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Butyltin and phenyltin compounds in eels (*Anguilla anguilla*)

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Tributyltin (TBT) and its degradation products, dibutyltin (DBT) and monobutyltin (MBT), together with triphenyltin (TPT), were investigated in eels from the Thames Estuary and the Weston Canal (Merseyside). Within individual eels, the concentrations of organotin (OT) compounds varied considerably between tissues. Tributyltin concentrations were highest in heart and gall bladder and lowest in muscle and gonad. Tributyltin was generally the most predominant of butyltin (BT) compounds present in eel tissues and DBT the least. Phenyltins were detected in eels from both locations, notably the Weston Canal where TPT was present up to 0.367 $\mu g\,g^{-1}$ (as Sn) in liver samples. Concentrations of OTs in liver (and muscle) were independent of weight and length in the eel populations examined. In a survey of OTs in eel populations along the Thames Estuary hepatic TBT levels ranged from 0.066–0.347 $\mu g\,g^{-1}$ dry wt (as Sn) in liver of eels and were generally highest in the mid-section of the estuary, resembling the distribution pattern of TBT in sediment. Proportions of TBT to total BTs were also elevated in eel from this section of the waterway, consistent with continuing inputs in this region, albeit at relatively low levels. Major sewage treatment plants are sited here and may represent a possible source.

INTRODUCTION

Tributyltin (TBT) and triphenyltin (TPT) compounds continue to be of great environmental concern because of their persistence and extremely high toxicity to some aquatic organisms. It is well known that these compounds, released into the aquatic environment, principally, from antifouling paint on ships hulls, caused significant declines in the populations of oysters *Crassostrea gigas* (Laughlin & Linden, 1987) and in dogwhelks *Nucella lapillus* (Gibbs & Bryan, 1986); imposex and related endocrine-disrupting phenomena have since been extensively reported worldwide (see reviews by Matthiessen & Gibbs, 1998; Vos et al., 2000; Santillo et al., 2001).

In many countries, legislation on the use and application of organotin (OT) compounds—mainly prohibition on vessels <25 m—was introduced between 1982 and 1992. Monitoring studies carried out since show that despite the fact that TBT concentration in water has usually decreased as a result of control measures, this has often not been matched by comparable reductions of TBT in sediment (Langston & Pope, 1995; Harino et al., 1999). In addition, relatively high concentrations of TBT are still detected in marine organisms such as mussel and fish at a variety of locations (Morcillo et al., 1997; Harino et al., 1998, 2000).

The common eel *Anguilla anguilla* is an important component of estuarine and freshwater ecosystems throughout Europe. Prior to their return to the Sargasso Sea for spawning, 'yellow' eels are territorial and maintain local home-ranges in rivers and estuaries (Slayter, 1981), residing in mud, weed beds or shady pools during the day (Naismith & Knights, 1990). Eels feed on benthic invertebrates and other aquatic fauna occurring within the area (Slayter, 1981). Because of their diet and benthic habitat, and their possible utilization as a localized food source for humans, the accumulation of OTs in eel is of concern. To date, however, field data on contamination levels in eels are extremely limited (Stab et al., 1996).

The object of this study was to assess the accumulation and speciation of OTs in various tissues of eels sampled along the length of the Thames Estuary, from freshwater to the sea. A population from the brackish Weston Canal, a spur of the Manchester Ship Canal complex, near Runcorn, Merseyside, was analysed for comparison. Commercial fisheries for eels operate at both locations.

MATERIALS AND METHODS

Sampling description

Eel samples were collected at 13 stations along the entire length of the tidal Thames in October 1999 (Figure 1) and from a site in the Weston Canal (grid reference SJ 510796), Runcorn, in November 1999. All samples were collected in fyke-nets set parallel to the shore in pairs and left for at least one night, over one tide. Nets were recovered and the lengths and weights of captured eels were measured. The number of eels sampled at each site was eight, except at Brentford (5), Richmond (7) and Coalhouse Fort (7), in the Thames. After sacrifice, some of the eels were dissected and tissues (heart, gall bladder, kidney, liver, muscle and gonad) analysed individually. Remaining eels were frozen until required for analysis of spatial trends (livers only).

Analytical procedure

The method used for the determination of butyltin (BT) and phenyltin (PT) compounds in eel samples was based

