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Effects of coastal eutrophication on the spawning grounds of the Baltic herring in the SW Archipelago of Finland

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Abstract

In the last 14 years, trapnet catches of the Baltic herring (*Clupea harengus membras* L.) have decreased drastically in the inner zones of the bays studied, but increased in the outer zones in the sea area of Turku, SW Finland. We deduce that the reasons for the decrease of catches have been eutrophication and sedimentation of the bays.

The spawning grounds of the Baltic herring were studied by SCUBA-diving in the sea area of Turku in 1981–86. We studied 134 locations but found eggs in only 20 locations. Herring did not lay eggs on all suitable grounds, but regularly and intensively used some few locations from year to year.

The most important spawning grounds were situated in the outer zones of the bays. We found eggs at 0–8 meters depth. In the inner parts of the bays, we did not find eggs with the exception of one shore, which is kept free of sediments by water currents.

The spawning grounds comprised mainly sand and gravel. Most of them were covered by vegetation. Eggs were attached to *Cladophora glomerata, Potamogeton perfoliatus,* and red algae *Furcellaria lumbricalis* and *Phyllophora truncata.* In the innermost zones of the bays the original littoral hard bottoms have changed to soft, muddy bottoms and consequently no eggs could be found there.

Introduction

The spring-spawning Baltic herring (*Clupea harengus membras* L.) has traditionally been the main catch of the fisheries in the Archipelago Sea, SW Finland. The yearly catches range from 23 000–30 000 tons including catches from trawling, trapnets and herring nets (ANON. 1981–1985). The most economical method of harvesting the spawning herring has been the use of trapnets, because herring schools swim along shores on the way to the spawning grounds.

The sea area close to Turku is one of the most important spawning areas of the Baltic herring on the Finnish coasts. But in the last ten years catches have changed radically. In the inner zones of shallow bays, where earlier abundant catches of herring were taken, catches have now decreased to such an extent that the local fisheries are barely profitable. On the other hand, catches have simultaneously increased in the outer parts of the bays.

There are many possible reasons for changes of this kind. Because the spawning grounds are primarily situated in areas influenced by municipal and industrial discharges,

and especially by loadings from cultivated areas, eutrophication and sedimentation are possible factors behind the changed situation.

Our main question is: Why have spawning herrings disappeared from the inner zones of the former spawning bays? In this paper we report our studies on the herring catches, spawning and spawning grounds in the area (RAJASILTA et al. 1986, RAJASILTA and KÄÄRIÄ 1986, HALLIKAINEN et al. 1987) and relate our results to some monitoring studies on the water quality.

Material and methods

The study area is located in the southwestern Archipelago of Finland, comprising the sea area of the town of Turku (Airisto Sound) and three bays nearby (the bays of Askaistenlahti, Mynälahti and Paimionlahti, Fig. 1). The western part of Airisto Sound is 40–100 m deep, whereas the eastern part is shallower (15–20 m, HEINO 1979). The bays are mainly less than 20 m deep. The bays as well as Airisto Sound, receive discharge from one or several rivers, one of the largest being the River Aurajoki (MQ = 6.6 $m^3 s^{-1}$, ANON. 1977).

The salinity in the outer parts of the study area is 6.0 $^0/_{00}$, decreasing to the mouths of the rivers. The turbidity of the water is high, both in the inner zones of the bays (Askaistenlahti bay: range = 1.5–4.5 FTU (Formazin Turbidity Units), JUMPPANEN and KOLEHMAINEN 1984, Paimionlahti Bay: range = 3.2–35.0 FTU, EKHOLM 1986) and in the northern part of Airisto Sound. In the outer zones and the central parts of Airisto, the turbidity is lower (Airisto: range 1.0–2.2 FTU, JUMPPANEN and KOLEHMAINEN 1984; Paimionlahti Bay: range = 2.8–4.4 FTU, EKHOLM 1986). Inner zones of the bays studied are classified as eutrophied or slightly eutrophied water areas (ANON. 1985). The phytoplankton primary production in 1983 was in Askaistenlahti Bay 77g $C m^{-2} a^{-1}$; in northern Airisto 87–224 g $C/m^2/a$ and in southern Airisto 42g $C m^{-2} a^{-1}$ (JUMPPANEN and KOLEHMAINEN 1984).

