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Polychlorinated biphenyls (PCBs) in marine organisms from four harbours in Guam

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The marine environment has been a major source of protein for the people of Guam, and despite the influx of imported foods, local inhabitants continue to harvest algae, molluscs, crustaceans, sea cucumbers and many different kinds of fish for sale and for home consumption. The isolation of Guam (located in the tropical western Pacific at 13°28′N, 144°45′E) has largely protected these living marine resources from the adverse effects of global pollution. However, the US military has been prominent on the island since WWII and has contributed significantly to disturbances in environmental quality in and around their bases. Moreover, Guam has undergone extensive urban and commercial development over the last 30 years with particular expansion in the hospitality and tourism industries. Such developments have greatly increased problems associated with waste disposal, pollution and environmental management. As a result, coastal waters around much of the island have suffered some form of degradation in recent years.

The precise impacts of recent human activities in the coastal areas of Guam have received minimal detailed scientific study. While the use and disposal of many chemicals are known to have occurred, the degree of chemical contamination has not been quantified. Such information is critical if the ecological, recreational and commercial potential of nearshore areas is to be maintained. This paper reports on the PCB status of various marine organisms taken from four harbours located along the western edge of the southern half of the island (Fig. 1a). Clean and contaminated sites were identified from sediment analysis in an earlier investigation (Denton et al., 1997, 2005). Species selected for study were dominant ecosystem representatives and included organisms from various trophic levels (Table 1). Special attention was given to those with bioindicator potential as well as those frequently harvested for human consumption. The vast majority of samples were collected from sites a–g in Apra Harbour, the largest and oldest port in Guam (Fig. 1c). Biota collection sites within each of the other harbours (Agana Boat Basin, Agat Marina and Merizo Pier) are shown in Fig. 1 (inset b, d and e, respectively).

The analytical procedures were adapted from the US EPA SW 846 methods (US EPA, 1996) for the physical and chemical evaluation of solid waste, in addition to those recommended by the NOAA National Status and Trends Program for Marine Environmental Quality (NOAA, 1993). Briefly, tissue homogenates (~3 g) were twice extracted with 20 ml of methylene chloride in 50-ml Teflon

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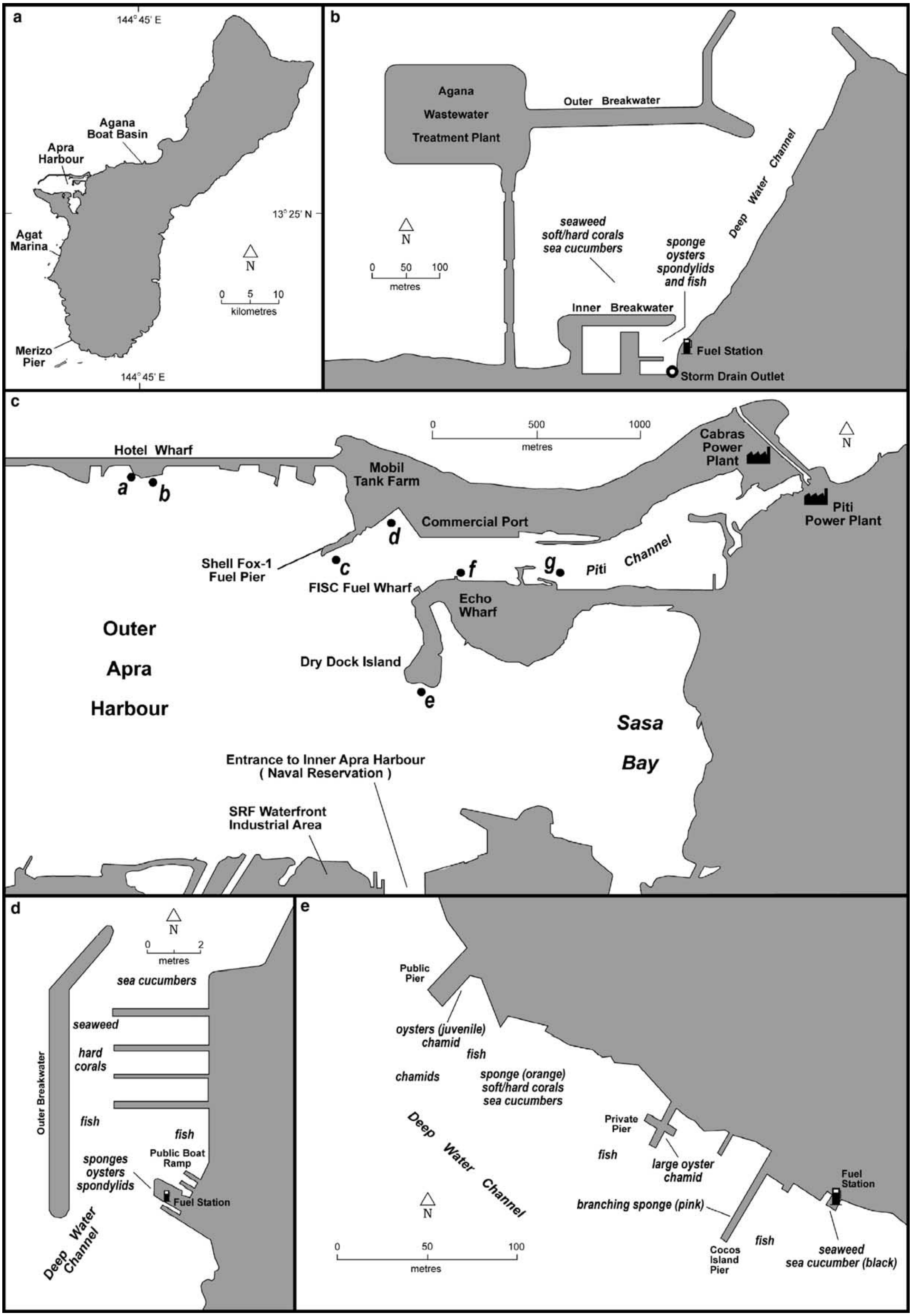

Fig. 1. (a) Locations of harbours studied on Guam and biota sampling sites at: (b) Agana Boat Basin, (c) Outer Apra Harbour, (d) Agat Marina and (e) Merizo Pier.

Table 1
Flora and fauna analyzed in this study

Species collected for analysis	Agana Boat Basin	Apra Harbour (site a)	Apra Harbour (site b)	Apra Harbour (site c)	Apra Harbour (site d)	Apra Harbour (site e)	Apra Harbour (site f)	Apra Harbour (site g)	Agat Marina	Merizo Pier
Brown alga										
Padina sp.	x	x		x	x	x	x		x	x
Sponges										
Callyspongia diffusa									x	
Cinachyra sp.	x									x
Clathria vulpina?									x	x
Dysidea sp.				x	x		x		x	
Liosina cf. granularis						x				
Stylotella aurantium			x			x				x
Yellow bread sponge									x	
Yellow sponge (red outside)				x						
Brown wart sponge			x			x	x			
Orange brown wart sponge						x				
Hard corals										
Acropora formosa						x				
Fungia concinna				x						
Fungia echidata						x				
Herpolitha limax				x		x				
Pocilopora damicornis	x			x	x		x		x	x
Soft corals										
Sinularia sp.	x			x		x				x
Sea cucumbers										
Bohadschia argus	x		x	x		x			x	x
Holothuria atra	x					x		x	x	x
Bivalve mollusks										
Chama brassica					x					
Chama lazarus			x	x	x	x	x			x
Saccostrea cuccullata				x						x
Spondylus? multimuricatus	x								x	
Striostrea cf. mytiloides	x	x				x	x		x	x
Cephalopod mollusk										
Octopus cyanea				x						
Stomatopod crustacean										
Gonodactylus sp. (mantis shrimp)						x				
Tunicates										
Ascidia sp.			x			x				
Rhopalaea				x	x	x				
Fish										
Acanthurus xanthopterus	x			x			x			
Balistoides viridescens										x
Bolbometopon muricatum				x						
Caranx ignobilis	x									
Caranx melampygus			x			x				
Caranx sexfasciatus	x			x	x					
Cephalopholis sonnerati										x
Cheilinus chlorourus									x	
Cheilinus fasciatus				x						
Cheilinus trilobatus										x
Ctenochaetus binotatus					x					
Ctenochaetus striatus						x	x		x	
Epibulus insidiator				x		x				
Epinephelus merra										x
Gerres argyreus	x				x					
Gymnothorax javanicus			x							
Leiognathus equulus									x	
Lethrinus rubrioperculatus									x	x

Table 1 (*continued*)

Species collected for analysis	Agana Boat Basin	Apra Harbour (site a)	Apra Harbour (site b)	Apra Harbour (site c)	Apra Harbour (site d)	Apra Harbour (site e)	Apra Harbour (site f)	Apra Harbour (site g)	Agat Marina	Merizo Pier
Lutjanus kasmira										x
Monodactylus argenteus	x				x					
Naso annulatus						x				
Naso unicornis		x	x							
Odenus niger									x	
Parupeneus barberinus										x
Parupeneus cyclostomus										x
Parupeneus multifasciatus										x
Saurida gracilis	x								x	
Saurida nebulosa			x							x
Scarus sordidus						x				
Siganus spinus	x									
Sufflamen chrysoptera						x				
Valamugil engeli				x						

Key to Apra Harbour sites: Apra Harbour (site a)—Western end of Hotel Wharf; Apra Harbour (site b)—Central Hotel Wharf; Apra Harbour (site c)—Shell Fox-1 Fuel Pier; Apra Harbour (site d)—Northwestern end of Commercial Port; Apra Harbour (site e)—Southern end of Dry Dock Island; Apra Harbour (site f)—Eastern end of Echo Wharf; Apra Harbour (site g)—Off Port Authority Beach.

centrifuge tubes containing 10 g of anhydrous sodium sulfate and 100 μl of the surrogate congener, PCB 103 (100 pg/μl). After centrifugation, the combined extract was solvent exchanged with hexane and reduced to a final volume of ~0.2 ml under a gentle stream of nitrogen in a water bath (45 °C).

