 80–280 g per 1 kg of the feed used and 110–150 g per 1 kg of fish produced (Mäkinen, 1991). If the water movement is negligible, sludge is deposited under the cages. However, with strong currents, it may transported to a distance of 1 km or even more from the cages. Thus, the process is highly controlled by the area's topography (Braaten, 1991).

The accumulation of organic substance has a local impact. It is considered more dangerous on the so-called accumulative bottoms, less dangerous on moving bottoms (Hansen et al., 1991).

Chemicals and medicines

Antifouling agents (substances aimed at inhibiting the growth of seaweeds on the cages), disinfectants, medicines, and other chemicals used in fish farming may cause local pollution. The concentration of Zn, Fe, and Cu increases in the sludge under cages (Uotila, 1991). Zn originates from feed and Cu from antifouling agents (Kangur, 1993). Antibiotics are of limited use in the fish farming in the Baltic Sea area. The fish are usually vaccinated against the most dangerous diseases (e.g. vibriosis). Antibiotics may pose problems when accumulated from water, sediment, and feed objects in high concentrations into the organisms consumed for food by man. However, it seems that this kind of threat from chemical substances and medicines is purely theoretical (Braaten, 1991).

FISH FARMING IMPACT ON HYDROBIONTS

Eutrophication of water bodies

Eutrophication is a serious problem throughout the whole Baltic Sea. As already mentioned, the loading of nutrients from fish farms does not play a decisive role in the total pollution load. However, the nutrients have a local effect. The warmer the water and the slower its turnover, the higher the intensity of eutrophication of the water body. The situation becomes critical at the end of the vegetation period, that is during the massive decomposition of algae, when secondary pollution develops. It is accompanied by oxygen deficiency. As a result of permanent oxygen deficiency, the growth of the fish in cages slows down, and the amount of the feed used and pollution of the environment increase.

Zoobenthos

The species composition and biomass of zoobenthos are controlled by the sea bottom topography under the cages and the hydrology of the area. Immediately under the cages, in the conditions of intensive accumulation of organic matter and permanent oxygen deficiency, the bottom fauna is not abundant. In terms of both species composition and abundance, macrobenthos reaches its maximum at a distance of 70 to 240 m from a fish cage farm, in the so-called semipolluted area (Henriksson, 1991).

The bottom fauna has served for years as a bioindicator in monitoring the pollution load from fish farming. An effective and internationally acknowledged method is the so-called “mussel watch” or monitoring of molluscs. Poisonous chemicals that have accumulated in mollusc tissues can be detected even in very small concentrations. Poisons preserve in mollusc tissues over long periods, providing therefore much more reliable basis for monitoring long-term pollution loads than random mud or water analyses. The tissues of molluscs take up anti-fouling agents, disinfectants, and medicines used in fish farming, but also Zn and Cu.

Impact on local fish fauna

Eutrophication causes changes in natural fish communities. This applies to the fish farms in fresh water areas, but also to the fish cage farms located in the coastal sea.

In the coastal waters of the Baltic Sea where the salinity is low, the fish fauna consists mainly of fresh-water species. The check catches show that in the vicinity of fish farms the abundance of trout, whitefish, burbot, and pike decreases, while the abundance and biomass of roach, white bream, and ruff increase. The density of roach and ruff is high around the cages, and therefore their growth is slow. The species sensitive to pollution have retreated towards the open sea, away from the fish cages. Small fish and juveniles dominate in the immediate vicinity of the cages (Henriksson, 1991).

The waters around the Kesknõmme fish farm abound in perch, roach, dace, ide, and viviparous blenny. Whitefish occurs in very low numbers. It should be pointed out that the abundance of whitefish in the Estonian coastal sea is fluctuating and, primarily, due to eutrophication.

POSSIBILITIES OF REDUCING POLLUTION LOADING FROM FISH FARMING

The HELCOM Recommendations 15/3 call the nations who have joined the Helsinki Convention to take appropriate measures to reduce discharges from marine fish farming. HELCOM recommends evaluating the pollution load from fish farming on the basis of the content of nutrients in feed and the quantity of fish produced, differentiating fish farms according to the removal of sludge. Annually, the amount of nutrients per 1 kg of fish produced cannot exceed 10 g of P and 80 g of N. The use of bioactive chemicals at fish farms must be effectively controlled to minimize hazards to the environment.

The measures required by HELCOM had to be taken before 1 January 1995. From 1997, HELCOM should be reported annually about the loadings of nutrients from fish farming and every three years about the measures taken to reduce the pollution from fish farms.

On 15 December 1993, the Parliament of the Republic of Estonia adopted a law regulating compensation for pollution damages. The "polluter pays principle" is a considerable financial instrument contributing to minimization of the discharge of pollutants and wastes into the natural environment, and providing supplementary means for financing the activities aimed at environmental protection. Elaboration of methods for pollution load assessment and introduction of pollution taxes are under way in the Ministry of the Environment of the Republic of Estonia.

At the fish farms the pollution load can be reduced by means of using qualitative feeds, improving feeding technologies, and avoiding excessive application of medicines and other chemicals. Water and sludge samples should be regularly taken for analysis at the fish farms. The state of hydrobionts in the area of fish farming should be subject to permanent monitoring.

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KALAKASVATUSE MÕJU EESTI RANNIKUMERE SEISUNDILE

Anu HERMAN

Kalakasvatuse poolt merekeskkonnale avaldatava mõju hindamiseks ja prognoosimiseks käivitas Põhjamaade Ministrite Nõukogu 1987. aastal ühise uurimisprojekti, mille peamised tulemused avaldati 1991. aastal.

Valdavalt mõjutavad keskkonda vette sattuvad biogeenid, tekkiv ja settiv heljum (orgaaniline aine) ning kalakasvatamisel kasutatavad keemilised ühendid. Muud tuntud reostusallikad on mere saastamisel siiski palju olulisemad kui kalakasvandused. Mereveel baseeruva kalakasvatuse laiendamisel on tähtis, et areng toimuks loodust säästvas suunas. Viimase tagab loodussõbralike söötade ja materjalide kasutamine merefarmides, sööda toitainete täielikumat ärakasutamist võimaldavate söötmismeetodite rakendamine ja farmide rajamine sobiva hüdroloogilise režiimiga kohtadesse.

Kalakasvatus on reguleeritud seadustega. 1994. aasta märtsis määratles HELCOM oma soovitusega kalakasvatuse osa merekeskkonna reostuses ja esitas metoodilise materjali kalakasvatuse reostuskoormuse hindamiseks. 15. detsembril 1993 võttis Eesti Vabariigi Riigikogu vastu saastekahju hüvituse seaduse. 1996. aasta veebruaris võeti uuendatud kujul vastu Eesti Vabariigi veeseadus, mis kehtestab, et kalakasvatus kui üks veekasutuse liikidest vajab veekasutamise luba. Alates 1. jaanuarist 1977 peab kõigil Eesti kalakasvandustel olema veeluba ja neil tuleb tasuda saastekahju hüvitist.