The fisheries statistics were collected from the local fisheries association (Varsinais-Suomen Kalastajaliitto), where statistics on herring fisheries are existing from 1973 onward. The statistics consist of the total annual herring catches per fisherman and the total number of trapnets used per fisherman yearly. Only those trapnets which were situated in the area studied were taken into account. The bays were divided into two categories according to water quality data: inner zones and outer zones (Fig. 1).

The spawning grounds of the herring were investigated by SCUBA-diving. The shores in the Airisto area and its surroundings have been monitored from 1981–86. In 1986, a survey was made in the bays of Askaistenlahti, Paimionlahti and Mynälahti. Altogether, 134 locations have been studied. Most of the locations were visited once during the breeding season (May – July), but some of them have been monitored throughout the whole breeding season. In each location, divers studied a transect from the shoreline to the depth where aquatic plants did no longer exist (4–12 m, depending on the location). Along the transect, notes were made of the bottom quality, vegetation and the slope of the shore. If eggs were found, also the substrate on which they were attached to and the depth of occurrence were determined.

Results

The herring trapnet catches have decreased drastically since 1973 in the inner zones of the bays, for example in Askaistenlahti bay (Area 1, Fig. 1) from 9.5 tons to 0.7 tons/trapnet/year (Fig. 3). In the outer parts, on the other hand, the catches have continuously increased. In Askaistenlahti bay (Area 2, Fig. 1) for instance, from 5.9 to 19.7 tons per trapnet and year within 14 years.

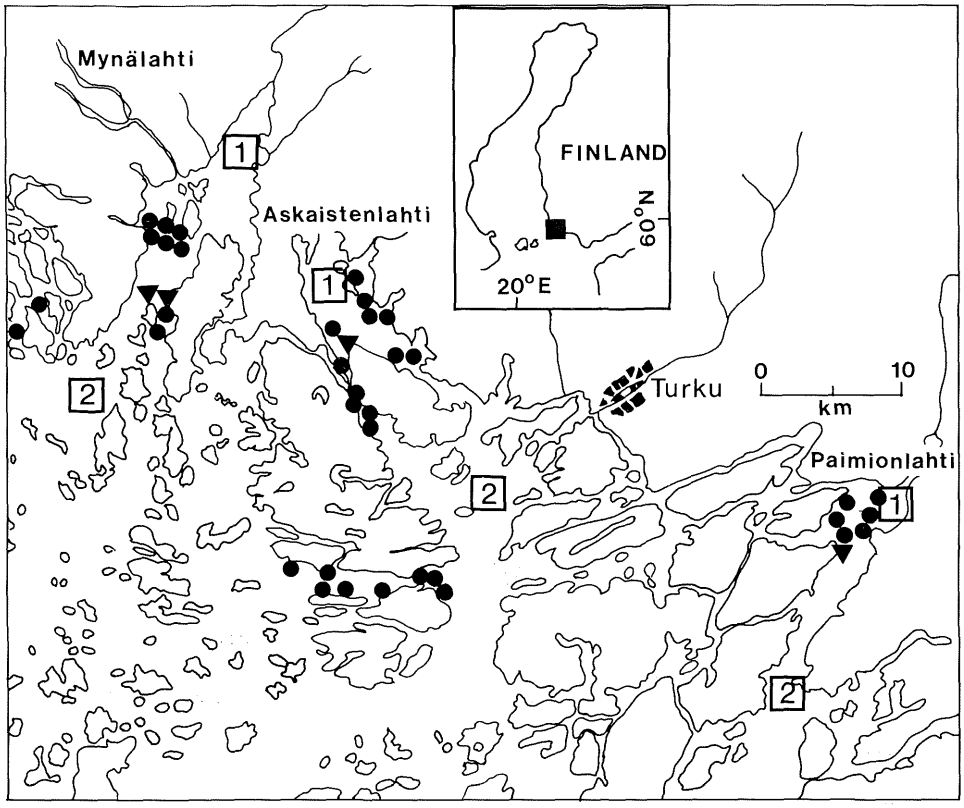

Figure 1

The study area. The zones studied are indicated by numbers 1 (the inner zones) and 2 (the outer zones). The circles indicate one visit during the breeding season in 1986 (▼ = eggs found, ● = no eggs found).

