IMPACT OF LAND-BASED SOURCES OF POLLUTION ON COASTAL WATER QUALITY OF SAIPAN, COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS (CNMI): ARSENIC, MERCURY AND PCBs IN POPULAR TABLE FISH FROM SAIPAN LAGOON

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WATER AND ENVIRONMENTAL RESEARCH INSTITUTE
OF THE WESTERN PACIFIC
UNIVERSITY OF GUAM

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For Cap

Jacinto (Cap) Taman: January 7, 1954 - March 8, 2008

Plate 1: View of the northern half of Saipan Lagoon (Tanapag Lagoon) from Suicide Cliff in the northern part of the island

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Plate 2: Long-time captain of the DFW research boat, Jacinto (Cap) Taman, demonstrates his legendary fishing skills to division colleagues

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ABSTRACT

Popular table fish were taken from 11 sites in the northern half of Saipan Lagoon and analyzed for total arsenic, total mercury and 20 PCB congeners, as part of an ongoing pollution monitoring and assessment program for Saipan's coastal waters. In all, 340 specimens representing 67 different species from four different trophic levels (20 herbivores, 7 planktivores, 5 omnivores and 35 carnivores) were collected between October 2004 and January 2005. Arsenic and mercury levels were determined in the axial muscle of all 340 representatives and in the hepatic tissues of 259 of them. PCB analysis was conducted only on axial muscle of 324 specimens.

Total arsenic levels in muscle and liver tissues range from 0.03-36.2 µg/g and 0.07-104 µg/g wet weight respectively. The majority of tissue samples analyzed yielded values of less than 5 µg/g wet weight. While no obvious site-dependant difference in arsenic availability emerged from the data, there were clear trophic level-dependant differences with herbivores generally containing the lowest concentrations. The planktiverous genera, *Myripristis*, were particularly noteworthy accumulators of this element. Other representatives with a propensity for arsenic included *Parupeneus multifasciatus* (multi-barred goatfish), *Neoniphon opercularis* (black-finned squirrelfish), *Thalassoma trilobatum* (Christmas wrasse) and *Rhinecanthus* spp. (trigger fish).

Total mercury concentrations in muscle and liver tissues ranged from 0.001-0.616 µg/g wet weight and 0.004-9.931 µg/g weight respectively. Levels in the former tissues were less than 0.10 µg/g in over 80% of fish analyzed. In the latter tissue, levels were less than 0.20 µg/g in approximately the same percentage. Inter-site data comparisons revealed a clear north to south increase in mercury availability with the highest levels generally occurring in fish from the Hafa Adai Beach area (Site 9). Despite some considerable variability within trophic levels, the data strongly supported the concept of mercury biomagnification with the overall average value in carnivores exceeding that in herbivores by approximately one order of magnitude.

Σ_{20}PCB levels in fish axial muscle tissue ranged from 0.04-145 ng/g dry weight with close to 90% of all fish analyzed yielding values of less than 20 ng/g. Wet weight approximations were computed from the raw data assuming muscle to be 77% water. Total PCBs levels in fish muscle were estimated by doubling Σ_{20}PCB concentrations. No obvious site- or trophic level-dependant differences emerged from the data. PCBs 101, 118 and 153 were the most frequently encountered congeners and were detected in over 80% of samples analyzed. They also ranked among the most abundant congeners, accounting for 8-28% of Σ_{20}PCBs on average. While the more toxic coplanar chlorobiphenyls, PCB 77 and PCB 126, were detected in 33% and 15% of all samples respectively, they had a collective average abundance of only 3.1%.

The toxicological significance of the data is discussed from a human health stand-point in light of national and international food standards and fish consumption advisories. For this purpose, total mercury and arsenic values determined in each fish were assumed to represent 100% and 1% of methylmercury and inorganic arsenic concentrations respectively. Total PCB approximations were obtained by doubling the Σ_{20}PCB values. It was concluded that fish from the northern half of Saipan Lagoon contained inorganic arsenic and PCBs in their edible tissue at levels below toxicological thresholds of concern, and could be eaten on an unrestricted basis. In contrast, methylmercury levels in carnivorous species from the more southerly sites visited were generally above those considered acceptable for unrestricted fish consumption.

INTRODUCTION

Saipan is the second most densely populated island in Micronesia and is located approximately 200 km north of Guam in the Mariana Archipelago. It is about 20 km long, 9 km wide and covers an area of approximately 115 sq km. A barrier coral reef system on the western side creates a large lagoon that extends almost the entire length of the island. The lagoon contains large expanses of patch reef interspersed with sand and rubble. This provides for a diversity of shallow water habitats that harbor rich assemblages of flora and fauna (Doty and Marsh 1977, Amesbury *et al.* 1979). Aside from the lagoon's ecological significance, it also supports a variety of recreational activities, and local people traditionally harvest many of its fisheries resources for food. Protecting and preserving this fragile environment and its resources for future generations is, therefore, of great importance to the people of Saipan.

Prior to the last world war, Saipan was essentially a small, rural community, free of many of the environmental pressures seen on the island today. Sources of pollution were minimal and largely associated with the disposal of domestic wastes from small settlements dotted around the coast. As a result, Saipan's coastal waters were relatively pristine from a water quality standpoint. Today, things are somewhat different, particularly on the western side of the island where the bulk of the population now exists. This area has undergone considerable urban growth and economic expansion in recent years. Such development has, in turn, greatly added to the waste disposal, urban runoff, chemical pollution and environmental management problems that the island currently has to deal with. The shoreline running along the northern half of Saipan Lagoon, for example, is replete with pollution sources that have significantly impacted water quality over the years. These include a major sea port, two small boat marinas, bulk fuel holding facilities, a sewer outfall, the largest power plant on island, several large garment factories (all now closed), auto and boat repair shops, junk yards, government vehicle maintenance yards and storage areas for old lead-acid batteries, PCB-laden electrical transformers and waste oil, and a municipal dump (closed February 2003) that is rumored to contain a plethora of toxic chemicals of both military and civilian origin (Ogden 1994). Such anthropogenic activities are far less pronounced further south, although the impact of stormwater drainage on beach erosion and sediment deposition is nonetheless apparent. The potential impact of all these pollution sources on fisheries resources within the lagoon is currently unknown.

Only recently have we started to gather fundamental data describing the abundance and distribution of persistent and potentially toxic pollutants within Saipan Lagoon. A contaminant assessment of surface sediments within the northern half of the lagoon was undertaken in 2000 (Denton *et al.* 2001, 2006a) and identified several heavy metals and PCBs as the contaminants of primary concern. Shortly thereafter, a survey of heavy metals in dominant ecological representatives from nearshore sites in this area was completed (Denton *et al.* 2008, 2009).

The investigation reported herein builds upon these earlier studies and extends the monitoring and assessment program to mercury, arsenic and PCBs in popular table fish from further offshore within the northern half of the lagoon. All three contaminants are potentially toxic and readily accumulated by fish. The study is therefore of special significance from a human health standpoint and should command the interest of local environmental regulators, water quality managers and public health officials throughout the region.

MATERIALS AND METHODS

SAMPLE COLLECTION AND PREPARATION

Between October 2004 and January 2005, 340 fish were captured by hook and line, spear gun or Hawaiian sling from 11 offshore sites between the villages of San Jose in the central section of Saipan Lagoon and San Roque in the north (Figure 1). Sites 1-3 were distanced from any significant anthropogenic sources of heavy metal and PCB contamination and were considered to serve as suitable reference (control) sites. The remaining sites were exposed to varying degrees of contamination from a variety of sources including, but not limited to, a sea port, shipping and small boat activities, solid and domestic waste disposal facilities, and stormwater discharges.

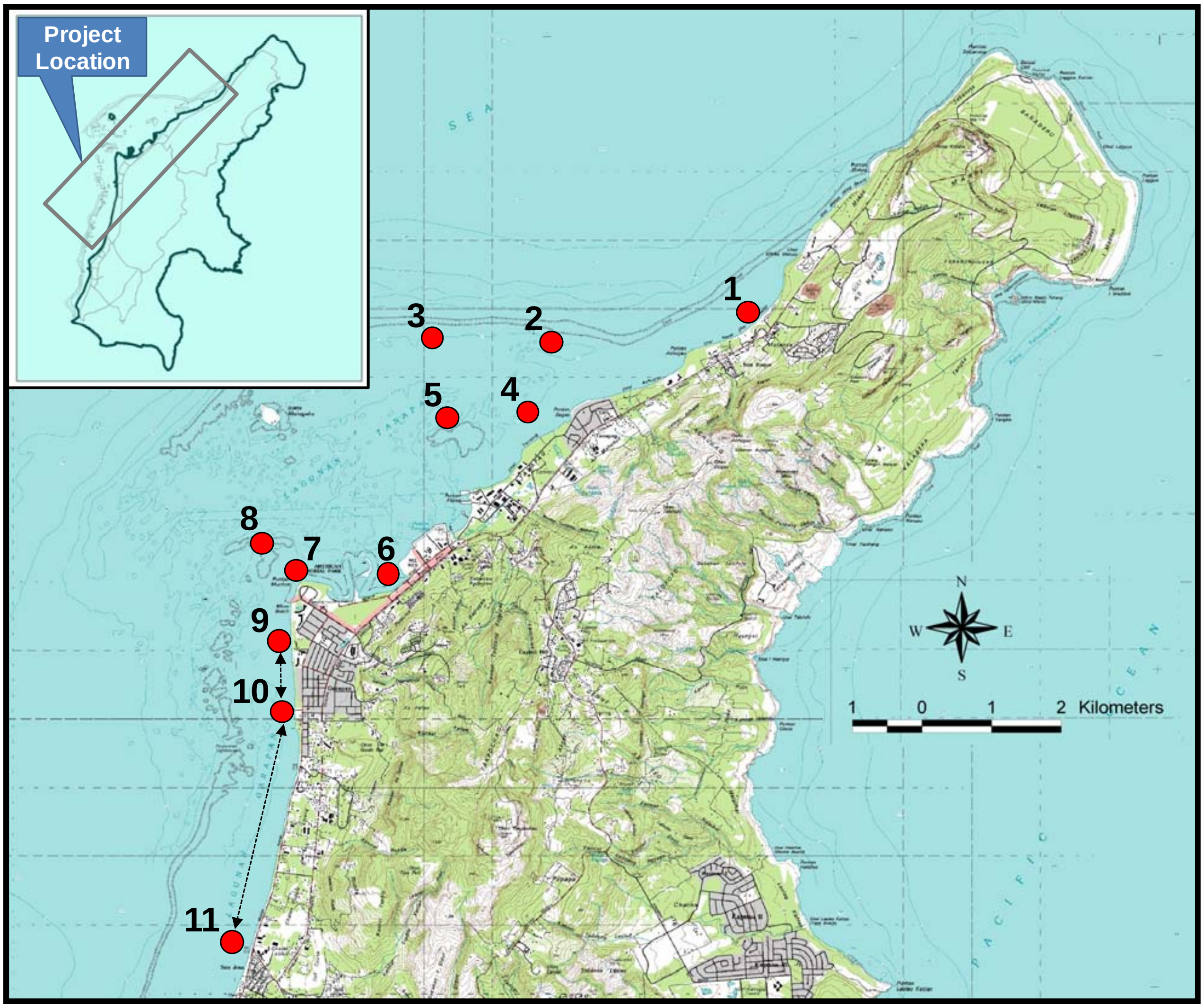

Figure 1: Fish sampling sites in the northern half of Saipan Lagoon. Site 1: Pau Pau shoals; Site 2: Dankulo Rock; Site 3: unnamed outer lagoon site; Site 4: Tanapag shoals; Site 5: Seaplane (Tanapag) Reef; Site 6: Puerto Rico Dump (seaward edge); Site 7: Micro Beach Point; Site 8: Micro Reef; Site 9: Hafa Adai Beach (nearshore patch reef); Site 10: Fishing Base (seagrass beds); Site 11: Beach Road-Chalan Monsignor Leon Guerrero intersection. Fish also collected at various points between Sites 9, 10 and 11 (dashed arrows).

A complete list of fish species taken over the study period is presented in Table 1. In all, 67 different species (35 carnivores, 20 herbivores, 7 planktivores and 5 omnivores) were collected and processed for analysis. While samples were generally collected on a haphazard basis, some preference was given to favored table species and those with restricted foraging ranges. All specimens were placed on ice following capture and transported to the Saipan Division of Fish and Wildlife laboratory in insulated containers. Here, they were weighed, measured (fork length) and their reproductive status assessed. All tissue dissections were performed using high quality stainless steel instruments. Axial muscle was taken from directly under the dorsal fin on the left side of the fish for mercury and arsenic analyses, and on the right side for PCB determinations. Hepatic tissues, if available, were analyzed for arsenic and mercury only. Tissues for metal analyses were stored in acid cleaned polypropylene vials while those for PCB determinations were individually wrapped in aluminum foil and sealed in Ziploc® bags. The great majority of fish were processed within a few hours of capture. The remainder were deep-frozen as quickly as possible and processed within one month. All tissue samples for chemical analyses were stored at -20^{o}C prior to shipment to the WERI Water Quality Laboratory in Guam.

CHEMICAL ANALYSIS

Arsenic and mercury analyses were performed on wet tissues owing to the relatively high volatility of these elements. PCB analysis was performed on freeze dried samples. In the latter instance, frozen tissue homogenates were lyophilized for 24 hours in glass jars loosely covered with aluminum foil, then re-homogenized and stored in glass vials at -20°C for later analysis.

Arsenic and Mercury:

The analytical procedure involved digesting approximately 1 g of wet fish tissue in 10 ml of 2:1 concentrated nitric and sulfuric acids in 80-ml polypropylene tubes. The charged tubes were loosely capped with Teflon stoppers and allowed to cold digest overnight before refluxing at 100^{o}C for 3 hours. Upon cooling, the digests were topped up to 50 ml with distilled water ready for final analysis. Arsenic determinations were accomplished by hydride generation atomic absorption spectrometry (AAS) whereby inorganic arsenic in the sample digest is reduced to arsine gas (AsH_3) with 3% sodium borohydride in 1% sodium hydroxide. Calibration standards (1-10 µg/l) for this element were made up in 10% nitric acid. Mercury was analyzed by flameless (cold vapor) AAS (Hatch and Ott 1968) and involved the reduction of Hg^{2+} to elemental mercury vapor (Hg^{0}). The technique was facilitated using the syringe technique described by Stainton (1971). All calibration standards (5-20 ng/l) for mercury were made up in 10% nitric acid containing 0.05% potassium dichromate as a preservative (Feldman 1974).

PCBs:

Samples underwent pressurized fluid extraction with n-hexane in a DIONEX Accelerated Solvent Extractor 200 (ASE) equipped with 22-ml extraction cells. Each cell was loaded with 5.0g of Florisil followed by ~0.5g of sample mixed with 1.0 g Hydromatrix (diatomaceous earth). This arrangement achieved in-cell clean-up of the sample extracts. Each cell was then spiked with 25µl of 2ppm of the surrogate standard 4,4′-dibromooctafluorobiphenyl (DBOFB) before topping with Hydromatrix and capping. Extraction conditions were as follows: oven temperature: 125°C; pressure: 1750 psi; static time: 5 min (after 5 min pre-heat equilibration); flush volume: 70% of the cell volume; nitrogen purge: 50 sec at 150 psi; static cycles: 2.

Table 1: Fish Collected from the Northern Half of Saipan Lagoon during this Study

Species	Trophic Level and Foraging Characteristics[1]	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
		Pau-Pau Shoals	Outer Lagoon 1 (Dankulo Rock)	Outer Lagoon 2 (unnamed site)	Tanapag Shoals	Seaplane Reef	Puerto Rico Dump (seaward edge)	Micro Reef	Micro Beach Point	Hafa Adai Beach	From Hafa Adai Beach to Fishing Base	From Fisherman's Base to Micro Toyota
Acanthurus blochii	H, DI, R								1			
Acanthurus lineatus	H, DI, S	2	3			12	1	20		1		
Acanthurus nigricans	H, DI, R				1					1		
Acanthurus nigricauda	H, DI, R				1		1					
Acanthurus nigrofuscus	H, DI, S			1			2					
Acanthurus olivaceous	O, DI, R		1									
Acanthurus triostegus	H/P, DI, R	1	1									
Balistiodes viridescens	C, DI, S						1					
Calotomus carolinus	H, DI, R					1				2		
Caranx melampygus	C, DI, R					2						
Chaetodon ornatissimus	C, DI, S					1						
Cheilinus chlorous	C, DI, R		1									
Cheilinus trilobatus	C, DI, R			1	1	2						
Cheilo inermis	C, DI, R		1									
Chlorurus frontalis	H, DI, R		1									
Coris aygula	C, DI, R					1						
Ctenochaetus striatus	H, DI, S	1	2		4					1		
Epinephelus maculatus	C, DI, S		1									
Epinephelus howlandi	C, DI, S					2						
Epinephelus merra	C, DI, S		1			1						
Gnathodentex aurolineatus	C, NO, R	1	1		1					1		
Halichoeres trimaculatus	C, DI, R		1									
Hemigymnus melapterus	C, DI, R			2								
Heteropriacanthus cruentatus	C, NO, S									1		
Kyphosus biggibus	H, DI, R		1									
Lethrinus atkinsoni	C, NO, R		1								2	11
Lethrinus erythracanthus	C, NO, R		1									
Lethrinus harak	C, NO, R	1	1		4	5	3		1		13	5
Lethrinus obsoletus	C, NO, R			1							2	
Lethrinus olivaceous	C, NO, R		2									
Lethrinus xanthochilus	C, NO, R	2	3								3	
Lutjanus fulvus	C, NO, R		1							1		
Lutjanus kasmira	C, NO, R		1		2	1						
Lutjanus monostigmus	C, NO, R								1			
Myripristis amaena	P/C, NO, S	7	1							2		
Myripristis berndti	P/C, NO, S	1	7		1	2	10			1		
Myripristis kuntee	P/C, NO, S									1		
Myripristis murdjan	P/C, NO, S									1		
Myripristis pralina	P/C, NO, S				4					2		
Myripristis violacea	P/C, NO, S	10					4			7		
Myripristis sp.	P/C, NO, S				1							
Naso annulatus	H, DI, R		1									
Naso lituratus	H, DI, R	15	1		5	15	14		1	3		
Naso unicornis	H, DI, R	1		1	1		1					
Naso vlamingii	H, DI, S				1							
Neoniphon argenteus	C, NO, S		1									
Neoniphon opercularis	C, NO, S						1					
Neoniphon sammara	C, NO, S	3								3		

Table 1 (cont.): Fish Collected from the Northern Half of Saipan Lagoon during this Study

Species	Trophic Level and Foraging Characteristics[1]	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
		Pau-Pau Shoals	Outer Lagoon 1 (Dankulo Rock)	Outer Lagoon 2 (unnamed site)	Tanapag Shoals	Seaplane Reef	Puerto Rico Dump (seaward edge)	Micro Reef	Micro Beach Point	Hafa Adai Beach	From Hafa Adai Beach to Fishing Base	From Fisherman's Base to Micro Toyota
Parupeneus barberinus	C, DI, R	2		1	1							
Parupeneus multifasciatus	C, DI, R		1				2			1		
Plectropomis laevis	C, DI, R				1							
Pseudobalistes fuscus	C, DI, S		2									
Rhinecanthus aculeatus	O, DI, S				4				1			
Rhinecanthus rectangulus	O, DI, S					1						
Sargocentron spiniferum	C, NO, S	6	1			1	1					
Scarus ghobban	H, DI, R			3		2				1		
Scarus globiceps	H, DI, R			2								
Scarus psittacus	H, DI, R		1			2						
Scarus sordidus	H, DI, R		4		3							
Scarus sp.	H, DI, R					1						
Siganus spinus	H, DI, R	1			1		1					
Sphyraena flavicauda	C, DI, R					2						
Sufflamen chrysoptera	O, DI, S		1									
Thalassoma trilobatum	C, DI, R		1									
Triaenodon obesus	C, NO, R					1						
Trigger fish (unknown sp.)	C, DI, S				1							
Zanclus cornutus	O, DI, R					1						

[1] H = herbivore, P = planktivore, C = carnivore, O = omnivore, R = roving/large home range, S = sedentary/small home range, NO = nocturnal feeder, DI = diurnal feeder

The extracts were collected in calibrated vials and concentrated to ~0.1 ml under a gentle stream of filtered air in a Zymark® TurboVap. The concentrated extracts were spiked with 25µl of 2 mg/L of the internal standard, pentachloronitrobenzene (PCNB) and adjusted to final volumes of 0.2 ml with hexane using a Pasteur pipette. After gently touching each sample to a vortex mixer, they were transferred to 2ml glass vials fitted with 250 µl inserts, capped and stored at 4°C.

PCB analyses were performed with a VARIAN 3800 gas chromatograph fitted with an electron capture detector and a 60m x 0.25mm i.d. fused silica MDN-5S, polymethyl-5% phenylsiloxane (0.25µm film thickness) capillary column (SUPELCO). Gas flows through the column (helium) and the detector (nitrogen) were set at 1 ml/min and 30 ml/min respectively. During injection, the split ratio 100:1 was maintained for 1 minute. The initial column temperature was maintained at 50°C for the first minute of each run. It was then ramped up to 150°C at 30°/min, then to 280°C at 25°/min where it was held for 10 minutes. Finally, the column temperature was ramped up to 315°C at 20°/min and held for 5 minutes for a total run time of 73 minutes. 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 to Cl_{10} (NOAA 1993a,b). The congeners were selected on the basis of their potential toxicity and prevalence in the environment (Table 2). Complete chromatographic separation of all congeners was achieved although several of them are known to co-elute with other PCB congeners present in commercial PCB mixtures (Table 2).

