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Anthropogenic impacts on the Baltic Sea – problems and solutions

By Brian MacKenzie

Abstract

The Baltic Sea is a semi-enclosed estuarine ecosystem in northern Europe and is subjected to multiple human impacts. Overfishing/hunting, eutrophication, contamination and species introductions have all occurred in the past century and are still continuing. These impacts are affecting both the biodiversity and the functioning of the ecosystem. The international response in the Baltic region to these impacts has been to develop and implement monitoring systems and to produce new science-based guidelines and regulations to encourage positive changes in societal behaviours that affect the Baltic ecosystem. These activities have originated in organisations such as HELCOM (www.helcom.fi) and ICES (www.ices.dk).

The Baltic Sea is a semi-enclosed sea in northern Europe. Its watershed contains nine countries and is home to over 80 million people. The presence of a large population in a relatively small area has resulted in several human impacts on the Baltic ecosystem. These include (over) exploitation of living resources, eutrophication, pollution by hazardous substances, extensive marine mammal hunting, shipping, and introduction of non-native species (Helcom 2002). This review briefly summarises the main effects of these impacts on the Baltic ecosystem, its biodiversity and how society and the scientific community are taking steps to improve the Baltic ecosystem.

Hydrographic considerations

Human impacts on the Baltic Sea are amplified by its hydrographic situation. Salinity is low because of large freshwater inputs and infrequent major inflows of saline water from the North Sea (Schinke and Matthäus 1998; Helcom 2002). Tides are negligible. Nutrients and contaminants introduced to the Baltic therefore have long residence times. Moreover, oxygen concentrations in the deep parts of the Baltic decrease between major seawater inflows and they frequently reach anoxic levels (Matthäus 1995; Schinke & Matthäus 1998; Helcom 2002). Seasonal hypoxia occurs in shallow areas due to high temperature and eutrophication (Ærtebjerg *et al.* 2003).

Biodiversity

The biodiversity of the Baltic Sea is much lower in terms of species richness than other marine areas of comparable size (e.g. North Sea, Black Sea; Figs. 1, 2). The main reason for the decrease in species' numbers is low salinity. This imposes a physiological stress on marine organisms and on freshwater species inhabiting coastal areas (Voipio 1981; Helcom 2002).

Some species have physiological and genetic adaptations to the low salinity in the Baltic (cod *Gadus morhua*; Vallinn *et al.* 1999; Nielsen *et al.* 2001; the polychaete *Marenzelleria cf. viridis*; Schiedek 1997). However, in some years even these adaptations are insufficient to ensure reproductive success (e.g., cod: Köster *et al.* 2001; MacKenzie *et al.* 2002).

Human impacts on biodiversity and the ecosystem of the Baltic

(i) Exploitation of living resources

Fishing and hunting probably have the longest history of human impact on the Baltic biodiversity and ecosystem. Fish populations in coastal areas and rivers have been exploited by local fishermen since at least the medieval

period (Enghoff 1999; MacKenzie *et al.* 2002). Large marine and estuarine fauna such as sturgeon, seals and harbour porpoises have been hunted or exploited to near extinction (Elmgren 1989; Helcom 2002; MacKenzie *et al.* 2002). Fish landings have increased substantially during the 20th century (Fig. 2), primarily due to increases in fishing effort and technology (Bagge *et al.* 1994). High exploitation has reduced biomass of some species and populations (e.g., eastern Baltic cod, salmon) to levels which may not be sustainable (ICES 2004).

(ii) Species introductions

Approximately 100 species have been intentionally or accidentally introduced into the Baltic, particularly during the last 30-40 years. These introductions are mainly due to increased ship traffic (Leppäkoski *et al.* 2002) and can affect ecosystem structure and function. For example, the introduction of *M. cf. viridis* has changed soft-bottom community structure in coastal areas (Daunys *et al.* 2000; Leppäkoski *et al.* 2002).