The fishing effort, expressed as a number of the trapnets, has changed during the study period in almost all areas. In the inner zones of the two bays (Askaistenlahti and Paimionlahti), the number of trapnets has decreased, but in the third (Mynälahti) it has remained rather stable. However, the catches still showing a falling trend. In the outer parts, fewer trapnets were used at the end of the study period campared to the beginning. An exception was the outer part of the bay of Askaistenlahti, where the number of trapnets has increased from 9 in 1973 to 21 in 1983.

In the study area, herring spawn was found in only 20 locations out of the 134 studied (Fig. 1, 2). The fish have used certain few shores from year to year. The eggs occurred mostly at depths of 0–4 m. In the inner zones of the bays eggs were found only at one location (Fig. 1, 2).

The most important spawning areas are situated in the northern part of Airisto Sound (Fig. 2). In the spawning grounds, the bottom was usually covered with the bivalve *Mytilus edulis* and vegetation, *Cladophora glomerata, Potamogeton perfoliatus* and red algae *Furcellaria lumbricalis* and *Phyllophora truncata* being the dominant species. The bottom material consisted of rock and stones at the waterline, changing gradually to a mixture of gravel and sand. Deeper down, at a depth of 5 meters, muddy bottoms prevailed (Fig. 4).

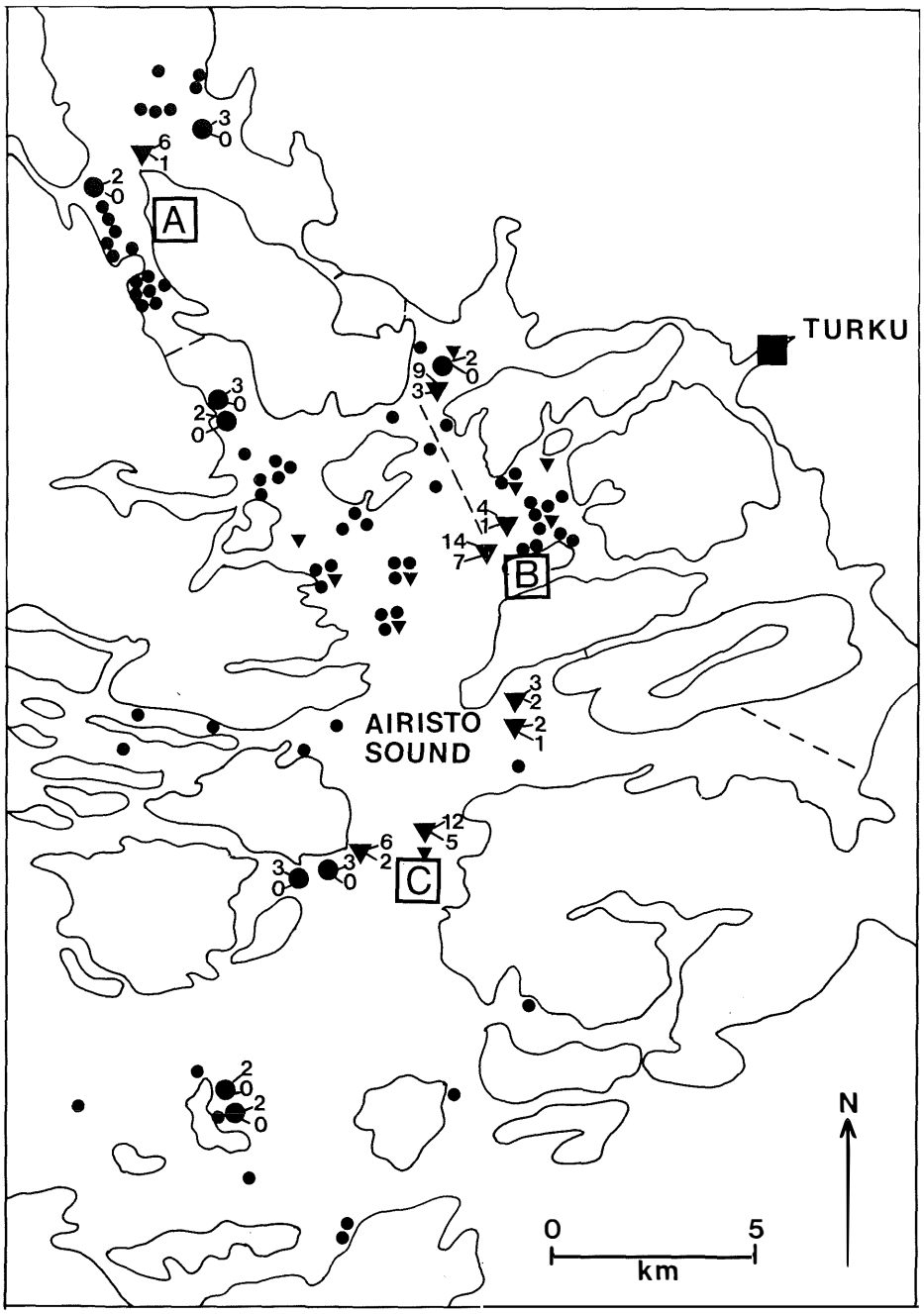

Figure 2

The diving locations in 1981–1985 (▼ = eggs found, ● = no eggs found; $\blacktriangledown^{x}_{y}$; x = the total number of visits in the same location, y = number of times when eggs have been found). Little dots and triangles indicate one visit. The annual mean of FTU (Formazin Turbidity Units) – values is $\geq$ 1.5 above the broken line. The letters A, B, C indicate the locations where more details are presented in Fig. 4.