Table 2: PCB Congeners in Calibration Standard Used for PCB Quantification in Popular Table Fish from the Northern Half of Saipan Lagoon

PCB Congeners in Calibration Standard			Co-eluting PCB Congeners		
IUPAC[1] Number	Chlorine Atoms/mol.	Structural Arrangement	IUPAC Number	Chlorine Atoms/mol.	Structural Arrangement
8[a] (A1221/1242)	2	2,4’	5[a]	2	2,3
18[b] (A1016/1242)	3	2,2’,5	15[a] (A1221/1242)	2	4,4’
28[b] (A1016/1242)	3	2,4,4’	31[a] (A1242)	3	2,4’,5
44[b] (A1242/1254)	4	2,2’,3,5’	none		
52[b] (A1242/1254)	4	2,2’,5,5’	43[a]	4	2,2’,3,5
66[b] (A1254)	4	2,3’,4,4’	80[a] 95	4 5	3,3’,5,5’ 2,2’,3,5’,6
77[a c]	4	3,3’,4,4’	154[a]	6	2,2’,4,4’5,6
101[b] (A1254/1260)	5	2,2’,4,5,5’	79[a]	4	3,3’,4,5’
105[b]	5	2,3,3’,4,4’	none		
118[b] (A1254/1260)	5	2,3’,4,4’,5	106[a]	5	2, 3,3’,4,5
126[a c]	5	3,3’,4,4’,5	129	6	2,2’,3,3’,4,5’
128[b]	6	2,2’,3,3’,4,4’	none		
138[b] (A1254/1260)	6	2,2’,3,4,4’,5’	158 [a]	6	2,3,3’,4,4’,6
153[b] (A1254/1260)	6	2,2’,4,4’,5,5’	none		
170[b] (A1260)	7	2,2’,3,3’,4,4’,5	none		
180[b] (A1260)	7	2,2’,3,4,4’,5,5’	none		
187[b]	7	2,2’,3,4’,5,5’,6	159[a] 182[a]	6 7	2,3,3’,4,5,5’ 2,2’,3,4,4’,5,6’
195[a]	8	2,2’,3,3’,4,4’,5,6	none		
206[a]	9	2,2’,3,3’,4,4’,5,5’,6	none		
209[a]	10	2,2’,3,3’,4,4’,5,5’,6,6’	none		

[a] not common (<10% occurrence) in environmental samples (from McFarland and Clarke 1989); [b] major component of environmental mixtures (from NOAA 1993a); [c] highly toxic planar PCB; [1] International Union of Pure & Applied Chemistry. Labels in parentheses indicate dominant components ($\geq$ 2% by wt.) of the commercial PCB mixtures: Aroclors 1016, 1221, 1242, 1254 & 1260 (from De Voogt *et al.* 1990). Compilation of chromatographic data from Ballschmiter and Zell (1980); Holden (1986); Ballschmiter *et al.* (1987); De Voogt *et al.* (1990); Rebbert *et al.* (1992); Wise *et al.* (1993); Schantz *et al.* (1993); Bright *et al.* (1995), using 60 m DB-5 (or equivalent) high resolution GC columns.

Calibration curves were established on the basis of six concentrations of diluted stock solution: 5, 10, 20, 50, 100 and 200 µg/L. Each of these solutions also contained the surrogate (DBOFB) and internal (PCNB) standards at concentrations of 100 µg/L throughout. Peaks were identified as target analytes if they were offset by no more than ± 0.03 min from the calibrated retention time. Congeners were quantified relative to peak area. Method detection limits for individual chlorobiphenyls in the standard mix ranged from 0.02-0.17 ng/g. The raw data was adjusted for recovery with respect to the surrogate and internal standards. The total PCB content of the sample was calculated by summing the individual congener data (Σ_{20}PCB). All results that fell below the method detection limit were eliminated from this computation.

QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC):

All reagents used for metal analysis were analytical grade and all plastic and glassware were acid-washed and deionized water rinsed prior to use. Likewise, all glassware used for PCB determinations were cleaned and solvent-rinsed with pesticide grade reagents and all standard stock solutions were purchased from a commercial supplier. Hydromatrix and Florisil were stored in a 100°C oven and kept in a desiccator during use. Approximately 10% of all samples were run in duplicate and were accompanied by appropriate method blanks and matrix spikes. Analyte recoveries from certified standard reference materials were within acceptable limits for arsenic and mercury and somewhat lower than expected for PCBs (Table 3) despite recovery corrections.

Table 3: Analysis of Standard Reference Materials

Analyte	Mean ± 95% Confidence Limits		Mean ± 95% Confidence Limits	
	This Study	**Certified Values**	**This Study**	**Certified Values**
	Marine Mussels (SRM 2974)		*Albacore Tuna (RM 50)*	
Arsenic	5.24 ± 0.41	7.4 ± 1.1	3.01 ± 0.12	3.30 ± 0.40
Mercury	0.156 ± 0.014	0.176 ± 0.013	0.93 ± 0.03	0.95 ± 0.10
PCB 8	no value	no value	no value	no value
PCB 18	14.9 (11.6 - 18.7)	26.8 (23.5 - 30.1)[a]	no value	no value
PCB 28	59.2 (41.5 -77)	79 (64 -94)[a]	no value	no value
PCB 44	50.6 (41.1 - 60.1)	72.7 (65 - 80.4)	no value	no value
PCB 52	76.5 (57.1 -93.9)	115 (103 - 127)	no value	no value
PCB 66	77.1 (62.1 - 86.3)	101 (96 -107)	no value	no value
PCB 77	no value	no value	no value	no value
PCB 105	41.6 (36.1 - 47.6)	53 (49.2 - 56.8)	no value	no value
PCB 126	no value	no value	no value	no value
PCB 128	13.1 (10.3 - 15.1)	22 (18.5 - 25.5)	no value	no value
PCB 138	65.5 (56.4 - 77.8)	134 (124 - 144)	no value	no value
PCB 153	92.5 (86.3 - 103)	145 (136 -154)	no value	no value
PCB 170	2.1 (1.2 - 2.8)	5.5 (4.4 - 6.6)	no value	no value
PCB 180	7.7 (5.1 - 9.3)	17.1 (13.3 - 20.9)	no value	no value
PCB 187	21.1 (17.9 - 23.3)	34 (31.5 - 36.5)	no value	no value
PCB 195	no value	no value	no value	no value
PCB 206	no value	no value	no value	no value
PCB 209	no value	no value	no value	no value

[a] unconfirmed reference value only

RESULTS AND DISCUSSION

The findings of the survey are summarized here and separately discussed for each contaminant in alphabetical order. All tables and graphs can be found at the end of each contaminant sub-section. Where appropriate, reference is made to levels found in fish from clean and polluted environments elsewhere. The raw data for each contaminant together with general specimen characteristics (size, sex and reproductive status) are listed in the appendices at the end of this document. All fish arsenic and mercury values referred to in the text are expressed on a wet weight basis unless otherwise indicated. The reverse applies to all referenced PCB values.

ARSENIC

Arsenic occurs naturally in the environment associated with various ores and minerals, e.g., orpiment and realgar (natural sulfides), arsenolite, arsenopyrite, cobaltite and niccolite. It is widely distributed in the biosphere and is commonly encountered in relatively high concentrations in soil and herbage located near copper smelters, mines, refineries and coal burning facilities (Wang and Rossman 1996). High arsenic levels can also come from certain fertilizers and animal feed operations. Arsenic trioxide, or white arsenic, is the most common inorganic form of this element and was used extensively for the production of calcium and lead arsenate insecticides, wood preservatives and herbicides during the latter part of the last century. Arsenic is also used in paints, dyes, metals, drugs, soaps and semi-conductors (Nriagu 1994a,b).

Although arsenic has several oxidation states, the chemical form normally encountered in the environment is not particularly toxic to aquatic organisms (Moore 1991). Soluble arsenic levels in seawater are normally around 2-4 µg/L (Riley and Chester 1971, Bowen 1979) while levels in uncontaminated sediments typically range between 1 and 5 µg/g (Bryan and Langston 1992). In highly contaminated environments, levels can exceed 1000 µg/g (Langston 1984, 1985). Recent investigations conducted in the northern half of Saipan Lagoon failed to detect any abnormal arsenic levels in nearshore biota (Denton *et al.* 2008, 2009) and only light enrichment in surface sediments from around the Puerto Rico Dump (Denton *et al.* 2001, 2006). These findings indicate that arsenic is not a problem element in these waters.

Appreciable and often highly variable amounts of arsenic are naturally found in many marine organisms, although seldom do levels exceed 100 µg/g. The highest levels tend to occur in the kidney tissue of bivalve mollusks (Benson and Summons 1981, Edmonds and Francesconi 1981) and the hepatopancreas of crustaceans (Chapman 1926). While inorganic arsenic is highly toxic, almost all of the arsenic found in marine organisms is present in non-toxic organic forms. In algae for example, lipid soluble dimethyl arsenate usually accounts for well over 90% of the total arsenic present (Klumpp and Peterson 1979). Similarly high values for organic arsenic in fish from American Samoa have recently been reported by Peshut *et al.* (2008).

Total arsenic concentrations in the marine fish generally tend to be lower than those reported for edible portions of algae, crustaceans and bivalve mollusks (Lunde 1977). Eisler (1981) conducted an extensive review of arsenic in fish and found most levels in muscle and liver ranged between 2.0 and 5.0 µg/g despite wide variability. He also noted that hepatic arsenic levels were usually higher than those found in muscle tissue, and there was no evidence for biomagnifications at higher trophic levels (Eisler, 1981, 1994).

Arsenic concentrations found in fish axial muscle and liver samples during the present study were highly variable and ranged from 0.03-36.2 µg/g and 0.07-104 µg/g in each tissue respectively. Overall geometric means were 1.19 µg/g in muscle and 2.31 µg/g in liver. Frequency distribution histograms for both tissues are presented in Fig. 2 and reveal arsenic concentrations of less than 5 µg/g in the majority of samples analyzed. Hepatic arsenic concentrations exceeded those in muscle tissue in ~75% of fish examined although rarely by more than an order of magnitude and usually by less than a factor of three. Arsenic concentrations in both tissues were positively correlated with one another in herbivorous (98 data sets) and carnivorous (112 data sets) species but the relationship was considerably stronger in the later trophic group (correlation coefficients: 0.796 and 0.429 respectively). The overall axial muscle data range was very similar to that determined earlier by Denton *et al.* (2009) in juvenile fish (0.29-37.9 µg/g) from the northern half of Saipan Lagoon, which suggests that arsenic levels in fish do not vary appreciably with age.

In contrast to Eisler's earlier conclusions that arsenic is not amplified within food webs, the data presented here clearly suggests that trophic level interactions do exist, although they are by no means clearly defined. Nevertheless, the herbivorous species examined generally contained lower tissue levels of arsenic than their higher trophic level counterparts (Fig. 3). Biomagnification among upper level consumers is obscured by considerable inter- and intra-specific variability plus the fact that certain representatives possess relatively high affinities for this element, which cannot be explained by food preferences alone. Notable accumulators among these groups include the soldier fish (*Myripristis* spp.), trigger fish (*Rhinecanthus* spp.), *Parupeneus multifasciatus, Neoniphon opercularis* and *Thalassoma trilobatum*.

Tables 4 and 5 respectively summarize the arsenic concentrations in axial muscle and liver of fish collected from each site within the study area. The data are arranged according to trophic level and again highlight the clear differences between herbivorous species and higher trophic levels members. No obvious inter-site differences emerged from these data and no clear size- or species-dependant relationships were evident for levels found in muscle tissue of the four most abundant genera captured during the current work (i.e., *Acanthurus* spp., *Naso* spp., *Myripristis* spp. and *Lethrinus* spp. (Figs. 4-11). Interestingly, arsenic concentrations in *Myripristis* spp. collected near the dump (Site 6) generally ranked among the lowest recorded for this group despite the higher levels recorded earlier in sediments from this area (Denton *et al.* 2001).

It has been suggested that fish are useful indicators of arsenic contamination (Papadopoulu *et al.* 1973, Grimanis *et al.* 1978) although this remains to be unequivocally demonstrated. Certainly the data provided earlier by Denton *et al.* (2006b) for fish from areas of arsenic enrichment within Guam Harbors does not support this contention. Moreover, levels in certain species appear to be negatively related to ambient arsenic concentrations. Peshut *et al.* (2008), for example, measured arsenic levels in muscle tissue of squirrel fish, *Sargocentron* spp., from American Samoa waters and found significantly lower concentrations in specimens from Faga'alu, a site close to Pago Pago Inner Harbor where arsenic contamination is known to exist. *Myripristis* spp. captured near the dump during the present study appeared to show a similar relationship, as noted above.

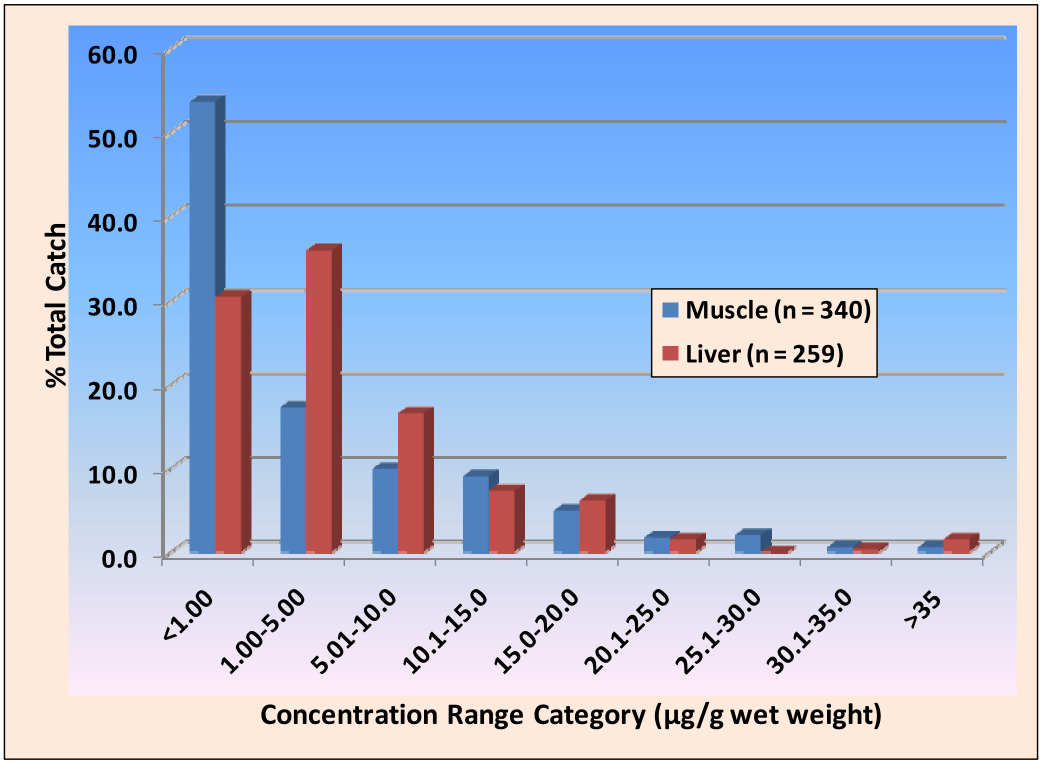

Figure 2: Frequency distribution histogram of total arsenic in tissues of fish from Saipan Lagoon

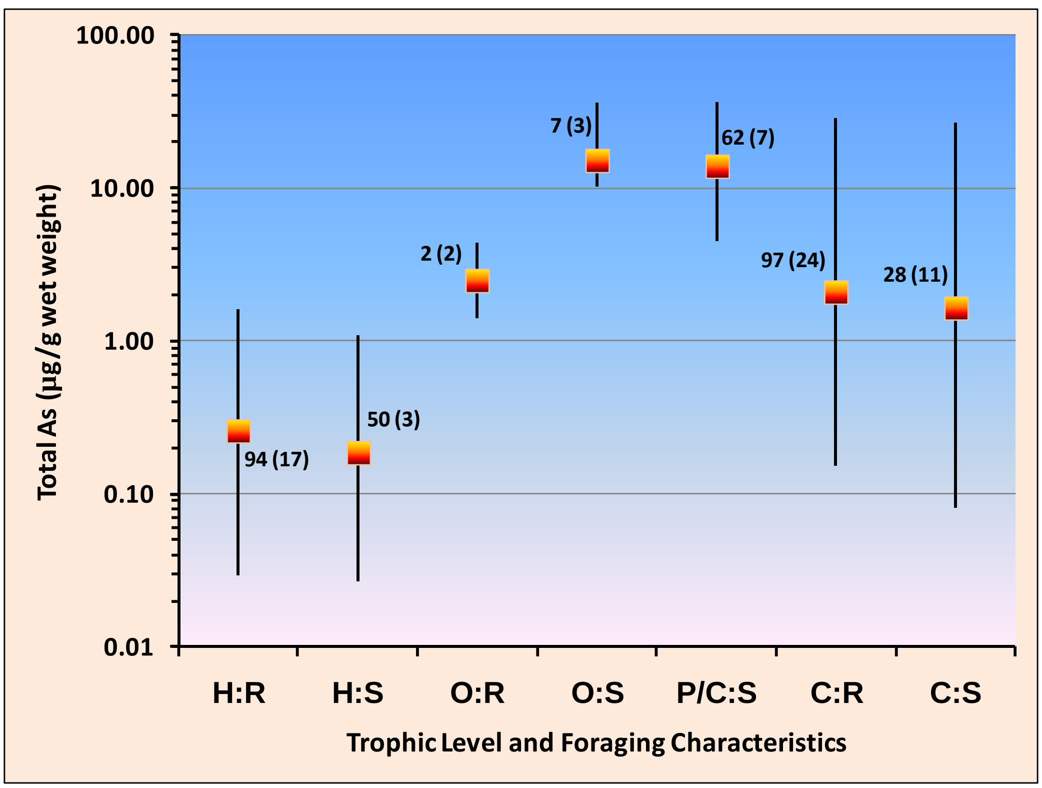

Figure 3: Total arsenic in axial muscle of fish from different trophic levels in Saipan Lagoon. Data are geometric means, ranges, numbers of fish and (species) analyzed at each level.

Table 4: Total Arsenic (µg/g wet weight) in Axial Muscle of Fish from Saipan Lagoon (arranged by site and trophic level)

Site	Location	Statistic[1]	Trophic Level[2]						
			H:R	H:S	O:R	O:S	P/C:S	C:R	C:S
1	Pau-Pau Reef Shoals	range:	0.09 - 0.43	0.15 - 0.16	-	-	5.99 -27.7	0.42 - 5.00	0.45 - 4.81
		median:	0.20	0.16	-	-	14.5	2.49	0.97
		mean	0.21	0.16	-	-	14.7	1.72	1.18
		# fish (species):	19 (5)	2 (1)	-	-	18 (3)	6 (4)	9 (2)
2	Outer Lagoon 1 (Dankulo Rock)	range:	0.23 - 1.10	0.16 - 0.78	1.43	11.6	8.47 -27.3	0.42 - 22.4	0.08 - 10.6
3	Outer Lagoon 2	median:	0.49	0.25	-	-	15.3	2.07	1.09
		mean	0.48	0.30	-	-	15.5	2.96	1.28
		# fish (species):	16 (10)	6 (3)	1 (1)	1 (1)	8 (2)	21 (17)	6 (5)
4	Tanapag Reef Shoals	range:	0.10 - 0.95	0.20 - 1.08	-	11.9 - 36.2	14.6 - 31.6	1.43 - 6.66	0.43
		median:	0.28	0.26	-	14.0	23.6	3.05	-
		mean	0.31	0.37	-	17.7	22.5	3.14	-
		# fish (species):	12 (6)	5 (2)	-	4 (1)	6 (3)	10 (6)	1 (1)
5	Seaplane Reef	range:	0.03 - 1.60	0.03 - 0.50	4.39	19.3	11.4 - 17.3	0.42 - 7.59	0.16 - 2.19
		median:	0.21	0.16	-	-	14.3	1.70	1.98
		mean	0.19	0.15	-	-	14.0	1.73	1.17
		# fish (species):	21 (5)	12 (1)	1 (1)	1 (1)	2 (1)	14 (7)	5 (4)
6	Puerto Rico Dump	range:	0.03 - 0.65	0.08 - 0.42	-	-	4.47 - 14.1	1.47 - 10.2	0.62 -26.9
		median:	0.35	0.40	-	-	7.50	7.41	8.13
		mean	0.27	0.24	-	-	8.20	5.54	5.14
		# fish (species):	17 (4)	3 (2)	-	-	14 (2)	5 (2)	3 (3)
7	Micro Point	range:	0.30 - 0.51	0.03 - 0.43	-	10.3	-	0.54 - 1.58	-
8	Micro Reef Complex	median:	0.41	0.19	-	-	-	1.06	-
		mean	0.39	0.15	-	-	-	0.93	-
		# fish (species):	2 (2)	20 (1)	-	1 (1)	-	2 (2)	-
9	Hafa Adai Beach	range:	0.11 - 0.29	0.12 - 0.46	-	-	8.93 - 36.1	3.16 - 28.6	1.60 - 3.90
		median:	0.16	0.29	-	-	16.6	11.2	2.47
		mean	0.18	0.24	-	-	17.0	10.0	2.48
		# fish (species):	7 (4)	2 (2)	-	-	14 (6)	3 (3)	4 (2)
10	Hafa Adai Beach to Fisherman's Base	range:	-	-	-	-	-	0.44 - 6.01	-
		median:	-	-	-	-	-	0.85	-
		mean	-	-	-	-	-	1.30	-
		# fish (species):	-	-	-	-	-	20 (4)	-
		# species:	-	-	-	-	-	4	-
11	Fisherman's Base to Micro Toyota	range:	-	-	-	-	-	0.15 - 7.05	-
		median:	-	-	-	-	-	2.43	-
		mean	-	-	-	-	-	1.49	-
		# fish (species):	-	-	-	-	-	16 (2)	-

[1] Mean = geometric mean; [2] H, C, P and O = herbivore, carnivore, planktivore and omnivore respectively; S = sedentary forager/small home range; R = roving forager/large home range; dashes = no data

Table 5: Total Arsenic (µg/g wet weight) in Liver Tissue of Fish from Saipan Lagoon (arranged by site and trophic level)