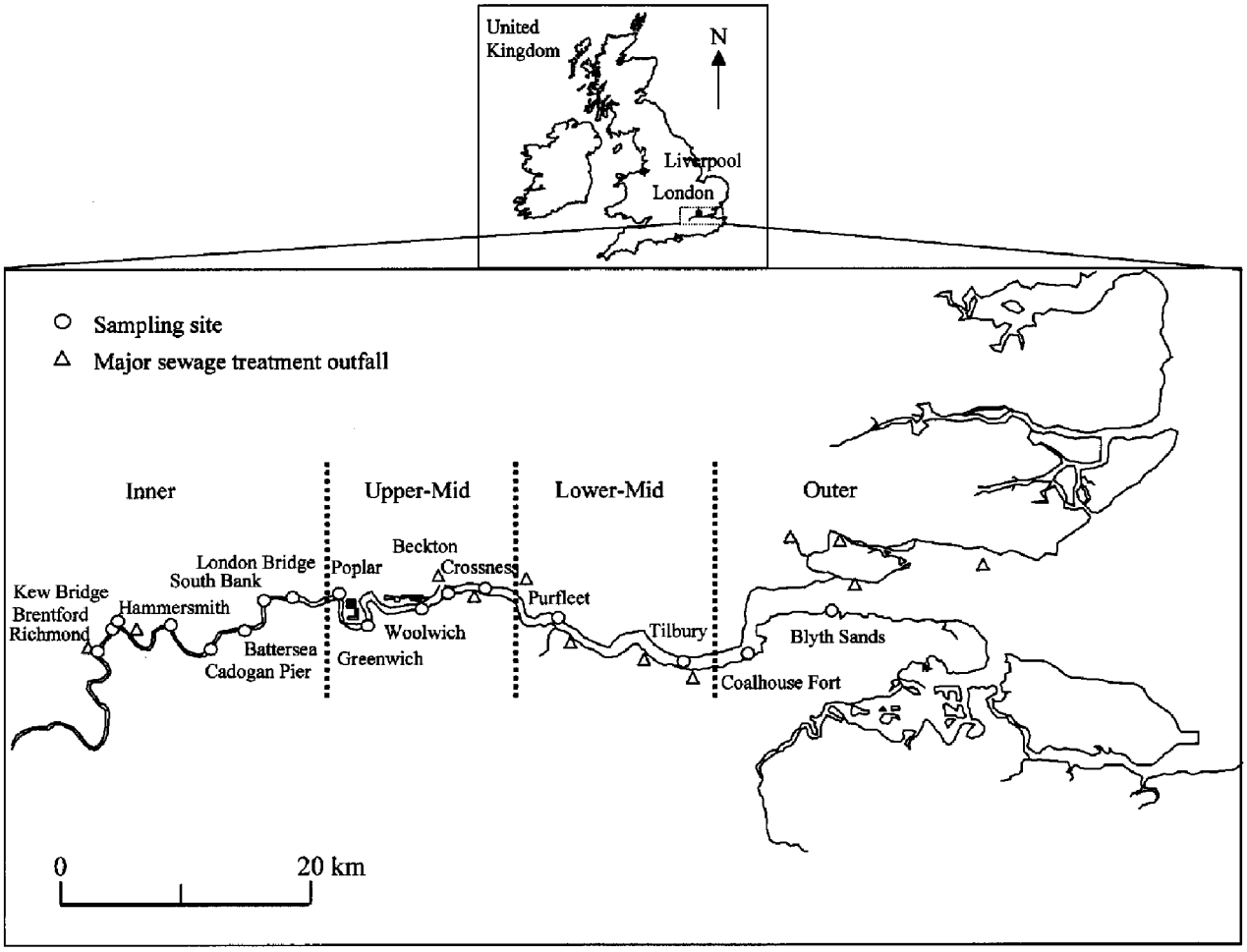

Figure 1. *Anguilla anguilla*. Sampling sites in the Thames Estuary and Weston Canal, Merseyside.

Table 1. Anguilla anguilla. *Recovery of organotins from eel liver spiked with organtin standards.*

Amounts of tissue (g)	OT spike (μg)	% Recovery: means (and standard deviations)					
		MBT	DBT	TBT	MPT	DPT	TPT
1	1	92 (6.7)	96 (3.9)	93 (3.3)	47 (6.7)	93 (1.7)	86 (2.2)

on that of Harino et al. (1992) with some modifications. One gram aliquots of eel tissue were homogenized twice with 10 ml of acetone after adding 5 ml of 1 M HCl. The supernatant was added to 100 ml of 25% NaCl solution and was re-extracted twice with 10 ml of 0.1% tropolone–benzene. The organic layer was concentrated to 1 ml after drying with anhydrous Na_2SO_4. After propylation with 2 ml of n-propyl magnesium bromide, 5 ml of 1 M H_2SO_4 and 50 ml of distilled water were added to the mixture. Organotins were then extracted twice with 10 ml of 10% benzene–hexane solution. The mixture was cleaned by passing through florisil Sep-Pak (Waters). The analytes were determined using a gas chromatograph equipped with a flame photometric detector.

Concentrations of the various organotin species are reported as $\mu g\,g^{-1}$ Sn (dry wt), throughout, unless stated otherwise. Mean recoveries and relative standard deviations (RSD) of analytes subjected to the analytical procedure are shown in Table 1. When 1 μg quantities of each of the OTs was added to 1 g of eel liver, recoveries and RSD of all OTs, except for monophenyltin (MPT), were in the range of 86–96% ±1.7–6.7%, respectively. Recoveries and RSD of MPT were 47% ±6.7%, respectively.

The detection limit for BTs, diphenyltin (DPT) and triphenyltin (TPT) in eel, corresponding to a signal-to-noise ratio of three, was 0.010 $\mu g\ g^{-1}$ dry wt. The detection limit for MPT was 0.02 $\mu g\ g^{-1}$ dry wt.

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Table 2. Anguilla anguilla. *Comparison of organotin concentrations ($\mu g\, g^{-1}\, dw$) in tissues of eels from the Thames Estuary (Brentford) and Weston Canal (Runcorn).*

