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Persistent organic pollutants (POP) in a benthic omnivore – A comparison between lake and stream crayfish populations

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Abstract

We investigated the accumulation of PCB and DDT in crayfish populations in 10 streams in southern Sweden. The results were compared with an earlier study on crayfish in lakes from the same area. We found that the concentration of pollutants in crayfish did not differ between the two types of systems. Variation in body burden was higher in stream living crayfish probably because of the higher influence from pollutants deposited in the catchment area and the more dynamic transport in streams. In streams, *p*,*p*′-DDE concentrations were positively correlated to trophic status (total phosphorous) while PCB did not show any correlation with the nutrient regime. Further, mean ΣPCB and *p*,*p*′-DDE concentrations in crayfish did not correlate in streams. We suggest that the sources of the two pollutants differ for stream living crayfish. The results indicate that crayfish in streams are affected to a higher degree to pollutants in the catchment area and the precipitation regime. In lakes, internal processes govern uptake of pollutants in crayfish.

Keywords: Persistent organic pollutants; Crayfish; Lakes; Streams; Trophic status; Land use; Stable isotopes

1. Introduction

Bioaccumulation of persistent organic pollutants (POP) in marine and freshwater ecosystems is a rather well investigated field when differences in individual or between species contamination is concerned. However, the impact of ecosystem related differences on POP concentrations in biota are still poorly investigated. Between lake ecosystems a few studies have revealed a negative relationship between trophic status and POP concentrations in pelagic biota (Taylor et al., 1991; Larsson et al., 1992; Kidd et al., 1999; Berglund et al., 2001). Recently, Holmqvist et al. (2005) showed that this relationship also is valid for profundal benthos mainly because these organisms feed on settling pelagic particles (phytoplankton), whereas no relationship between lake trophy and POP concentrations in littoral crayfish could be found. In streams even fewer studies concerning POP accumulation and between ecosystem differences have been conducted. Berglund et al. (1997, 2003, 2005) investigated POP accumulation in brown trout (*Salmo trutta*) across a trophic gradient of streams. The concentrations of POP in trout increased with increasing trophic status of the stream, that is the opposite relationship found in pelagic and profundal benthic biota in lakes. The increase of POP in streams with higher trophic status, i.e. high periphyton density, could be an effect of increasing retention of the pollutants in the increasing periphyton mats analogous to nutrients in the ‘‘spiralling hypotheses’’ (Newbold et al., 1981). The standing stock of periphyton could thereby act as an uptake route of POP into the food

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web of streams. The spiralling effect could thereby be "transferred" to consumers such as trout.

The transport of POP in streams and rivers has been reported to be dependent on the transport of organic material. Flooding events or other disturbances of the sediments will increase the transport of suspended organic matter and thereby the transport of associated POP (Quemerais et al., 1994; Rostad, 1997). The annual spring flooding in streams in the northern hemisphere will subsequently increase the transport of particle associated POP but also POP in the dissolved state peak in concentration due to the wash out by snow melt, containing accumulated POP of atmospheric origin (Quemerais et al., 1994).

The negative relationship between lake trophic status and POP has been explained by the fact that the increasing production in nutrient rich lakes will dilute the POP in the fast growing biomass (Taylor et al., 1991; Larsson et al., 1992). This dilution effect could act both on a system and on an individual organism level. POP enter pelagic food webs in lakes through the uptake in primary producing phytoplankton. According to the "growth dilution hypothesis" phytoplankton growth rate (i.e. cell division rate) in highly productive lakes could exceed the uptake rate of POP (Swackhamer and Skoglund, 1993). This dilution effect will then be transported up to higher trophic level through consumption of algae. Berglund et al. (2001) presented an alternative explanation in that nutrient stress induces higher lipid content in phytoplankton in nutrient poor lakes. The higher lipid content in phytoplankton could be an individual adaptation but also due to shifts in species composition in the phytoplankton community. The higher lipid content could be a factor explaining the higher phytoplankton accumulation of POP in oligotrophic lakes. Larsson et al. (1992) found a negative relationship between lake trophic status and POP in the piscivorous northern pike (*Esox lucius*), similar to what have been found in plankton. The high growth rate of pikes, due to the high abundance of prey, in highly productive systems will dilute the POP resembling the principles in growth dilution in phytoplankton.

In this study we compare accumulation of POP in crayfish across a trophic gradient of streams with results from lakes obtained in an earlier study (Holmqvist et al., 2005). Crayfish is one of few species that are abundant in both streams and lakes and thereby offer a rare opportunity to compare bioaccumulation of POP in the two systems. The signal crayfish (*Pacifastacus leniusculus*) is an omnivorous invertebrate feeding mainly on invertebrates, primary producers and detritus and inhabiting a wide range of freshwater ecosystems. The species were first introduced in Sweden in the 1960s and is today widespread and occur in more than one thousand streams, ponds and lakes in Sweden. Diet examinations of crayfish has shown that individuals utilize a broad spectrum of food sources and shifts in diet may be induced by age/size, changing food resources as well as changing environment (Nyström, 1999).

In 2002 an extensive sampling campaign including 10 streams in southern Sweden were conducted. In seven of the streams two different sites were sampled, one with low canopy cover and one with high to be able to investigate the influence of sunlight on periphyton biomass and thereby possible effects on POP accumulation (spiralling).

The overall aim of this study was to investigate the effect of trophic status of streams on bioaccumulation of POP in an obligate benthic organism. By using crayfish inhabiting both lakes and streams we also want to compare accumulation patterns of POP in streams with those found in lakes. By measuring periphyton biomass site-wise in the streams we want to investigate the effect of periphyton *per se* on bioaccumulation of POP in crayfish. Stable isotope measurements of ^{15}N and ^{13}C were used to trace differences in trophic position and carbon sources of crayfish in streams. It also made it possible to investigate if these factors are important in explaining relationships between stream specific differences in POP accumulation of biota.

2. Material and methods

2.1. Study area and study organism

All streams included in the study are located in the southern of Sweden (Table 1) and were sampled during August 2002. At 7 out of 10 streams two sites were selected; one with high canopy cover (60–95%) and one with low cover (0–15%). At 3 streams the second site were excluded due to lack of suitable canopy cover or the fact that no crayfish were trapped at the site.

The vegetation in the catchment area varied from being dominated by deciduous forests and agriculture areas to total dominance of boreal coniferous forests. All sites had similar bank vegetation (i.e. rich deciduous forests dominated by *Alnus gluttinosa*) and the stream sites had similar characteristics with suitable crayfish habitat (i.e. rocks and boulders) and well oxygenated water (riffle).

Contacts were taken with landowners in order to establish a rough picture of the crayfish population number and distribution. In this study only streams and lakes with an established crayfish populations were included. The populations were considered "established" if (i) the mean CPUE (Catch Per Unit Effort) were above 5 individuals trap^{-1} (ii) the population was older than 5 years.

Crayfish were caught using baited traps and followed Swedish standard sampling methodology for crayfish (Edsman and Söderbäck, 1999). At each site 30 traps connected with a line were used and the distance between the traps were 10 m. Of the total catch of each site at least 100 crayfish were further examined measuring length, determining sex etc. From the 100 crayfish 6 crayfish (3 males and 3 females) between 80 and 100 mm in total length were randomly picked out for POP and lipid analysis. The crayfish were individually frozen at −20 °C within 24 h after capture.

At each site water samples for analysis of tot-P, tot-N and DOC were collected ($n = 5$). Chlorophyll *a* density and organic carbon was determined by taking five randomly