Site	Location	Statistic[1]	Trophic Level[2]						
			H:R	H:S	O:R	O:S	P/C:S	C:R	C:S
1	Pau-Pau Reef Shoals	range:	0.44 - 3.30	0.59 - 0.97	-	-	3.37 - 36.2	1.05 -11.9	0.42 - 6.68
		median:	1.01	0.78	-	-	13.2	5.17	0.75
		mean	0.93	0.75	-	-	12.1	3.7	0.95
		# fish (species):	18 (4)	2 (1)	-	-	17 (3)	6 (4)	9 (3)
2	Outer Lagoon 1 (Dankulo Rock)	range:	0.62 - 19.3	0.38 - 1.88	0.93	12.5	4.82 - 10.8	0.19 - 75.3	0.25 - 5.00
3	Outer Lagoon 2	median:	1.05	1.22	-	-	6.97	5.38	1.68
		mean	1.26	0.98	-	-	6.99	4.80	1.50
		# fish (species):	15 (9)	5 (3)	1 (1)	1 (1)	6 (2)	21 (17)	6 (5)
4	Tanapag Reef Shoals	range:	0.18 - 2.60	0.44 - 8.59	-	8.22 - 14.8	5.44 - 16.6	0.78 - 19.8	8.80
		median:	0.86	1.22	-	12.1	12.2	4.58	-
		mean	0.88	1.37	-	11.5	10.2	4.04	-
		# fish (species):	10 (4)	4 (3)	-	4 (1)	6 (3)	8 (6)	1 (1)
5	Seaplane Reef	range:	0.11 - 3.44	0.07 - 1.07	-	7.23	7.49 -104	1.37 - 18.3	0.37 - 2.95
		median:	0.73	0.55	-	-	55.7	4.37	2.30
		mean	0.67	0.41	-	-	27.9	3.96	1.53
		# fish (species):	21 (6)	12 (1)	-	1 (1)	2 (1)	14 (7)	5 (4)
6	Puerto Rico Dump	range:	2.39	-	-	-	-	-	1.10
		median:	-	-	-	-	-	-	-
		mean	-	-	-	-	-	-	-
		# fish (species):	1 (1)	-	-	-	-	-	1 (1)
7	Micro Point	range:	0.54 - 0.75	-	-	10.4	7.43 - 33.7	2.19 - 2.53	-
8	Micro Reef Complex	median:	0.65	-	-	-	14.0	2.36	-
		mean	0.54	-	-	-	13.6	2.35	-
		# fish (species):	2 (2)	-	-	1 (1)	11 (4)	2 (2)	-
9	Hafa Adai Beach	range:	0.27 - 1.51	0.24 - 1.43	-	-	-	6.61 - 23.6	1.92 - 3.34
		median:	0.58	0.84	-	-	-	11.7	2.63
		mean	0.64	0.59	-	-	-	12.2	2.53
		# fish (species):	8 (5)	2 (2)	-	-	-	3 (3)	2 (2)
10	Hafa Adai Beach to Fisherman's Base	range:	-	-	-	-	-	0.48 - 11.4	-
		median:	-	-	-	-	-	1.98	-
		mean	-	-	-	-	-	1.92	-
		# fish (species):	-	-	-	-	-	17 (4)	-
11	Fisherman's Base to Micro Toyota	range:	-	-	-	-	-	0.55 - 9.86	-
		median:	-	-	-	-	-	3.67	-
		mean	-	-	-	-	-	2.97	-
		# fish (species):	-	-	-	-	-	16 (2)	-

[1] Mean = geometric mean; [2] H, C, P and O = herbivore, carnivore, planktivore and omnivore respectively; S = sedentary forager/small home range; R = roving forager/large home range; dashes = no data

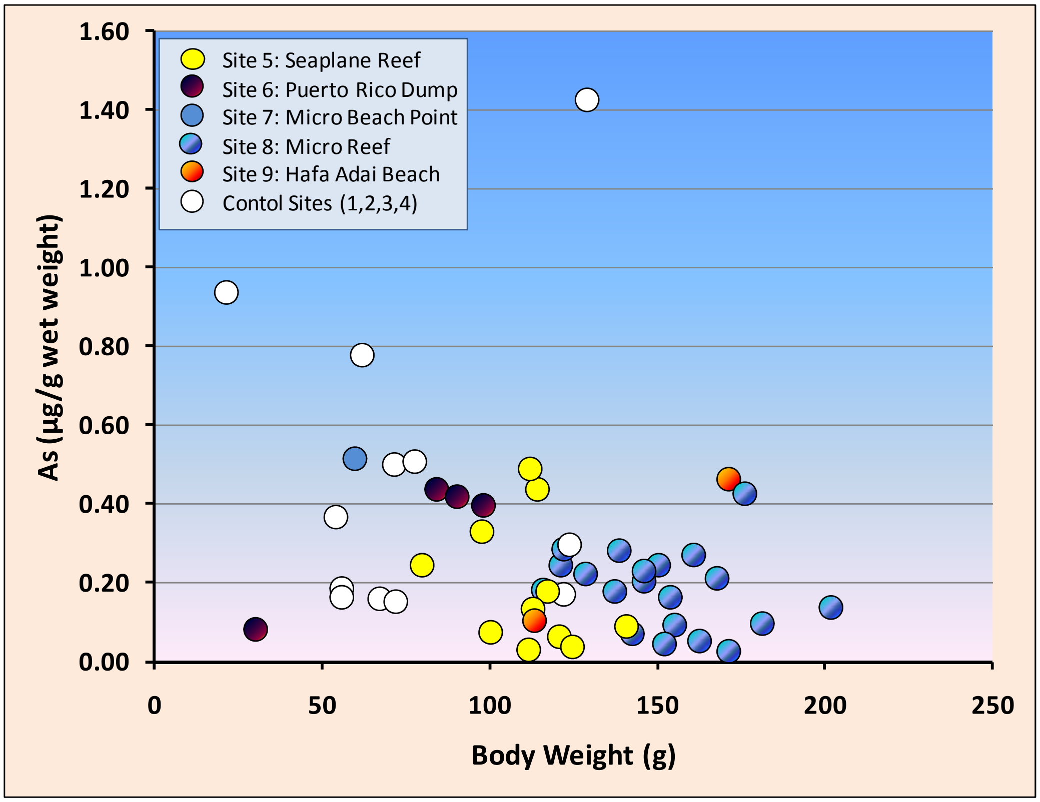

Figure 4: Total arsenic in axial muscle of *Acanthurus* spp. (H:S) in relation to size and site

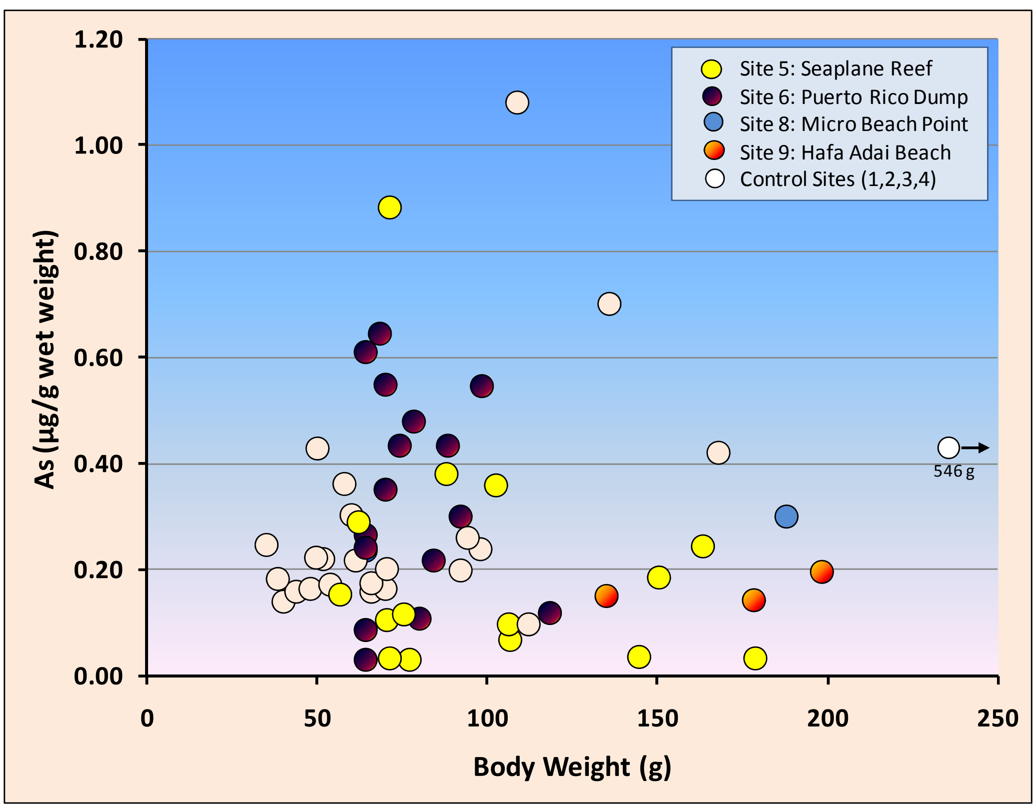

Figure 5: Total arsenic in axial muscle of *Naso* spp. (H:R) in relation to size and site

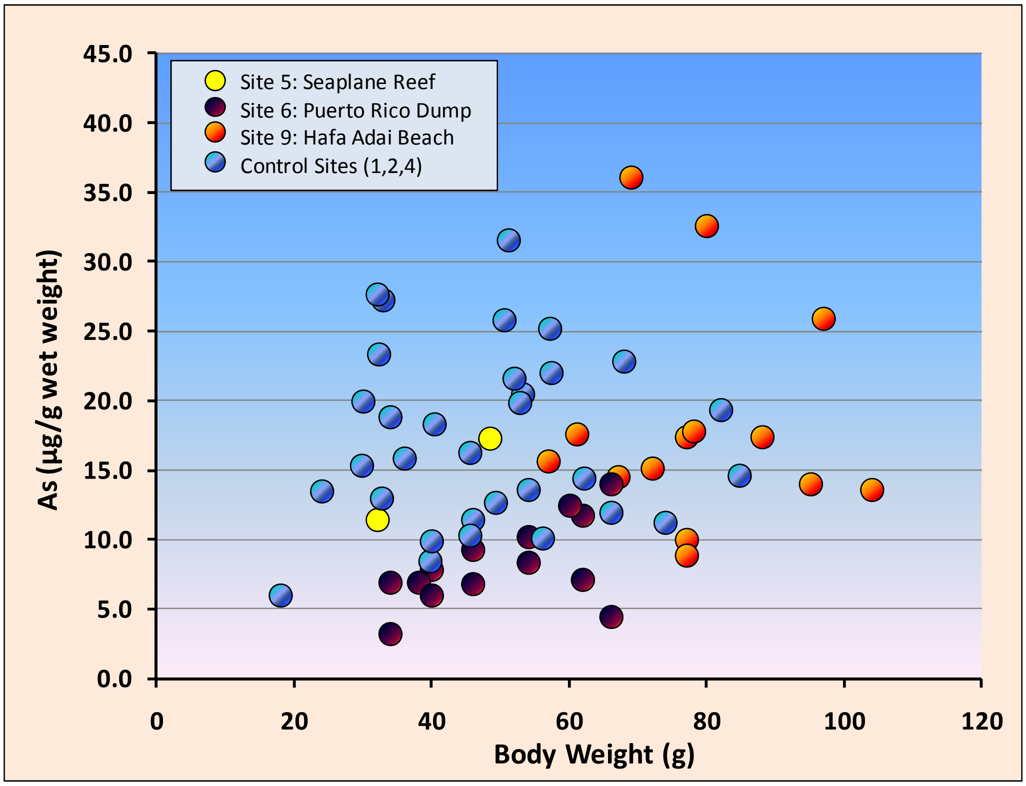

Figure 6: Total arsenic in axial muscle of *Myripristis* spp. (P/C:S) in relation to size and site

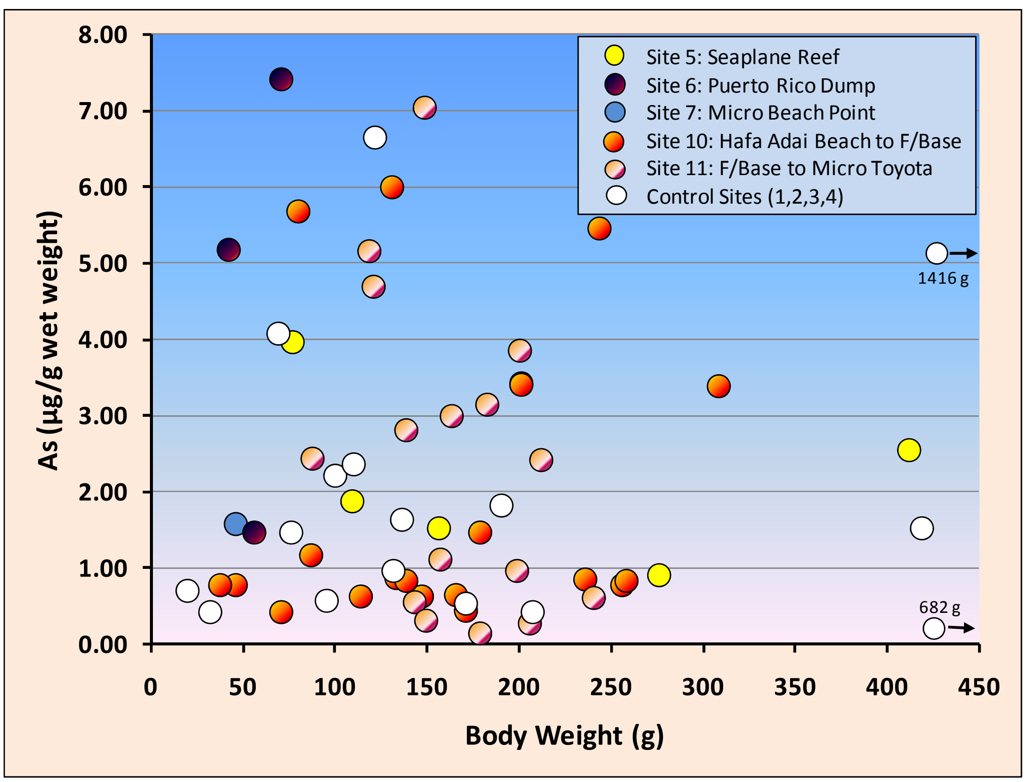

Figure 7: Total arsenic in axial muscle of *Lethrinus* spp. (C:R) in relation to size and site

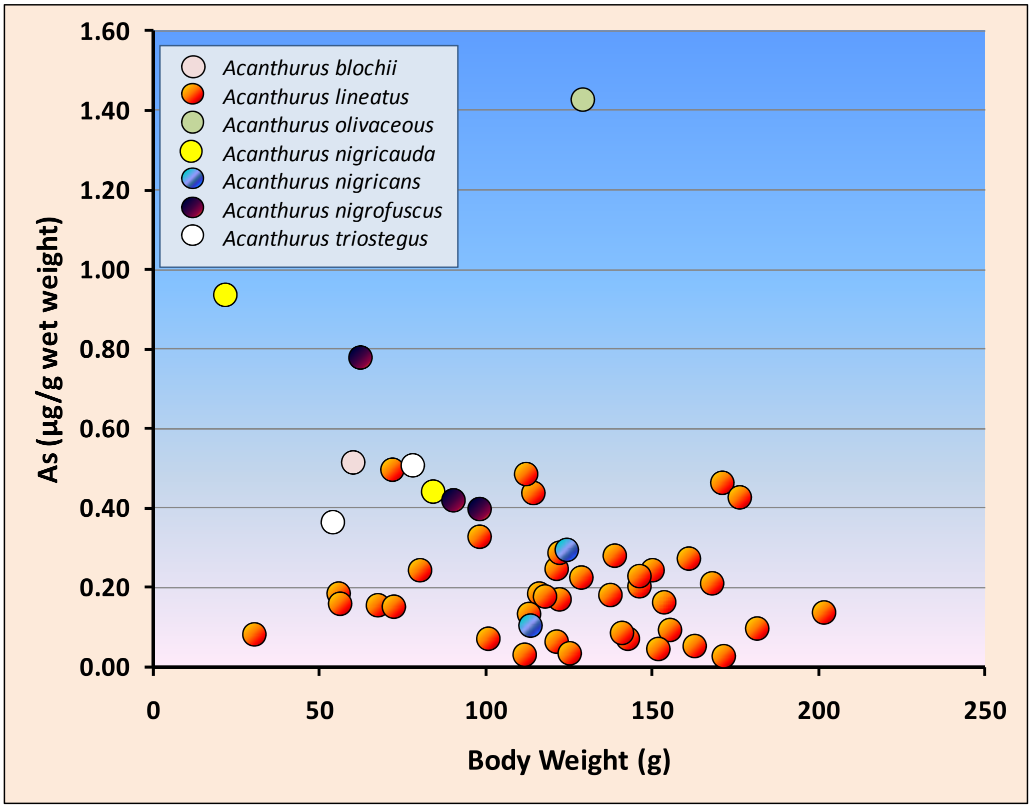

Figure 8: Total arsenic in axial muscle of *Acanthurus* spp. (H:S) in relation to size and species

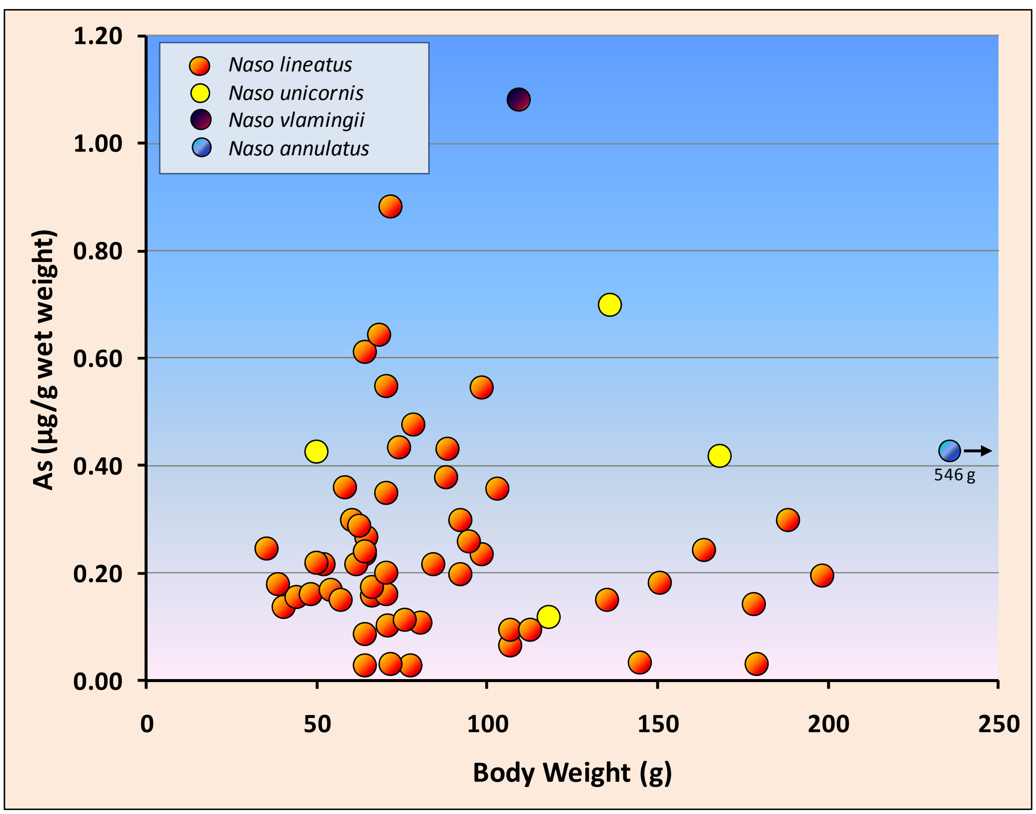

Figure 9: Total arsenic in axial muscle of *Naso* spp. (H:R) in relation to size and species

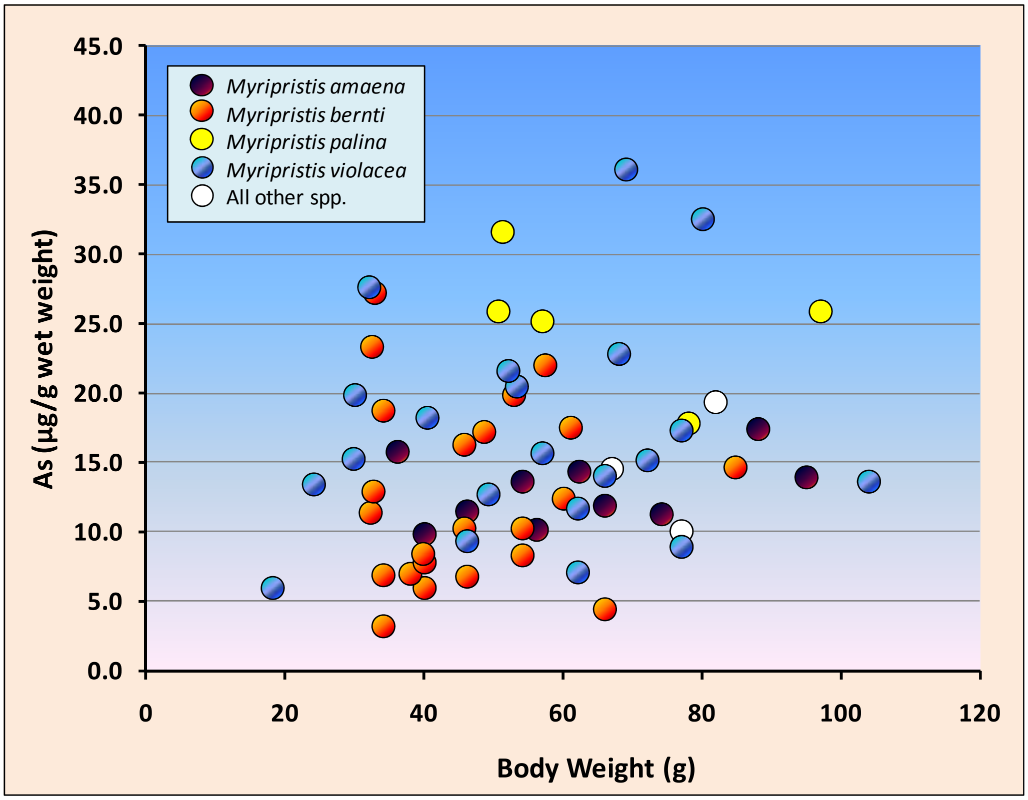

Figure 10: Total arsenic in axial muscle of *Myripristis* spp. (P/C:S) in relation to size and species

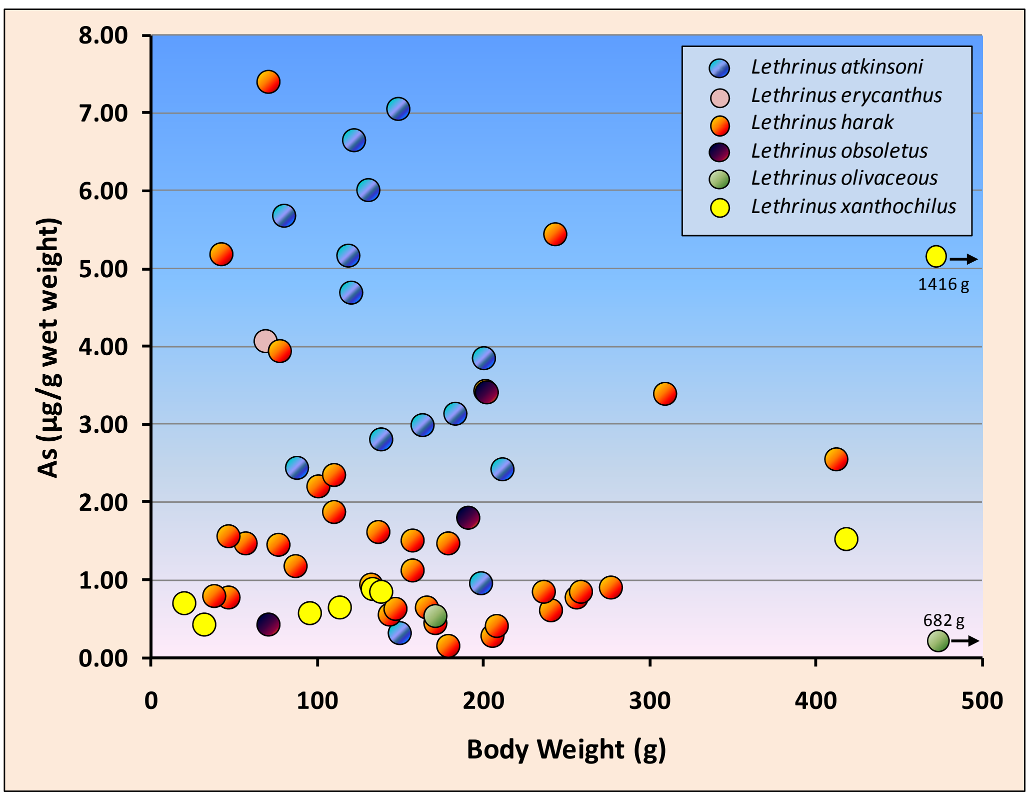

Figure 11: Total arsenic in axial muscle of *Lethrinus* spp. (C:R) in relation to size and species

MERCURY:

Geological deposits of mercury are most often found in cinnabar, a mercury sulfide mineral that contains up to 86% mercury. Other crustal rocks normally contain 0.1-0.2 µg/g. Various natural processes, including volcanic eruptions, the weathering of rocks, and undersea vents, release mercury into the environment. At least half the mercury present in the environment today is of anthropogenic origin with power plants slated as the primary source in the USA (Moore 2000).