Cleanup was accomplished on 7 mm diameter glass columns of silica gel (2 g) over alumina (1 g) using 5 ml of pentane (discarded) and 10 ml of 50% methylene chloride as the eluting solvents. The extract was solvent exchanged into hexane and reduced to a final volume of 0.1 ml before adding 10 μl of the internal standard, pentachloronitrobenzene (250 pg/μl). All solvents used were pesticide grade and were checked for interfering contaminants following a 500-fold reduction in volume before analysis.

Analysis was carried out by gas chromatography (Varian 3400CX) using an electron capture detector and a 60 m × 0.25 mm i.d. fused silica MDN-5S, polymethyl-5% phenyl-siloxane (0.25 μm film thickness) capillary column (Supelco). Gas flows (nitrogen) through the column and the detector were 1 ml/min and 30 ml/min respectively. The initial column temperature was maintained at 50 °C

Table 2
Recovery of PCBs from marine mussel standard reference material (SRM 2974) and spiked oyster composite

PCB congener	Certified mean (ng/g) (±95% confidence limits)	This study: (ng/g) mean and (range)	Spike added (ng)	Recovered amount (ng) mean and (range)
SRM 2974: Marine mussel			*Oyster composite*	
PCB 8	No value	No value	10	11 (9.8–12.1)
PCB 18	26.8 (23.5–30.1)[a]	14.9 (11.6–18.7)	10	9.8 (8.9–10.6)
PCB 28	79 (64–94)[a]	59.2 (41.5–77)	10	13.4 (11.9–15)
PCB 52	115 (103–127)	76.5 (57.1–93.9)	10	5.0 (3.1–6.9)
PCB 44	72.7 (65–80.4)	50.6 (41.1–60.1)	10	12.2 (10.9–13.6)
PCB 66	101.4 (96–106.8)	77.1 (62.1–86.3)	10	12.2 (10.6–13.7)
PCB 101	128 (118–138)	102.9 (75.8–119.1)	10	8.9 (6–11.8)
PCB 77	No value	No value	10	15.8 (13.7–18)
PCB 118	130.8 (125.5–136.1)	125.5 (101.7–144.4)	10	11.1 (9.5–12.7)
PCB 153	145.2 (136.4–154)	92.5 (86.3–103.3)	10	7.5 (6.9–8)
PCB 105	53 (49.2–56.8)	41.6 (36.1–47.6)	10	11.7 (9.9–13.6)
PCB 138	134 (124–144)	65.5 (56.4–77.8)	10	7.2 (6.3–8.3)
PCB 126	No value	No value	10	13.8 (11.2–16.3)
PCB 187	34 (31.5–36.5)	21.1 (17.9–23.3)	10	6.4 (5.1–7.8)
PCB 128	22 (18.5–25.5)	13.1 (10.3–15.1)	10	8.8 (7.5–10.2)
PCB 180	17.1 (13.3–20.9)	7.7 (5.1–9.3)	10	5.5 (4.6–6.5)
PCB 170	5.5 (4.4–6.6)	2.1 (1.2–2.8)	10	6.9 (5.8–8.1)
PCB 195	No value	No value	10	5.6 (4.7–6.5)
PCB 206	No value	No value	10	3.2 (2.5–3.9)
PCB 209	No value	No value	10	1.8 (1.3–2.3)

[a] Unconfirmed reference value only.

Table 3
PCB congeners in biota from Guam Harbours

Species	Location (site)	Date	Tissue	PCB Congener Concentration (ng/g wet wt.)																				Σ_{20}PCB
				8	18	28	44	52	66	77	101	105	118	126	128	138	153	170	180	187	195	206	209	
				(Cl-2)	(Cl-3)	(Cl-3)	(Cl-4)	(Cl-4)	(Cl-4)	(Cl-4)	(Cl-5)	(Cl-5)	(Cl-5)	(Cl-5)	(Cl-6)	(Cl-6)	(Cl-6)	(Cl-7)	(Cl-7)	(Cl-7)	(Cl-8)	(Cl-9)	(Cl-10)	
ALGAE																								
Padina sp.	Agana Boat Basin	18-Dec-98	Frond	0.69	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.74
Padina sp.	Apra Harbour (a)	5-Jun-98	Frond	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Padina sp.	Apra Harbour (c)	3-Jun-98	Frond	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05	BDL	0.04	0.06	0.13	0.02	0.07	0.07	BDL	BDL	BDL	0.44
Padina sp.	Apra Harbour (d)	9-Jun-98	Frond	BDL	BDL	BDL	BDL	0.27	0.29	BDL	0.15	0.13	0.25	BDL	0.09	0.16	0.20	0.08	0.11	0.11	BDL	BDL	BDL	1.85
Padina sp.	Apra Harbour (e)	9-Jun-98	Frond	BDL	BDL	0.54	BDL	BDL	BDL	BDL	0.10	BDL	0.08	BDL	0.07	BDL	0.45	0.12	0.26	0.19	BDL	BDL	BDL	1.81
Padina sp.	Apra Harbour (f)	12-Jun-98	Frond	0.47	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.16	BDL	0.07	0.06	BDL	BDL	BDL	0.76
Padina sp.	Agat Marina	21-Dec-98	Frond	0.39	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.39
Padina sp.	Merizo Pier	22-Dec-98	Frond	0.59	0.15	0.20	BDL	BDL	BDL	BDL	BDL	BDL	0.10	BDL	0.06	0.04	0.05	BDL	BDL	0.07	BDL	BDL	BDL	1.26
SPONGES																								
Callyspongia diffusa	Agat Marina	21-Dec-98	Whole	BDL	BDL	BDL	BDL	0.53	BDL	BDL	BDL	0.41	0.27	BDL	BDL	BDL	0.42	BDL	0.31	0.10	BDL	BDL	BDL	2.04
Clathria vulpina?	Agat Marina	21-Dec-98	Whole	0.71	BDL	BDL	BDL	BDL	BDL	BDL	0.27	BDL	0.14	BDL	0.19	BDL	BDL	BDL	6.67	BDL	BDL	BDL	BDL	7.98
Clathria vulpina?	Merizo Pier	22-Dec-98	Whole	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.11	BDL	0.09	BDL	0.13	0.05	0.15	0.07	0.04	BDL	BDL	0.65
Dysidea sp.	Apra Harbour (c)	3-Jun-98	Whole	367	BDL	BDL	258	1839	BDL	BDL	1848	BDL	1278	BDL	522	693	1281	190	1037	405	22.0	BDL	BDL	9740
Dysidea sp.	Apra Harbour (d)	9-Jun-98	Whole	7.92	BDL	BDL	29.2	168	BDL	BDL	163	34.3	110	BDL	24.0	63.5	58.5	8.21	26.7	17.8	BDL	BDL	BDL	712