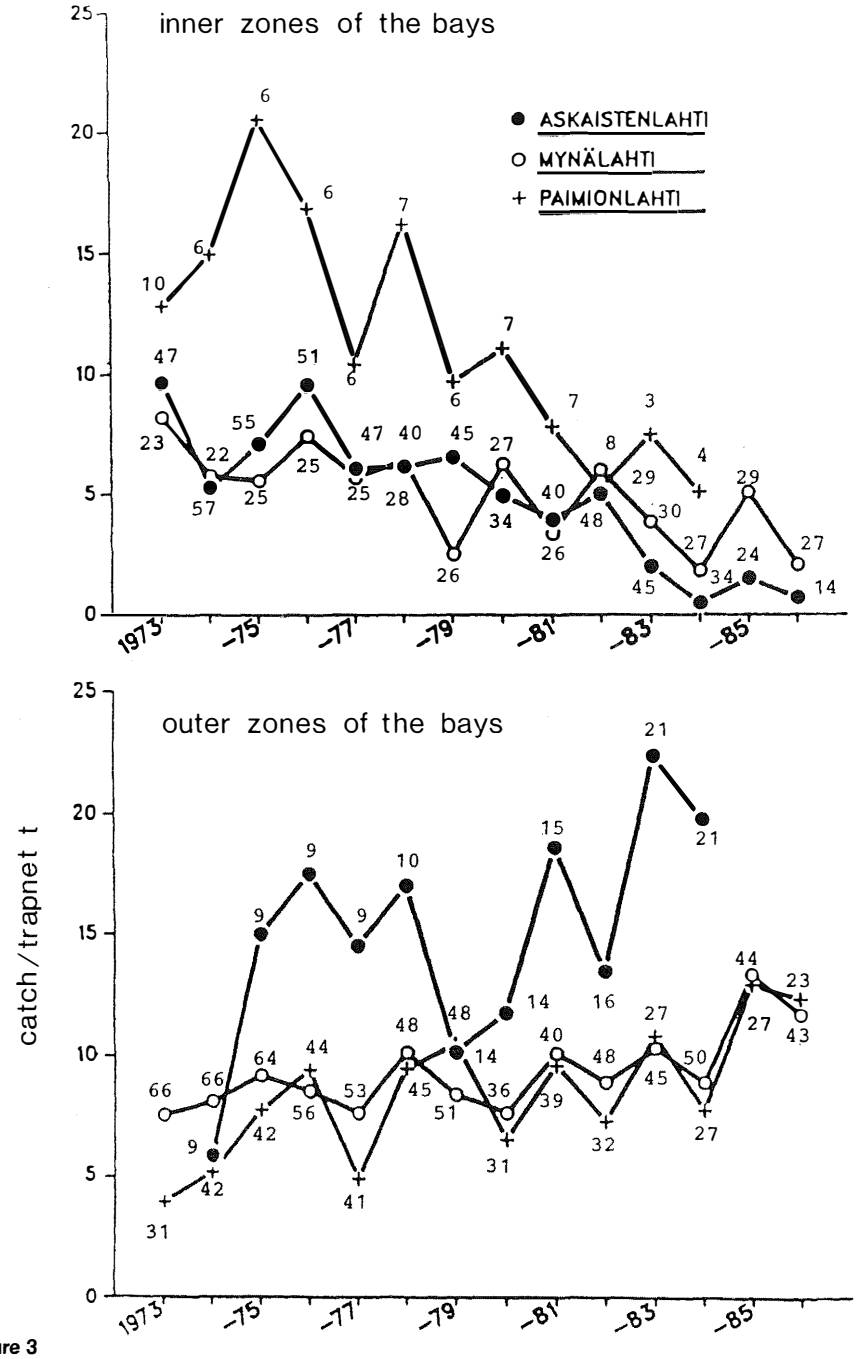

Figure 3

The development of herring trapnet catches in the inner and outer zones of the bays Askaistenlahti, Mynälahti and Paimionlahti. Yearly number of trapnets are presented in every bay studied.