Mercury is highly toxic to aquatic organisms, particularly in the organic form (Moore 1991). Concentrations of dissolved mercury in the open ocean typically range from <0.001-0.003 µg/L (Miyake and Suzuki 1983) whereas values of 0.003-0.20 µg/L are typically found closer to shore and polluted estuarine waters may contain up to 0.060 µg/L (Baker 1977).

Mercury levels in unpolluted, non-geochemically enriched areas are usually <30 ng/g (Bryan and Langston 1992, Benoit *et al.* 1994) and may be as low as 2 ng/g in clean bioclastic sediments (Denton *et al.* 1997, 2001). Estuarine sediments, adjacent to heavy industrialized areas or mercury mining activities, can be three to five orders of magnitude higher than this (Langston 1985, Benoit *et al.* 1994). Values in excess of 2000 µg/g were found in sediments from the contaminated Minimata Bay area in Japan, following the mass mercury-poisoning episode of the late 1950's, and probably rank among the highest values ever reported (Tokuomi 1969).

Levels recently found in intertidal sediments along the northern half of Saipan Lagoon ranged from less than 5 ng/g in clean, coarse beach sands to a maximum of 75 ng/g in sediment collected near the dump (Denton *et al.* 2008). Earlier studies determined mean mercury levels ranging from 101-151 ng/g in sediments from the latter area (DEQ 1987, Denton *et al.* 2001).

In non-polluted situations, mercury levels in fish muscle generally lie between 0.001-0.100 µg/g (Holden 1973, Denton and Burdon-Jones 1986) although higher concentrations have been noted in long-lived, predatory species, particularly sharks, tuna, marlin and swordfish (Bligh and Armstrong 1971, Rivers *et al.* 1972, Nishigaki *et al.* 1973, Beckett and Freeman 1974, Mackay *et al.* 1975, Shultz and Crear 1976, Denton and Breck 1981). Since fish possess little ability to regulate tissue levels of mercury in the same way as they do essential elements, like copper and zinc, they serve as useful biological indicators for this metal (Phillips 1980). Fish flesh analyzed from Minimata Bay, for example, contained mercury levels >300 µg/g, well above that considered safe for human consumption (Fujiki 1963). It is noteworthy that mercury has caused more problems to consumers of fish than any other inorganic compound (Irukayama *et al.* 1961).

Denton *et al.* (2009) recently examined mercury in small, juvenile fish from shallow, nearshore waters within the study area and reported values all less than 0.100 µg/g. Levels found during the present work, for larger fish captured further offshore, ranged from 0.001-0.616 µg/g in axial muscle and from 0.004-9.931 µg/g in liver tissue. Approximately 80% of fish analyzed yielded concentrations lower than 0.10 µg/g and 0.20 µg/g in these tissues respectively (Fig. 12).

Levels in hepatic tissue were higher than corresponding muscle values in ~75% of carnivorous species and 100% of all other trophic level representatives examined. Concentration differences between the two tissues appeared to be trophic level-dependant and varied by an order of magnitude, or more, in approximately 60% of herbivores, 12% of omnivores and planktivores, and 4% of carnivores analyzed. Mercury levels in both tissues were positively related in all consumer groups. Correlation coefficients obtained with the pooled raw data-sets for each group were strongest in the carnivores (0.6985) and planktivores (0.5465) and weakest in the omnivores (0.4765) and herbivores (0.4290).

Mercury concentrations found in the axial muscle of fish from all trophic levels considered are presented graphically in Figure 13. Despite appreciable variability within trophic groups, mean concentrations increased from primary to secondary consumers typifying mercury's tendency to biogmagnify at higher trophic levels. This phenomenon certainly explains why less than 5% of all herbivorous and omnivorous representatives yielded axial muscle mercury concentrations above the generally accepted upper benchmark (0.100 µg/g) for uncontaminated fish, compared with 21% and 32% of all planktiverous and carnivorous types respectively.

Tables 6 and 7 summarize the fish tissue data-sets by site, trophic level and foraging characteristics. It can be seen that mean mercury concentrations in both muscle and liver were consistently lower in trophic level representatives from the more remote sites in the northern part of the lagoon (Sites 1-4). Inter-site differences in species composition and/or age structure of fish examined may have accounted for at least some of this difference, especially since dominant representatives (e.g., *Acanthurus* spp., *Naso* spp., *Myripristis* spp. and *Lethrinus* spp.) from this part of the lagoon were generally smaller than their more southerly counterparts (Figs. 14-17). This notwithstanding, the data generally supports a north to south increase in mercury availability and is to be expected given the greater number of potential mercury sources in the latter region. No obvious inter-specific differences in axial mercury concentrations emerged between members of the dominant genera, *Acanthurus*, *Naso*, and *Myripristis* (Figs. 18-20) in contrast to *Lethrinus,* which revealed clear differences between the more well represented species (Fig. 21). To what extent such discrepancies are related to differences in growth rates, feeding habits, food preferences, or ambient mercury availability, remains to be determined.

There are obvious limitations in attempting to evaluate inter-site difference in mercury abundance using data from fish catches that differ markedly in species composition, numbers and size. Nevertheless, primary and secondary consumers taken from most sites during the present study were sufficiently well represented to permit a preliminary assessment of mercury availability throughout the study area. To this end, Fig. 22 clearly depicts the north to south increase in mercury abundance referred to earlier, while Table 9 shows that only 2-3% of the collective catch from Sites 1-4 had axial muscle mercury concentrations greater than 0.100 µg/g compared with 63% from Site 9 at Hafa Adai Beach. The generally higher levels of mercury noted in fish from this site were surprising, in view of the relatively large distance separating it from known sources of mercury contamination in the area (e.g., sewer outfall, docks and dump). More recent work identified relatively high mercury levels in storm drain sediments at the southern end of Hafa Adai Beach. The source of this contamination was traced back to an old incinerator site at the Commonwealth Health Center (Denton *et al.* 2010).

The relatively high exceedence percentages at Sites 10-11 (Table 8) are also noteworthy and suggest that coastal waters along this stretch of the lagoon may be impacted by multiple sources of mercury. The fact that these numbers are based upon limited catch sizes composed entirely of carnivorous (*Lethrinus*) species, however, calls for additional data from other trophic representatives in the area before any firm conclusions can be drawn.

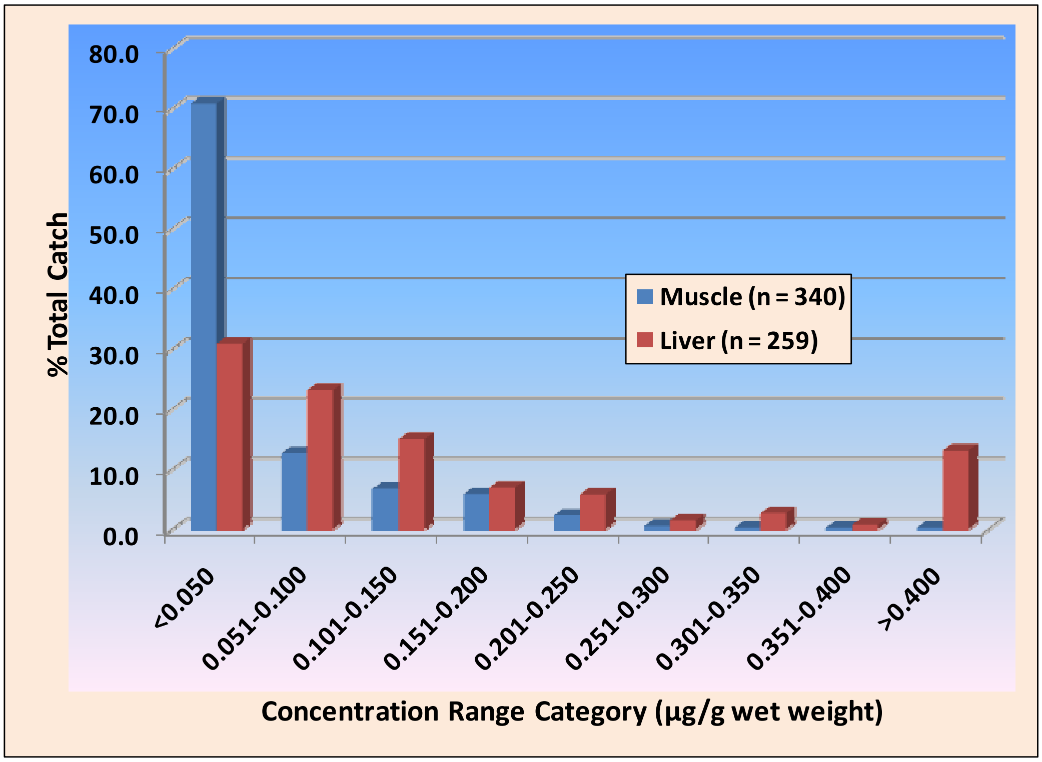

Figure 12: Frequency distribution histogram of total mercury in tissues of fish from Saipan Lagoon

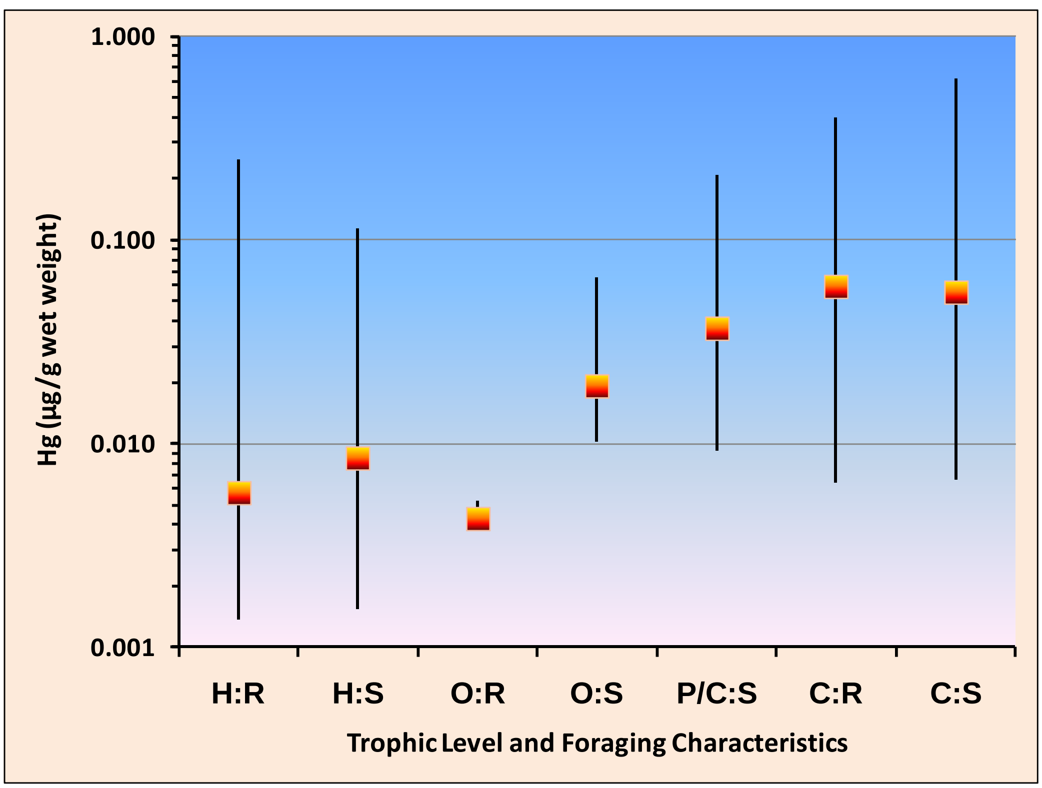

Figure 13: Total mercury in axial muscle of fish from different trophic levels in Saipan Lagoon. Data are geometric means, ranges, numbers of fish and (species) analyzed at each level.

Table 6: Total Mercury (µg/g wet weight) in Axial Muscle of Fish from Saipan Lagoon (arranged by site and trophic level)

Site	Location	Statistic[1]	Trophic Level[2]						
			H:R	H:S	O:R	O:S	P/C:S	C:R	C:S
1	Pau-Pau Reef Shoals	range:	0.001 - 0.037	0.002 - 0.002	-	-	0.009 - 0.060	0.008 - 0.146	0.027 - 0.063
		median:	0.002	0.002	-	-	0.019	0.018	0.044
		mean	0.004	0.002	-	-	0.019	0.022	0.042
		# fish (species):	19 (5)	2 (1)	-	-	18 (3)	6 (4)	9 (2)
2	Outer Lagoon 1 (Dankulo Rock)	range:	0.001 - 0.028	0.002 - 0.007	0.004	0.018	0.012 - 0.023	0.006 - 0.116	0.014 - 0.078
3	Outer Lagoon 2	median:	0.003	0.002	-	-	0.020	0.026	0.018
		mean	0.004	0.003	-	-	0.018	0.029	0.023
		# fish (species):	16 (10)	6 (3)	1 (1)	1 (1)	8 (2)	21 (17)	6 (5)
4	Tanapag Reef Shoals	range:	0.002 - 0.022	0.002 - 0.010	-	0.010 - 0.033	0.014 - 0.050	0.010 - 0.161	0.007
		median:	0.004	0.003	-	0.013	0.018	0.037	-
		mean	0.004	0.003	-	0.015	0.020	0.040	-
		# fish (species):	12 (6)	5 (2)	-	4 (1)	6 (3)	10 (6)	1 (1)
5	Seaplane Reef	range:	0.002 - 0.248	0.003 - 0.114	0.005	0.066	0.054 - 0.153	0.016 - 0.396	0.026 - 0.616
		median:	0.010	0.005	-	-	0.104	0.084	0.091
		mean	0.009	0.008	-	-	0.091	0.069	0.100
		# fish (species):	21 (5)	12 (1)	1 (1)	1 (1)	2 (1)	14 (7)	5 (4)
6	Puerto Rico Dump	range:	0.002 - 0.014	0.003 - 0.009	-	-	0.030 - 0.052	0.069 - 0.110	0.076 - 0.297
		median:	0.005	0.006	-	-	0.039	0.079	0.178
		mean	0.005	0.006	-	-	0.039	0.085	0.159
		# fish (species):	17 (4)	3 (2)	-	-	14 (2)	5 (2)	3 (3)
7	Micro Point	range:	0.004 - 0.013	0.004 - 0.109	-	0.017	-	0.027 - 0.144	-
8	Micro Reef Complex	median:	0.008	0.016	-	-	-	0.086	-
		mean	0.007	0.019	-	-	-	0.063	-
		# fish (species):	2 (2)	20 (1)	-	1 (1)	-	2 (2)	-
9	Hafa Adai Beach	range:	0.011 - 0.133	0.007 - 0.059	-	-	0.070 - 0.207	0.125 - 0.194	0.029 - 0.398
		median:	0.020	0.033	-	-	0.151	0.142	0.204
		mean	0.024	0.020	-	-	0.141	0.151	0.139
		# fish (species):	7 (4)	2 (2)	-	-	14 (6)	3 (3)	4 (2)
10	Hafa Adai Beach to	range:	-	-	-	-	-	0.029 - 0.212	-
	Fisherman's Base	median:	-	-	-	-	-	0.062	-
		mean	-	-	-	-	-	0.073	-
		# fish (species):	-	-	-	-	-	20 (4)	-
11	Fisherman's Base to	range:	-	-	-	-	-	0.041 - 0.276	-
	Micro Toyota	median:	-	-	-	-	-	0.177	-
		mean	-	-	-	-	-	0.145	-
		# fish (species):	-	-	-	-	-	16 (2)	-

[1] Mean = geometric mean; [2] H, C, P and O = herbivore, carnivore, planktivore and omnivore respectively; S = sedentary forager/small home range; R = roving forager/large home range; dashes = no data

Table 7: Total Mercury (µg/g wet weight) in Liver of Fish from Saipan Lagoon (arranged by site and trophic level)

Site	Location	Statistic[1]	Trophic Level[2]						
			H:R	H:S	O:R	O:S	P/C:S	C:R	C:S
1	Pau-Pau Reef Shoals	range:	0.017 - 0.251	0.065 - 0.078	-	-	0.026 - 0.338	0.025 - 0.167	0.018 - 0.121
		median:	0.087	0.071	-	-	0.043	0.038	0.099
		mean	0.073	0.071	-	-	0.047	0.045	0.067
		# fish (species):	18 (4)	2 (1)	-	-	17 (3)	6 (4)	9 (3)
2	Outer Lagoon 1 (Dankulo Rock)	range:	0.004 - 1.22	0.067 - 0.417	0.103	0.145	0.028 - 0.044	0.019 - 0.358	0.027 - 0.226
3	Outer Lagoon 2	median:	0.033	0.151	-	-	0.031	0.080	0.044
		mean	0.034	0.154	-	-	0.033	0.086	0.066
		# fish (species):	15 (9)	5 (3)	1 (1)	1 (1)	6 (2)	21 (17)	6 (5)
4	Tanapag Reef Shoals	range:	0.019 - 0.091	0.015 - 1.39	-	0.055 - 0.116	0.021 - 0.117	0.011 - 0.496	0.047
		median:	0.040	0.112	-	0.068	0.026	0.084	-
		mean	0.040	0.125	-	0.074	0.033	0.082	-
		# fish (species):	10 (4)	4 (2)	-	4 (1)	6 (3)	8 (6)	1 (1)
5	Seaplane Reef	range:	0.021 - 0.764	0.100 - 0.619	-	0.100	0.434 - 9.13	0.054 - 0.453	0.065 - 1.44
		median:	0.099	0.178	-	-	4.78	0.138	0.167
		mean	0.930	0.184	-	-	1.99	0.138	0.217
		# fish (species):	21 (5)	12 (1)	-	1 (1)	2 (1)	14 (7)	5 (4)
6	Puerto Rico Dump	range:	0.118	-	-	-	-	-	0.331
		median:	-	-	-	-	-	-	-
		mean	-	-	-	-	-	-	-
		# fish (species):	1 (1)	-	-	-	-	-	1 (1)
7	Micro Point	range:	0.153 - 0.271	-	-	0.059	0.341 - 2.44	0.043 - 0.234	-
8	Micro Reef Complex	median:	0.212	-	-	-	0.671	0.138	-
		mean	0.204	-	-	-	0.805	0.100	-
		# fish (species):	2 (2)	-	-	1 (1)	11 (4)	2 (2)	-
9	Hafa Adai Beach	range:	0.058 - 0.488	0.221 - 0.714	-	-	-	0.143 - 0.310	0.177 - 1.467
		median:	0.104	0.467	-	-	-	0.289	0.822
		mean	0.123	0.397	-	-	-	0.234	0.51
		# fish (species):	6 (4)	2 (2)	-	-	-	3 (3)	2 (2)
10	Hafa Adai Beach to	range:	-	-	-	-	-	0.34 - 0.246	-
	Fisherman's Base	median:	-	-	-	-	-	0.075	-
		mean	-	-	-	-	-	0.085	-
		# fish (species):	-	-	-	-	-	17 (4)	-
11	Fisherman's Base to	range:	-	-	-	-	-	0.034 - 4.38	-
	Micro Toyota	median:	-	-	-	-	-	0.556	-
		mean	-	-	-	-	-	0.399	-
		# fish (species):	-	-	-	-	-	16 (2)	-

[1] Mean = geometric mean; [2] H, C, P and O = herbivore, carnivore, planktivore and omnivore respectively; S = sedentary forager/small home range; R = roving forager/large home range; dashes = no data