Location	Length (cm)	Weight (g)	Organs	MBT	DBT	TBT	MPT	DPT	TPT	Wet dry^{-1} ratio
Thames (Brentford)	57.5	365	Heart	0.231	0.145	0.256	<0.020	<0.010	<0.010	4.8
			Gall bladder	0.103	0.071	0.149	<0.020	<0.010	<0.010	5.7
			Liver	0.066	0.026	0.143	<0.020	<0.010	<0.010	4.1
			Gonad	0.099	0.023	0.105	<0.020	<0.010	<0.010	3.7
			Kidney	0.069	0.038	0.102	<0.020	<0.010	<0.010	5.1
			Muscle	0.066	0.024	0.060	<0.020	<0.010	<0.010	4.1
	74.5	910	Heart	0.040	0.041	0.111	<0.020	<0.010	<0.010	4.3
			Gall bladder	0.051	0.059	0.165	<0.020	<0.010	<0.010	3.7
			Liver	0.133	0.079	0.139	<0.020	<0.010	<0.010	4.1
			Gonad	0.063	0.041	0.092	<0.020	<0.010	<0.010	3.2
			Kidney	0.119	0.063	0.107	<0.020	<0.010	<0.010	4.4
			Muscle	0.019	0.023	0.031	<0.020	<0.010	<0.010	2.7
Weston Canal	66.0	550	Heart	0.118	0.079	0.161	<0.020	<0.010	0.080	4.3
			Gall bladder	0.117	0.089	0.113	<0.020	0.054	0.036	6.1
			Liver	0.048	0.033	0.077	<0.020	0.017	0.367	3.8
			Gonad	0.025	0.020	0.019	<0.020	<0.010	0.018	3.2
			Kidney	0.041	0.037	0.093	<0.020	<0.010	0.075	4.4
			Muscle	0.035	0.012	0.053	<0.020	<0.010	0.027	2.8
	53.0	220	Heart	0.166	0.066	0.199	<0.020	<0.010	<0.010	4.3
			Gall bladder	0.107	0.141	0.113	<0.020	<0.010	<0.010	5.2
			Liver	0.029	0.041	0.082	<0.020	0.021	0.256	3.9
			Gonad	0.086	0.052	0.079	<0.020	<0.010	<0.010	4.0
			Kidney	0.035	0.023	0.083	<0.020	<0.010	0.047	4.7
			Muscle	0.020	0.021	0.055	<0.020	<0.010	0.031	3.5

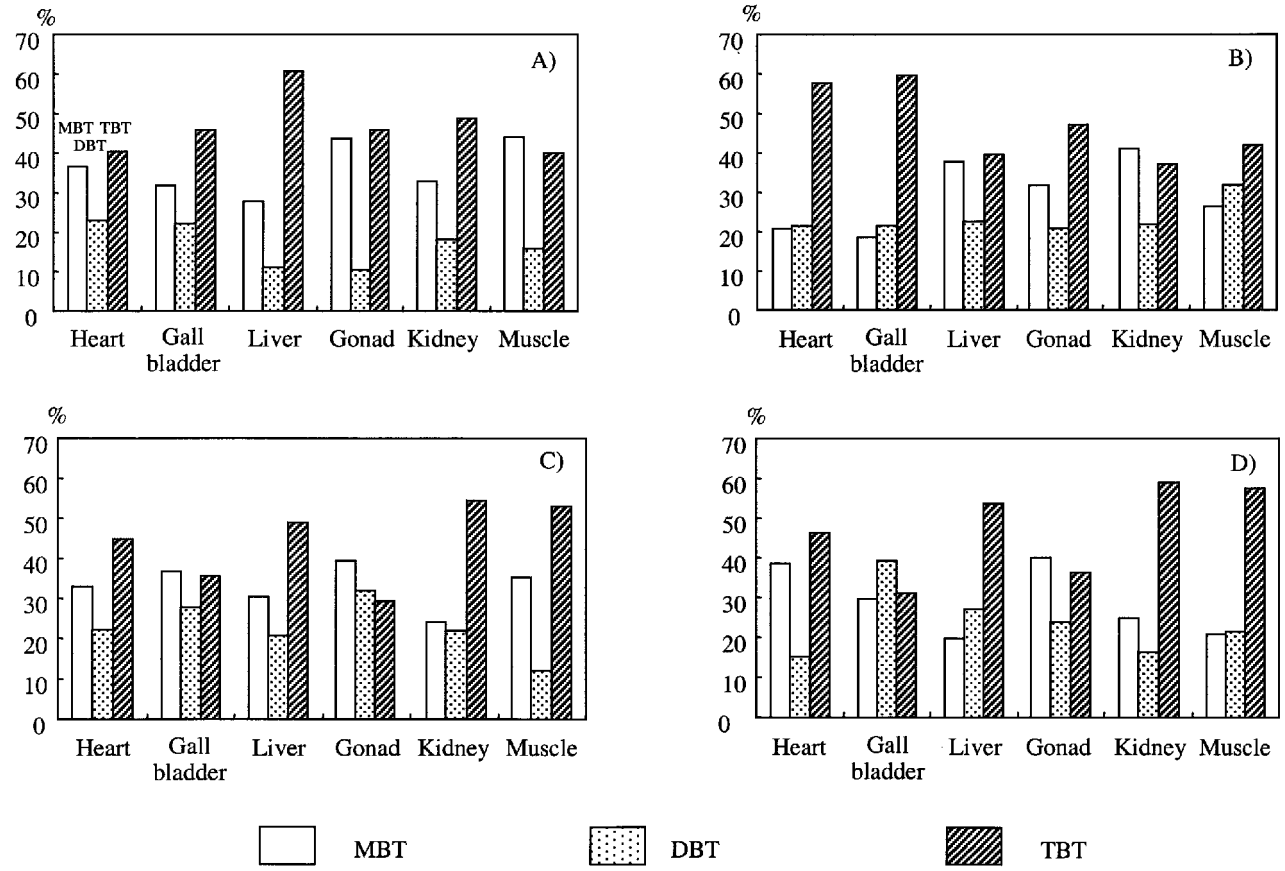

Figure 2. *Anguilla anguilla*. The composition of butyltins (%) in tissues of individual eels from the Thames Estuary at Brentford (A,B), and the Weston Canal, Merseyside (C,D). Lengths and weights of eels given in Table 2.