Dysidea sp.	Apra Harbour (f)	12-Jun-98	Whole	610	BDL	BDL	204	1733	BDL	BDL	951	BDL	334	BDL	269	241	95.3	60.5	456	176	BDL	BDL	BDL	5128
Liosina cf. granularis	Apra Harbour (b)	5-Jun-98	Whole	0.11	BDL	BDL	BDL	0.27	0.64	BDL	0.47	0.15	0.73	BDL	0.28	0.57	2.31	0.70	1.40	1.44	0.09	BDL	0.17	9.32
Liosina cf. granularis	Apra Harbour (e)	9-Jun-98	Whole	BDL	0.12	BDL	BDL	0.58	BDL	BDL	0.96	0.08	0.92	0.68	0.45	2.86	11.6	2.69	6.50	9.51	0.53	0.10	0.43	38.0
Stylotella aurantium	Apra Harbour (b)	5-Jun-98	Whole	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.94	BDL	1.16	BDL	0.40	1.96	5.42	1.07	3.37	3.07	0.25	BDL	0.24	17.9
Stylotella aurantium	Apra Harbour (e)	9-Jun-98	Whole	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.64	BDL	1.61	0.56	0.69	5.04	19.0	4.81	7.65	14.60	0.86	BDL	0.61	57.0
Stylotella aurantium	Merizo Pier	22-Dec-98	Whole	1.00	1.10	BDL	0.80	0.64	BDL	BDL	0.13	BDL	BDL	BDL	1.12	BDL	BDL	0.51	8.44	0.06	0.39	BDL	0.48	14.7
Brown wart sponge	Apra Harbour (e)	9-Jun-98	Whole	0.17	0.16	BDL	BDL	0.21	1.03	BDL	0.49	BDL	0.57	0.38	0.30	1.92	5.83	1.74	3.14	4.30	0.45	BDL	0.14	20.8
Brown wart sponge	Apra Harbour (f)	12-Jun-98	Whole	0.13	0.08	BDL	BDL	0.28	0.85	BDL	0.69	0.08	0.62	BDL	0.28	1.46	5.54	1.03	2.74	3.37	0.13	BDL	0.20	17.5
Orange wart sponge	Apra Harbour (e)	9-Jun-98	Whole	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.92	BDL	2.85	1.73	1.46	9.51	31.18	9.20	16.19	21.24	2.02	BDL	0.62	98.9
Yellow bread sponge	Agat Marina	21-Dec-98	Whole	BDL	BDL	BDL	0.12	0.79	BDL	BDL	0.76	0.13	0.39	BDL	0.10	0.18	0.25	0.03	0.15	0.11	BDL	BDL	BDL	3.02
Yellow sponge (red outside)	Apra Harbour (c)	3-Jun-98	Whole	0.24	0.75	2.79	1.74	4.17	BDL	BDL	5.79	3.16	9.12	BDL	2.922	10.41	23.52	3.53	8.58	10.09	0.26	BDL	BDL	87.1
SOFT CORALS																								
Sinularia sp.	Apra Harbour (e)	9-Jun-98	Whole	0.48	1.73	BDL	BDL	7.6	BDL	BDL	8.56	BDL	1.88	BDL	0.70	3.43	13.9	0.87	4.01	2.08	0.04	BDL	BDL	45.3
Sinularia sp.	Apra Harbour (c)	3-Jun-98	Whole	BDL	154	BDL	193	1688	BDL	BDL	733	BDL	324	BDL	BDL	292	BDL	108	486	126	BDL	BDL	BDL	4103
Sinularia sp.	Agana Boat Basin	18-Dec-98	Whole	0.25	0.09	BDL	BDL	0.10	BDL	BDL	0.12	BDL	BDL	BDL	0.09	BDL	BDL	BDL	3.07	BDL	BDL	BDL	BDL	3.72
Sinularia sp.	Merizo Pier	22-Dec-98	Whole	2.93	3.39	BDL	0.89	1.16	BDL	BDL	0.27	BDL	BDL	BDL	2.88	BDL	BDL	0.88	59.6	BDL	BDL	0.77	BDL	72.7
SEACUCUMBERS																								
Bohadschia argus	Agana Boat Basin	18-Dec-98	Hemal system	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05	BDL	0.04	BDL	0.06	BDL	BDL	0.12	BDL	BDL	BDL	0.26
			Hemal system	BDL	BDL	BDL	BDL	0.41	BDL	BDL	0.39	BDL	2.22	BDL	1.39	1.17	2.10	BDL	BDL	2.67	BDL	BDL	BDL	10.4
Bohadschia argus	Apra Harbour (b)	5-Jun-98	Body wall	BDL	BDL	0.13	BDL	1.13	BDL	BDL	1.77	0.49	2.26	0.15	0.72	1.27	2.91	BDL	BDL	2.00	BDL	BDL	BDL	12.8
			Hemal system	0.42	BDL	0.85	BDL	3.78	BDL	BDL	8.63	4.34	14.4	0.71	5.30	6.14	14.1	BDL	BDL	7.92	BDL	BDL	BDL	66.5
Bohadschia argus	Apra Harbour (c)	12-Jun-98	Body wall	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.11	0.09	0.27	BDL	0.14	0.26	0.58	BDL	BDL	0.69	BDL	BDL	BDL	2.15
Bohadschia argus	Apra Harbour (e)	9-Jun-98	Body wall	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.18	BDL	0.19	0.06	0.11	0.30	1.11	BDL	BDL	1.10	BDL	BDL	BDL	3.05
			Hemal system	0.16	BDL	0.14	BDL	1.24	BDL	BDL	2.95	0.48	3.89	0.54	1.65	4.57	25.8	BDL	BDL	21.5	BDL	BDL	BDL	63.0
Bohadschia argus	Agat Marina	21-Dec-98	Body wall	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.03	BDL	BDL	BDL	0.03
			Hemal system	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.04	0.11	BDL	BDL	BDL	0.12	BDL	BDL	BDL	0.28
Bohadschia argus	Merizo Pier	22-Dec-98	Body wall	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.26	BDL	0.09	0.11	0.20	0.04	BDL	0.16	BDL	BDL	BDL	0.86
			Hemal system	0.10	BDL	BDL	BDL	BDL	BDL	0.32	BDL	0.62	3.37	0.14	1.01	0.78	1.52	BDL	BDL	0.86	BDL	BDL	BDL	8.71
Holothuria atra	Agana Boat Basin	18-Dec-98	Body wall	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.07	BDL	BDL	0.09	0.23	BDL	BDL	0.54	BDL	BDL	BDL	0.94
			Hemal system	1.04	BDL	BDL	0.20	BDL	BDL	BDL	BDL	BDL	2.14	BDL	1.49	0.86	3.77	BDL	BDL	11.9	BDL	BDL	BDL	21.4
Holothuria atra	Apra Harbour (f)	12-Jun-98	Body wall	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.23	BDL	0.20	BDL	0.08	0.38	1.10	BDL	0.14	0.65	BDL	BDL	BDL	2.77
			Hemal system	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.51	0.11	0.63	0.14	0.23	1.75	5.18	BDL	BDL	2.50	BDL	BDL	BDL	11.1

