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The occurrence of organic contaminants in European eel (*Anguilla anguilla*) in Poland: An environmental quality assessment

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HIGHLIGHTS

- Large variety of contaminants and fat content in eel were determined.
- Results are evaluated in terms of environmental quality and consumer health.
- PBDE levels found in European eels are a cause for concern.
- Concentrations of contaminants and eel muscle fat contents did not correlate.

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ABSTRACT

The objective of the present study was to provide information on the levels of pollutants in the tissues of eels caught in Polish waters. The contaminants included in the study are those which have not yet been widely studied in eel stocks, but which arouse concern in relation to the environment. An overview of the pollutant levels in eels caught in other European waters was also conducted. The results are evaluated in terms of environmental quality and consumer health. The mean concentrations of ΣPBDEs and ΣHBCDs in muscles of eels sampled in Polish waters were between 1 and 2 ng g^{-1} ww. The mean TBT concentrations were between 2 and 4 ng g^{-1} ww with the exception of samples from the Szczecin Lagoon, in which the mean TBT concentration was about tenfold higher.

1. Introduction

Glass eels (*Anguilla anguilla*) stocks are declining throughout Europe, and their status is currently considered to be below safe biological limits. While the cause of the eel stock collapse has yet to be identified, it has been suggested that the accumulation of contaminants might be a factor in the decreasing quality of potential spawners, which negatively affects the reproductive success of the species (van Ginneken and van den Thillart, 2000; Robinet and Feunteun, 2002; Darnerud, 2003).

The toxic effects on eel of pollutants such as polybrominated diphenyl ethers (PBDEs), polybrominated biphenyls (PBBs), and hexabromocyclododecane (HBCDD), which belong to the brominated flame retardants (BFRs) group, are not well known and must be thoroughly studied. However, studies of other fish species indicate that BFRs can cause developmental effects, endocrine disruption, immunotoxicity, and reproductive effects (Hajslova et al., 2007; Norman et al., 2007; Rattfelt et al., 2008; Geeraerts and Belpaire, 2010).

Another group of contaminants that could pose a threat for aquatic organisms are organotin compounds (OTs), which have been used extensively in a variety of products including marine antifouling paints, agricultural pesticides, and plastic stabilizers (Arai 2012; Harino et al., 2000). Studies on the effects of organotins on aquatic organisms have demonstrated the high toxicity of TBT, which acts as an endocrine disruptor.

Those contaminants have not yet been widely studied in eel stocks and therefore they are included into the scope of this study. Other organic contaminants that are traditionally monitored in aquatic environments are also included in the study, as is an overview of pollutant levels in eels caught in other European waters.

It is important to note that this investigation of contaminant levels in eels provides useful information for the assessment of

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ecosystem quality. Because of its life cycle (van Ginneken and Maes, 2005), eel is the most susceptible to anthropogenic pressure during the continental phase of its life cycle when inhabiting coastal, estuarine, and inland waters. The study conducted by Tapie et al. (2011) revealed relatively low levels of contaminants in glass eels that penetrate continental freshwater systems. Glass eels do not feed, so in this stage of life they are exposed to contaminants through direct exposure to abiotic compartments. However, after pigmentation (yellow eels), the majority of individuals are feeding. At this stage of the life cycle, eels accumulate the pollutants present in the environment and in food (Tapie et al., 2011). The biomagnification of pollutants along food chains increases levels of pollutants and reflects the quality of the environments inhabited by eels.

The objectives of the present study were to provide information on the levels of pollutants in the tissues of eels collected in Polish waters and to compare these to levels of pollutants in eels from different European countries. Acquiring an overview of the chemical status of eel populations from all over Europe is an important objective for eel management.

