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

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Abstract

A battery of biochemical biomarkers and the ∑PCB concentration in adult female perch (*Perca fluviatilis*) verified an aquatic pollution gradient with the city of Stockholm (Sweden) as a point source of anthropogenic substances. The investigation included both an upstream gradient, 46 km westwards through Lake Mälaren, and a downstream gradient, 84 km eastwards through the Stockholm archipelago. Besides the main gradient from Stockholm, there were strong indications of pollution coming from the Baltic Sea. The results indicated a severe pollution situation in central Stockholm, with poor health status of the perch, characterised by increased specific EROD activity in the liver, increased liver EROD somatic index, decreased AChE activity in the muscle, increased amount of DNA adducts in the liver, and a high concentration of biliary 1-pyrenol. In addition, laboratory exposure to common EROD inducers elicited an abnormal response, suggestive of chronic intoxication.

Keywords: AChE; DNA adducts; EROD; Metallothionein; PAH metabolites; PCB

1. Introduction

This paper presents the results of the analyses of biochemical biomarkers and the quantification of polychlorinated biphenyls (∑PCB, defined below), hexachlorobenzene (HCB), and hexachlorocyclohexanes (∑HCH, defined below) in the muscle of 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 biochemical biomarkers and measuring muscle concentrations of ∑PCB, HCB, and ∑HCH; (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. ∑PCB was chosen as a pollution indicator, since it is a good representative for the pollution from

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Stockholm, and has been so for a long time. 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. To facilitate the interpretation of the field data, two laboratory experiments were performed. In 2001 feral perch were injected with benzo[*a*]pyrene (B[*a*]P) and in 2002 cultured juvenile sea trout (*Salmo trutta*) were exposed to sediments collected at the stations where the perch were caught.

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 northerly to easterly direction (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).

2.2. Choice of control station

The most distant station, 10-Björkskär, was originally selected as the local control station. During the progress of the work, however, we found that Stockholm was not the only important source of pollution in the investigated area. Strong indications of pollution coming from the Baltic Sea made 10-Björkskär inappropriate as a local control station. It is reasonable to assume that the pollution from a large city is different from that coming from the Baltic Sea,

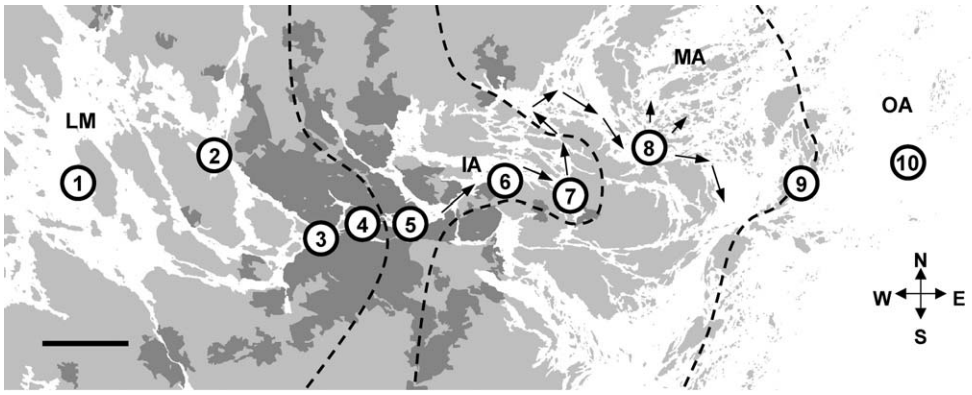

Fig. 1. The Stockholm recipient (Sweden): Lake Mälaren (LM), Inner archipelago (IA), Middle archipelago (MA), Outer archipelago (OA). Upstream stations: 1-Adelsön, 2-Lövstafjärden, 3-Klubben, 4-Riddarfjärden. Downstream stations: 5-Waldemarsudde, 6-Tegelön, 7-Torsbyfjärden, 8-Gällnöport (control), 9-Lökholmen, 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.