Holothuria atra	Merizo Pier	22-Dec-98	Body wall	BDL	BDL	BDL	BDL	0.45	BDL	BDL	1.65	0.63	1.89	BDL	0.59	2.07	2.24	0.15	0.22	0.58	BDL	BDL	BDL	10.5
			Hemal system	2.60	BDL	4.33	6.06	19.1	BDL	BDL	45.0	9.05	591	BDL	4.76	22.9	570	0.29	0.35	3.41	BDL	BDL	BDL	1279
Holothuria atra	Apra Harbour (e)	9-Jun-98	Body wall	BDL	BDL	BDL	BDL	0.39	BDL	BDL	0.92	0.12	0.73	0.35	0.39	2.20	7.00	BDL	0.74	4.75	BDL	BDL	BDL	17.6
			Hemal system	BDL	BDL	BDL	0.23	0.83	BDL	0.97	1.21	0.30	1.29	0.12	0.39	1.82	3.82	BDL	BDL	1.78	BDL	BDL	BDL	12.8
Holothuria atra	Agat Marina	21-Dec-98	Body wall	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.03	BDL	0.06	BDL	BDL	0.17	BDL	BDL	BDL	0.27
Holothuria atra	Agat Marina	21-Dec-98	Body wall	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05	BDL	0.03	0.06	BDL	BDL	BDL	0.14
			Hemal system	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.06	BDL	BDL	0.08	0.10	BDL	BDL	0.22	BDL	BDL	BDL	0.46
BIVALVES (pool size)																								
Oysters																								
Striostrea cucculata (10)	Apra Harbour (c)	5-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.62	0.38	1.69	BDL	0.59	1.74	6.62	BDL	0.22	2.33	BDL	BDL	BDL	14.2
Striostrea cucculata (juv.) (7)	Merizo Pier	22-Dec-98	Whole flesh	BDL	BDL	BDL	BDL	0.82	BDL	BDL	BDL	BDL	0.22	BDL	0.12	BDL	BDL	BDL	BDL	0.14	BDL	BDL	BDL	1.30
Striostrea mytiloides (4)	Agana Boat Basin	18-Dec-98	Whole flesh	0.48	BDL	BDL	0.95	BDL	BDL	BDL	1.61	BDL	3.58	BDL	BDL	2.17	4.19	0.03	BDL	1.73	BDL	BDL	BDL	14.7
Striostrea mytiloides (2)	Apra Harbour (a)	5-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.37	BDL	1.01	BDL	0.27	1.32	4.33	0.01	BDL	1.23	BDL	BDL	BDL	8.54
Striostrea mytiloides (2)	Apra Harbour (a)	5-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.31	BDL	0.61	BDL	0.16	0.51	2.47	BDL	BDL	0.73	BDL	BDL	BDL	4.79
Striostrea mytiloides (1)	Apra Harbour (a)	5-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.60	BDL	0.67	BDL	0.18	0.94	2.82	BDL	BDL	0.77	BDL	BDL	BDL	5.97
Striostrea mytiloides (2)	Apra Harbour (a)	5-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.21	BDL	0.23	BDL	0.08	0.39	1.23	0.04	0.04	0.33	0.05	BDL	BDL	2.60
Striostrea mytiloides (5)	Apra Harbour (a)	5-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.29	BDL	0.32	BDL	0.08	0.48	1.58	0.02	0.02	0.44	BDL	BDL	BDL	3.22
Striostrea mytiloides (1)	Apra Harbour (c)	5-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.50	0.31	1.50	BDL	0.33	1.44	4.09	0.03	0.02	1.06	BDL	BDL	BDL	10.3
Striostrea mytiloides (4)	Apra Harbour (e)	9-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	3.42	BDL	2.33	0.34	0.57	6.40	13.2	0.08	BDL	8.21	BDL	BDL	BDL	34.5
Striostrea mytiloides (6)	Apra Harbour (e)	9-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	3.12	0.26	2.19	0.30	0.60	5.46	20.9	0.07	BDL	5.93	BDL	BDL	BDL	38.8
Striostrea mytiloides (1)	Apra Harbour (e)	9-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4.81	0.62	3.41	0.47	1.07	7.24	21.8	0.11	BDL	7.41	0.04	BDL	0.03	47.0
Striostrea mytiloides (3)	Apra Harbour (f)	12-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.09	0.73	BDL	1.81	0.87	3.51	0.06	BDL	1.09	BDL	BDL	BDL	8.15
Striostrea mytiloides (1)	Apra Harbour (f)	12-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.47	0.25	1.40	BDL	1.87	1.75	6.56	0.08	BDL	2.11	0.03	BDL	BDL	14.5
Striostrea mytiloides (1)	Apra Harbour (f)	12-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.16	BDL	0.12	0.25	1.09	0.07	0.04	0.42	0.04	BDL	0.04	2.23
Striostrea mytiloides (1)	Apra Harbour (f)	12-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.42	0.25	1.31	BDL	1.10	1.52	5.23	0.06	BDL	1.65	BDL	BDL	BDL	11.5
Striostrea mytiloides (2)	Agat Marina	21-Dec-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.08	BDL	BDL	BDL	0.32	0.02	0.05	0.73	BDL	BDL	BDL	1.20
Chamids																								
Chama brassica (2)	Apra Harbour (d)	9-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	0.37	0.68	BDL	BDL	0.19	0.62	BDL	0.10	0.33	0.62	0.09	0.16	0.21	BDL	BDL	BDL	3.36
Chama brassica (2)	Apra Harbour (f)	9-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.07	BDL	BDL	0.12	0.55	0.07	0.19	0.22	BDL	BDL	BDL	1.21
Chama lazarus (3)	Apra Harbour (b)	5-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.07	BDL	BDL	0.06	0.25	0.05	0.12	0.11	BDL	BDL	BDL	0.66
Chama lazarus (3)	Apra Harbour (b)	5-Jun-98	Whole flesh	BDL	BDL	0.11	BDL	0.17	BDL	BDL	0.10	BDL	0.16	0.19	0.12	0.14	0.30	0.14	0.16	0.12	0.08	BDL	0.08	1.87
Chama lazarus (1)	Apra Harbour (c)	5-Jun-98	Whole flesh	BDL	BDL	0.11	BDL	0.09	BDL	BDL	0.09	BDL	0.09	BDL	BDL	0.09	0.25	0.04	0.09	0.10	BDL	BDL	BDL	0.95
Chama lazarus (1)	Apra Harbour (c)	5-Jun-98	Whole flesh	0.18	BDL	0.11	BDL	BDL	BDL	BDL	0.07	BDL	0.08	BDL	BDL	0.06	0.17	0.03	0.06	0.07	BDL	BDL	BDL	0.82
Chama brassica (2)	Apra Harbour (d)	9-Jun-98	Whole flesh	0.15	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05	0.18	BDL	BDL	0.10	0.22	0.03	0.06	0.07	BDL	BDL	BDL	0.88
Chama brassica (2)	Apra Harbour (d)	9-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	0.22	0.38	BDL	0.07	0.10	0.23	BDL	0.07	0.13	0.27	0.07	0.10	0.10	0.05	BDL	BDL	1.78
Chama brassica (2)	Apra Harbour (e)	9-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	0.17	BDL	BDL	0.06	BDL	0.09	BDL	BDL	0.18	0.87	0.18	0.42	0.36	0.03	BDL	BDL	2.36
Chama brassica (2)	Apra Harbour (e)	9-Jun-98	Whole flesh	BDL	BDL	BDL	BDL	0.56	BDL	BDL	0.40	BDL	0.42	BDL	0.21	0.76	2.58	0.65	1.27	0.97	0.10	BDL	0.07	7.98
Chama brassica (2)	Apra Harbour (f)	12-Jun-98	Whole flesh	0.11	BDL	0.12	BDL	0.10	BDL	BDL	BDL	BDL	0.08	BDL	BDL	0.09	0.43	0.07	0.17	0.15	BDL	BDL	BDL	1.32
Chama brassica (2)	Apra Harbour (f)	12-Jun-98	Whole flesh	0.10	BDL	BDL	BDL	0.16	BDL	BDL	0.08	BDL	0.09	BDL	0.05	0.10	0.53	0.07	0.17	0.16	BDL	BDL	BDL	1.50
Chama lazarus (1)	Merizo Pier	22-Dec-98	Whole flesh	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.03	0.07	0.19	BDL	BDL	BDL	0.29
Spondylids																								
Spondylus? Multimuricatus (2)	Agana Boat Basin	18-Dec-98	Whole flesh	0.15	BDL	1.84	1.14	BDL	BDL	BDL	0.29	BDL	2.00	BDL	BDL	1.13	3.09	0.23	0.38	1.03	0.02	BDL	BDL	11.30
Spondylus? Multimuricatus (1)	Apra Harbour (e)	9-Jun-98	Whole flesh	1.92	2.25	BDL	BDL	2.05	BDL	BDL	0.83	BDL	1.98	BDL	BDL	2.01	10.6	1.15	3.24	4.33	0.08	BDL	0.08	30.5
Spondylus? Multimuricatus (1)	Apra Harbour (e)	9-Jun-98	Whole flesh	0.97	BDL	BDL	BDL	3.16	BDL	BDL	2.58	BDL	2.23	BDL	0.38	3.45	18.8	1.56	5.01	5.92	0.11	BDL	BDL	44.2
Spondylus? Multimuricatus (4)	Agat Marina	21-Dec-98	Whole flesh	0.36	BDL	BDL	0.35	1.91	BDL	0.25	BDL	BDL	0.19	BDL	BDL	BDL	0.50	BDL	0.07	0.56	BDL	BDL	BDL	4.19
OCTOPUS																								
Octopus cyanea	Apra Harbour (c)	5-Jun-98	Tentacle	0.19	BDL	0.19	BDL	BDL	BDL	BDL	0.23	0.34	1.01	0.12	0.22	1.04	2.49	0.56	1.34	0.98	0.07	BDL	BDL	8.78
		3-Jun-98	Liver	0.30	0.31	6.27	0.47	2.63	10.9	1.58	5.47	8.09	28.8	0.63	3.97	24.1	742	BDL	414	22.0	BDL	BDL	BDL	1271
MANTIS SHRIMP																								
Gonodactylus sp.	Apra Harbour (e)	9-Jun-98	Tail muscle	BDL	BDL	0.29	BDL	0.20	BDL	BDL	BDL	0.20	1.42	0.22	0.43	3.99	17.0	2.18	7.37	4.96	BDL	BDL	BDL	38.2