(iii) Eutrophication

Eutrophication was one of the major impacts on the Baltic Sea during the 20th

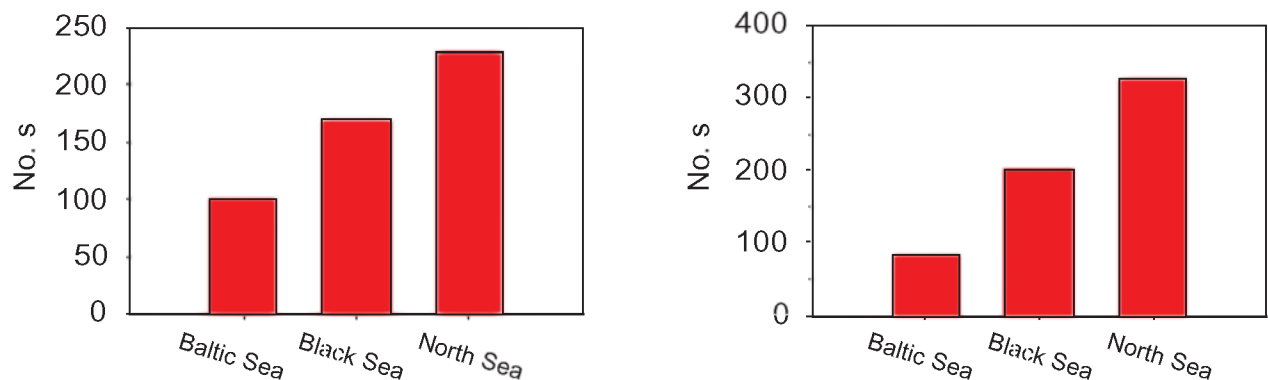


Fig 1. Comparison of biodiversity (species richness) of the fish (left panel) and phytobenthos (right panel) communities in three marine ecosystems of comparable area. Data source: EEA 2002.

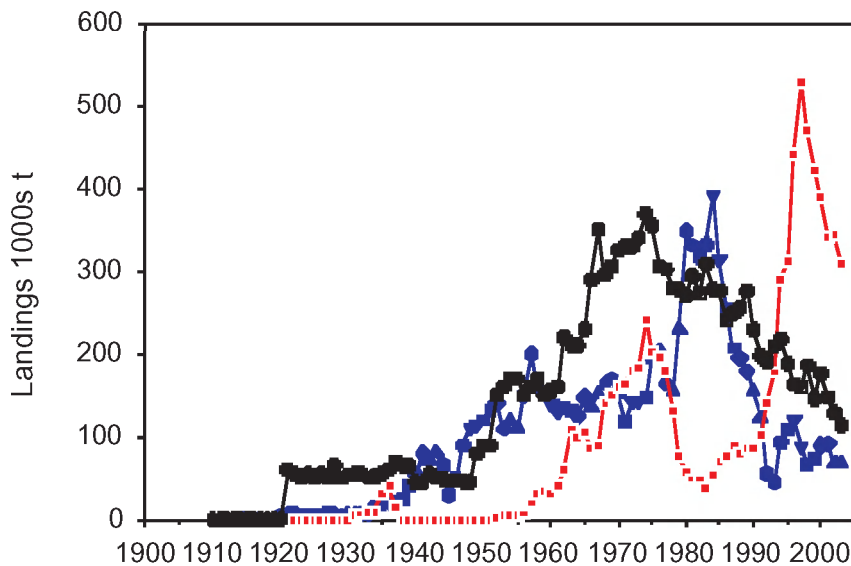


Fig 2. Landings of the three commercially most important fish species (cod, herring, sprat) in the Baltic Sea during the 20th century. Triangles: cod; circles: sprat; diamonds: herring. Data sources: (Sparholt 1994; ICES 2004).

century (Helcom 2002; Figs. 3, 4). Increased rates of organic matter production have led to more frequent and more extensive anoxia events in the deeper parts of the Baltic Sea (Helcom 2002). These events kill benthic life, which is only renewed following major inflows of saline, oxygen-rich water from the North Sea (Helcom 2002). As a consequence, eutrophication has had some negative effects on Baltic biodiversity over restricted time and space scales.

In addition, eutrophication probably reduces reproductive success in the cod population because of the more extensive and frequent anoxia conditions in deep waters where cod spawn. Hence eutrophication may have accentuated the effects of reduced inflow frequency in recent decades on cod spawning habitat and reproduction (Köster *et al.* 2001; MacKenzie *et al.* 2002).

Eutrophication may have contributed, along with a large increase in fishing effort and improved technology, to the overall increase in fish landings during the 20th century (Thurow 1997). However, this link has not been conclusively demonstrated (Hansson & Rudstam 1990; MacKenzie *et al.* 2002).

