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Mercury concentration trend as a possible result of changes in cod population demography

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ABSTRACT

Mercury (Hg) in Atlantic cod (*Gadus morhua*) is one of many parameters that are monitored through OSPAR's Joint Assessment and Monitoring Programme. Time series for cod in the Inner Oslofjord (Norway) go back to 1984. Until 2014, annual median Hg-concentrations in cod from the Inner Oslofjord showed both significant upward long-term (whole time series) and short-term (recent 10 years) trends (when 2015 was included, the short-term trend was not significant). However, the median length of the cod sampled also showed upward trends. This may have been caused by low cod recruitment in the area since the start of the 2000s, as indicated by beach seine surveys. To investigate how length would impact the trend analysis, the Hg-concentrations in the cod were normalised to 50 cm. No significant short-term trend in Hg-concentrations could be detected for length-normalised concentrations. The results indicated that most of the upward trend in Hg-concentrations could be attributed to the sampling of larger fish. The reasons for the apparent change in the cod population demography are not conclusive, however, sampling bias must also be considered.

1. Introduction

Mercury (Hg) is an element entering the biosphere from natural and anthropogenic sources. In aquatic systems, anoxic conditions favour the bacterial transformation of inorganic Hg to methylmercury (MeHg), which is the most toxic form of Hg. It acts as a neurotoxin and may cause harmful effects on organisms (Dietz et al., 2013). Methylmercury also has a greater potential for bioaccumulation than elemental Hg and is subject to biomagnification (i.e. the concentration in an organism exceeds that in the organism's diet due to dietary absorption, thus the concentration increases with higher trophic level; Kidd et al., 2012; Ruus et al., 2015). Therefore, high concentrations of Hg (mostly in the form of MeHg) may accumulate in fish tissues (Julshamn et al., 2011; Teffer et al., 2014). Since fish is a main route of Hg exposure to humans (WHO, 1990), high concentrations of Hg in fish food is of concern in a human health context.

Mercury in Atlantic cod (*Gadus morhua*) is one of many parameters that are monitored through the Norwegian contribution to the Hazardous Substances Theme of OSPAR's (Oslo and Paris Commission) Joint Assessment and Monitoring Programme (JAMP). This contribution is conducted by the Norwegian Institute for Water Research (NIVA) by contract from the Norwegian Environment Agency. JAMP has protocols for sampling and data treatment to facilitate common practice among the contracting countries that border the Northeast Atlantic Ocean (OSPAR, 2008, 2012). The current focus of the Norwegian contribution is on the levels, trends and effects of hazardous substances. The results from Norway and other OSPAR countries provide a basis for a holistic assessment of the state of the marine environment in this region. OSPAR receives guidance from the International Council for the Exploration of the Sea (ICES).

Due to improved regulations, the loads of Hg entering the European marine environment has declined substantially since 1990 (OSPAR, 2009). For instance, riverine inputs of total Hg to the North Sea and Celtic Sea decreased by 75% and 85%, respectively, during the period 1990–2006. In some areas these numbers are partly impacted by changes in the analytical limit of detection (LoD),

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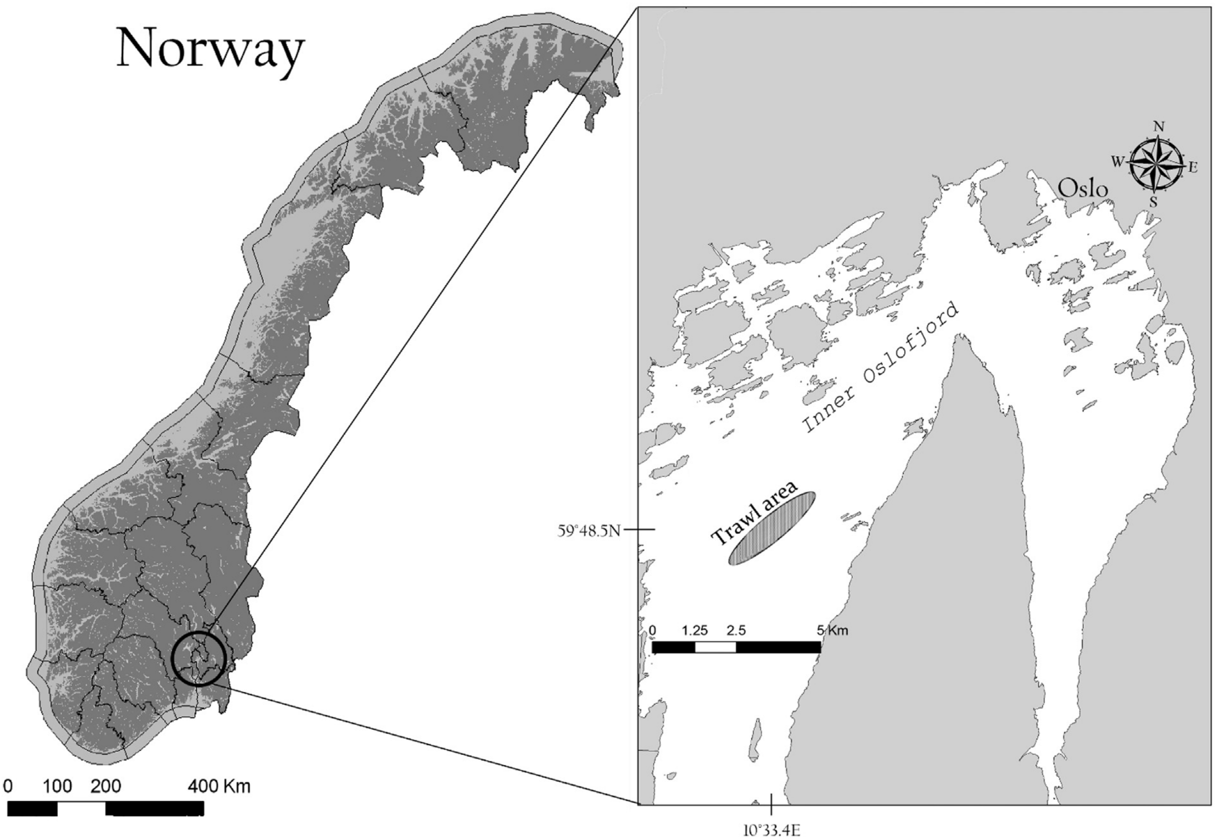

