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ScienceDirect
Marine Pollution Bulletin 53 (2006) 437–450
MARINE POLLUTION BULLETIN
www.elsevier.com/locate/marpolbul

Basic physiological biomarkers in adult female perch (*Perca fluviatilis*) in a chronically polluted gradient in the Stockholm recipient (Sweden)

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Abstract

By measuring a battery of basic physiological biomarkers and the concentration of ∑DDT in adult female perch (*Perca fluviatilis*), an assumed aquatic pollution gradient was confirmed, with the city of Stockholm (Sweden) as a point source of anthropogenic substances. The investigation included an upstream gradient, westwards through Lake Mälaren (46 km), and a downstream gradient, eastwards through the Stockholm archipelago (84 km). The results indicated a severe pollution situation in central Stockholm, with poor health status of the perch: retarded growth, increased frequency of sexually immature females, low gonadosomatic index, and disturbed visceral fat metabolism. ∑DDT, measured as a pollution indicator, was 10–28 times higher than the background in perch from the Baltic Proper. Besides the main gradient other sources of pollution also influenced the response pattern of the measured biomarkers. In particular, there were strong indications of pollution coming from the Baltic Sea.

Keywords: DDT; Growth; Maturation status; Normalisation; Reproduction; Visceral fat

1. Introduction

This paper presents the results of the analyses of basic physiological biomarkers and the quantification of dichlorodiphenyltrichloroethane and its metabolites (∑DDT, defined below) in adult female perch (*Perca fluviatilis*) from a pollution gradient in Lake Mälaren and the Stockholm archipelago (Baltic Sea) in 1999, 2000, and 2001. The main objectives of the investigation were: (1) to investigate an assumed aquatic pollution gradient with the city of Stockholm as a point source of anthropogenic substances using a battery of basic physiological biomarkers and measuring muscle concentrations of ∑DDT, (2) to investigate the health status of a stationary fish species in the Stockholm recipient, and (3) to evaluate the selected biomarkers. No similar biomarker studies of fish have been performed in the Stockholm recipient previously. Stockholm is an old city and its population, including the suburbs, has grown from 370,000 inhabitants in 1900 (Ahlberg, 1958) to 1,000,000 in 1950 and 1,670,000 in 2000 (Anonymous, 2005a). Due to the well-known production, public handling and common occurrence of a multitude of chemicals, the pollution situation can be regarded as chronic. ∑DDT was chosen as a pollution indicator, since it is a good representative for the pollution from Stockholm. The reason for this is that old DDT containing products, material, and waste is still in circulation in Stockholm, while emissions from agriculture ceased already in the 1970s, when DDT was banned in Sweden. This investigation differed from most biomarker studies in that the source of pollution was a large city and not a more or less specific industrial site. Accordingly we may assume that the Stockholm recipient is polluted by a wide variety of xenobiotics emanating from human activities, rather than by more specific chemical waste.

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doi:10.1016/j.marpolbul.2006.02.007

2. Material and methods

2.1. Time and area of investigation

Adult female perch were caught between 22 September and 9 October in the years 1999, 2000, and 2001 at four upstream stations in Mälaren and six downstream stations in the Stockholm archipelago (Fig. 1, Table 1). The length of the entire gradient was 95 km by air (35 km in Mälaren and 60 km in the Stockholm archipelago), and 130 km by water (46 km in Mälaren and 84 km through the Stockholm archipelago). Perch has a documented stationary behaviour (Böhling and Lehtonen, 1985), so the results can be assumed to reflect the area where the perch were caught.

Station 1-Adelsön, the most distant station in Mälaren, has both agricultural and woodland surroundings. Station 2-Lövstafjärden is situated close to an old refuse dump for household and industrial waste. The refuse dump covers about 130,000 m^2 and is situated near the shoreline. Stations 3-Klubben, 4-Riddarfjärden, and 5-Waldemarsudde are situated in central Stockholm. Two sewage treatment plants have their outlets near 5-Waldemarsudde. A third sewage treatment plant has its outlet midway between 5-Waldemarsudde and 6-Tegelön. The three sewage treatment plants receive water from households as well as small to middle sized industries. Stations 6-Tegelön and 7-Torsbyfjärden belong to the inner archipelago, 8-Gällnöport belongs to the middle archipelago, and 9-Lökholmen and 10-Björkskär belong to the outer archipelago (Fig. 1).