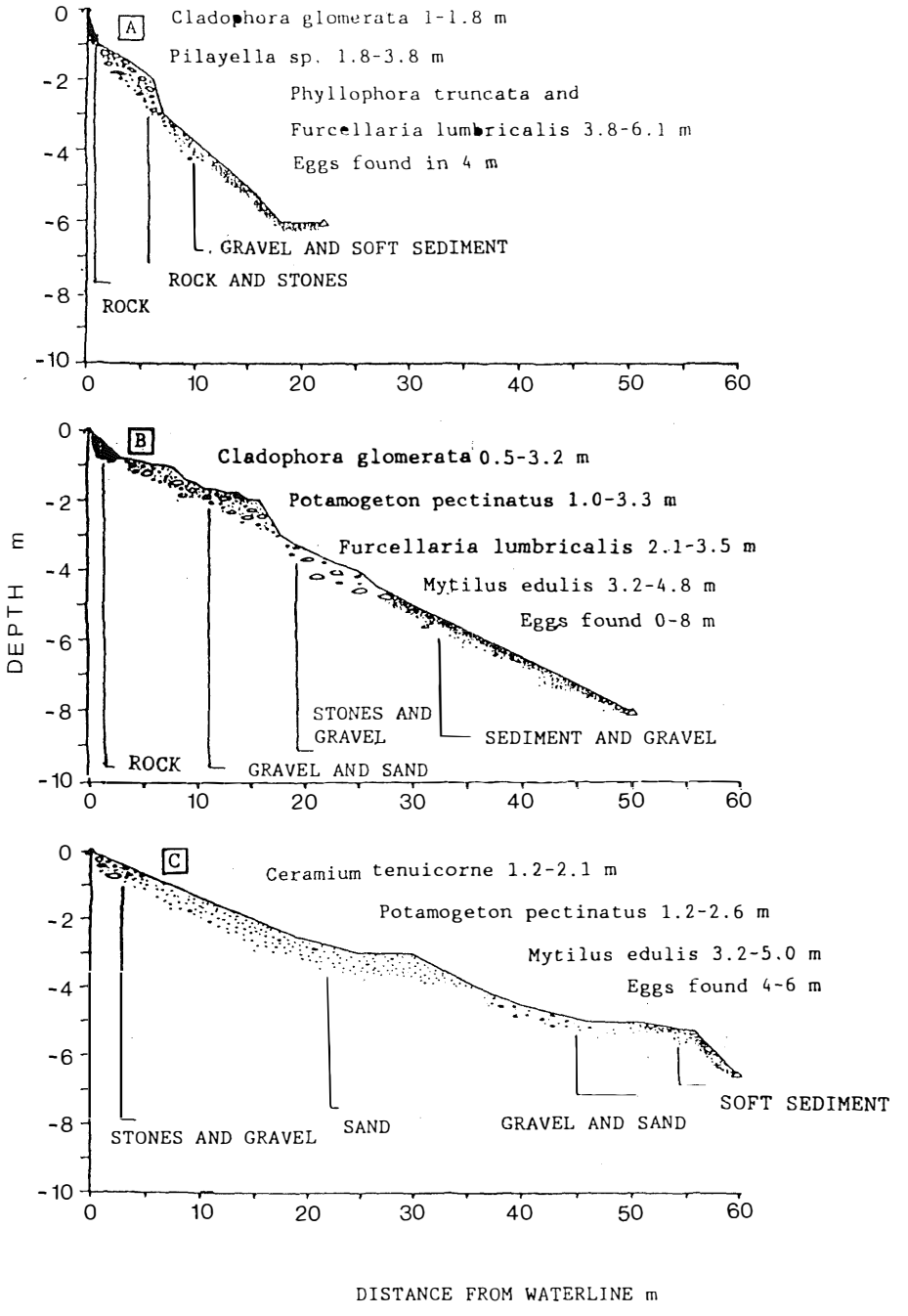

Figure 4

The profile and quality of the bottoms in some spawning grounds of the Baltic herring. The locations of the shores (A, B, C) is given in Fig. 2. The dominant plant species and *Mytilus edulis* (cover % > 20) and the depth of their occurrence are given.

In the outer parts of the bays, the bottoms in the upper littoral were free of soft sediments, due to the high degree of exposure to water currents. In the inner zones of the bays where no eggs were found, the bottoms were almost covered by loose organic sediments, starting at the depth of one meter. In the only spawning ground situated in this zone, the bottom material consisted of gravel on which only a thin layer of sedimented matter was found (Fig. 4A). In many places, vegetation was absent or scarce, the species composition still being typical for the coastal areas (*Fucus, Cladophora, Potamogeton,* red algae).

Discussion

The common feature of the bays studied is that they are all recipients of river discharges. Especially the loading from cultivated areas has influenced the coastal waters, which are shallow and contain numerous islands. The catchment area of the Archipelago Sea is intensively cultivated, and this has led to a continuous increase in the nutrient load from land (LAAKSONEN 1970, PITKÄNEN 1986). Soil erosion has increased in recent decades, mainly as a consequence of the changed structure of agriculture in the region (MANSIKKANIEMI 1982). During the flood periods in spring and autumn, the increased amounts of suspended matter and nutrients influence extensive sea areas. This can be seen in the inner zones of the bays as increased deposition, which has modified the original gravel and sand bottoms.

The fact that herring prefers as a spawning substrate vegetation growing on gravel and stone bottoms is well documented in the Baltic sea (RANNAK 1959, ANEER and NELLBRING 1982, OULASVIRTA et al. 1985, RAJASILTA et al. 1986). In our study area, eggs have never been found on soft bottoms, and this seems to be the case in other areas, too.