(*continued on next page*)

Table 3 (*continued*)

Species	Location (site)	Date	Tissue	PCB Congener Concentration (ng/g wet wt.)																					Σ_{20}PCB
				8	18	28	44	52	66	77	101	105	118	126	128	138	153	170	180	187	195	206	209	
				(Cl-2)	(Cl-3)	(Cl-3)	(Cl-4)	(Cl-4)	(Cl-4)	(Cl-4)	(Cl-5)	(Cl-5)	(Cl-5)	(Cl-5)	(Cl-6)	(Cl-6)	(Cl-6)	(Cl-7)	(Cl-7)	(Cl-7)	(Cl-8)	(Cl-9)	(Cl-10)	
ASCIDIANS																									
Ascidia sp.	Apra Harbour (e)	9-Jun-98	Whole	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.41	BDL	BDL	BDL	BDL	0.17	0.59	0.31	0.50	0.36	0.04	BDL	BDL	2.38
Rhopalaea	Apra Harbour (c)	3-Jun-98	Whole	0.41	BDL	BDL	BDL	BDL	BDL	BDL	0.16	0.06	0.18	BDL	0.08	0.22	0.54	0.15	0.29	0.23	BDL	BDL	0.06	2.39
Rhopalaea	Apra Harbour (d)	9-Jun-98	Whole	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.34	0.18	0.47	BDL	0.11	0.32	0.69	0.16	0.37	0.36	BDL	BDL	BDL	3.00
Rhopalaea	Apra Harbour (b)	5-Jun-98	Whole	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.07	BDL	0.03	BDL	BDL	BDL	BDL	0.10
FISH (fork length: cm)																									
Acanthurus xanthopterus (36.0)	Agana Boat Basin	18-Dec-98	Axial muscle	0.98	BDL	2.78	0.40	1.94	BDL	BDL	1.81	0.79	2.51	BDL	0.68	BDL	4.29	0.81	2.44	1.62	0.13	BDL	BDL	21.2
			Liver	1.85	BDL	25.8	4.14	16.3	BDL	BDL	12.7	BDL	19.3	0.80	5.24	BDL	19.6	BDL	6.66	5.69	0.51	0.27	BDL	119
Acanthurus xanthopterus (22.0)	Agana Boat Basin	30-Dec-98	Axial muscle	BDL	BDL	0.20	BDL	0.37	BDL	BDL	BDL	BDL	0.09	BDL	BDL	0.12	0.29	0.11	0.22	0.14	BDL	BDL	BDL	1.53
Acanthurus xanthopterus (18.0)	Agana Boat Basin	30-Dec-98	Axial muscle	0.57	BDL	0.75	0.37	1.17	BDL	BDL	0.84	BDL	1.07	BDL	0.22	BDL	BDL	0.24	0.44	0.44	BDL	BDL	BDL	6.11
Acanthurus xanthopterus (14.5)	Agana Boat Basin	30-Dec-98	Axial muscle	BDL	BDL	0.28	BDL	0.27	BDL	BDL	BDL	BDL	0.13	BDL	BDL	BDL	0.25	BDL	0.12	0.15	BDL	BDL	BDL	1.22
Acanthurus xanthopterus (38.0)	Apra Harbour (c)	3-Jun-98	Axial muscle	BDL	BDL	1.91	1.12	17.7	BDL	BDL	17.2	5.04	16.5	BDL	3.04	6.00	10.2	1.36	2.62	2.11	0.19	BDL	BDL	85.0
			Liver	BDL	BDL	BDL	3.40	32.5	BDL	BDL	57.5	7.57	30.7	BDL	BDL	23.2	20.3	BDL	4.51	4.17	0.58	BDL	BDL	184
Acanthurus xanthopterus (30.5)	Apra Harbour (c)	3-Jun-98	Axial muscle	BDL	BDL	0.14	0.09	0.88	BDL	BDL	1.49	0.31	1.20	0.13	0.28	0.92	4.29	0.63	1.92	1.66	0.10	BDL	0.06	14.1
			Liver	BDL	BDL	1.46	0.97	6.06	BDL	BDL	13.7	2.29	9.98	0.82	2.17	6.40	34.4	BDL	12.1	11.6	0.60	0.54	0.39	103
Acanthurus xanthopterus (29.0)	Apra Harbour (c)	3-Jun-98	Axial muscle	0.38	BDL	BDL	BDL	0.66	BDL	BDL	1.95	0.10	0.67	0.30	0.30	1.98	8.07	1.13	3.30	3.21	0.13	BDL	BDL	22.2
			Liver	BDL	BDL	2.94	BDL	25.8	BDL	BDL	67.2	BDL	26.2	BDL	16.6	63.0	208	42.2	79.9	79.0	3.97	BDL	BDL	615
Acanthurus xanthopterus (16.5)	Apra Harbour (f)	12-Jun-98	Axial muscle	0.36	BDL	BDL	BDL	0.43	BDL	BDL	0.15	BDL	0.10	BDL	BDL	0.16	0.78	0.12	0.41	0.35	BDL	BDL	BDL	2.86
Acanthurus xanthopterus (15.5.)	Apra Harbour (f)	12-Jun-98	Axial muscle	0.44	BDL	0.28	0.28	0.74	0.23	BDL	0.30	0.19	0.25	0.19	0.19	0.25	0.62	0.21	0.34	0.36	0.15	BDL	0.14	5.15
Acanthurus xanthopterus (12.8)	Apra Harbour (f)	12-Jun-98	Axial muscle	0.19	BDL	BDL	BDL	0.58	BDL	BDL	BDL	BDL	0.11	BDL	BDL	0.09	0.52	0.12	0.37	0.35	0.04	BDL	0.09	2.45
Acanthurus xanthopterus (11.0)	Apra Harbour (f)	12-Jun-98	Axial muscle	0.21	BDL	BDL	BDL	0.53	BDL	BDL	0.32	0.06	0.25	0.08	0.08	0.36	2.17	0.32	1.29	1.19	0.06	BDL	0.20	7.13
Balistoides viridescens (18.5)	Merizo Pier	22-Dec-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.07	0.19	BDL	0.06	0.27	0.34	0.05	0.14	0.03	BDL	BDL	BDL	1.15
			Liver	1.09	BDL	4.62	0.92	5.00	6.22	BDL	13.0	9.67	52.3	BDL	8.70	51.14	68.5	7.17	18.9	5.07	1.52	0.77	BDL	255
Bolbometopon muricatus (52.0)	Apra Harbour (c)	3-Jun-98	Axial muscle	0.27	BDL	BDL	BDL	BDL	BDL	BDL	0.33	BDL	0.14	BDL	0.30	0.10	0.73	BDL	0.10	0.52	BDL	BDL	BDL	2.50
			Liver	BDL	BDL	3.82	BDL	21.6	BDL	BDL	6.84	2.29	16.6	4.10	6.88	19.8	245	32.9	116	148	BDL	BDL	BDL	623
Caranx ignobilis (26.5)	Agana Boat Basin	18-Dec-98	Axial muscle	0.62	BDL	0.24	0.32	0.68	BDL	BDL	1.37	BDL	2.47	BDL	0.55	2.30	3.18	0.74	1.92	1.27	0.14	BDL	BDL	15.8
			Liver	0.70	BDL	2.24	2.24	3.53	BDL	BDL	10.4	BDL	21.5	0.81	4.26	10.9	27.4	5.08	12.9	9.51	0.94	1.42	0.64	114
Caranx melampygus (26.5)	Apra Harbour (b)	5-Jun-98	Axial muscle	BDL	BDL	BDL	BDL	1.02	BDL	BDL	3.00	1.65	4.98	BDL	1.38	4.37	12.3	1.88	4.93	4.91	0.15	BDL	0.06	40.6
Caranx melampygus (33.0)	Apra Harbour (e)	9-Jun-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.11	0.17	1.14	BDL	0.59	3.63	16.2	2.99	8.81	8.07	0.33	BDL	0.22	43.3
			Liver	BDL	BDL	0.20	0.19	3.03	BDL	BDL	17.1	3.23	17.5	9.66	7.92	178	10810	121	5430	403	3.16	2.23	1.53	17009
Caranx sexfasciatus (25.0)	Agana Boat Basin	30-Dec-98	Axial muscle	0.39	BDL	0.32	BDL	0.36	BDL	BDL	0.55	0.44	1.21	BDL	0.38	1.57	2.91	0.80	1.49	0.74	0.08	BDL	BDL	11.2
Caranx sexfasciatus (23.0)	Agana Boat Basin	30-Dec-98	Axial muscle	0.40	BDL	0.38	BDL	0.39	BDL	BDL	0.35	0.14	0.49	BDL	0.15	0.41	1.04	0.21	0.65	0.46	BDL	BDL	BDL	5.08
Caranx sexfasciatus (22.0)	Apra Harbour (c)	3-Jun-98	Axial muscle	0.16	BDL	0.05	BDL	0.24	BDL	BDL	1.05	0.12	0.62	0.29	0.23	1.63	6.66	0.78	2.27	2.70	0.07	BDL	BDL	16.9
Caranx sexfasciatus (17.0)	Apra Harbour (d)	9-Jun-98	Axial muscle	BDL	BDL	BDL	BDL	0.93	BDL	BDL	2.59	1.53	4.06	0.09	1.02	3.35	4.58	0.60	1.38	1.15	0.05	BDL	BDL	21.3
Cephalopholis sonnerati (16.5)	Merizo Pier	22-Dec-98	Axial muscle	0.38	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.09	BDL	0.06	0.04	BDL	BDL	BDL	0.57
Cheilinus chlorous (22.5)	Agat Marina	22-Jan-98	Axial muscle	0.15	BDL	BDL	BDL	0.26	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.05	0.16	0.05	0.10	0.07	BDL	BDL	BDL	0.84
Cheilinus fasciatus (24.5)	Apra Harbour (c)	3-Jun-98	Axial muscle	BDL	BDL	0.07	BDL	0.10	BDL	BDL	0.15	0.05	0.14	0.04	BDL	BDL	0.68	0.35	1.17	1.12	0.04	BDL	0.15	4.07
Cheilinus fasciatus (24.5)	Apra Harbour (c)	3-Jun-98	Axial muscle	0.23	BDL	0.40	BDL	0.20	BDL	BDL	0.26	0.21	0.62	0.07	0.03	BDL	1.73	0.43	1.38	1.42	0.05	BDL	0.09	7.12
Cheilinus fasciatus (19.0)	Apra Harbour (c)	3-Jun-98	Axial muscle	BDL	BDL	0.08	BDL	BDL	BDL	BDL	0.12	0.04	0.12	BDL	BDL	BDL	0.54	0.19	0.64	0.63	0.02	BDL	0.06	2.43
			Liver	BDL	BDL	2.69	1.04	4.51	BDL	BDL	8.03	BDL	12.2	0.95	BDL	BDL	38.0	BDL	48.4	37.5	BDL	BDL	BDL	153
Cheilinus trilobatus (19.5)	Merizo Pier	22-Dec-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.08	BDL	BDL	BDL	0.09	0.03	0.07	BDL	BDL	BDL	BDL	0.26
Cheilinus trilobatus (19.0)	Merizo Pier	22-Dec-98	Axial muscle	0.22	BDL	BDL	BDL	0.21	BDL	BDL	BDL	0.12	0.29	BDL	0.19	BDL	0.33	BDL	0.07	0.11	BDL	BDL	BDL	1.53
Ctenochaetus binotatus (21.0)	Apra Harbour (d)	9-Jun-98	Axial muscle	0.13	BDL	0.12	BDL	1.99	BDL	BDL	1.73	0.65	2.36	0.12	0.51	1.26	3.92	0.58	1.58	1.36	0.07	BDL	0.04	16.4
			Liver	0.36	BDL	BDL	BDL	1.47	BDL	BDL	1.93	0.65	2.79	BDL	0.41	1.23	4.20	BDL	1.37	1.27	0.08	BDL	BDL	15.8
Ctenochaetus striatus (12.5)	Apra Harbour (e)	9-Jun-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.17	0.78	BDL	0.39	3.06	7.17	2.20	5.81	3.32	0.49	0.18	0.60	24.2
Ctenochaetus striatus (13.0)	Apra Harbour (f)	12-Jun-98	Axial muscle	0.38	BDL	0.09	BDL	0.37	BDL	BDL	0.12	0.11	0.39	BDL	0.15	0.52	2.46	0.42	1.24	0.87	0.06	BDL	BDL	7.17
Ctenochaetus striatus (12.5)	Agat Marina	22-Jan-98	Axial muscle	0.47	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.15	0.04	0.10	0.08	BDL	BDL	BDL	0.83