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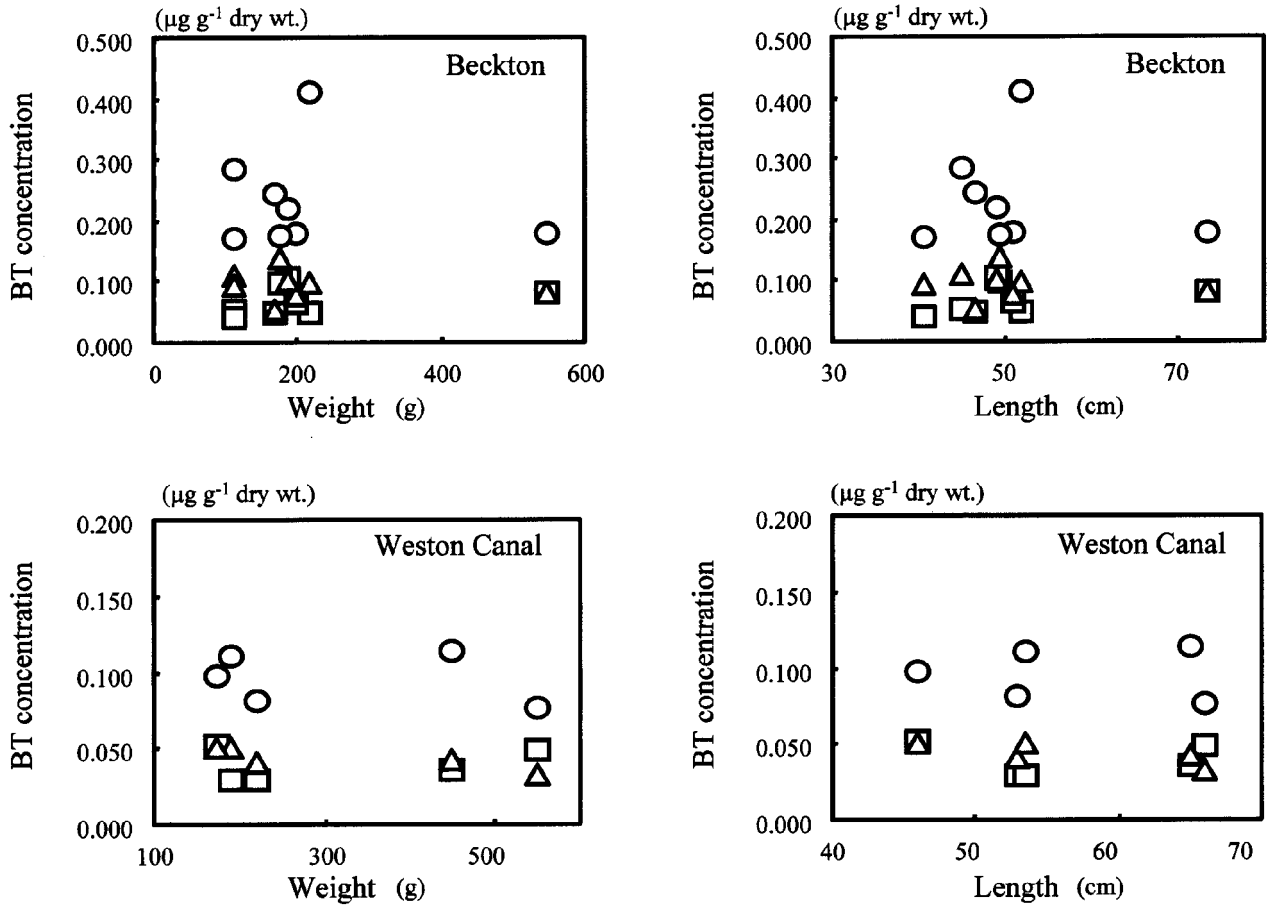

Figure 3. *Anguilla anguilla*. Relationship between butyltin concentration in liver and size (weight, length) of eel for Thames (Beckton) and Weston Canal populations. ○, TBT; △, DBT; □, MBT.

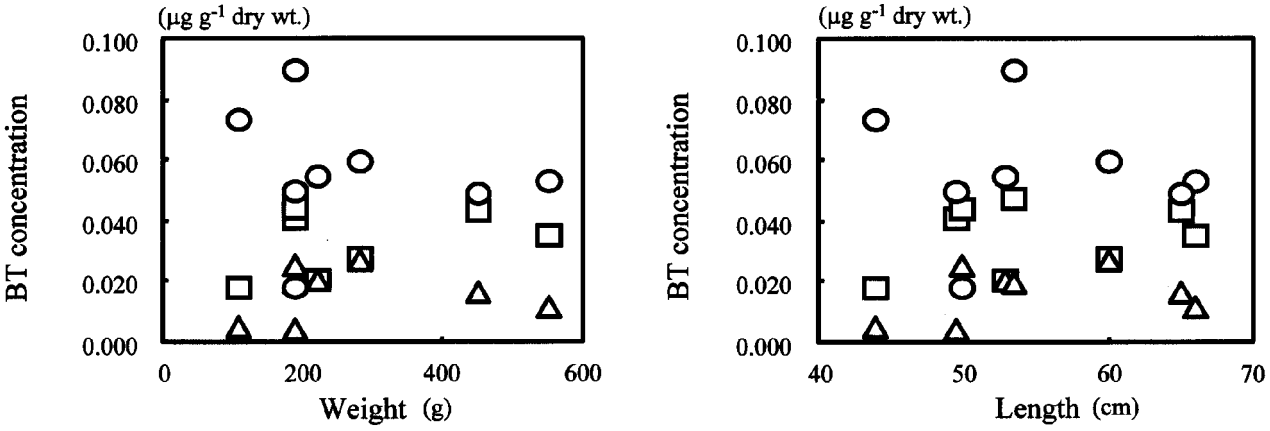

Figure 4. *Anguilla anguilla*. Relationship between butyltin concentration in muscle and size (weight, length) of eel (Weston Canal). ○, TBT; △, DBT; □, MBT.