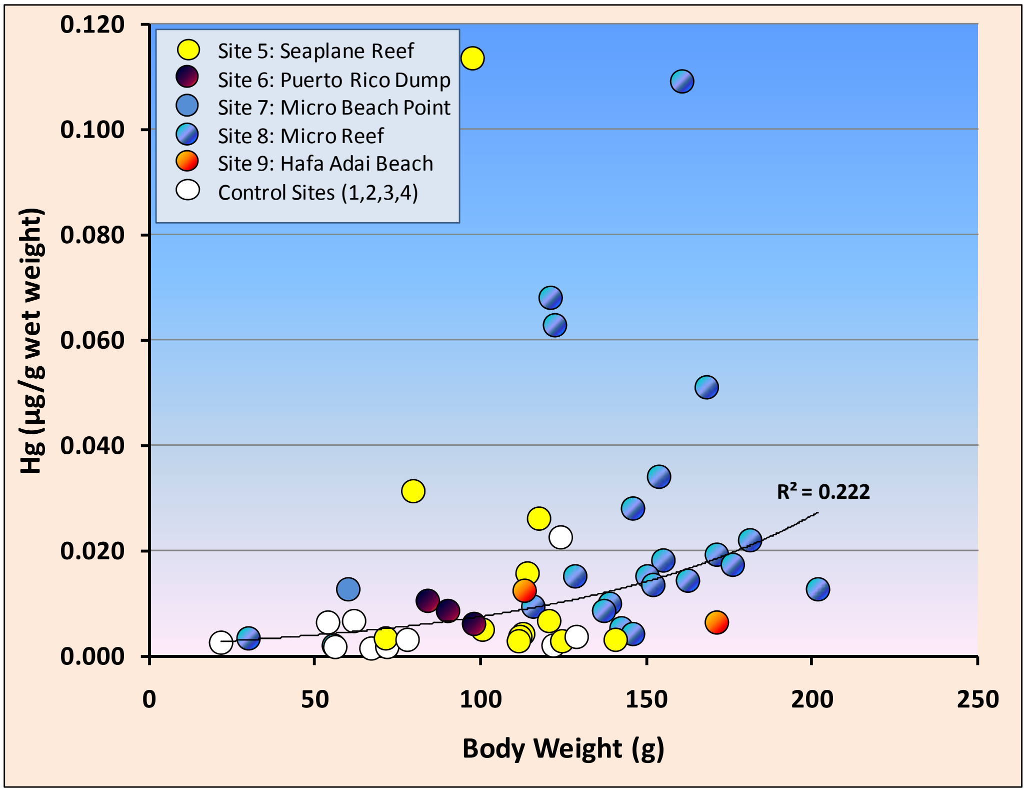

Figure 14: Total mercury in axial muscle of *Acanthurus* spp. (H:S) in relation to size and site

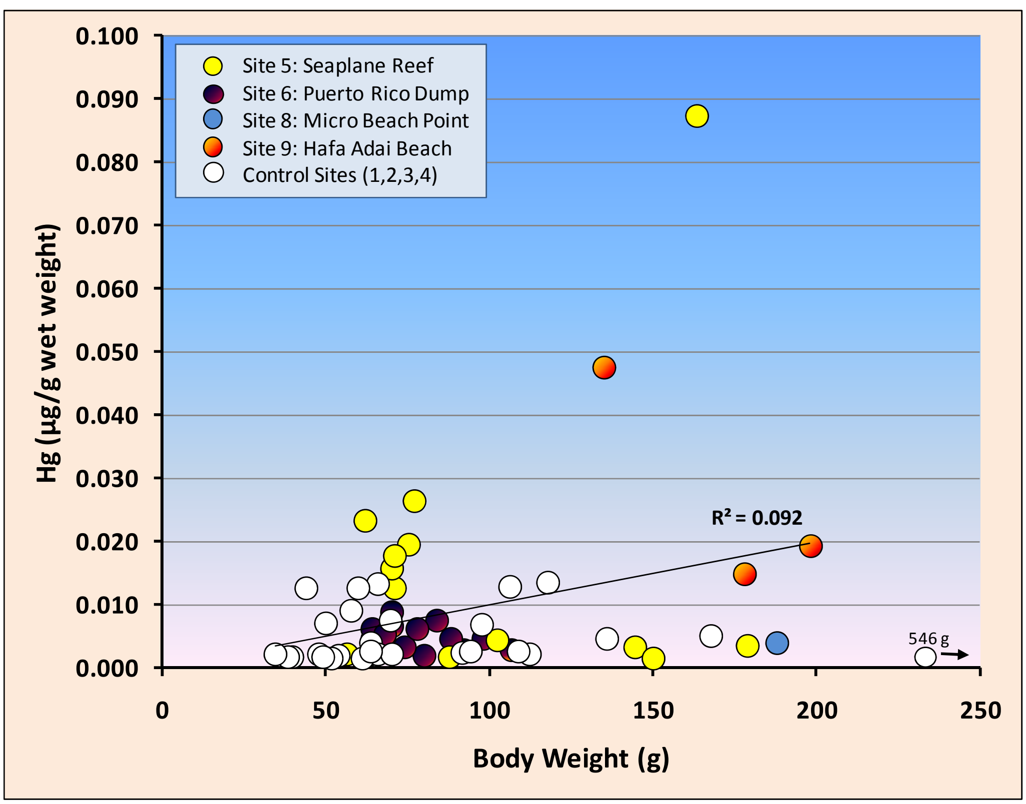

Figure 15: Total mercury in axial muscle of *Naso* spp. (H:R) in relation to size and site

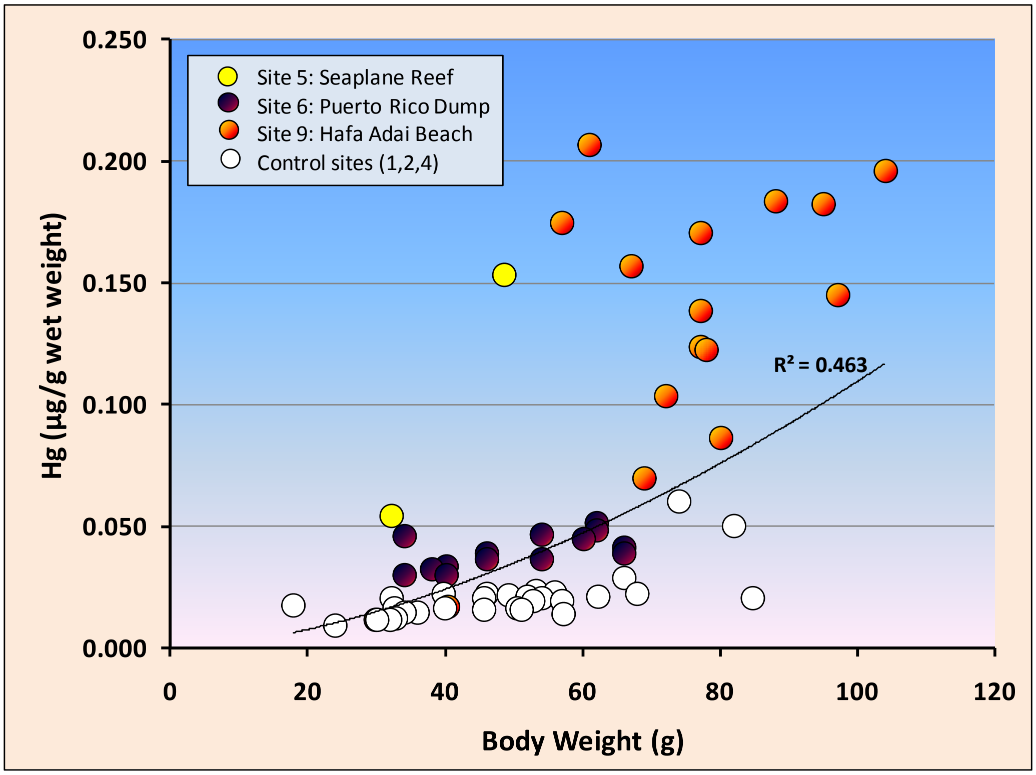

Figure 16: Total mercury in axial muscle of *Myripristis* spp. (P/C:S) in relation to size and site

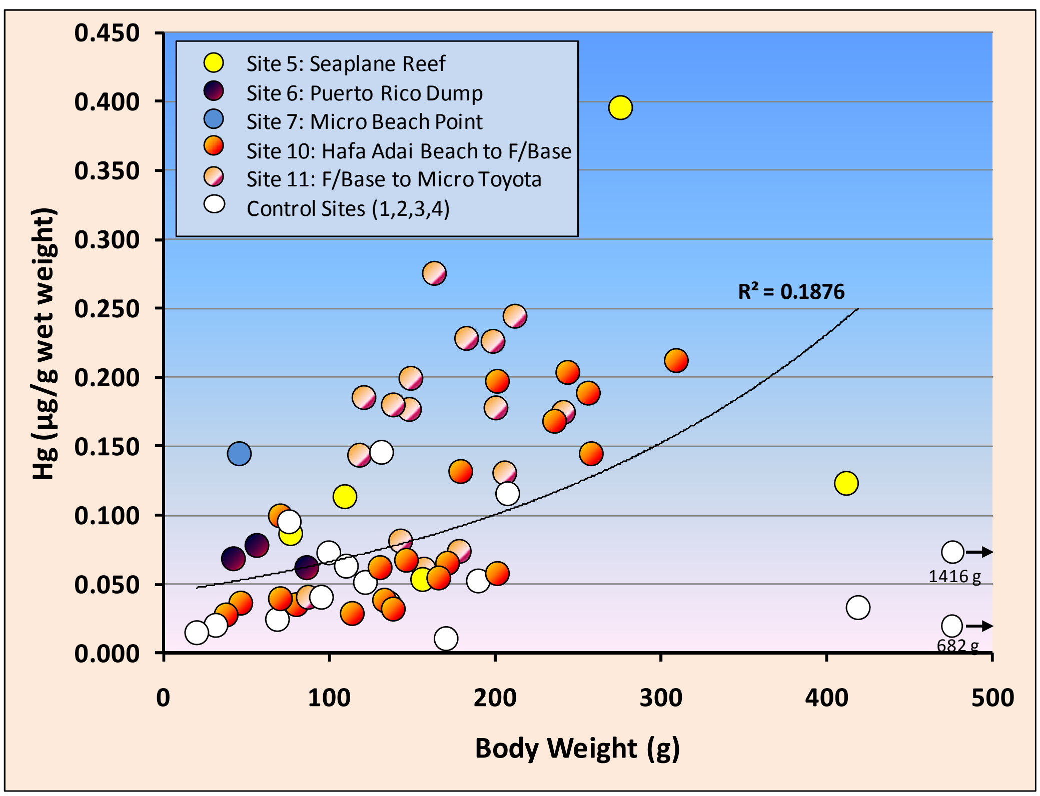

Figure 17: Total mercury in axial muscle of *Lethrinus* spp. (C:R) in relation to size and site

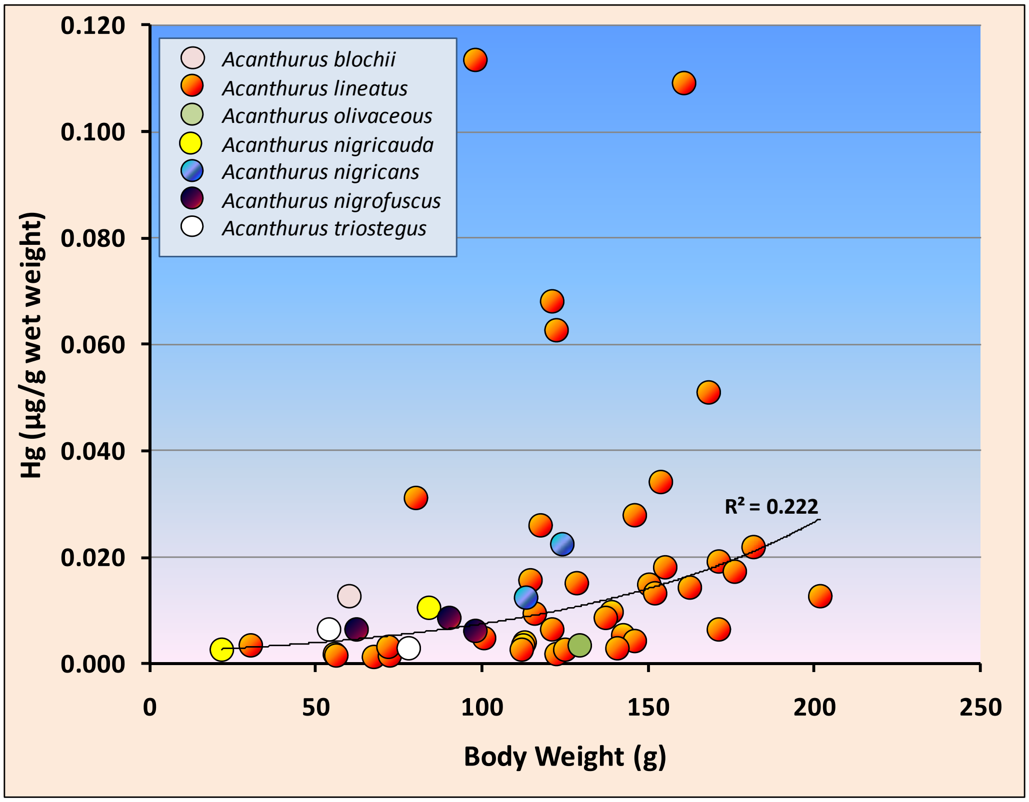

Figure 18: Total mercury in axial muscle of *Acanthurus* spp. (H:S) in relation to size and species

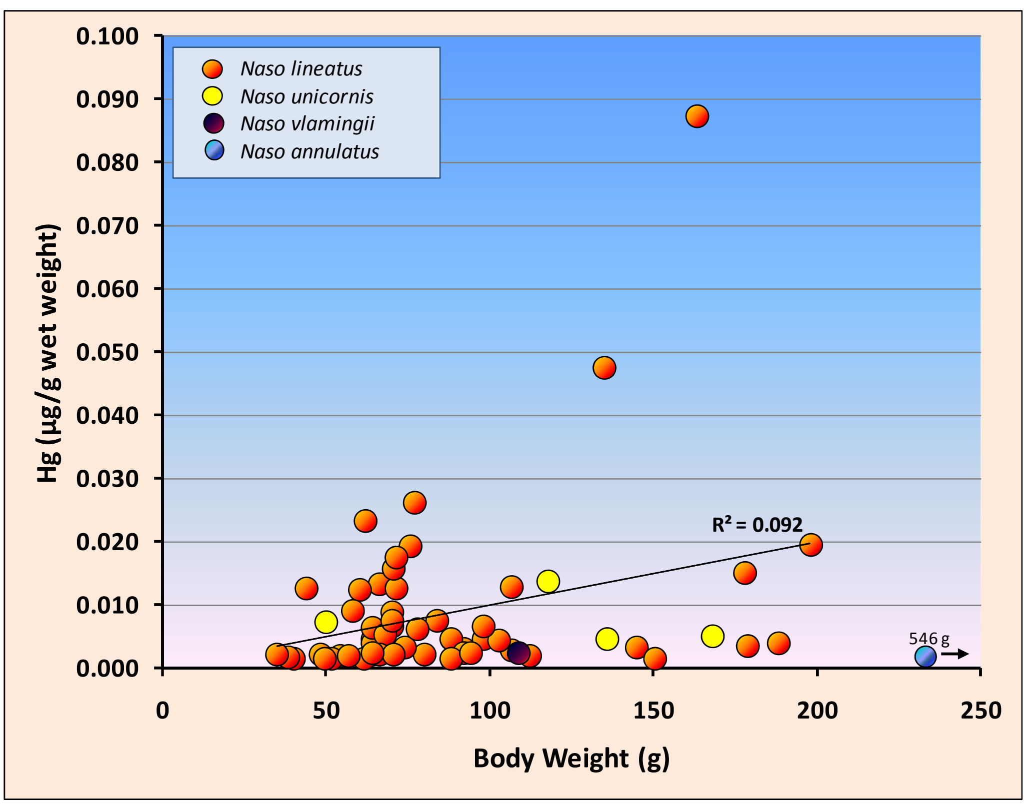

Figure 19: Total mercury in axial muscle of *Naso* spp. (H:R) in relation to size and species

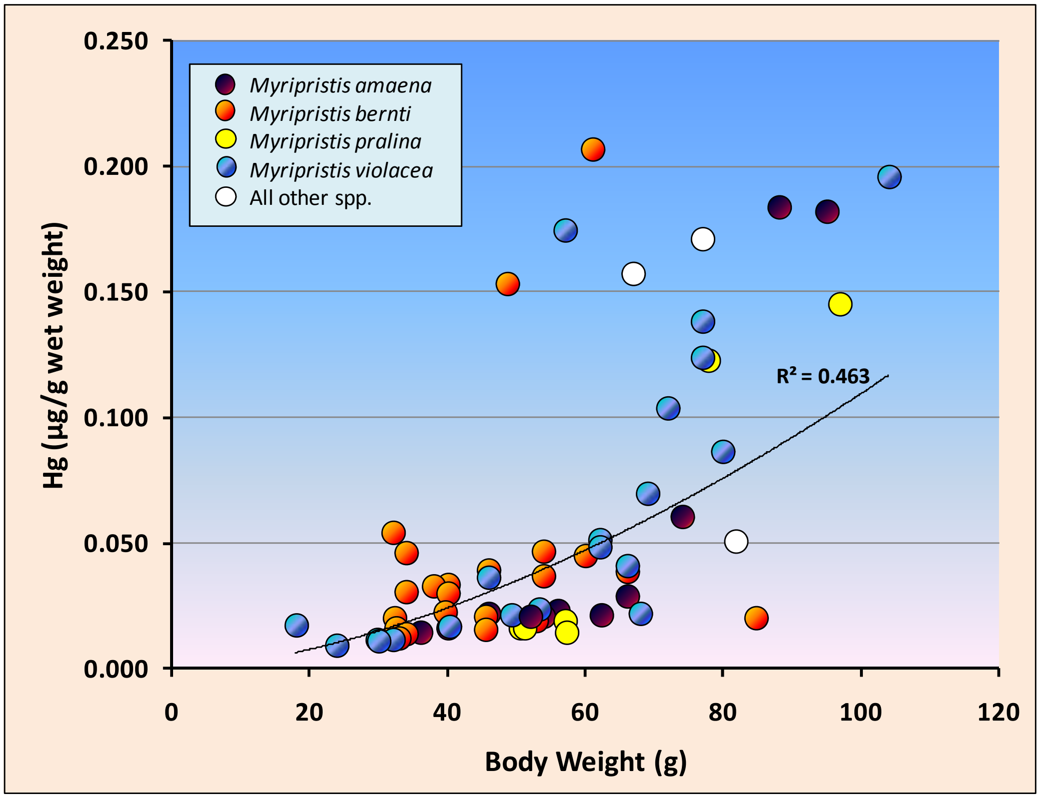

Figure 20: Total mercury in axial muscle of *Myripristis* spp. (P/C:S) in relation to size and species

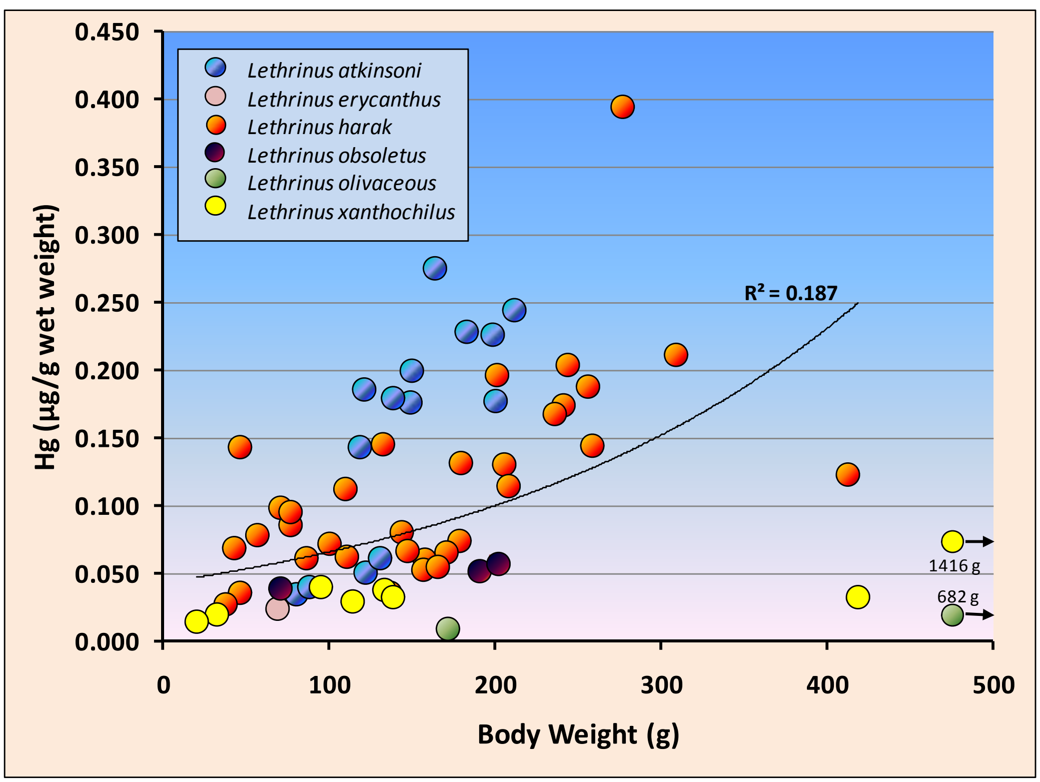

Figure 21: Total mercury in axial muscle of *Lethrinus* spp. (C:R) in relation to size and species

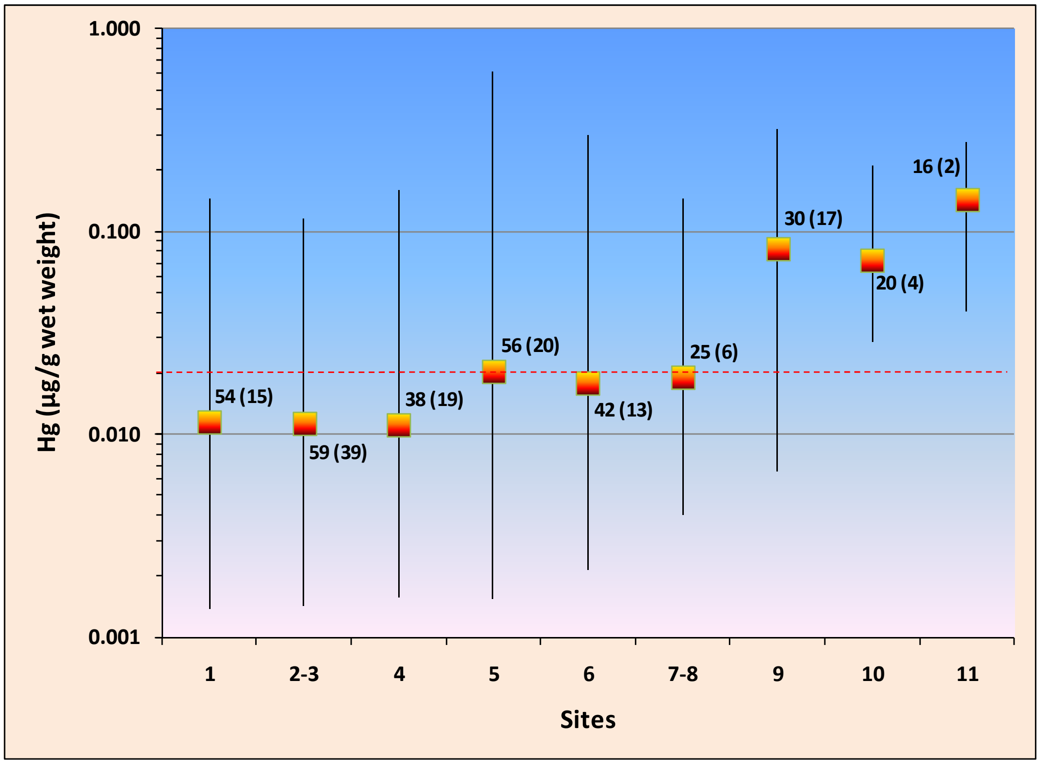

Figure 22: Total mercury in axial muscle of all fish from all sites in Saipan Lagoon. Data are geometric means, ranges, numbers of fish and (total species) analyzed at each site. The overall geometric mean is indicated by the red dashed line.