High phytoplankton production and high water turbidity are common features both in northern Airisto and the three bays studied. However, as fish continue to spawn in the former area, the poor visual conditions or water quality cannot explain the changed behaviour of the fish. A high load of suspended matter from rivers is also common to these areas, but in Airisto this has not led to sedimentation of the shores as in the inner parts of the bays. Towards the more open sea area, wave action keeps the bottoms clean, whereas in the sheltered bays sedimentation rates are high.

Changes in the fishing effort do not suggest possible reasons for the changed catches. However, the poor catches are most obviously not a result of overfishing, as the bays have traditionally been intensively fished. According to the local fishermen, e.g. in Askaistenlahti Bay, the number of trapnets has decreased only because fishing is unprofitable, and many fishermen have moved their trapnets to the outer parts, where the yield is greater.

We thus conclude that lack of suitable spawning grounds may have resulted in the decrease of catches in the inner parts of the bays. The causality seems obvious, but the details of this process are still unknown. If the spawning fish do not avoid the bay areas because of the poor water quality, what cues do they follow in searching for a suitable spawning ground? The spawning substrate and bottom quality are tested first when spawning (see STACEY and HOURSTON 1982), and thus the fish should at last visit the bays, if they do not spawn there. This again, would not lead to a decrease of catches. One possible reason could be that each of the bays has its own herring stock, and these are near extinction because the breeding areas have been destroyed. The present increase in catches in outer zones of the bays, in turn, could partly be a result of the general increase in herring catches (ANEER 1985).

Another possibility is that the fish change their spawning areas over a long time span, using different places in different years. This kind of behaviour has been found e.g. in Pacific herring (HAY and KRONLUND 1987). Our study period is still too short to show any long-term changes, and it is possible the fish will return to the inner parts of the bays in the future. However, as there are only a few suitable grounds left in the bays for spawning, the production of offspring will remain permanently low in these areas.

Acknowledgements

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