RESULTS

Organotin distribution in eel tissue

Concentrations of TBT and other OTs in various tissues of duplicate eel samples from the Thames (Brentford) and the Weston Canal are shown in Table 2. The differences between maximum and minimum tissue TBT concentrations was 0.134 and 0.196 $\mu g\,g^{-1}$ dry weight in the two Thames individuals. These differences in concentrations between tissues were bigger for TBT than for the other OT compounds measured. Heart and gall bladder contained the highest TBT concentrations and muscle and gonad the lowest.

The proportions of the total BT burden present as MBT, DBT and TBT were calculated and the representative patterns in tissues of Thames eels are plotted in Figure 2A,B. In general, the composition of BTs decreased in the sequence TBT > MBT > DBT, depending on tissue,

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Table 3. Anguilla anguilla. *Organotins concentrations ($\mu g\, g^{-1}$) in liver of eels from the Thames Estuary.*

Location	Length (cm)	Weight (g)	MBT	DBT	TBT	TPT	Wet dry^{-1} ratio
Richmond	46.0	165	0.082	0.043	0.050	0.019	3.6
	39.0	95	0.036	0.041	0.081	0.045	4.1
Brentford	41.5	180	0.031	0.016	0.090	0.020	4.0
	42.0	140	0.031	0.021	0.084	<0.010	3.8
Hammersmith	42.5	150	0.071	0.087	0.206	<0.010	4.3
	53.0	210	0.052	0.034	0.140	0.025	3.8
Battersea	48.0	220	0.097	0.068	0.192	0.036	4.5
	49.0	190	0.52	0.087	0.243	0.015	4.2
Poplar	45.0	122	0.080	0.063	0.176	0.046	4.1
	48.0	154	0.086	0.063	0.131	0.029	4.4
Greenwich	46.5	118	0.084	0.079	0.255	0.049	4.8
	44.0	108	0.144	0.125	0.305	0.036	4.9
Woolwich	44.5	150	0.113	0.064	0.184	<0.010	4.0
	41.5	80	0.143	0.146	0.289	0.169	4.0
Beckton	49.0	188	0.104	0.100	0.219	<0.010	4.2
	49.5	178	0.096	0.137	0.177	0.029	4.3
Crossness	49.0	163	0.106	0.140	0.339	0.033	4.1
	49.0	158	0.095	0.082	0.355	0.034	3.8
Purfleet	42.0	108	0.091	0.165	0.249	0.122	3.7
	48.0	168	0.071	0.079	0.158	0.080	3.7
Tilbury	46.0	163	0.065	0.162	0.141	0.044	3.6
	41.0	123	0.120	0.093	0.176	0.067	4.3
Coldhouse Fort	59.0	391	0.080	0.113	0.158	0.066	4.2
	56.5	261	0.086	0.096	0.099	0.090	4.0
Blyth Sands	48.5	145	0.049	0.190	0.086	0.042	3.3
	44.0	136	0.085	0.111	0.123	0.059	3.8

Mono- and di-phenyltin were not detected.

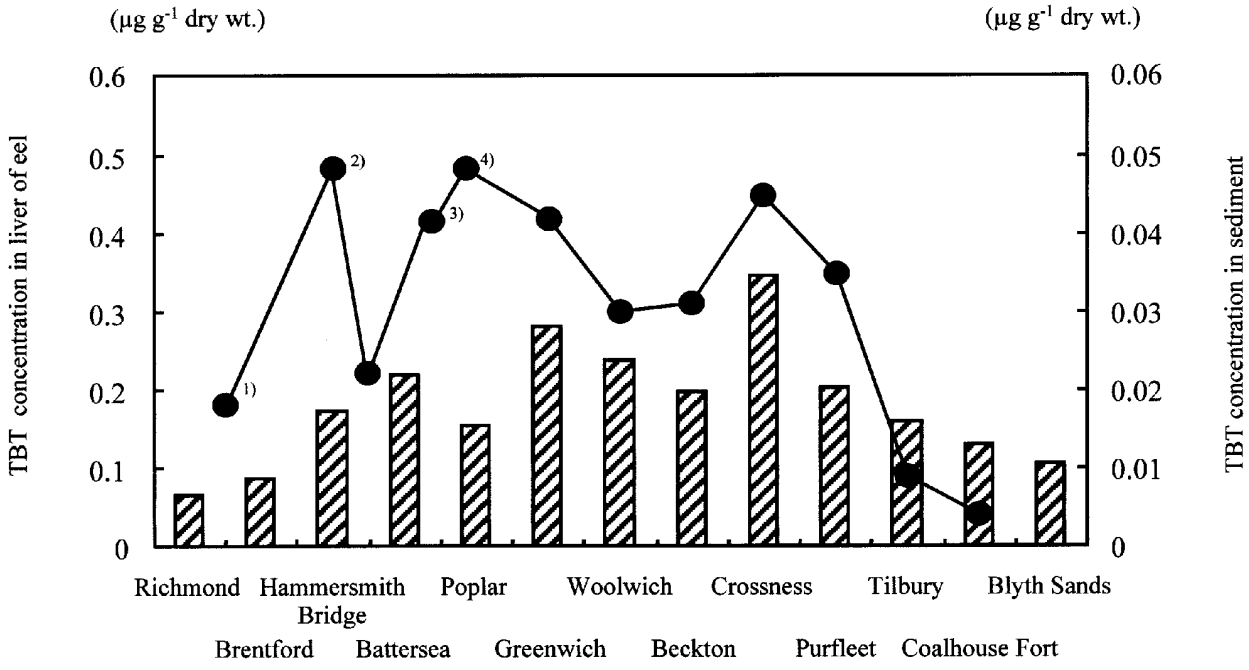

Figure 5. *Anguilla anguilla*. Concentration of tributyltin ($\mu g\, g^{-1}$) in liver of eel and in sediment, Thames Estuary. ▨ TBT liver of eel; ●, TBT in sediment; [1], Kew Bridge; [2], Cadogan Pier; [3], South Bank; [4], London Bridge.