Table 8: Fish Catch Statistics and Axial Muscle Mercury Levels >0.10 µg/g (wet weight)

Location	Total Fish (spp.) per Site	% Total Fish at Each Trophic Level[a]				% Total Fish
		H	O	P/C	C	>0.10 µg Hg/g wet wt.
Pau Pau Shoals (Site 1)	54 (15)	39	0	33	28	2
Outer Lagoon (Site 2) Outer Lagoon (Site 3)	59 (39)	37	2	14	47	2
Tanapag Shoals (Site 4)	38 (19)	45	11	16	29	3
Seaplane Reef (Site 5)	56 (20)	59	4	4	34	18
Puerto Rico Dump (Site 6)	42 (13)	48	0	33	19	7
Micro Beach Point, (Site 7) Micro Reef (Site 8)	25 (6)	88	4	0	8	8
Hafa Adai Beach (Site 9)	30 (17)	30	0	47	23	63
Hafa Adai Beach to Fishing Base (Site 10)	20 (4)	0	0	0	100	35
Fishing Base to Micro Toyota (Site 11)	16 (2)	0	0	0	100	75

[a]H = Herbivore; O = Omnivore; P/C = Planktivore/Carnivore; C = Carnivore

PCBs:

PCBs are a group of heat stable, chemically inert, man-made compounds that were once widely used in industry, particularly the electrical business. They were manufactured in the US by Monsanto Corporation under the trade name 'Aroclor'. These commercial mixtures typically had total chlorine contents ranging from 21% (Aroclor 1221) to 68% (Aroclor 1268) (Cairns *et al.* 1990).

Unfortunately, the very properties that made PCBs desirable for industry facilitated their build-up in the environment. Today, PCBs are ubiquitous contaminants occurring in all environmental compartments of the planet. As a group, they consist of 209 theoretically possible congeners with widely different physical, chemical and toxicological properties. Not all were present in the commercial formulations produced and only about half prevail in the environment. In fact, based on their potential toxicity, environmental prevalence and abundance in animal tissues, the number of environmentally threatening PCBs reduces to about 36 (McFarland and Clarke 1989).

PCB levels in open ocean waters are highly variable with reported levels ranging from <2-6 pg/L in the Arctic Ocean (Hargrave *et al*. 1992), up to 590 pg/L in the northwestern Pacific Ocean (Tanabe *et al.* 1984). PCB concentrations in marine coastal waters that are distanced from potential sources of local contamination are normally in the low ng/L range (Niimi 1996). The highest waterborne concentrations of PCB are typically found near point-source discharges, with concentrations in the range of 50-500 ng/L (Tanabe *et al.* 1989, El-Gendy *et al.* 1991).

World baseline levels for PCBs in clean coastal sediments are <1 ng/g whereas levels as high as 61,000 ng/g have been reported in heavily contaminated environments (Nisbet 1976). Σ_{20}PCB concentrations in Guam harbor sediments were previously found to range from a low of <1 ng/g at the more remote facilities to a high of 549 ng/g at the commercial port (Denton *et al.* 1999, 2006). Mean levels recently recorded in sediments from Saipan Lagoon north of Micro Beach were generally clean by Guam standards and ranged from <1 ng/g in outer lagoon samples to 16.6 ng/g in samples collected near the Puerto Rico dump (Denton *et al.* 2001; 2006a).

PCBs in the axial muscle of marine fish generally range from the low ng/g level in remote areas to concentrations several orders of magnitude higher in specimens from grossly contaminated environment. On Guam, for example, Σ_{20}PCB concentrations in axial muscle of fish from relatively clean coastal areas ranged from 0.4-79 ng/g dry weight (mean: 4.9 ng/g) compared with 5-369 ng/g (mean: 36 ng/g) in specimens from moderately contaminated sites (Denton *et al.* 1999, 2006c). A more recent Guam study identified a maximum PCB concentration in excess of 300 mg/g (as Aroclor 1254) in whole fish caught near the seawall of a PCB contaminated military dumpsite on the Orote Peninsula on the western side of the island (ATSDR 2002). Although this facility was recently capped, intruding groundwater continues to mobilize PCBs into the area from a source or sources currently unknown (Shaible 2010).

In the present study, Σ_{20}PCB concentrations in the flesh of fish from Saipan Lagoon ranged from 0.04-145 ng/g dry weight with close to 90% of all fish analyzed yielding values of less than 20 ng/g (Fig. 23). These data support earlier contentions that the area is only lightly contaminated by PCBs (Denton *et al.* 2001). The fact that the overall mean (5.3 ng/g) was very close to that given above for fish from relatively clean sites on Guam lends weight to this conclusion.

The congener data for all specimens analyzed are summarized in Appendix B. Co-eluting congeners of possible significance are identified in the legend. Profiles were generally dominated by the mid range homologues (Cl_4-Cl_7) as seems to be the case for most environmental samples (McFarland and Clarke 1989).

An analysis of congener prevalence and abundance is presented in Table 9. Average abundances generally paralleled prevalence with eight of the ten most frequently occurring chlorobiphenyls ranking among the ten most abundant. PCBs 101, 118 and 153 were the most prevalent congeners and were detected in over 70% of fish analyzed. They also ranked among the most abundant congeners accounting for 8-28% of Σ_{20}PCBs on average.

While the more toxic coplanar chlorobiphenyls, PCB 77 and PCB 126, were detected in 33% and 15% of all samples respectively, they had a collective average abundance of only 3%. Quantifiable levels of these congeners, when expressed on a wet weight basis, ranged from 0.01-1.90 ng/g for PCB 77 and 0.01-1.01 ng/g for PCB 126. Both congeners are trace constituents of commercial PCB mixtures (De Voogt *et al.* 1990) and are typically low in environmental matrices (McFarland and Clarke 1989).

Of the remaining chlorobiphenyls, PCBs 52, 105, 128, and 180 were detected in >50% of all samples and had average abundances of 3.2-8.2%. PCBs 18, 28, 44, 138, 170 and 187 were found in 20-50% of samples and had average abundances ranging from 1.7-2.8% of Σ_{20}PCBs. Less commonly encountered in <20% of all samples were PCBs 8, 195, 206, 209 with a collective average abundance of 3.1%. PCB 66 was unusual in that it was detected in only 33% of samples, but in relatively large quantities giving it a relatively high abundance (15%) overall.

Despite the wealth of published data supporting PCB biomagnification at higher trophic levels, there was no clear evidence for this among the various groups analyzed here. On the contrary, some of the highest levels encountered were found in the primary consumers (Fig. 24). Previous work on Guam also failed to demonstrate food chain magnification of PCBs in fish from four harbor sites (Denton *et al.* 1999). These data suggest that bioconcentration processes involving the direct partitioning of aqueous PCBs across surface membranes of the gills and buccal cavity of fish, as proposed by Connell (1990) are more important than the accumulation via the food chain in low level exposure environments.

Site specific data summaries for each trophic level are presented on a dry and wet weight basis in Tables 10 and 11 respectively. No clear site-dependant differences in PCB abundance were mirrored by any trophic group considered, suggesting a relatively even distribution of PCBs throughout the study area. Scatter plots of individual data sets for the four dominant genera sampled (i.e., *Acanthurus* spp., *Naso* spp., *Myripristis* spp. and *Lethrinus* spp.) provided further evidence for this and also revealed no obvious specifies- or size-dependant differences in Σ_{20}PCB levels within each genera (Figs. 25-32). The suggestion is, therefore, that factors other than those directly related to diet are predominantly responsible for the inter- and intra-specific variability encountered during the present study. Physiological and biological characteristics of importance here would of course include lipid content, gender and reproductive status.

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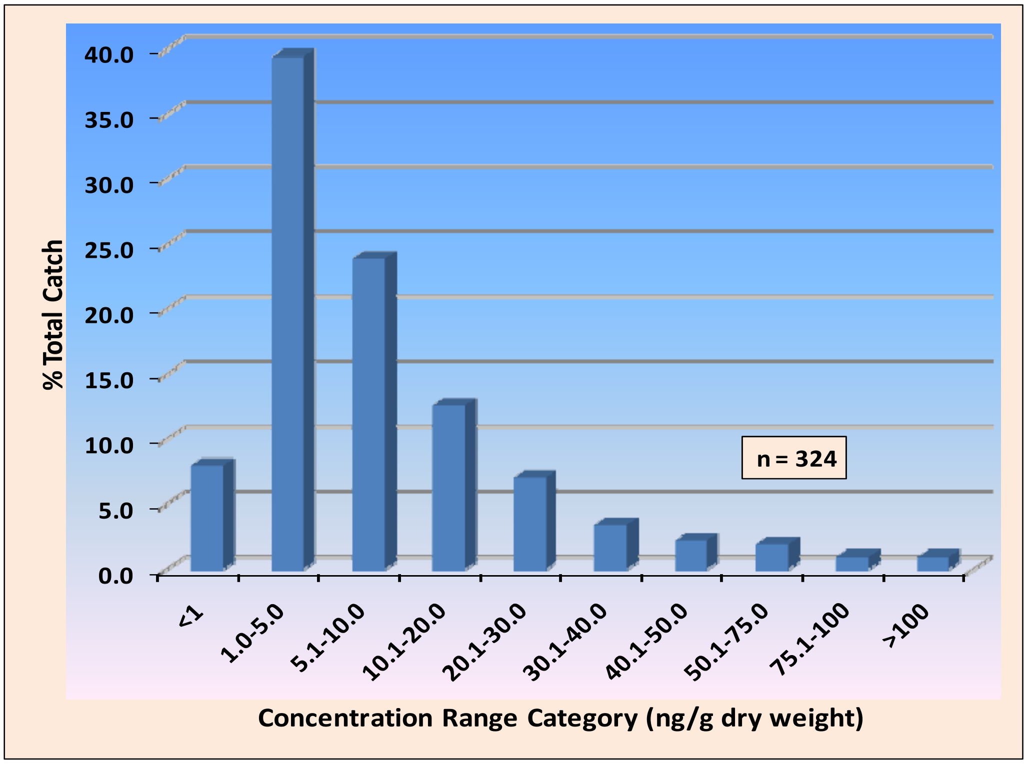


Figure 23: Frequency distribution histogram of Σ_{20}PCB in axial muscle of fish from Saipan Lagoon

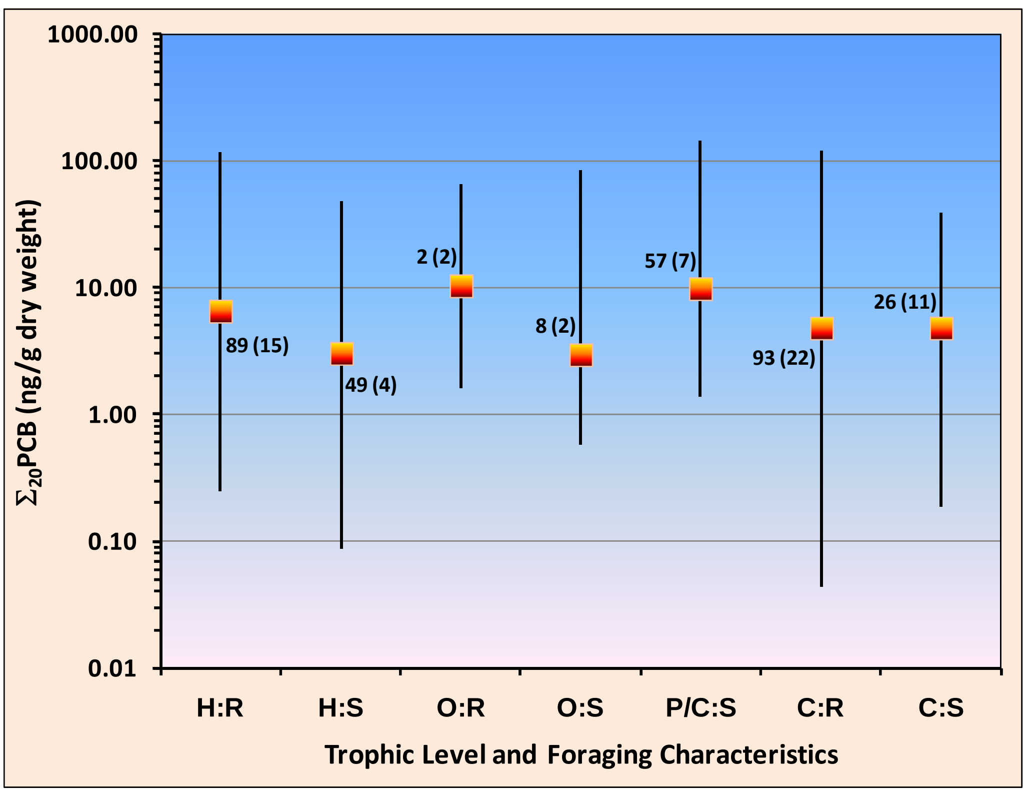


Figure 24: Σ_{20}PCBs in axial muscle of fish from different trophic levels in Saipan Lagoon. Data are geometric mean and range, numbers of specimens and (species) analyzed

Table 9: Prevalence and Abundance of PCBs in Axial Muscle of Fish from Saipan Lagoon

Ranking	Prevalence[a]		Average Abundance[b]	
	Congener	Frequency (%)	Congener	% of $\sum_{20}$PCB
1	118	82	101	28
2	101	74	66	15
3	153	73	118	11
4	52	66	153	8.2
5	180	56	44	7.0
6	128	56	52	6.1
7	105	53	138	3.2
8	187	50	8	2.9
9	138	47	180	2.8
10	44	44	187	2.3
11	170	35	105	2.3
12	66	33	28	2.0
13	77	33	128	2.0
14	28	25	18	1.9
15	18	20	209	1.7
16	8	18	77	1.5
17	206	17	170	0.9
18	126	15	206	0.8
19	195	13	126	0.5
20	209	12	195	0.3

[a] Prevalence = Congener detection frequency expressed as % of total fish analyzed; N = 327

[b] Average abundance = [Σ(% of the Σ_{20}PCB represented by each congener in each sample)]/total samples

Average abundances based on total PCBs (Σ_{20}PCB x 2) may be estimated for each conger by halving their respective percentages shown above.

Table 10: Σ_{20}PCBs (ng/g dry weight) in Axial Muscle of Fish from Saipan Lagoon (arranged by site and trophic level)

Site	Location	Statistic[1]	Trophic Level[2]						
			H:R	H:S	O:R	O:S	P/C:S	C:R	C:S
1	Pau-Pau Reef Shoals	range:	0.88 - 38.7	7.77 - 48.2	-	-	1.36 - 145	0.43 - 33.5	0.19 -32.2
		median:	8.50	13.5	-	-	4.41	9.88	2.71
		mean	8.27	17.1	-	-	8.37	7.07	2.82
		# fish (species):	18 (4)	3 (2)	-	-	17(3)	6 (4)	9 (2)
2	Outer Lagoon 1 (Dankulo Rock)	range:	1.33 - 57.0	0.96 - 41.8	1.62	0.58 - 5.18	3.09 - 9.48	0.18 - 24.4	1.44 - 5.20
3	Outer Lagoon 2	median:	4.74	2.12	-	0.87	6.47	2.75	5.04
		mean	5.85	3.58	-	1.37	6.09	3.49	3.71
		# fish (species):	15 (10)	6 (3)	1 (1)	3 (3)	7 (1)	21 (17)	4 (4)
4	Tanapag Reef Shoals	range:	0.27 - 24.3	0.71 - 4.84	-	0.81 - 83.0	5.40 - 72.4	0.76 - 22.5	21.2
		median:	4.49	3.90	-	1.67	36.1	3.99	-
		mean	2.87	2.89	-	4.82	31.5	4.77	-
		# fish (species):	10 (5)	5 (2)	-	3 (1)	6 (3)	9 (5)	1 (1)
5	Seaplane Reef	range:	0.59 - 14.5	0.69 - 3.79	64.9	10.36	3.44 - 70.0	0.04 - 35.4	1.35 - 24.1
		median:	4.61	1.46	-	-	36.7	3.04	5.15
		mean	4.03	1.52	-	-	15.5	3.02	5.58
		# fish (species):	20 (6)	10 (1)	1 (1)	1 (1)	2 (1)	11 (7)	5 (4)
6	Puerto Rico Dump	range:	3.07 - 116	1.89 - 13.4	-	-	2.33 - 24.8	9.24 - 79.9	3.34 - 12.2
		median:	12.8	2.32	-	-	9.22	27.0	4.10
		mean	14.4	3.88	-	-	8.68	27.2	5.51
		# fish (species):	17 (4)	3 (2)	-	-	11 (2)	5(2)	3 (3)
7	Micro Point	range:	11.0	0.09 -32.1	-	-	-	1.87 - 3.34	-
8	Micro Reef Complex	median:	-	2.39	-	-	-	2.61	-
		mean	-	2.88	-	-	-	2.50	-
		# fish (species):	1 (1)	20 (1)	-	-	-	2 (2)	-
9	Hafa Adai Beach	range:	0.30 - 42.1	-	-	1.22	3.24 - 21.9	1.24 - 84.7	6.40 - 22.9
		median:	9.80	-	-	-	8.41	5.78	7.95
		mean	8.78	-	-	-	8.75	5.73	9.80
		# fish (species):	8 (4)	-	-	1 (1)	14 (6)	9 (4)	4 (2)
10	Hafa Adai Beach to Fisherman's Base	range:	-	-	-	-	-	0.67 - 4.67	-
		median:	-	-	-	-	-	1.92	-
		mean	-	-	-	-	-	2.05	-
		# fish (species):	-	-	-	-	-	10 (4)	-
11	Fisherman's Base to Micro Toyota	range:	-	-	-	-	-	0.47 - 120	-
		median:	-	-	-	-	-	6.04	-
		mean	-	-	-	-	-	7.23	-
		# fish (species):	-	-	-	-	-	20 (3)	-

[1] Mean = geometric mean; [2] H, C, P and O = herbivore, carnivore, planktivore and omnivore respectively; S = sedentary forager/small home range; R = roving forager/large home range; dashes = no data

Table 11: Σ_{20}PCBs (ng/g wet weight) in Axial Muscle of Fish from Saipan Lagoon (arranged by site and trophic level)

Site	Location	Statistic[1]	Trophic Level[2]						
			H:R	H:S	O:R	O:S	P/C:S	C:R	C:S
1	Pau-Pau Reef Shoals	range:	0.20 - 8.90	1.79 - 11.1	-	-	0.31 - 33.4	0.10 - 7.71	0.04 - 9.02
		median:	1.95	3.09	-	-	1.01	2.27	0.62
		mean	1.90	3.94	-	-	1.92	1.63	0.65
		# fish (species):	18 (4)	3 (2)	-	-	17 (3)	6 (4)	9 (2)
2	Outer Lagoon 1 (Dankulo Rock)	range:	0.31 - 13.1	0.22 - 9.62	0.37	0.13 - 1.19	0.71 - 2.18	0.04 - 5.61	0.33 - 1.20
3	Outer Lagoon 2	median:	1.09	0.49	-	0.20	1.49	0.63	1.16
		mean	1.35	0.82	-	0.32	1.40	0.80	0.85
		# fish (species):	15 (10)	6 (3)	1 (1)	3 (3)	7 (1)	21 (17)	4 (4)
4	Tanapag Reef Shoals	range:	0.06 - 5.59	0.16 - 1.11	-	0.19 - 19.1	1.23 - 16.7	0.17 - 5.17	4.88
		median:	1.03	0.90	-	0.38	8.29	0.92	-
		mean	0.66	0.66	-	1.11	7.23	1.10	-
		# fish (species):	10 (5)	5 (2)	-	3 (1)	6 (3)	9 (5)	1 (1)
5	Seaplane Reef	range:	0.13 - 3.34	0.16 - 0.87	14.9	2.38	0.79 - 16.1	0.01 - 8.14	0.31 - 5.53
		median:	1.06	0.34	-	-	8.54	0.70	1.18
		mean	0.93	0.35	-	-	3.57	0.70	1.28
		# fish (species):	20 (6)	10 (1)	1 (1)	1 (1)	2 (1)	11 (7)	5 (4)
6	Puerto Rico Dump	range:	0.71 - 26.7	0.43 - 3.07	-	-	0.54 - 5.71	2.12 - 18.4	0.77 - 2.81
		median:	2.94	0.53	-	-	2.12	6.21	0.94
		mean	3.31	0.89	-	-	2.00	6.27	1.27
		# fish (species):	17 (4)	3 (2)	-	-	11 (2)	5 (2)	3 (3)
7	Micro Point	range:	2.53	0.02 - 7.39	-	-	-	0.43 - 0.77	-
8	Micro Reef Complex	median:	-	0.55	-	-	-	0.60	-
		mean	-	0.66	-	-	-	0.58	-
		# fish (species):	1 (1)	20 (1)	-	-	-	2 (2)	-
9	Hafa Adai Beach	range:	0.09 - 9.67	0.90 - 3.20	-	0.28	0.74 - 5.03	0.29 - 19.5	1.47 - 5.26
		median:	2.25	2.05	-	-	1.93	1.33	1.83
		mean	2.02	1.70	-	-	2.01	1.32	2.25
		# fish (species):	8 (4)	2 (2)	-	1 (1)	14 (6)	9 (4)	4 (2)
10	Hafa Adai Beach to Fisherman's Base	range:	-	-	-	-	-	0.15 -1.08	-
		median:	-	-	-	-	-	0.44	-
		mean	-	-	-	-	-	0.47	-
		# fish (species):	-	-	-	-	-	10 (4)	-
11	Fisherman's Base to Micro Toyota	range:	-	-	-	-	-	0.11 - 27.5	-
		median:	-	-	-	-	-	1.39	-
		mean	-	-	-	-	-	1.66	-
		# fish (species):	-	-	-	-	-	20 (3)	-