2. Materials and methods

2.1. Sampling

Fish samples were collected from sites in various geographic regions and catchments with differing land use pressures. More than 150 eel samples were collected and examined during the 2010–2012 period. Sampling was conducted in the Vistula and Szczecin lagoons, the Puck Buy, the Mazurian Lakes: Śniardwy, Mamry, and Nidzkie lakes, and in Lake Jamno. Five eel samples were collected in the Vistula River near Toruń; these were all males with low body masses, so pooled samples comprising 3–5 individuals were prepared. The characteristics of the samples are presented in Table 1. The Szczecin Lagoon is a shallow, inland water basin situated in the southwestern part of the Baltic Sea at the mouth of the Oder River. The total area of the lagoon is 912 km^2, of which 457 km^2 lie within Polish borders, and the remainder is in Germany. The Vistula Lagoon is the largest brackish water basin in the southern Baltic. It is shared by Russia and Poland, and 328 km^2 of the total area of 838 km^2 is inside Polish borders. This highly eutrophic lagoon is connected to the Gulf of Gdansk by the Pilawska Strait. The mouths of a few branches of the Vistula and Pasleka rivers flow into the lagoon. The Gulf of Gdańsk is a partially enclosed basin which is exposed to high anthropogenic pressure from the three large coastal cities of Gdynia, Sopot, and Gdansk. The Vistula River, the longest river in Poland, passes through several large cities and also drains into the gulf. The Bay of Puck is the shallow, western part of the Gulf of Gdansk, and is separated from the Baltic Sea by the Hel Peninsula Sandbar.

The Mazurian lakes, located in northeastern Poland, comprise the largest complex of lakes connected by canals in the country and occupy approximately 20% of the surface area of the Mazurian Lake District. The area is heavily developed for tourism. The location sites are shown on a map provided as the Supplementary information.

Lake Jamno is located in northwest Poland and is connected to the Baltic Sea by the Jamieński Nurt canal. The lake is supplied by two rivers.

All of the fish samples were frozen immediately after catch and stored at -18 °C until the analyses were performed.

2.2. Chemical analysis

The detailed description of chemical analysis, standards and reference materials used as well as the description of quality assurance/control procedures and validation parameters are provided as the Supplementary information.

2.3. Data analysis

Statistical analyses were conducted with the STAT statistical software package (Statistica, Version 8.0). A significance level of $p < 0.05$ was applied. The analysis were performed for samples grouped according to a collection site.

3. Results and discussion

3.1. Lipid content in eel muscle

Lipid content is considered to be a general indicator of eel population health related to inter alia a reproductive success of the species. Eels inhabit different environments (freshwater, marine, estuarian) that differ in food webs and feeding conditions. Those factors have an effect on the fat content in fish. In addition it was postulated that some pollutants, like pesticides and PCBs, can affect eel lipid metabolism and reduce their ability to migrate and reproduce (Belpaire et al., 2009). Fat content above 20% is thought to be the minimum level required for normal migration and reproduction (Belpaire et al., 2009).

The extractable lipid percentages in the muscle tissues of the samples studied ranged from 4.89% to 30.90%. The data obtained for individuals grouped according to collection site are presented in Table 1. The highest lipids content were observed in samples from the Puck Bay, while fish caught in the Vistula River were characterized by the lowest lipid content. Lipid levels above 20% were observed in 37% of the samples from the Vistula Lagoon, 43% of the samples from the Szczecin Lagoon, 56% of the samples from the Puck Bay, and 26% of the samples from lakes.

Larger individuals were characterized by higher lipid contents than were smaller ones. However, Pearson's correlation analysis revealed statistically significant positive correlations between lipid content and fish body weight only in eels caught in the Vistula ($R^2 = 0.56$; $p < 0.0005$) and Szczecin ($R^2 = 0.229$; $p < 0.0005$) lagoons. The relation between lipid content and concentrations of contaminants in the samples studied is discussed later.

3.2. Pollutant distribution in eel samples

Studies of contaminants in fish are often conducted in view of consumer exposure, which is why they focus on muscle tissue. However, levels of contaminants in muscles do not necessarily

Table 1
Collection sites and samples characteristic.

Species	Location	Number of samples	Min–Max length (cm)	Min–Max weight (g)	Fat content in muscle tissue (%) Mean ± SD (Min–Max)
Eel	Vistula Lagoon	43	41–94	135–1606	20.03 ± 5.06 (9.52–30.90)
	Szczecin Lagoon	34	51–90	220–1920	19.79 ± 3.75 (11.37–28.64)
	Puck Bay	25	61–101	431–1860	23.87 ± 2.32 (19.57–27.16)
	River Vistula	5	34–64	100–192	12.92 ± 7.57 (4.89–22.21)
	Lakes	46	50–93	257–1586	18.74 ± 2.97 (9.72–23.15)