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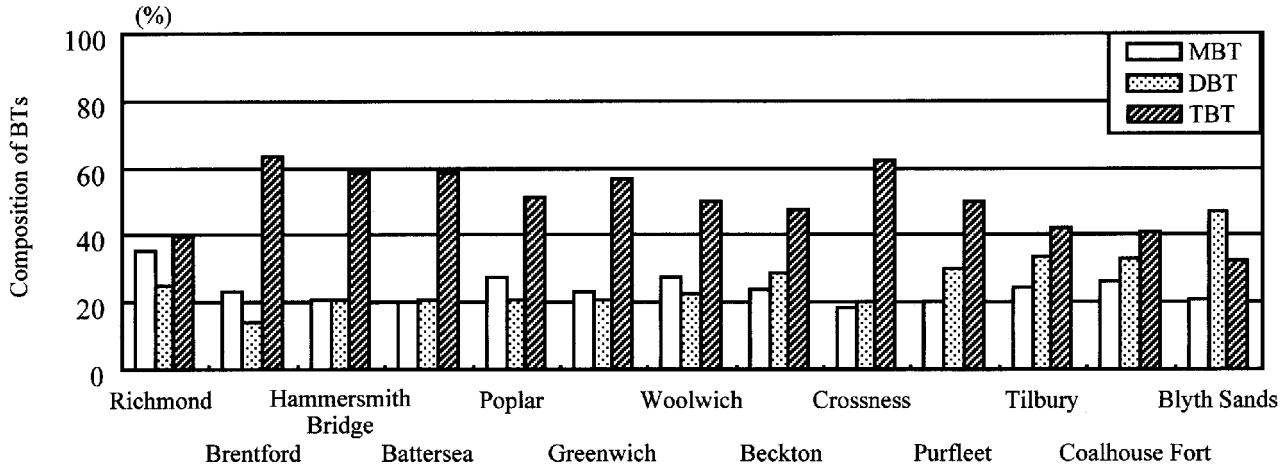

Figure 6. *Anguilla anguilla*. Composition (%) of butyltins in liver of eels, Thames Estuary.

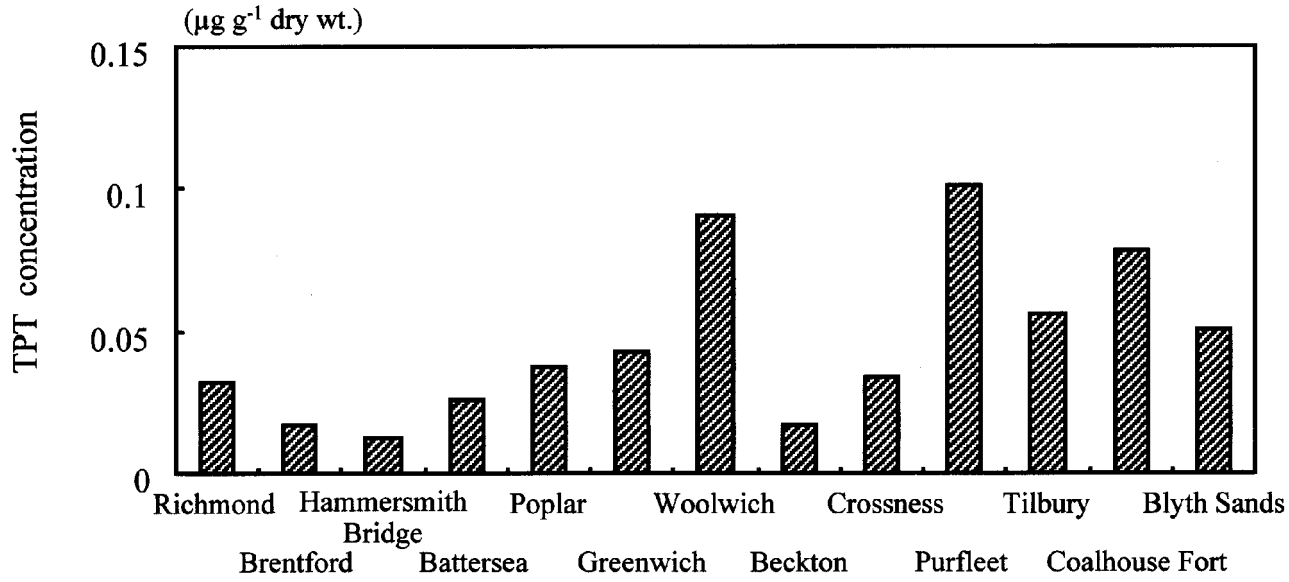

Figure 7. *Anguilla anguilla*. Concentration of triphenyltins (μg g^{-1}) in liver of eels, Thames Estuary.

proportions ranging between 37.0–60.8% for TBT, 27.9–44.2% for MBT and 10.2–31.9% for DBT.

The concentrations and distribution of BTs amongst tissues of eels from the Weston Canal, close to the Mersey Estuary at Runcorn, were comparable to those from the Thames. Differences between maximum and minimum TBT concentrations in different tissues were 0.142 and 0.144 mg kg^{-1} dry wt in the two Weston eels (Table 2). The composition of BTs was also ranked comparably (TBT > MBT > DBT) with proportions ranging between 29.1–59.1% for TBT, 19.5–39.9% for MBT and 11.8–39.2% for DBT in Weston eels (Figure 2C,D). Tributyltin concentrations were again highest in heart and gall bladder and lowest in muscle and gonad. Thus despite the geographical separation of sampling locations, and differences in contaminant sources, the distribution of BTs in tissues of eels from the Thames and Mersey systems displayed similar patterns.