[1] Mean = geometric mean; [2] H, C, P and O = herbivore, carnivore, planktivore and omnivore respectively; S = sedentary forager/small home range; R = roving forager/large home range; dashes = no data

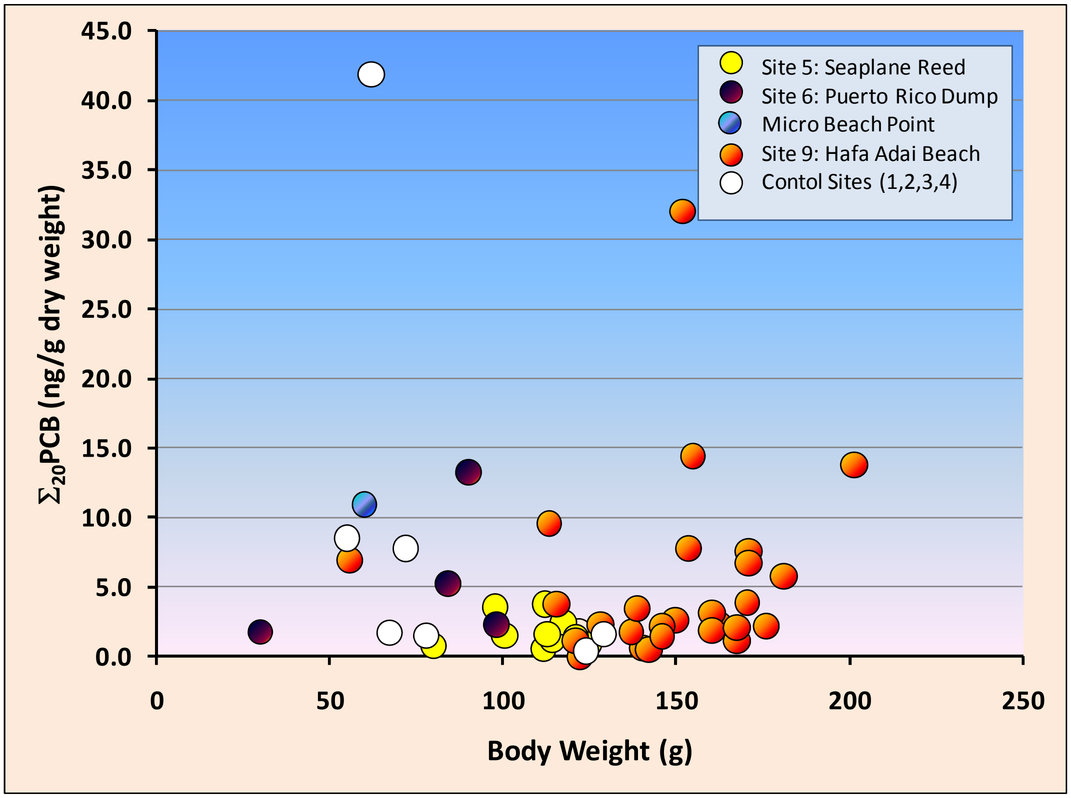


Figure 25: Σ_{20}PCBs in axial muscle of *Acanthurus* spp. (H:S) in relation to size and site

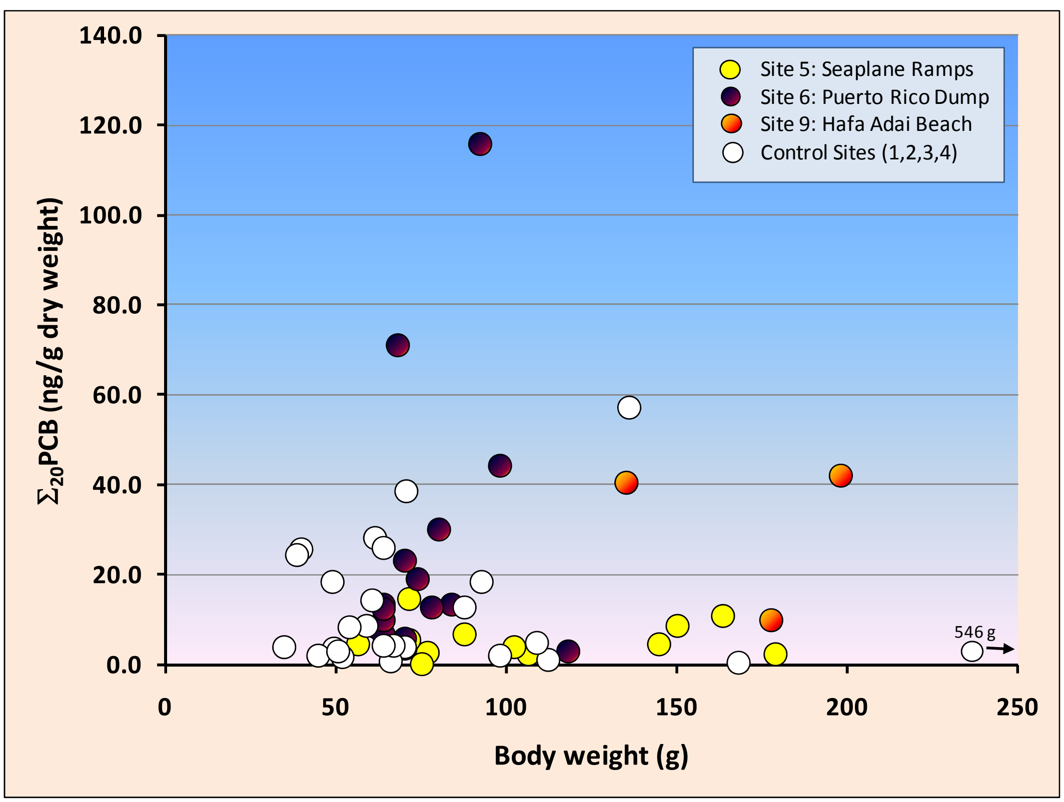


Figure 26: Σ_{20}PCBs in axial muscle of *Naso* spp. (H:R) in relation to size and site

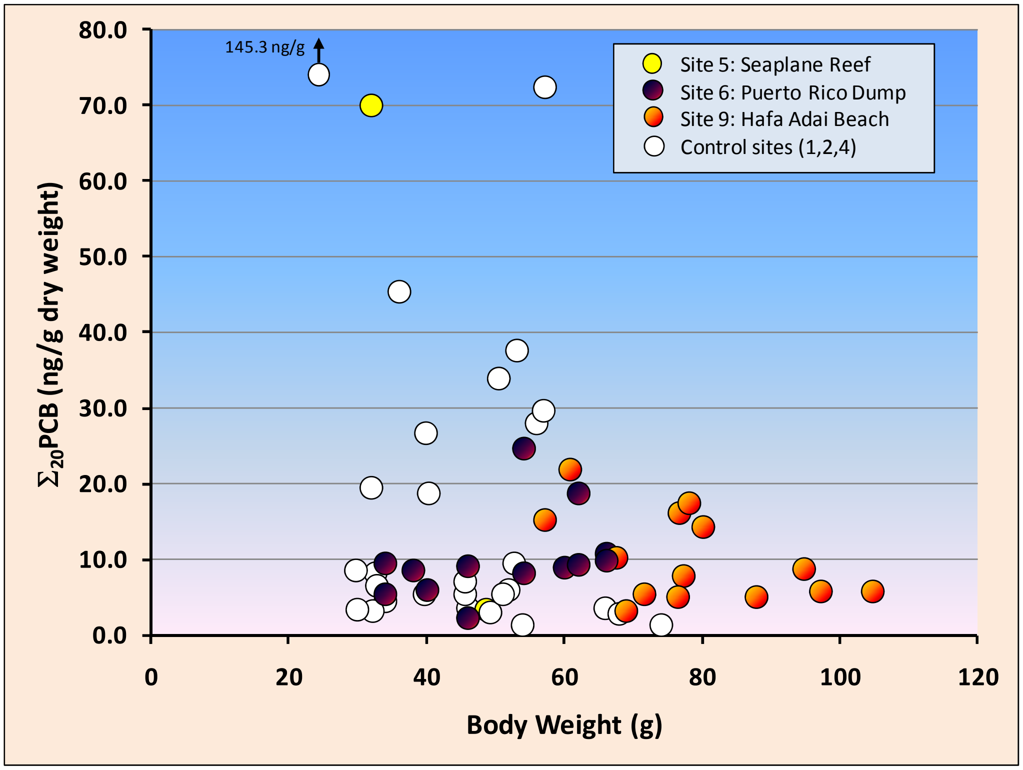


Figure 27: Σ_{20}PCBs in axial muscle of *Myripristis* spp. (P/C:S) in relation to size and site

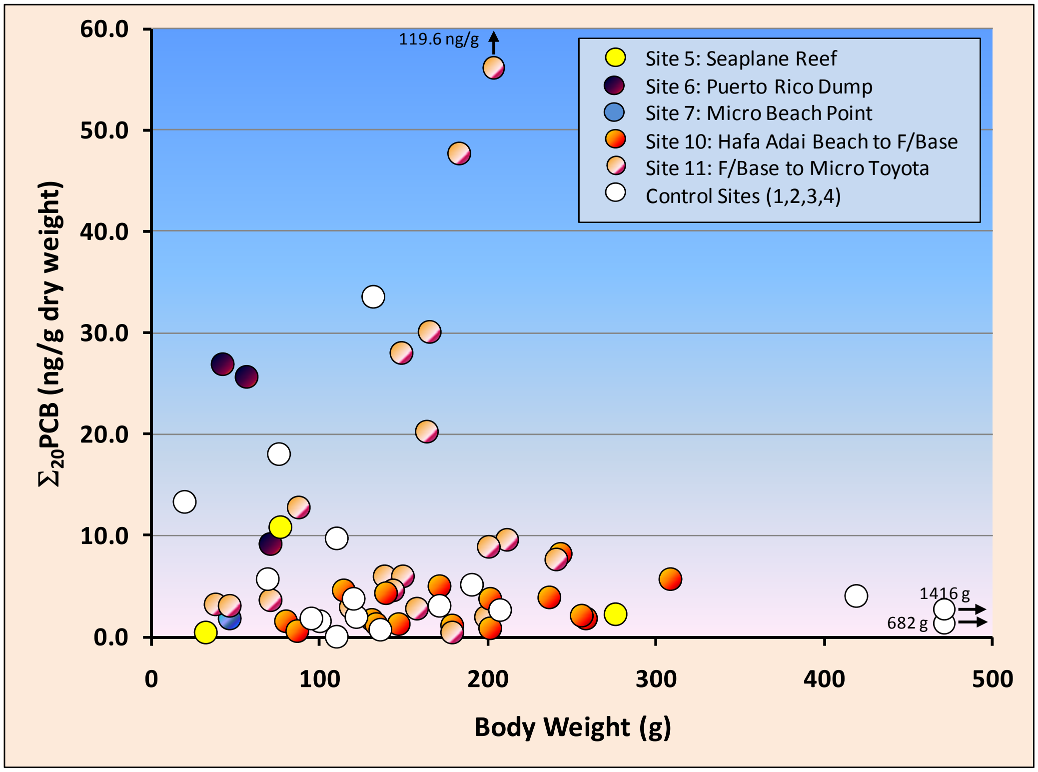


Figure 28: Σ_{20}PCBs in axial muscle of *Lethrinus* spp. (C:R) in relation to size and site

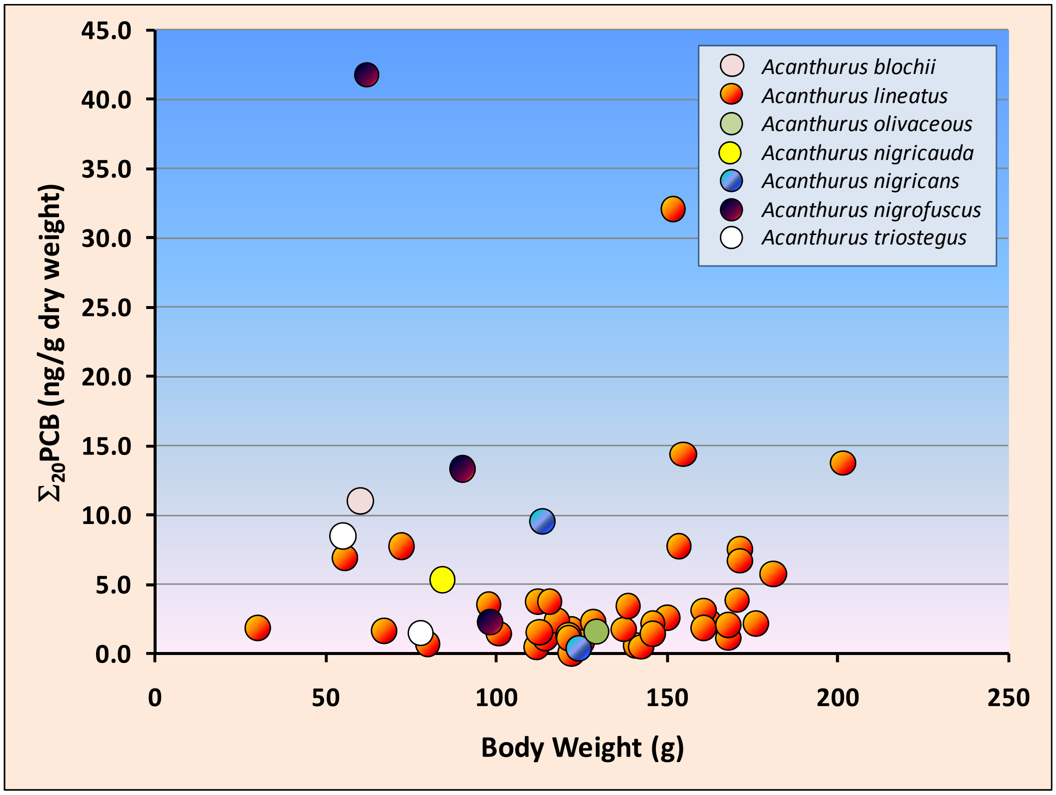


Figure 29: Σ_{20}PCBs in axial muscle of *Acanthurus* spp. (H:S) in relation to size and species

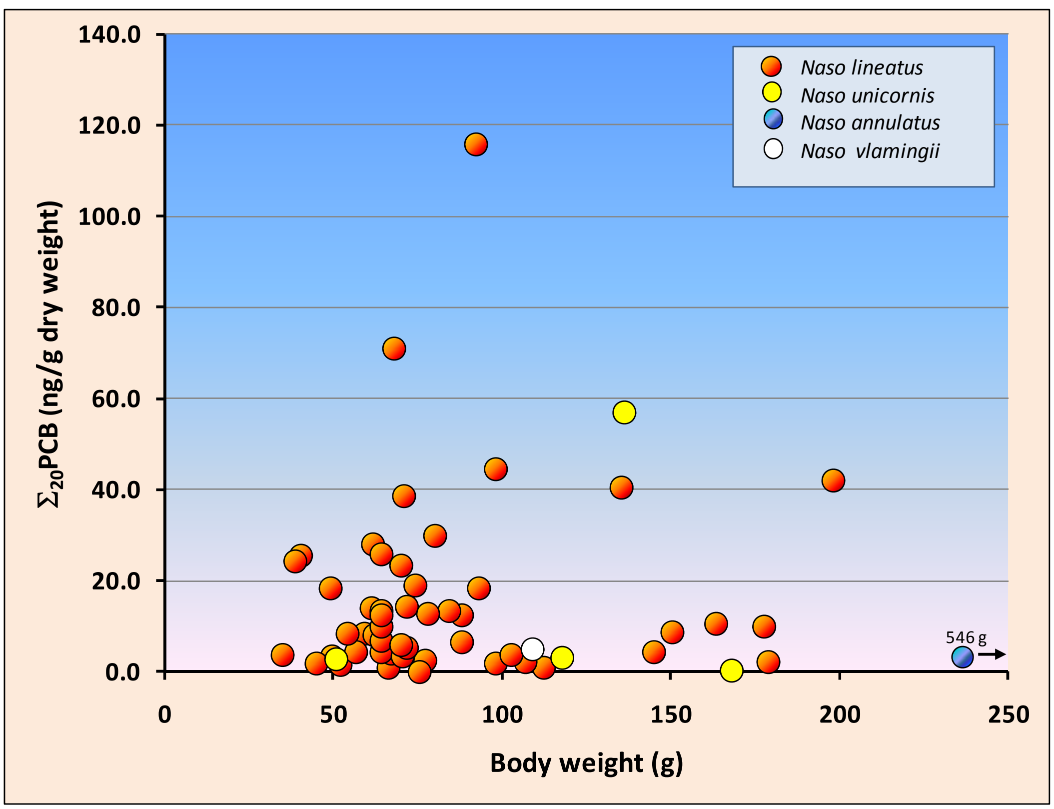


Figure 30: Σ_{20}PCBs in axial muscle of *Naso* spp. (H:R) in relation to size and species

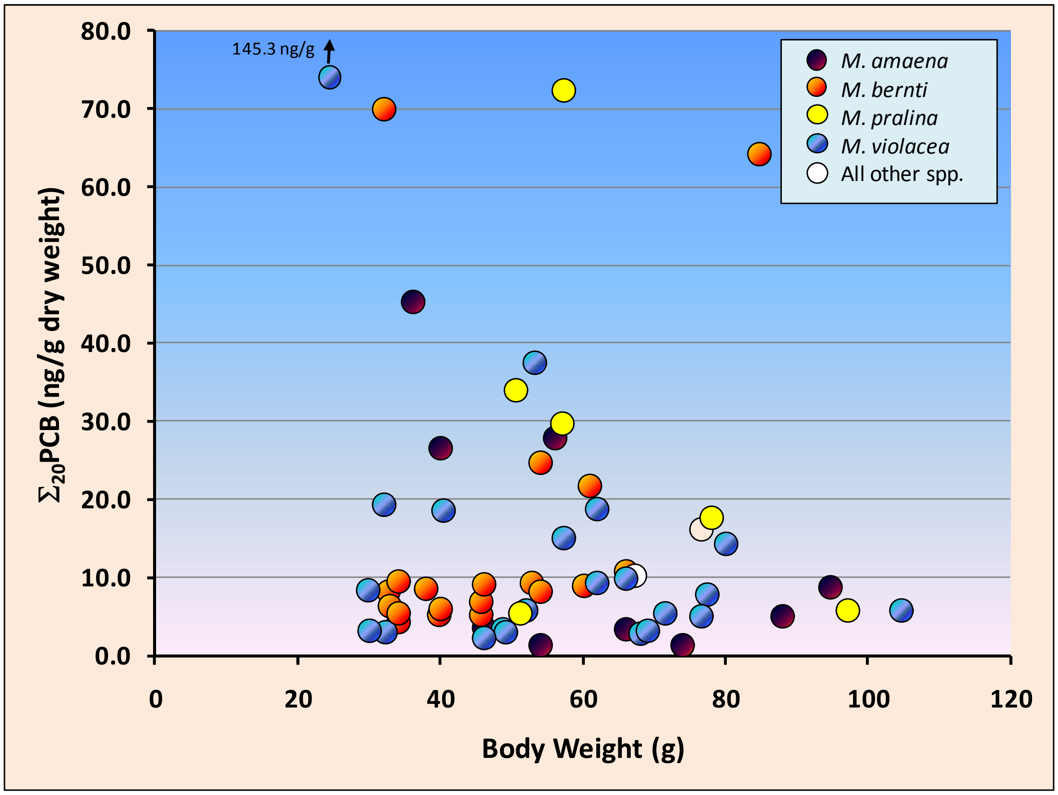


Figure 31: Σ_{20}PCBs in axial muscle of *Myripristis* spp. (P/C:S) in relation to size and species

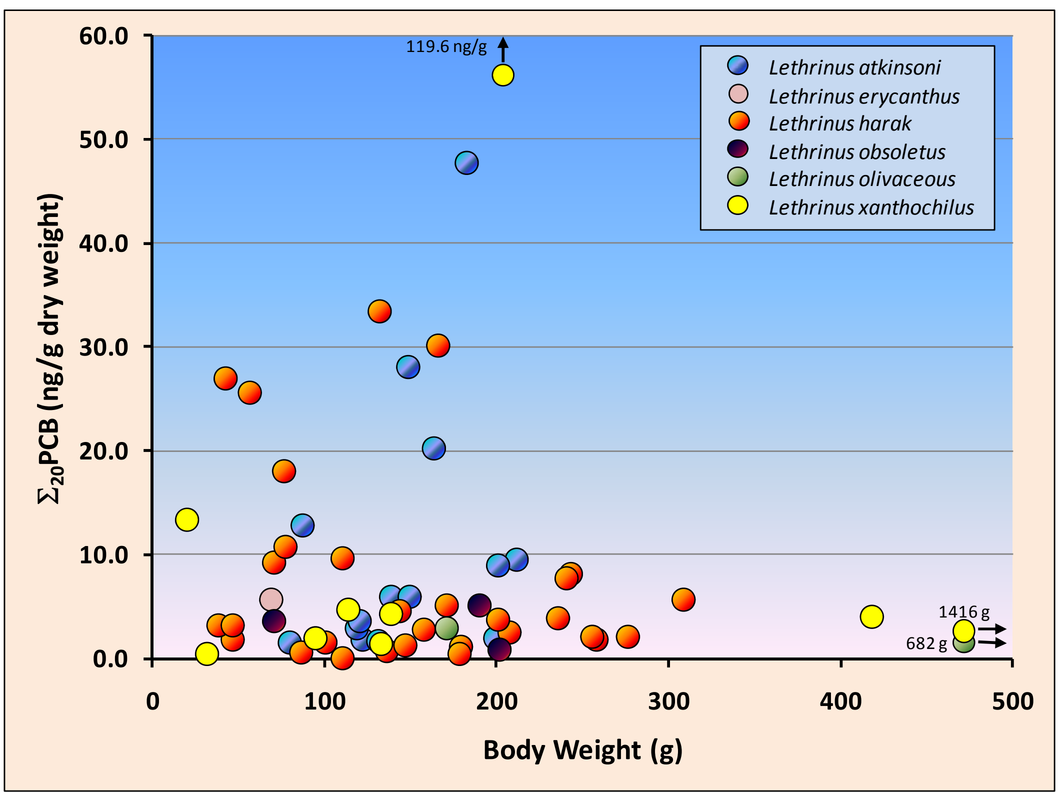


Figure 32: Σ_{20}PCBs in axial muscle of *Lethrinus* spp. (C:R) in relation to size and species

CONCLUSIONS AND RECOMMENDATIONS

The data presented herein represents the first comprehensive study of arsenic, mercury and PCBs in food fish from Saipan Lagoon. The data are especially valuable to environmental regulators and public health officials concerned with the potential impact of these contaminants on local residents who harvest fisheries resources from the lagoon for food. A final comment on the toxicological significance of the data from a fish advisory standpoint would therefore seem appropriate here.