According to Engqvist and Andrejev (2003) the main current from the mouth of Mälaren in the very centre of Stockholm (midway between 4-Riddarfjärden and 5-Waldemarsudde) runs eastwards from Stockholms Ström (5-Waldemarsudde), via Fjäderholmsområdet, Askrikefjärden (6-Tegelön), Torsbyfjärden (7-Torsbyfjärden), Solöfjärden, Trälhavet, Västra Saxarfjärden, and Östra Saxarfjärden to Sandöfjärden (8-Gällnöport), whereafter water exchange occurs in directions between north and east (Fig. 1). (The names of the basins are those used by Engqvist and Andrejev, 2003.) In Saxarfjärden the main current from Stockholm is also mixed with a large northerly net supply of water from Norrfjärden via Furusundsleden (Engqvist and Andrejev, 2003).

The possibility to relate our results to the waterway distance from central Stockholm was investigated by comparing the distance with the dilution of the water from Mälaren on its way through the Stockholm archipelago. There was, in fact, a good negative correlation ($r = -0.992$, $p = 0.0060$) between these variables. The dilution, defined as the relative concentration of a solute, was calculated from the increasing salinity from central Stockholm towards the open Baltic Sea at 4 m depth (data from Stockholm Vatten, Christer Lännergren, Sweden).

The salinity gradient ranged from practically 0 in Mälaren to 5.4 in the open Baltic Sea. It is unlikely that the differences in salinity between the stations would have had any significant effect on the investigated variables, since it has been shown that perch maintains homeostasis up to a salinity of the surrounding water of at least 10 (Lutz, 1972).

It is also unlikely that any differences in temperature or dissolved oxygen would have significantly affected the investigated variables. At 4 m depth the temperature differences between the sampling occasions were generally in the range 0–2 °C (data from Stockholm Vatten, Christer Lännergren). There was a good similarity in water temperature between the investigated stations during the year and between years (Lännergren, 2002; Anonymous, 2004). The only obvious difference was a slightly higher amplitude (4–5 °C) of the annual temperature cycle in Mälaren than in the Stockholm archipelago (Lännergren, 2002; Anonymous, 2004). This means that the temperature history of the perch is also practically the same for all investigated stations.

At the time of sampling the oxygen concentration at 0–10 m depth ranged between 7 and 10 mg/L (data from

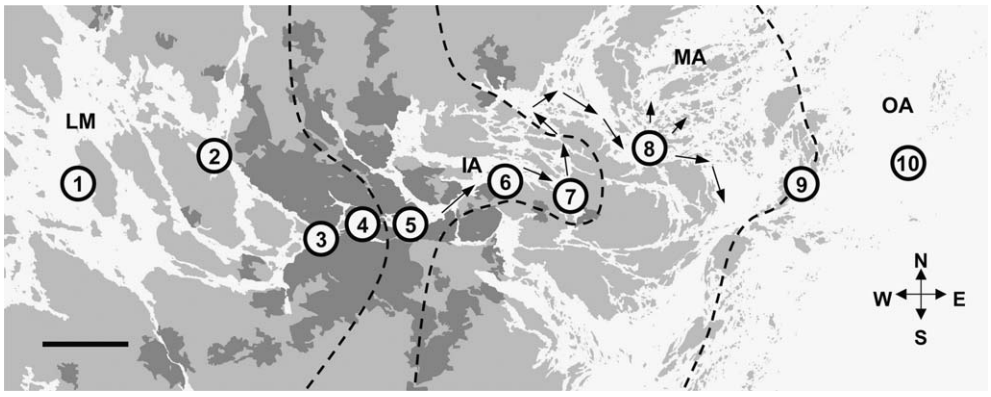

Fig. 1. The Stockholm recipient (Sweden): Lake Mälaren (LM), Inner archipelago (IA), Middle archipelago (MA), Outer archipelago (OA). Upstream stations: 1-Adelsön, 2-Lövstafjärden, 3-Klubben, 4-Riddarfjärden. Downstream stations: 5-Waldemarsudde, 6-Tegelön, 7-Torsbyfjärden, 8-Gällnöport (control), 9-Lökholmen, 10-Björkskär. White: water. Grey: land. Dark grey: urban area (Stockholm). Broken lines: delimitations between the four parts of the recipient. Arrows: main current from Lake Mälaren through the Stockholm archipelago. Scale: 1:900,000. Scale bar: 10 km.