The concentrations of phenyltins (PTs) in tissues of *Anguilla anguilla* are also shown in Table 2. Phenyltins were not detected in this subset of Thames eel samples, however TPT was measurable in most tissues from the Weston eels. Notably, the TPT concentration in liver ranged from 0.256–0.367 μg g^{-1} dry wt—higher than the other tissues analysed. Diphenyltin was also present in liver of Weston eels in the range 0.017–0.021 mg kg^{-1} dry wt. Monophenyltin was not detected in any of the tissues sampled. Traces of TPT were subsequently found in livers of some Thames eels in the larger sample shown in Table 3.

The relationship between BT concentrations and size of eels

The effect of size on BT concentration in liver of eels from Beckton, in the Thames Estuary, and the Weston Canal was investigated (Figure 3). The weights of captured eels ranged from 50 to 910 g and their lengths ranged from 32.0 to 74.5 cm. Correlation coefficients between BTs and weight or length were under 0.723 ($P < 0.05$), therefore, the concentrations of BTs in liver were not considered to be significantly related to these parameters.

The relationships between BTs in muscle and fish length or weight was also examined for the Weston eels

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(Figure 4). The weights and the total lengths of these samples were in the range of 110–550 g and 44.0–66.0 cm, respectively. The correlation between BTs in muscle and size were even less significant ($r^2 < 0.0686$) than in the liver. Thus, accumulation of BTs in eels does not appear to be dependent on biometric features.

Distribution of OTs in liver of eels along the tidal Thames

Hepatic BT concentrations were measured in eels sampled along the length of the Thames tideway between Richmond (freshwater, see Figure 1) and Blyth Sands (marine, outer estuary). Tributyltin concentrations (means of two observations at each site) ranged from 0.066 to 0.347 μg g^{-1} dry wt (Table 3). Figure 5 shows the spatial pattern in TBT concentrations with distance downstream from Richmond. The concentration of TBT in eels from the upper estuary increased between Richmond and Battersea and remained at a relatively high level between Battersea and Tilbury in mid-estuary. Thereafter, TBTs decreased seawards toward Blyth Sands.

Patterns of TBT contamination in surface sediment, collected in a separate survey (Langston et al., 2000), are also shown in Figure 5 for comparison. The distribution of sediment-bound TBT is very similar to that in eel livers implying that *A. anguilla* is a suitable bio-indicator of TBT contamination levels in the environment.

The composition of hepatic BTs in different eel populations is illustrated in Figure 6. In the upstream Richmond sample MBT, DBT and TBT were present in similar proportions. However in eels sampled downstream, between Brentford and Purfleet, TBT was the dominant species (>50% ΣBT). At the more seaward sites, toward Blyth Sands, the proportion of total BT present as TBT again decreased. These findings suggest exposure to continuing low-level inputs of TBT in the mid-estuarine region. In contrast, the proportion of DBT was low (~20%) between Richmond and Crossness but increased, gradually, seaward and became the dominant species (47%) at Blyth Sands. Monobutyltin represented a fairly constant 20% of the total BT burden along the length of the tideway.

Hepatic TPTs were detected in the range 0.019–0.169 μg g^{-1} dry wt in Thames eels (Table 3) and their spatial distribution along the estuary is shown in Figure 7. Generally, the concentration of TPT was highest in eels from the mid-lower section of the estuary and lowest upstream.

DISCUSSION

From the standpoint of protection of aquatic organisms and potential transfer of OT residues to consumers, it is important to have an understanding of the distribution of OT burdens in different tissues of fish. Eels have significant potential for bioaccumulation because of their benthic feeding habits and close association with sediment (known to be a persistent sink of OTs—Langston & Pope, 1995). In the current study, butyl- and phenyl-tin species were determined in heart, gall bladder, liver, gonad, kidney and muscle of eel from two waterways impacted by major industrial and urban conurbations (Greater London and Merseyside). The differences in TBT concentrations between tissues were consistent. Tributyltin concentrations in liver were 1.5–4.5 times higher than that in muscle, a mean difference equivalent to approximately 0.100 mg kg^{-1} dry wt. These proportions are comparable to the 2–5 fold liver:muscle TBT ratio described in eels from a lake in the Netherlands (Stab et al., 1996).

In Thames and Weston eels some of the highest TBT values were present in the heart. Suzuki et al. (1992) indicate similar preferential uptake of BTs by this organ in yellowtail (*Seriola quinqueradiata*) whilst Oshima et al. (1997) report relatively high concentrations of TBT in the blood of fish. Enriched TBT concentrations in the heart of *Anguilla anguilla* may therefore be due to the influence of blood, including haemocytes which are recognized targets for BTs. The observation that muscle of *A. anguilla* contains relatively low concentrations of TBT is also consistent with other published studies on fish. Thus, Morcillo et al. (1997) were able to measure TBT in liver, gills and digestive tissues of grey mullet (*Liza aurata*) and red mullet (*Mullus barbatus*) but could not detect TBT in muscle. The relatively low levels of TBT in muscle should therefore minimize the toxicological concerns for consumers of eels.