Epibulus insidiator (24.5)	Apra Harbour (c)	3-Jun-98	Axial muscle	0.29	BDL	0.07	BDL	0.59	BDL	BDL	0.62	1.65	6.26	0.14	0.15	4.39	8.24	0.80	2.12	1.69	0.09	BDL	BDL	27.1
Epibulus insidiator (16.0)	Apra Harbour (e)	12-Jun-98	Axial muscle	0.33	BDL	0.19	0.17	BDL	BDL	BDL	0.35	0.25	1.29	BDL	0.14	3.25	15.2	2.51	7.61	4.94	0.39	BDL	0.22	36.8
Epinephelus merra (24.0)	Merizo Pier	22-Dec-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.03	0.07	BDL	0.03	0.09	0.13	0.06	0.14	0.05	BDL	BDL	BDL	0.59
Gerres argyreus (24.0)	Agana Boat Basin	30-Dec-98	Axial muscle	0.41	BDL	1.43	0.30	1.13	BDL	BDL	0.72	BDL	0.84	BDL	0.16	0.86	1.72	0.23	0.74	0.60	BDL	BDL	BDL	9.13
			Liver	2.19	BDL	78.8	10.1	47.9	BDL	BDL	30.7	13.4	39.8	BDL	4.52	31.2	333	BDL	20.3	18.5	0.56	0.53	BDL	632
Gerres argyreus (15.5)	Agana Boat Basin	30-Dec-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.25	BDL	BDL	0.33	0.50	0.17	0.28	0.15	BDL	BDL	BDL	1.67
Gerres argyreus (16.5)	Apra Harbour (d)	9-Jun-98	Axial muscle	0.37	BDL	BDL	BDL	0.78	BDL	BDL	1.48	1.17	3.26	BDL	0.57	2.24	2.98	0.36	0.78	0.70	BDL	BDL	BDL	14.7
Gerres argyreus (15.0)	Apra Harbour (d)	9-Jun-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.64	0.30	1.04	BDL	0.24	1.15	2.59	0.45	1.26	1.01	BDL	BDL	BDL	8.67
Gerres argyreus (14.5)	Apra Harbour (d)	9-Jun-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.12	0.19	0.40	BDL	0.15	0.57	0.95	0.20	0.54	0.37	BDL	BDL	BDL	3.49
Gymnothorax javanicus (60.0)	Apra Harbour (a)	5-Jun-98	Axial muscle	0.19	BDL	BDL	BDL	0.60	BDL	BDL	0.42	BDL	0.61	0.05	0.19	0.54	2.07	0.25	0.70	0.68	0.02	BDL	BDL	6.33
			Liver	BDL	BDL	BDL	BDL	1.18	BDL	BDL	2.00	BDL	3.01	BDL	BDL	2.61	10.2	1.38	3.13	3.24	BDL	BDL	0.18	27.0
Leiognathus equulus (14.0)	Agat Marina	22-Jan-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.15	0.41	0.28	0.28	2.14	6.57	1.52	4.08	2.53	0.20	BDL	BDL	18.2
Lethrinus rubrioperculatus (24.5)	Agat Marina	21-Dec-98	Axial muscle	BDL	BDL	0.14	BDL	BDL	BDL	BDL	0.10	0.17	0.51	BDL	BDL	0.77	1.38	0.35	1.09	0.70	0.07	BDL	BDL	5.27
			Liver	BDL	BDL	5.89	BDL	BDL	BDL	BDL	BDL	BDL	14.7	9.55	BDL	32.2	38.8	17.6	17.8	10.8	1.55	BDL	BDL	149
Lethrinus rubrioperculatus (20.5)	Merizo Pier	22-Dec-98	Axial muscle	0.40	BDL	BDL	BDL	BDL	BDL	BDL	0.17	0.11	0.32	BDL	0.07	0.23	0.29	0.04	0.06	0.06	BDL	BDL	BDL	1.74
Lutjanus kasmira (13.5)	Merizo Pier	22-Dec-98	Axial muscle	0.68	BDL	0.11	BDL	0.20	BDL	BDL	BDL	BDL	BDL	BDL	0.10	BDL	0.32	0.05	0.12	0.22	BDL	BDL	BDL	1.81
Monodactylus argenteus (14.5)	Agana Boat Basin	18-Dec-98	Axial muscle	0.41	BDL	1.02	0.53	0.92	1.09	BDL	0.74	0.62	1.28	BDL	0.26	0.56	1.27	0.25	0.68	0.62	0.03	BDL	BDL	10.3
Monodactylus argenteus (17.8)	Apra Harbour (d)	9-Jun-98	Axial muscle	0.60	BDL	0.08	BDL	0.80	BDL	BDL	0.89	0.15	0.73	0.13	0.15	1.10	3.95	0.37	1.13	1.34	0.03	BDL	BDL	11.5
			Liver	0.26	BDL	1.20	2.32	8.58	BDL	BDL	23.0	6.16	32.1	BDL	7.11	1449	4938	BDL	2772	2103	1.70	0.98	0.68	11346
Monodactylus argenteus (17.0)	Apra Harbour (d)	9-Jun-98	Axial muscle	BDL	BDL	0.19	0.38	1.85	BDL	BDL	2.37	0.83	2.54	0.13	0.57	2.06	6.34	0.53	1.52	1.71	0.04	BDL	BDL	21.0
			Liver	0.36	BDL	0.86	1.06	6.05	BDL	0.28	18.4	7.18	31.2	BDL	6.30	43.1	2672	13.1	986	39.8	1.03	0.71	0.51	3827
Monodactylus argenteus (17.0)	Apra Harbour (d)	9-Jun-98	Axial muscle	0.21	BDL	0.19	0.18	1.89	BDL	BDL	2.60	0.39	1.82	0.37	0.50	3.47	14.6	1.36	4.17	4.29	0.13	BDL	BDL	36.1
Monodactylus argenteus (17.0)	Apra Harbour (d)	9-Jun-98	Axial muscle	0.74	BDL	0.13	BDL	1.40	BDL	BDL	1.61	0.32	1.42	0.12	0.28	1.51	5.13	0.40	1.15	1.36	BDL	BDL	BDL	15.6
Monodactylus argenteus (16.8)	Apra Harbour (d)	9-Jun-98	Axial muscle	BDL	BDL	0.55	0.51	2.78	BDL	BDL	2.65	0.79	1.64	0.12	0.44	1.44	4.33	0.39	0.99	1.12	0.04	BDL	BDL	17.8
Monodactylus argenteus (16.5)	Apra Harbour (d)	9-Jun-98	Axial muscle	0.31	BDL	0.61	BDL	2.34	BDL	BDL	2.45	0.61	2.29	0.20	0.53	2.21	7.24	0.81	2.09	2.43	0.07	BDL	BDL	24.2
			Liver	1.10	BDL	3.13	2.49	17.0	BDL	BDL	29.0	8.79	38.0	2.64	8.91	38.1	124	13.8	50.7	47.8	1.50	1.67	1.34	390
Naso annulatus (13.5)	Apra Harbour (e)	12-Jun-98	Axial muscle	BDL	BDL	BDL	BDL	1.03	BDL	BDL	0.22	BDL	BDL	BDL	BDL	BDL	2.25	0.19	0.88	1.36	0.07	BDL	0.07	6.08
Naso unicornis (18.5)	Apra Harbour (a)	5-Jun-98	Axial muscle	1.57	BDL	0.06	BDL	0.25	BDL	BDL	0.21	0.04	0.15	0.06	0.07	0.33	1.42	0.19	0.58	0.55	0.02	BDL	BDL	5.51
Naso unicornis (25.0)	Apra Harbour (a)	5-Jun-98	Axial muscle	0.19	BDL	BDL	BDL	0.38	BDL	BDL	0.20	BDL	0.16	BDL	0.06	0.23	1.02	0.13	0.35	0.35	BDL	BDL	BDL	3.06
Odonus niger (17.0)	Agat Marina	22-Jan-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.11	0.22	0.05	0.14	0.09	BDL	BDL	BDL	0.61
Parupeneus barberinus (26.0)	Merizo Pier	22-Dec-98	Axial muscle	0.30	BDL	0.12	BDL	0.29	BDL	BDL	0.14	0.08	0.25	BDL	0.06	BDL	0.38	0.11	0.35	0.21	BDL	BDL	BDL	2.30
Parupeneus barberinus (16.0)	Merizo Pier	22-Dec-98	Axial muscle	0.21	BDL	BDL	BDL	0.23	BDL	BDL	BDL	BDL	0.14	BDL	BDL	0.12	0.16	0.02	0.05	0.03	BDL	BDL	BDL	0.96
Parupeneus cyclostomus (25.0)	Merizo Pier	22-Dec-98	Axial muscle	0.33	BDL	0.09	BDL	BDL	BDL	BDL	0.17	BDL	0.43	BDL	BDL	0.38	0.95	0.09	0.25	0.20	BDL	BDL	BDL	2.90
Parupeneus multifasciatus (17.5)	Merizo Pier	22-Dec-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.10	BDL	0.55	BDL	0.23	0.40	1.00	0.12	0.36	0.26	BDL	BDL	BDL	3.02
Saurida gracilis (23.0)	Agana Boat Basin	30-Dec-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.20	BDL	BDL	0.24	0.50	0.14	0.35	0.20	BDL	BDL	BDL	1.64
			Liver	BDL	BDL	12.1	4.67	14.1	3.13	BDL	20.4	BDL	56.6	BDL	10.6	49.5	143	BDL	71.7	33.6	2.98	BDL	0.45	423
Saurida gracilis (19.5)	Agana Boat Basin	30-Dec-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.22	BDL	0.06	0.26	0.51	0.14	0.25	0.17	BDL	BDL	BDL	1.60
Saurida gracilis (16.5)	Agana Boat Basin	30-Dec-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.16	0.39	BDL	0.12	0.59	1.42	0.30	0.68	0.41	0.03	BDL	BDL	4.11
Saurida gracilis (15.5)	Agana Boat Basin	30-Dec-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.26	BDL	0.61	BDL	0.19	0.73	1.49	0.28	0.73	0.42	0.03	BDL	BDL	4.75
Saurida gracilis (20.0)	Agat Marina	31-Dec-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.10	0.22	0.08	0.25	0.13	BDL	BDL	BDL	0.78
Saurida gracilis (19.0)	Agat Marina	31-Dec-98	Axial muscle	0.26	BDL	BDL	BDL	0.26	BDL	BDL	BDL	BDL	0.11	BDL	BDL	0.11	0.30	0.09	0.29	0.21	BDL	BDL	BDL	1.63
Saurida gracilis (17.5)	Agat Marina	31-Dec-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.09	BDL	0.06	0.06	BDL	BDL	BDL	0.21
Saurida nebulosa (21.5)	Apra Harbour (a)	5-Jun-98	Axial muscle	BDL	BDL	BDL	BDL	0.28	BDL	BDL	0.47	0.19	0.90	BDL	0.25	1.69	5.74	1.30	3.39	2.93	0.16	BDL	0.14	17.4
Saurida nebulosa (16.5)	Merizo Pier	22-Dec-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.03	BDL	0.04	0.02	BDL	BDL	BDL	0.09
Scarus sordidus (16.0)	Apra Harbour (e)	12-Jun-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.04	0.67	0.46	1.48	0.75	0.10	BDL	BDL	3.50
Scarus sordidus (15.0)	Apra Harbour (e)	9-Jun-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.43	BDL	0.65	0.30	0.04	BDL	0.08	1.50
			Liver	3.25	BDL	BDL	3.13	7.52	BDL	BDL	1.70	BDL	BDL	3.74	0.64	BDL	27.3	BDL	116	36.9	8.12	14.6	10.8	234
Scarus sordidus (14.0)	Apra Harbour (e)	12-Jun-98	Axial muscle	0.20	BDL	0.21	0.20	BDL	0.15	BDL	0.19	0.17	0.18	0.17	0.15	0.14	0.32	0.31	0.74	0.37	0.17	BDL	0.19	3.86
Siganus spinus (15.0)	Agana Boat Basin	18-Dec-98	Axial muscle	0.34	BDL	0.58	0.18	0.82	BDL	BDL	0.60	BDL	0.56	BDL	0.15	0.64	0.84	0.14	0.38	0.31	BDL	BDL	BDL	5.54
Sufflamen chrysopterus (17.0)	Apra Harbour (e)	12-Jun-98	Axial muscle	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.93	BDL	0.41	0.20	BDL	BDL	16.5	0.54	12.8	5.75	0.06	BDL	0.38	37.6
			Liver	1.11	BDL	BDL	BDL	26.1	BDL	BDL	65.8	BDL	41.3	BDL	1.51	BDL	62.9	BDL	97.6	31.5	4.15	39.2	19.4	390
Valamugil engeli (37.5)	Apra Harbour (b)	5-Jun-98	Axial muscle	0.35	BDL	0.20	BDL	0.80	BDL	BDL	0.53	0.16	0.59	BDL	0.13	0.05	1.35	0.25	0.65	0.62	0.04	BDL	0.06	5.79
			Liver	0.84	0.42	3.90	0.62	8.70	BDL	BDL	9.46	2.43	9.09	BDL	1.59	4.06	20.3	2.13	6.59	7.93	0.34	0.38	0.36	79.1

BDL = below detection limits.