(iv) Contamination by hazardous substances

The Baltic has received large inputs of toxic compounds (e.g. persistent organic pollutants, heavy metals) since the mid-1900s (Helcom 2002), but effects on biota remain poorly documented (Lehtonen & Schiedek 2004). Nevertheless, populations of some higher trophic level species (e.g. seals, fish-eating eagles) have declined partly due to contaminant-induced reproductive problems (Helcom 2002).

Fortunately, loading rates and concentrations in biota of many of these compounds (e.g. PCBs, DDTs, mercury and cadmium) have fallen during the last 20-30 years (Helcom 2002; MacKenzie *et al.* 2004; Fig. 4) due to international bans on their use and production. However, concentrations of some substances are still high and new toxic substances are being developed and produced by society (Helcom 2002). For example, dioxin concentrations in herring and salmon in the southern Baltic were above maximum acceptable levels in 2003 and 2004 (DVFA 2004). As a result, some authorities closed fisheries for these species in 2004 (DVFA 2004).

It seems unlikely that contaminants have totally eradicated any species from the Baltic, although contaminants have affected relative abundances of species either directly (via impaired reproduction) or indirectly (e.g. via bans on exploitation of some species).

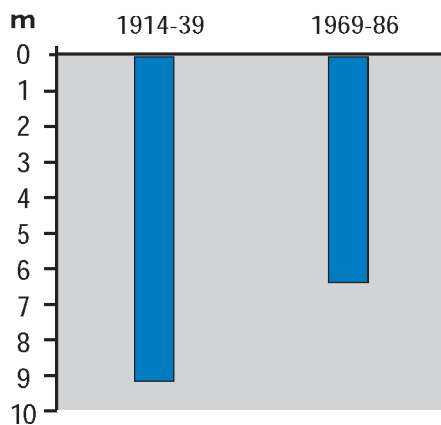


Fig 3. Change in water transparency (m) of the Baltic Sea during the early and late 20th century (EEA 2002).

(v) Climate change and species composition

There is increasing evidence that society is altering global climate (IPCC 2001). Some of these changes appear to be affecting conditions in the Baltic. Spring/early-summer temperatures in the Baltic Sea in the last 10-15 years have been above average (MacKenzie & Köster 2004) and most winters in the same time period have been mild (FIMR 2004). Warmer temperatures (Fig. 5) benefit some Baltic herring and sprat populations (Axenrot & Hansson 2003; MacKenzie & Köster 2004) and change the species composition of the Baltic zooplankton community (Dippner *et al.* 2000; Möllmann *et al.* 2002).

Increases in precipitation are another expected consequence of climate change (IPCC 2001). High precipitation reduces Baltic salinities (Hänninen *et al.* 2000), which in turn lead to changes in the species composition of the zooplankton community (Viitasalo *et al.* 1995; Vuorinen *et al.* 1998). Future climate change will have a major impact on biodiversity of the Baltic ecosystem.

(vi) Interactions between anthropogenic impacts

Anthropogenic impacts can interact with each other and can amplify the effects of single impacts operating individually. For example, the combination of high fishing rates since the 1980s and eutrophication has probably reduced the cod stock faster than would have been the case if one of these factors was not occurring.

Solutions to anthropogenic impacts

Anthropogenic impacts on the biodiversity and ecosystem of the Baltic Sea have occurred over decades and centuries. Some of these impacts are potentially reversible but will take a long time to reverse. Prerequisites for reducing the negative impacts of society on Baltic biodiversity are a recognition that problems exist and the identification of ways to overcome them. In the Baltic, many of the problems first became evident only when they became severe enough to directly impact the public (e.g., appearance of algal blooms on seashores, reductions in catches and sightings of certain species). The public interest stimulated authorities, including the scientific community, to develop monitoring and scientific programmes to identify causes of changes. In situations where causes have been identified, and where remedial actions can be taken, new national and international regulations have been developed and implemented to prevent or reduce further impacts.