The general composition of BTs in tissues of *A. anguilla* decreased according to the sequence TBT > MBT > DBT. Proportions of MBT, DBT and TBT ranged between 20–38, 11–27 and 40–61%, respectively. The highest proportions of TBT were observed in liver tissue. The dominance of the parent compound in eels contrasts with the relative proportions found in other fish species: TBT accounted for about 25% of the total BT concentrations in livers of *Lateolabrax japonicus*, *Pennehia argentatus* and *Seriola quinqueradiata* (Harino et al., 2000), and was exceeded by both MBT and DBT. Kannan et al. (1995) also reported that MBT burdens were higher than TBT in livers of various Australian fish (*Nemadactylus douglasii*, *Aptchotrema rostrata*, *Achoerodus viridis*, *Mugil cephalus*, *Lutjanus vitta*, *Salmo salar*, *Platycephalus fuscus*, *Caranx sexfasciatus* and *Dicentrarcus labrax*). Thus whilst TBT is probably degraded in the liver of all fish, the ability of eel to metabolize the parent compound may be relatively low by comparison, as reflected in the higher proportion of TBT. Sample location may also be a factor since eels from the Thames and Mersey systems were probably collected closer to potential sources of TBT than many of the other fish species described.

Triphenyltin residues were a significant feature of *A. anguilla* from the Weston Canal, ranging in concentration from 0.018–0.367 μg g^{-1} dry wt. To our knowledge, this is the first published report on the contamination of fish by TPT in UK waterways. Apart from its occasional use in antifouling preparations (less common than TBT) TPT is used principally in agricultural chemicals and, in particular, TPT hydroxide has been used as a crop-protectant for over 30 years (Langston, 1995). Kannan & Lee (1996) demonstrated the potential significance of this source to aquatic biota: in ponds near a recently sprayed pecan orchard, significant phenyltin concentrations (up to 22 μg g^{-1} MPT) were determined in fish. The presence of TPT in eels from the Weston Canal may therefore be associated with use as a fungicide, or even the manufacture, since a myriad of chemical industries are located in the catchment area of this site.

Among the tissues and organs examined, the concentration of TPT was highest in the liver of eels, consistent with

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findings for red mullet *Laza aurata* (Morcillo et al., 1997), Japanese sea perch *Lateolabrax japonicus*, white crocker *Pennehia argentatu* and yellowtail *Seriola quinqueradiata* (Harino et al., 2000). Experimental exposures of red sea bream (*Pagrus major*), via feed containing TPTCl, also resulted in preferential accumulation of TPT in liver, with decreasing concentrations observed in digestive tract > gill > head > skin > muscle (Yamada et al., 1994). The distribution of TPT in eel tissue is therefore reasonably typical of other fish species. The fact that TPT was the dominant phenyltin species in eel suggests a fairly slow degradation rate in the liver of eel.

Tributyltin concentrations in liver and muscle of *A. anguilla* were independent of weight or length of eels. This, too, appears to be a consistent feature in fish. For example Harino et al. (2000) noted the absence of any correlation between TBT concentration and fish length in *L. japonicus*, *Pennehia argentatu* and *S. quinqueradiata*. Butyltin residues in fish are more likely to reflect the recent history of TBT contamination in their environment and are not greatly affected by size. Based on this evidence organotins are not likely to be accumulated significantly over the lifetime of the fish.

Regional comparisons of OT distributions, based on residues in the liver of *A. anguilla* proved useful in depicting contamination trends along the Thames Estuary. However there are few other eel studies available for comparison of the scale of impact. Stab et al. (1996) describe TBT levels ranging from 113–1051 μg g^{-1} dry wt in livers of eels from marinas on lake Grote Poel, Holland. Tributyltin concentrations in eels from Thames Estuary (Table 3) are lower in comparison, which is perhaps not surprising since samples were from the main part of the Thames tideway, not near obvious major BT sources such as marinas. Nevertheless, there is evidence from the current work of enhanced bioaccumulation of TBTs in mid region of the Thames Estuary which probably arises from a variety of sources including inputs from major sewage plants in the region: waste treatment operations have previously been suggested as one of the most important potential sources of chronic low-level OT inputs (Harino et al., 2002). Natural processes such as a high degree of sediment resuspension in this region may also contribute to the apparent mid-estuarine 'peak' in TBT contamination.

Nevertheless, the similarity between the spatial patterns in TBT concentrations in sediment and eels along the tidal Thames is striking (Figure 5), and could be interpreted as an indication that sediment is an important vector for TBT uptake for these benthic fish. Furthermore the higher proportion of total hepatic BTs present as TBT in eels from the mid region of the estuary (Figure 6) is consistent with closer influence here from chronic low-level inputs. Upstream and downstream of this central zone the degradation of TBT in eels appears to be sufficient to overcome the influence of these fresh inputs and is reflected in roughly equal proportions of TBT and its metabolites (DBT and MBT). Though TPT concentrations in Thames eels were lower than in those from the Weston Canal ($P < 0.001$, Student t-test), residues were detected at all sites except Brentford, Hammersmith and Beckton (Table 3). Shipping, domestic sewage, and sprayed agricultural chemicals, could represent sources though their relative importance is unknown. Compared with TBT there are surprisingly few data describing TPT distributions in marine environment of Europe (Stab et al., 1997; Yamada et al., 1997; Fent et al., 1991; Tolosa et al., 1992).

CONCLUSIONS

This study has described how different OTs partition among tissues of the common eel *Anguilla anguilla*, a functionally and commercially important component of most freshwater and estuarine ecosystems throughout Europe. Tributyltin accumulates preferentially in heart and gall bladder whilst the liver is a target organ for accumulated TPT. Since spatial trends in TBT concentrations in livers of *A. anguilla* populations have been shown to reflect those in sediment, hepatic measurements could serve as a useful indicator of TBT bioavailability in future sediment contamination assessments. Clearly, contamination by OTs continues more than a decade after initial legislation (1987 in the UK). Further surveillance of the status and trends of OTs in these benthic fish should be carried out to broaden our understanding of the impact and relative importance of different sources of these compounds. Results may also prove useful in the debate surrounding the recent International Maritime Organization proposal to eliminate all traces of organotin from antifouling paints within the next few years.

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