Method detection limits (ng/g) were as follows: PCB 8 (0.38), PCB 18 (0.46), PCB 28 (0.23), PCB 44 (0.26), PCB 52 (0.46), PCB 66 (0.23), PCB 77 (0.43), PCB 101 (0.26), PCB 105, (0.11), PCB 118 (0.15), PCB 126 (0.16), PCB 128 (0.10), PCB 138 (0.11), PCB 153 (0.22), PCB 170 (0.06), PCB 180 (0.05), PCB 187 (0.07), PCB 195 (0.06), PCB 206 (0.08), and PCB 209 (0.12). Known co-eluting peaks (Ballschmiter et al., 1989; Bright et al., 1995) detected in environmental samples (McFarland and Clarke, 1989) are: PCB 5 with PCB 8; PCB 15 with PCB 18; PCB 31 with PCB 28; PCB 110 with PCB 77; PCB 80 and PCB 95 with PCB 66; PCB 90 with PCB 101; PCB 158 with PCB 126, and PCB 132 with PCB 153.

for the first minute of each run. It was then ramped to 150 °C at 30 °C/min, then to 280 °C at 25 °C/min, where it was held for 20 min to give a total run time of 76 min. Both the injector and detector temperatures were held constant at 280 °C and 310 °C, respectively.

PCB quantification was accomplished using a 20-congener calibration standard representing PCB homologues Cl_2–Cl_{10} (NOAA, 1993). The congeners were selected on the basis of their potential toxicity, bioaccumulation and/or frequency of occurrence in environmental samples. All calculations were based on peak area comparisons of components sharing identical retention times in both sample and standard. The "total" PCB content of the sample was calculated from the sum of the individual congener data ($\sum_{20}$PCB). Undetectable congeners were set to zero for this process. Congener recoveries from the certified standard reference material (marine mussel: SRM 2974) and a spiked oyster composite were generally within acceptable limits (Table 2). Method detection limits for individual chlorobiphenyls in the standard mix ranged from 0.02 to 0.15 ng/g.

The congener data for all biotic groups are summarized in Table 3 (all as ng/g wet weight) with no adjustments for recoveries. Co-eluting congeners of possible significance are identified in the legend. Selected PCB data for similar and related species from elsewhere are presented in Table 4 for comparative purposes. In the current work, PCB profiles were dominated by the lower chlorinated homologues (Cl_2–Cl_4) in the brown alga, *Padina* sp., and the mid range homologues (Cl_4–Cl_7) in most other organisms analyzed. An overall analysis of congener prevalence and abundance is presented in Table 5. In both instances, rank orders generally mirrored congener abundance in the technical PCB mixtures, Aroclor 1254 and 1260 (De Voogt et al., 1990). PCB 66, a major component of A1254, was the notable exception here. This congener was detected in <10% of all samples analyzed and had an average abundance of <1%.

PCBs 153 and 187 were the two most commonly encountered congeners, respectively detected in 98% and 97% of all samples analyzed. Overall, they were also the most abundant congeners examined representing 27% and 16% of $\sum_{20}$PCB estimates respectively. In contrast, the more toxic planer chlorobiphenyl, PCB 77, a trace constituent of commercial mixtures, was the least prevalent (2.7%) and abundant (0.1%) congener detected. It was detected in only five samples at concentrations ranging from 0.25 to 1.58 ng/g. The highest level was confined to the liver of an octopus taken from Apra Harbour. PCB 126, also a potent planar compound and minor component of commercial mixtures (De Voogt et al., 1990), was an order of magnitude more prevalent than PCB 77 and was detected in all biotic groups, except algae and soft corals. Quantifiable levels of this congener ranged from 0.04 to 9.66 ng/g with highest values occurring in the livers of various fish. It is noted here that PCB 158 co-elutes with PCB 126 under the chromatographic conditions employed during this study. The former congener is a major component of Aroclor 1260 (Ballschmiter et al., 1987) and one previously reported, albeit infrequently, in environmental samples (McFarland and Clarke, 1989). Consequently, it is possible that the apparent widespread occurrence of PCB 126 in our samples was due in part to the co-presence of PCB 158.

Rank orders of prevalence and abundance for the remaining congeners were generally similar. In summary, PCBs 52, 101, 118, 128, 138, 170 and 180 were detected in >50% of all samples and had average abundances of 3.4–11%. PCBs 8, 28, 44, 105, 195 and 209 were found in <50% and their collective average abundance was <10%. Less commonly encountered in <10% of all samples were PCBs 18 and 206 with a collective average abundance of <0.5%.

Total PCB concentrations ($\sum_{20}$PCBs) measured during this study varied substantially between and within the biotic groups examined. Concentrations in seaweed and ascidians were consistently <5 ng/g, even from sites previously identified as contaminated. Several sponges yielded values in the same order while others ranged between 10 and 100 ng/g. One encrusting variety (*Dysidea* sp.) had extremely high concentrations that approached 10,000 ng/g at a PCB hot spot, near the Fox-1 Fuel Pier, in Apra Harbour (Fig. 1c, site c). $\sum_{20}$PCBs found in an unidentified species of soft coral (*Sinularia* sp.) from this location were equally impressive and highlight the bioindicator potential of these organisms for future monitoring purposes. It is noteworthy that both *Dysidea and Sinularia* are rich in triglycerides, which would explain their high bioaccumulation capacity for PCBs, and presumably other lipophilic xenobiotics. *Dysidea* sp. for example has a lipid content of 20–30%.

PCBs in sea cucumbers were distinctly tissue-dependent, with the hemal system frequently containing levels an order of magnitude or more above those found in body wall muscle. The indigenous people of the western Pacific commonly eat the latter tissue; hence, the typically low PCB levels encountered here (all <20 ng/g) are of interest from a public health standpoint. The unusually high PCB concentration (1279 ng/g) noted in the hemal system of *Holothuria atra*, from a lightly contaminated site at Merizo Pier, is also significant and suggests these organisms may have bioindicator potential.

PCB concentrations in crustaceans and molluscs from uncontaminated waters usually fall within the range 1–10 ng/g (Sericano et al., 1995; Monod et al., 1995; Everaarts et al., 1998). Group representatives examined here also generally fell within this range for $\sum_{20}$PCBs. Exceedences were noted only among those from the contaminated Dry Dock Island site in Apra Harbour (Fig. 1c, site e) and ranged between 30 and 50 ng/g. The only cephalopod mollusc examined during the study was captured beneath the Fox-1 Fuel Pier and, while $\sum_{20}$PCBs in muscular tissue was less than 10 ng/g, the concentration in the liver exceeded 1000 ng/g, in line with that noted earlier for

Table 4
PCB concentrations in selected organisms[a] from various tropical and subtropical regions of the world

Species	Location	Total PCBs (ng/g wet wt.)	Reference
Algae			
Padina sp. (frond)	Guam harbours	0.39–1.85 ($\sum_{20}$PCBs)	This study
Various species	Eastern Sicily coastal waters	6–95[b]	Amico et al. (1979)
Various species	Lagoon of Venice	2–19b	Pavoni et al. (1990)
Dictyota acutiloba	Midway Atoll	7.14 (average; $\sum_{20}$PCBs)[b]	Hope et al. (1998)
Giffordia breviarticulata	Midway Atoll	4.7 (average: $\sum_{20}$PCBs)[b]	Hope et al. (1998)
Halophila ovalis	Midway Atoll	1.8 (average: $\sum_{20}$PCBs)[b]	Hope et al. (1998)
Sea cucumbers			
Bohadschia argus (body wall)	Guam harbours	0.03–12.8 ($\sum_{20}$PCBs)	This study
Bohadschia argus (hemal system)	Guam harbours	0.28–66.5 ($\sum_{20}$PCBs)	This study
Bohadschia argus (whole)	Midway Atoll	22 (average: $\sum_{20}$PCBs)[b]	Hope et al. (1998)
Holothuria atra (body wall)	Guam harbours	0.14 17.6 ($\sum_{20}$PCBs)	This study
Holothuria atra (hemal system)	Guam harbours	0.46–1279 ($\sum_{20}$PCBs)	This study
Holothuria atra (whole)	Midway Atoll	1.12 (average: $\sum_{20}$PCBs)[b]	Hope et al. (1998)
Bivalve molluscs (whole flesh)			
Chamids: *Chama brassica*	Apra Harbour, Guam	1.21–3.26 ($\sum_{20}$PCBs)	This study
Chamids: *Chama lazarus*	Guam harbours	0.29–7.98 ($\sum_{20}$PCBs)	This study
Chamids: *Chama iostoma*	Midway Atoll	7.6 (average: $\sum_{20}$PCBs)[b]	Hope et al. (1998)
Oysters: *Saccostrea cuccullata*	Guam harbours	1.3–14.2 ($\sum_{20}$PCBs)	This study
Oysters: *Striostrea cf. mytiloides*	Guam harbours	1.2–47.0 ($\sum_{20}$PCBs)	This study
Oysters: unidentified	Dominican Republic	3.1–8.2[b]	Sbriz et al. (1998)
Mussels: *Perna viridis*	Hong Kong waters	39–305[b]	Phillips (1985, 1986)
Mussels: *Mytillus galloprovincialis*	Catalan Coast, Mediterranean	2.19–51.1	Porte and Albaiges (1993)
Cephalopod molluscs			
Octopus: *Octopus cyanea* (tentacle)	Apra Harbour, Guam	8.78 ($\sum_{20}$PCBs)	This study
Octopus: *Octopus cyanea* (liver)	Apra Harbour, Guam	1271 ($\sum_{20}$PCBs)	This study
Octopus: unidentified (whole)	Saint Paul & Amsterdam Islands, Indian Ocean	2.1–5.0 ($\sum_{6}$PCBs)[b]	Monod et al. (1995)
Cuttlefish: *Sepia* sp. (whole)	East African waters	3.0 (average: $\sum_{7}$PCBs)	Everaarts et al. (1998)
Crustaceans			
Crab: *Macropipus tuberculata* (whole)	Catalan Coast, Mediterranean	10.2–90.5	Porte and Albaiges (1993)
Crab: *Carcinus mediterraneus* (whole)	Mediterranean	1448 (maximum)	Fowler (1987)
Mantis shrimp: *Gonodactylus* sp. (tail muscle)	Apra Harbour, Guam	38.2 ($\sum_{20}$PCBs)	This study
Shrimp: *Parapenaeus longirostris* (whole)	Mediterranean	mostly <30	Fowler (1987)
Shrimp: *Metapenaeus ensis* (whole)	Tonkin Bay, N. Vietnam	0.5–1.1[b]	Dang et al. (1998)
Fish (muscle)			
31 spp.	Guam harbours	0.09–85.0 ($\sum_{20}$PCBs)	This study
Several species	Six tropical Asian countries	0.38–110	Kannan et al. (1995)
6 spp.	Hong Kong waters	<0.001–9.6 ($\sum_{51}$PCBs)	Chan et al. (1999)
5 spp.	Brisbane River, Australia	nd–2100	Shaw and Connell (1980, 1982)
3 spp.	Catalan Coast, Mediterranean	3.10–482	Porte and Albaiges (1993)
Red mullet: *Mullus barbatus*	Alexandroupolis, Greece	7.9–14.6	Giouranovits-Psyllidou et al. (1994)
Fish (liver)			
15 spp.	Guam harbours	15.8–17.009 ($\sum_{20}$PCBs)	This study
Parrot fish: unidentified	Madeira, Portugal	44,000 ($\sum_{6}$PCBs)[c]	Ballschmiter et al. (1997)
Bluefin tuna: *Thunnus thynnus*	Catalan Coast, Mediterranean	112–275	Porte and Albaiges (1993)