Fig. 1. Map showing the Inner Oslofjord. Oslo, the capital of Norway, is situated in the innermost part of this area. The sampling area of cod (*Gadus morhua*) is indicated.

however, in other areas where LoD was not an issue, there were similar trends, e.g. Rhine/Meuse (71% decrease) and Elbe (69% decrease; OSPAR, 2009). These trends are not always reflected in corresponding trends in biota concentrations. One example is the Inner Oslofjord, where observations have indicated an upward time trend for Hg in cod muscle in recent years (e.g. Green et al., 2014). A reason for this apparent upward trend may be year-to-year variations in the size of the sampled cod. Mercury accumulates in fish tissue and older and larger fish thereby tend to have higher Hg-concentrations (e.g. Green and Knutzen, 2003; Sackett et al., 2013).

The objective of this study was to describe temporal changes in the Hg-concentrations in cod muscle from the Inner Oslofjord, based on annual sampling since 1984, and analyse how the annual size distribution of the cod may influence time trends.

2. Material and methods

2.1. Study site and sampling

Oslo, Norway's largest city (urban area population: 942 000; Fig. 1), is located in the Inner Oslofjord. In addition to municipal discharges, the Inner Oslofjord is also affected by industry, leisure boats, ferries, freighters, and cruise ships. Various compounds enter the Inner Oslofjord *inter alia* through surface water/storm water (Ruus et al., 2016). The sediments of the fjord are also contaminated with various persistent "legacy" contaminants, and rivers discharge contaminants from industrial areas and contaminated sites from past industry, as well as from long-range transport to the catchment area (Skarbøvik et al., 2015). There are also two large sewage treatment plants in the vicinity of Oslo, that use the Inner Oslofjord as a recipient. Environmental monitoring and screening for emerging contaminants have shown that different compartments of the fjord (water, sediment and/or organisms) are contaminated with *inter alia* metals, organochlorine compounds, brominated compounds, organotin, polycyclic aromatic hydrocarbons, pharmaceuticals, siloxanes, bisphenols and UV filter chemicals (Ruus et al., 2016; Thomas et al., 2014). The Inner Oslofjord is connected to the Skagerrak region of the North Sea through a narrow sound (the Drøbak sound) with a sill depth of 20 m, which limits water exchange (Staalstrom and Roed, 2016).

Cod were collected annually in the Inner Oslofjord (Fig. 1), in accordance with OSPAR guidelines (OSPAR, 2012).[1] Prior to 2012, the protocols required 25 individuals to be collected annually, but since 2012 only 15 cod were required annually. According to the sample protocol the age of the cod should preferably be within 1–3 years. Smaller fish should if possible be selected to reflect recent influence and reduce the effect of sex, as age determination without dissection is not possible. When the amount of tissue needed for all analyses within an integrated chemical and biological effect monitoring programme is not sufficient, selection of larger fish, or pooling of samples, may be appropriate. If possible, we aspired to collect cod within five size classes, with the same number of individuals within each class (i.e. 3 individuals in each class since 2012): 370–420 mm, 420–475 mm, 475–540 mm, 540–615 mm and 615–700 mm.

The fish were caught by benthic trawl (15 × 6.5 m opening; 1600 meshes; mesh size 20 × 20 mm; equipped with a separation grid), from R/V Trygve Braarud during autumn (mostly November) each year since 2005. Prior to that, the autumn catch was commissioned

[1] See also http://www.ospar.org/work-areas/hasec.