As a result, the combination of monitoring, scientific investigation, implementation of new

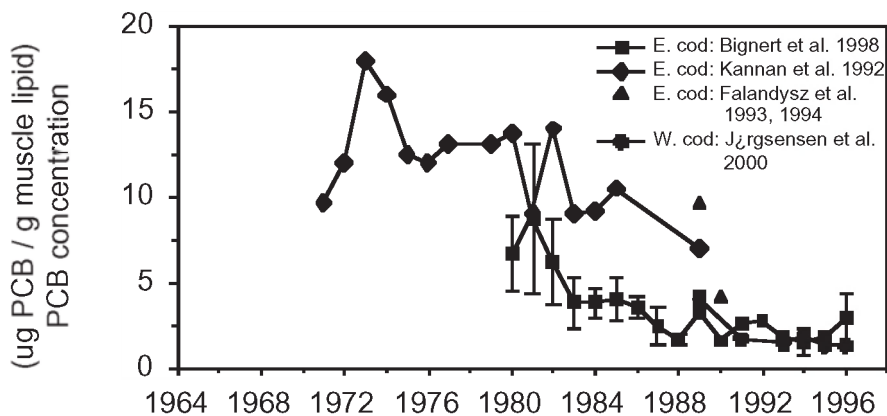
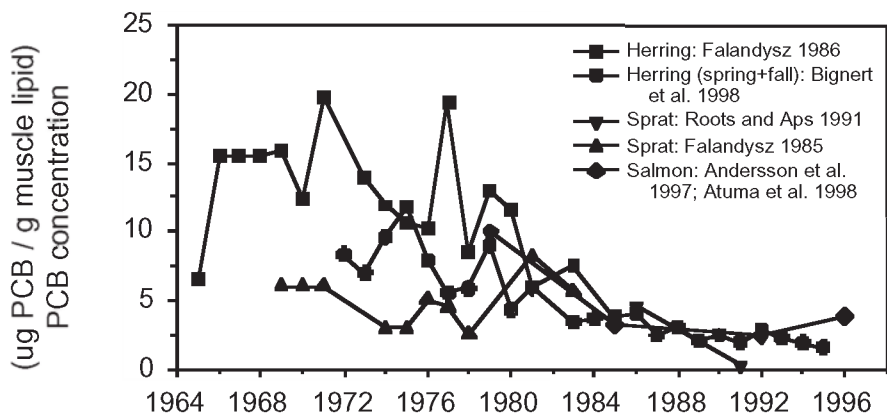


Fig 4. PCB concentrations in tissues of Baltic fish species during the past 30 years (top panel: herring, sprat, salmon; bottom panel: cod). See MacKenzie *et al.* (2004) for data sources.

environmental policies and governance has led to some substantial improvements in the Baltic Sea ecosystem. Scientific discussions have taken place, particularly within ICES, and the development of guidelines and implementation frameworks have occurred with the support of the Helcom agreement, and increasingly the EU and European Environmental Agency. Successful implementation has required strong political and public support, and recognition that a safe, clean and properly functioning Baltic ecosystem has significant ecological, cultural, social and economic value. This socio-cultural context appears to be present among countries bordering the Baltic Sea, and will need to persist and be strengthened in order to prevent further degradation of its biodiversity and ecosystem.

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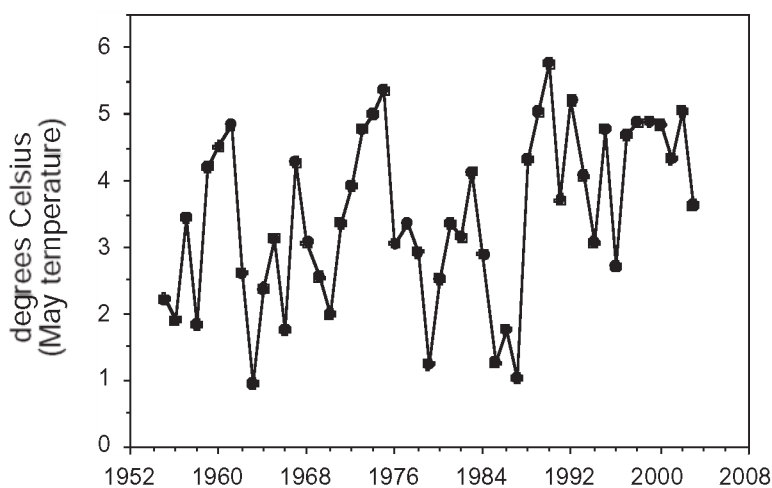


Fig 5. May temperature at 45-65m depth in the Bornholm Basin, Baltic Sea from 1955-2003 (MacKenzie & Köster 2004, with data for 2000-2003 provided by Dr H-H Hinrichsen, GEOMAR, Kiel).



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Fishing.

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