nd—not detected.

[a] No comparable data found in the literature for sponges, soft corals or ascidians.

[b] Original data (ng/g dry weight) converted to ng/g wet weight using average wet:dry weight ratios determined in present study (i.e., 6.3, 8.3, 6.3, 3.8, 4.5 and 4.3 for algae, sea cucumbers, bivalves, octopus, shrimp and fish muscle respectively).

[c] Original data reported as ng/g lipid weight converted to ng/g wet weight using a wet weight:lipid weight ratio of 2.5.

sponges (*Dysidea* sp.) and soft corals (*Sinularia* sp.) from this site.

Marine fish from uncontaminated waters usually contain PCBs in the low ng/g range in their axial muscle. In the present study, $\sum_{20}$PCBs ranged from 0.09 to 85 ng/g in the 74 specimens analyzed. Of these, 13 fish from Apra Harbour contained concentrations greater than 20 ng/g, while a further 13 fish, predominantly from Apra Harbour and Agana Boat Basin, gave values between 10 and 20 ng/g. About 40 specimens contained between 1 and 10 ng/g,

Table 5
PCB prevalence and abundance data in biota from Guam harbours

Ranking	Prevalence[a]		Average abundance[b]	
	Congener	Frequency (%)	Congener	% of $\sum_{20}$PCB
1	153	98	153	27
2	187	97	187	16
3	118	91	180	11
4	180	81	118	9.0
5	101	80	138	8.0
6	138	78	52	5.5
7	170	72	101	5.2
8	128	72	8	4.6
9	52	54	170	3.4
10	105	46	128	2.8
11	8	45	28	1.8
12	195	45	105	1.5
13	28	34	126	0.9
14	126	27	44	0.6
15	209	24	66	0.5
16	44	23	195	0.5
17	206	8.6	209	0.4
18	18	7.5	18	0.2
19	66	6.4	206	0.1
20	77	2.7	77	0.1

[a] Prevalence = frequency of occurrence (%) of each PCB congener for all samples analyzed.

[b] Average abundance = [Sum (% of the $\sum_{20}$PCB represented by each congener in each sample)]/total number of samples.

with representatives from all four harbours. All fish with concentrations of less than 1 ng/g were exclusively from Agat Marina and Merizo Pier. While PCB concentrations in all fish caught were well below the US Food and Drug Administration tolerance of 2 μg/g (ATSDR, 2000), levels in the great majority (83%) were above the more recent US EPA cancer risk (1:100,000) guideline of no more than 1.5 ng/g in fish consumed on an unrestricted basis (US EPA, 2000).

The livers of 20 fish were analyzed during the present investigation. In all cases, $\sum_{20}$PCBs greatly exceeded those found in axial muscle. No doubt, the higher lipid content of liver tissue greatly enhances its capacity to act as a reservoir for refractory, lipophilic compounds like PCBs. Concentrations exceeding 10,000 ng/g were found in two fish from Apra Harbour. The first fish, *Caranx melampygus*, a relatively large carnivorous species taken from site e, off Dry Dock Island, contained 17,009 ng/g in its liver, while 11,346 ng/g was measured in *Monodactylus argenteus*, a small omnivorous species captured at site d at the western end of Commercial Port. Chromatograms from both fish were not far removed from the commercial PCB mixture, Aroclor 1260. Several workers have explored the potential of fish liver as an indicator tissue for PCBs (Marthinsen et al., 1991; Pereira et al., 1994; Brown et al., 1998). The idea would seem to have merit providing the foraging ranges of species chosen for such purposes are known beforehand.

Overall, the study indicates moderate PCB contamination in biotic components from Apra Harbour. For sessile species, concentrations generally mirrored distribution patterns noted earlier in sediments (Denton et al., 1997, 2005) highlighting small, localized pockets of contamination in the Commercial Port and Dry Dock Island areas. A similar relationship with sediments was noted for biotic representatives collected from the other harbour sites, all of which were relatively clean by world standards. Clearly, Guam is not free of PCBs despite its remote location. Over the years, the improper disposal of waste oil, electrical equipment and other consumables containing PCBs, together with spillages from capacitors and transformers, have had a major impact on coastal waters around parts of the island. For example, a recent study identified a maximum PCB concentration of 80 ppm (as Aroclor 1254) in whole fish caught next to the seawall of a disused military dumpsite at the southern end of the Orote Point Peninsula, approximately 3 km south of Apra Harbour (ATSDR, 2002). Levels in *Padina* spp. (brown algae) samples collected along this stretch of coastline ranged from 0.19 ng/g at the harbour entrance, to 12.22 ng/g at the seawall (Denton, unpublished data). Additional studies are required to extend the database to other coastal areas around the island, particularly those adjacent to military bases, or close to river mouths, storm water discharge points or sewer outfalls.

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Source and distribution of trace metals in the Medway and Swale estuaries, Kent, UK

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Millions of tonnes of fine-grained sediment are dredged annually from Europe's estuaries to maintain navigation routes and permit access to commercial ports and berths. The majority of this material is removed using traditional dredging techniques and disposed of in landfill or at sea. However, the implementation of the EU Landfill Directive has increased the costs associated with the disposal of dredged material in landfill and there is a growing consensus within Europe to manage fine sediment sustainably and examine the beneficial re-use of dredged material. As a result alternative techniques for both sediment dredging and disposal are being investigated throughout Europe.

A number of fine sediment management techniques are currently in operation in the Medway and Swale estuaries. An extensive traditional dredging programme maintains navigation channels and water injection dredging (WID), a relatively novel dredging technique in the UK, is being used to enable continued access to industrial facilities. In addition, English Nature is keen to support a strategy of beneficial sediment re-use within the Medway, using dredged sediment to re-charge or re-create inter-tidal habitats that are currently under threat from sea level rise and associated sediment loss (English Nature, 1999). Water injection dredging involves the injection of jets of water into bottom sediments in situ, decreasing the cohesion between sediment particles and creating a turbulent water–sediment mixture. This mixture acts as a fluid with extremely low viscosity and is able to flow under the influence of gravity along the sediment water interface. Environmental concerns still surrounding the use of WID are the potential release of sediment-bound contaminants to the over-lying water column and the re-distribution of contaminated sediments over wider areas (Meyer-Nehls et al., 2000; Sullivan, 2000; Ospar Commission, 2004; Spencer et al., 2005).

Preliminary investigations have indicated that the Medway Estuary currently receives low but appreciable inputs of metal contaminants with numerous point and diffuse sources (Spencer, 2002) and a range of historical contaminant inputs are implied in the vertical distributions of heavy metals in salt marsh sediments (Spencer et al., 2003). However, data are yet to be presented providing a detailed picture of surface sediment quality across the estuary and no data are available for the Swale. Where sediment management practices involve the re-distribution of sediment via WID or the beneficial re-use of dredged sediment in habitat re-creation schemes it is vital that those responsible for the management of sediment have access to detailed and accurate information regarding sediment quality. In addition, the EU Water Framework Directive is likely to require the development of sediment environmental quality standards (EQS) enforceable on a pass/fail basis (Crane, 2003). Hence, in this study we have investigated the source, magnitude and distribution of metals within the surface sediments of the inter-tidal zone in the Medway and Swale estuaries and made assessments regarding sediment quality by comparison with published sediment quality guidelines.

Forty five surface sediment samples were collected from the inter-tidal zone during June and July 2000 (Fig. 1). Redox potential and pH were recorded in situ, once the sediment was returned to the laboratory it was stored at −40 °C until required.

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