HEALTH BENEFITS AND FISH CONSUMPTION RATES

The benefits of consuming marine fish are undeniable. Besides being a valuable source of high quality protein, essential omega-3 fatty acids, essential minerals (e.g., calcium, potassium, iodine, iron, zinc and selenium) and some vitamins (e.g., vitamins A, B_3, B_6 and D), marine fish are low in cholesterol, calories, sodium and saturated fats. This unique blend of dietary attributes provides us some protection against heart disease and cardiac arrest; reduces the risk of several types of cancer (especially prostate cancer and cancers of the digestive tract); and contributes towards our normal growth, well being and intellectual development. Other health benefits commonly touted in the literature include lowered risks of dementia, diabetes, depression, rheumatoid arthritis, psoriasis, stroke, hypertension and autoimmune disease (Abbot 2007).

The per capita consumption of fish in the CNMI is currently unknown but, considering the high Asian ethnicity of the islands, it is likely to be high (see Sechena *et al.* 2003**)** compared with the UK and many US mainland communities where consumption rates rarely exceed 200g per person per week (Washington Department of Ecology 1999; Henderson *et al.* 2002, Yokoyama *et al.* 2007). Many local people engage in both recreational or subsistence fishing and consume fish several times a week, some even daily (David Benavente, Saipan CRM Office, pers. com.).

HUMAN HEALTH RISKS

The fact that fish tend to accumulate arsenic, mercury and PCBs in their tissues has been of long-standing concern to scientists and public health officials, particularly in the absence of adequate toxicological data to evaluate the true impact of these chemicals on consumers. International regulatory limits for these contaminants in fish generally lack any solid scientific basis and vary considerably between countries (Nauen 1983). Moreover, they usually only apply to consignments offered for commercial sale and are not designed to protect recreational or subsistence fishers. Only in the last decade have we seen the emergence of fish advisories for such populations based on contaminant levels in fish that people eat; how often the fish are eaten, and how much is eaten at any one sitting.

The US Environmental Protection Agency has developed risk assessment procedures to determine consumption limits for 25 high priority chemical contaminants in fish. These limits were designed to provide guidance to state, local, regional and tribal health officials responsible for issuing fish consumption advisories for non-commercially caught fish (USEPA 2000). The consumption limits developed for arsenic, mercury and PCBs are used here to assess the data arising from the current work. For this purpose, all total mercury measurements in fish were treated as methylmercury; inorganic arsenic was approximated as 1% of total arsenic, and total PCBs were assumed to be twice the Σ_{20}PCB values.

Arsenic
Arsenic and its compounds are widely distributed in nature primarily in two oxidation states, arsenite (As^{3+}) and arsenate (As^{5+}). Traces of arsenic are found in most foods, with the highest concentrations found in fish and shellfish. Arsenic toxicity manifests itself in a variety of ways depending upon the severity of the poisoning and duration of exposure. Initial symptoms of poisoning by ingestion range from stomach irritation, confusion, headache, and fatigue (ATSDR 2006). Continued exposure can result in neurological, cardiovascular, hematological, hepatic and renal illnesses, and increase the risk of diabetes, stroke, skin cancer and tumors of the bladder, kidney, liver, and lung (Munoz *et al.* 1999).

The majority of arsenic in fish is present as organoarsenic species, metabolized from inorganic arsenic present in seawater, or accumulated from food sources such as algae, or other fish (Nash 2005). Arsenobetaine and arsenocholine sometimes referred to as 'fish arsenic' are the major arsenic species found in fish. Together, they often account for 50-90% of the total arsenic present and are considered to be non-toxic at levels normally consumed (Shrain *et al.* 1999). Inorganic arsenic species, though considerably more toxic than their organic counterparts, rarely add up to more than 3% of total arsenic levels in marine fish and usually account for less than 1% (Muñoz *et al.* 1999, FSA 2004 and 2005, Green and Crecelius 2006, Peshut *et al*. 2008).

The USA currently has no enforceable standard for total arsenic levels in fish. Standards adopted by countries range from 0.1-30 µg/g wet weight (Nauen 1983). Consumption advisories established by the USEPA for inorganic arsenic are presented in Table 12. Acceptable concentrations ranges are provided for up to 16 standard 8-oz (227 g) fish meals per month and are based on non-cancer and cancer health endpoints (USEPA 2000).

Mean total arsenic levels in fish examined during the present study ranged from 0.23 µg/g in herbivorous species to 13.9 µg/g in the planktivores. Based on these data and the assumption that inorganic arsenic levels are at least two orders of magnitude lower, the daily intake of inorganic arsenic for a 70 kg adult consuming one 8-oz meal of herbivorous fish per day would be less than 3% of the USEPA 0.3 µg/kg-d reference dose used in calculating the non-cancer guidelines. Likewise, an equivalent consumption rate of carnivorous species would provide no more than 25% of this value, whereas marginal exceedence might be expected from a meal of omnivorous or planktiverous species. Thus, the great majority of specimens analyzed here fell within the unrestricted consumption category (i.e., inorganic arsenic levels <0.088 µg/g) when weighed against USEPA (2000) guidelines based on non-cancer health endpoints (Table 12).

On the other hand, severe restrictions would be necessary for some species if consumption limits were based on USEPA cancer health endpoints. While most herbivorous species could still be consumed on an unrestricted basis, standard meals composed exclusively of carnivorous species should not really be eaten more than three times a month and certain species like *Hemigymnus melapterus, Parupeneus multifasciatus, Pseudobalistes fuscus* and *Thalassoma trilobatus* should not be eaten at all. It would also be prudent to avoid the omnivores *Sufflamen chrysoptera* and *Rhinecanthus* spp., and all planktiverous representatives of the genera *Myripristis*.

While there is clearly a case for further investigations to quantify inorganic arsenic in fish from Saipan Lagoon it is perhaps worth noting here that there are no documented accounts of arsenic related food poisonings from seafood anywhere in the world (Kaise *et al.* 1985, Yamauchi *et al.* 1986, Edmonds and Francesconi 1993). And, since total arsenic levels found in fish during the current study compare favorably with those reported for marine species from elsewhere, the likelihood of any contrary reports emerging from the CNMI seem most unlikely.

Table 12: Risk-Based Consumption Limits for Inorganic Arsenic in Fish (USEPA 2000)

Risk Based Consumption Limit[a]	Fish Tissue Concentrations (µg/g wet weight)	
Fish Meals/Month	**Noncancer Health Endpoints[b]**	**Cancer Health Endpoints[c]**
Unrestricted (>16)	0 - 0.088	0 - 0.002
16	>0.088 - 0.18	>0.002 - 0.0039
12	>0.18 - 0.23	>0.0039 - 0.0052
8	>0.23 - 0.35	>0.0052 - 0.0078
4	>0.35 - 0.7	>0.0078 - 0.016
3	>0.7 - 0.94	>0.016 - 0.021
2	>0.94 - 1.4	>0.021 - 0.031
1	>1.4 - 2.8	>0.031 - 0.063
0.5	>2.8 - 5.6	>0.063 - 0.13
none (<0.5)	>5.6	>0.13

[a]Arsenic is considered to be a carcinogen. Consumption limits calculated by USEPA were thus derived from both non-cancer and cancer health endpoints using a chronic reference dose (RfD) for inorganic arsenic of 3×10^{-4} mg/kg BW/day and a cancer slope factor (CSF) of 1.5 $(mg/kg/day)^{-1}$ respectively. The non-cancer *Provisional Tolerable Daily Intake* reference dose adopted by Australia and New Zealand for inorganic arsenic is the same as that prescribed by the USEPA. Until recently, the UK advocated an inorganic arsenic *Provisional Tolerable Weekly Intake* of 15×10^{-3} mg/kg BW. This standard, eqivalent to 2.1×10^{-3} mg/kg BW/day, was recently withdrawn by the Joint FAO/WHO Expert Committee on Food Additives (JECFA 2010). For the purpose of this table, it was assumed that fish provide 100% of all dietary arsenic and that all ingested inorganic arsenic is absorbed by the GI tract.

[b]Non-cancer based fish consumption limits were calculated as: $Tissue_{As} = RfD \times BW \times TAP/FM_{size} \times FM_{month}$, where BW = body weight of consumer (70 kg default); $Tissue_{As}$ = inorganic arsenic concentration in fish (µg/g wet weight); TAP = time averaging period (365.25 days/12 months = 30.44 days/month); FM_{size} = fish meal size (227 g default); FM_{month} = number of fish meals consumed per month.

[c]Cancer based consumption limits were calculated as: $Tissue_{As} = ARL \times BW \times AT/Fish_{size} \times CSV \times FM_{year} \times D$, where ARL = maximum acceptible individual lifetime risk level (unitless) (1 in 100,000 risk level $= 1 \times 10^{-5}$); AT = human lifespan (70 years default) expressed in days (25567.5 days); FM_{year} = number of fish meals consumed per year; D = duration of exposure (70 years default).

Notes:

1. USEPA (1997) defines the *reference dose* (RfD) as an estimate (with uncertainy spanning perhaps an order of magnitude) of a daily exposure level (mg/kg BW/day) for the human population, including sensitive subpopulations, that is likely to be without appreciable risk of deliterious effects during a lifetime. The value of the RfD is chemical and toxicological endpoint specific. The lower the value of the RfD the more toxic the substance.
2. The *Cancer Slope Factor* (CSF) is derived, usually but not always, as the 95th percent upper confidence limit of the low-dose linear slope of the dose response curve, and is expressed in units of $(mg/kg/day)^{-1}$. The CSF is most often derived from studies of laboratory animals, traditionally by application of dose-response models that assume no threshold for carcinogenic effects (i.e., any dose, no matter how small, will result in some risk) and allow for linearity in response at low dose. The value of the CSF is chemical specific. The greater the value of the CSF, the greater the carcinogenic potency of the substance (USEPA 1997).

Mercury

Fish naturally supply a greater proportion of dietary mercury to man than any other food component (Holden 1973). Of greater significance is the fact that almost all of the mercury in fish (80-100%) exists in the highly toxic methylmercury form (Bloom 1992, Joiris *et al.* 1999, Storelli *et al.* 2005), whereas mercury in other foods occurs mainly in the inorganic form and is of little toxicological significance. For the purpose of this discussion, total mercury values recorded during the present study were treated as methylmercury concentrations.

Methylmercury can induce toxic effects in several organ systems including liver, kidney, and reproductive organs, and it is particularly toxic to the nervous system. Neurotoxic effects of excessive methylmercury exposure include neuronal loss, ataxia, visual disturbances, impaired hearing, paralysis and death. The developing brain is thought to be the most sensitive target organ. High methylmercury intake by pregnant women has been linked to adverse effects in neurological developmental in children (JECFA 2003).

The U.S. Food and Drug Administration action level for methylmercury in fish sold commercially currently stands at of 1.0 µg/g (USFDA 1998). This enforceable standard was never intended to cover fish caught by recreational or subsistence fishers. The USEPA fish consumption guidelines for methylmercury bridge that gap and are listed in Table 13 alongside standards currently adopted by Canada, Australia, New Zealand and the UK. The default adult fish meal size employed by USEPA for these calculations is 8-oz or 227 g (uncooked weight).

While guidance estimates for the USA are considerably more conservative than those of the other countries listed, the great majority of fish caught north of Seaplane Reef yielded mercury levels in edible tissue that would not have presented a significant public health risk to local consumers. In fact, around 80% of all specimens taken from Sites 1-4 yielded concentrations below 0.029 µg/g indicating that fish from these areas can be consumed on an unrestricted (i.e., daily) basis by even the most sensitive of population sub-groups without any long-term ill effects (Table 14). In contrast, fish taken further south revealed progressively higher tissue concentrations with over 50% of all samples exceeding 0.029 µg/g at Sites 6, 75% at Site 9, and 95% and over at Sites 10-11. Data for the latter two sites, to some extent, reflect the nature of the catch, which was composed exclusively of lethrinids. Moreover, many of these carnivorous representatives were relatively large compared with others collected elsewhere in the study area. Nevertheless, the overall data does imply that fish from this region of the lagoon are generally higher in mercury than their more northerly counterparts.

The lethrinids are particularly popular table fish in Saipan and many local fishermen frequent the waters between Sites 10-11 in pursuit of them. *Lethrinus harak* and *L. atkinsoni* are perhaps the two most commonly captured emperors in these waters and regression analyses of their respective data-sets suggest size restrictions on fish consumed of less than 19 cm (*L. harak*) and 17 cm (*L. atkinsoni*) are necessary in order to stay within the 0.088 µg/g mercury benchmark for the general population (Fig. 33). Consumption frequencies for larger representatives were estimated from the regression equations and are presented in Fig. 34. These preliminary estimates will be refined as further data from this part of the lagoon become available.

The USEPA reference dose estimates and their international equivalents have associated levels of uncertainty that span orders of magnitude in some cases. Because of this, risk managers in the U.S. have some degree of flexibility in setting State fish advisories and do not always strictly adhere to USEPA guidelines. The Iowa Department of Public Health, for example, decrees that all fish containing less than 0.3 µg/g mercury are safe to consume with no meal restrictions. Consumption of up to one 8-oz meal per week of fish containing between 0.3 and 1.0 µg/g of mercury is also considered safe while fish containing over 1.0 µg/g of mercury should not be eaten at all. If Saipan were to adopt a similar policy then all lethrinids analyzed here would fall into the unrestricted consumption category. In fact, over 99% of all fish analyzed during the present study yielded mercury levels below 0.30 µg/g and none exceeded 1.0 µg/g.

Table 13: Risk-Based Consumption Limits for Methylmercury in Fish (USEPA 2000)

Risk Based Consumption Limit[a]	Fish Tissue Concentrations (µg/g wet weight)			
Fish meals/month	USA (USEPA)	Canada	Australia/New Zealand	UK
	General population[b]			
Unresticted (>16)	0 - 0.088	0 - 0.20	0 - 0.20	0 - 0.22
16	>0.088 - 0.18	>0.20 - 0.40	>0.20 - 0.40	>0.22 - 0.45
12	>0.18 - 0.23	>0.40 - 0.53	>0.40 - 0.53	>0.45 - 0.60
8	>0.23 - 0.35	>0.53 - 0.80	>0.53 - 0.80	>0.60 - 0.90
4	>0.35 - 0.70	>0.80 - 1.6	>0.80 - 1.6	>0.90 - 1.8
3	>0.70 - 0.94	>1.6 - 2.1	>1.6 - 2.1	>1.8 - 2.4
2	>0.94 - 1.4	>2.1 - 3.2	>2.1 - 3.2	>2.4 -3.6
1	>1.4 - 2.8	>3.2 - 6.4	>3.2 - 6.4	>3.6 - 7.2
0.5	>2.8 - 5.6	>6.4 - 13	>6.4 - 13	>7.2 - 14
None	>5.6	>13	>13	>14
	Women of childbearing age, nursing mothers and sensitive adults[c]			
Unresticted (>16)	0 - 0.029	0 - 0.085	0 - 0.096	0. - 0.11
16	>0.029 - 0.059	>0.085 - 0.17	>0.096 - 0.19	>0.11 - 0.22
12	>0.059 - 0.078	>0.17 - 0.23	>0.19 - 0.26	>0.22 - 0.29
8	>0.078 - 0.12	>0.23 - 0.34	>0.26 - 0.38	>0.29 - 0.44
4	>0.12 - 0.23	>0.34 - 0.68	>0.38 - 0.77	>0.44 - 0.87
3	>0.23 - 0.31	>0.68 - 0.90	>0.77 - 1.0	>0.87 -1.2
2	>0.31 - 0.47	>0.90 - 1.4	>1.0 -1.5	>1.2 - 1.7
1	>0.47 - 0.94	>1.4 - 2.7	>1.5 - 3.1	>1.7 - 3.5
0.5	>0.94 - 1.9	>2.7 - 5.4	>3.1 - 6.1	>3.5 -7.0
None	>1.9	>5.4	>6.1	>7.0

[a]Mercury is not considered to be a carcinogen. Consumption limits calculated by USEPA were therefore based on non-cancer health endpoints only. Adult body weights (BW) used in these calculations were 70 kg for USA, 70.1 kg for UK, and 66.8 kg for Canada. Australia and New Zealand adopt adult body weights of 67 kg for the general population and 66 kg for women of childbearing age. USA and UK consumption limits are based on standard adult fish meal sizes of 8 oz (227 g) and 5 oz (140 g) respectively, while those for Canada, Australia and New Zealand are based on an adult fish meal size of 150g (5.3 oz). For the purpose of this table it was assumed that fish provide 100% of all dietary mercury and that all mercury in fish is in the methylated form and is completely absorbed by the GI tract.

[b]Non-cancer consumption limits were calculated as: $Tissue_{CHg} = SD \times BW \times TAP/FM_{size} \times FM_{month}$, where $Tissue_{CHg}$ = methylmercury concentration in fish (µg/g wet weight); SD = 'safe dose' for methylmercury (mg/kg BW/day); TAP = time averaging period (365.25 days/12 months = 30.44 days/month); FM_{size} = fish meal size (g), and FM_{month} = number of fish meals per month. Safe dose estimates for methylmercury differ between countries. USEPA employs a chronic *Reference Dose* (RfD) of 3×10^{-4} mg/kg BW/day for the general population, whereas the UK, Australia and New Zealand adopt a *Provisional Tolerable Daily Intake* of 4.7×10^{-4} mg/kg BW/day, which is the same as the *Recommended Maximum Daily Intake* adopted by Canada.

[c]The USA methylmercury advisories for sensitive population groups are based on an RfD of 1×10^{-4} mg/kg BW/day. Less conservative estimates are currently adopted by Canada (2.0×10^{-4} mg/kg BW/day), Australia, New Zealand and the UK (2.3×10^{-4} mg/kg BW/day).

Notes:

1. USEPA (1997) defines the *reference dose* (RfD) as an estimate (with uncertainy spanning perhaps an order of magnitude) of a daily exposure level (mg/kg BW/day) for the human population, including sensitive subpopulations, that is likely to be without appreciable risk of deliterious effects during a lifetime. The value of the RfD is chemical and toxicological endpoint specific. The lower the value of the RfD the more toxic the substance.

Table 14: Exceedences of Methylmercury Unrestricted Consumption Benchmarks

Location	Total Fish (spp.) per Site	Mercury Benchmark Exceedences (%)[1] 0.088 µg/g wet wt.	0.029 µg/g wet wt.
Pau Pau Shoals (Site 1)	54 (15)	2	19
Outer Lagoon (Site 2) Outer Lagoon (Site 3)	59 (39)	2	17
Tanapag Shoals (Site 4)	38 (19)	5	21
Seaplane Reef (Site 5)	56 (20)	16	37
Puerto Rico Dump (Site 6)	42 (13)	10	52
Micro Beach Point, (Site 7) Micro Reef (Site 8)	25 (6)	8	24
Hafa Adai Beach (Site 9)	30 (17)	63	77
Hafa Adai Beach to Fishing Base (Site 10)	20 (4)	35	95
Fishing Base to Micro Toyota (Site 11)	16 (2)	75	100

[1]Mercury levels in fish consumed on an unrestricted (daily) basis should not exceed benchmarks of 0.088 µg/g wet weight for the general population and 0.029 µg/g wet weight for women of childbearing age, nursing mothers, children and sensitive adults (see Table 13).

Perhaps some mention should be made here of the protective effect afforded by selenium in mercury toxicity. First noted over 40 years ago in rats injected with inorganic mercury and maintained on a diet artificially enriched with inorganic selenium (Parizek and Ostadalova 1967), the interaction between these two elements has subsequently been demonstrated in all investigated animal groups (Raymond 2007). The fact that ocean fish are relatively rich in selenium has fueled speculation that humans ingesting fish high in mercury are similarly protected. While inorganic selenium has been shown to ameliorate both inorganic and organic mercury toxicity when present in equimolar concentrations, or higher (Stoesand *et al.* 1974, Kanko and Ralston 2007), it remains to be conclusively demonstrated that organo-selenium compounds found in fish afford the same degree of protection (Mergler 2009). Likewise, the evidence from most epidemiological studies is inconclusive (Lemire and Mergler 2009), although two recent studies designed to evaluate the neurological development of children in fish-consuming populations of the Faroe Islands and the Seychelles, produced data that some scientists regard as proof positive of selenium's protective effect (Raymond and Ralston 2004, Kanko and Ralston 2007). Adverse neurological outcomes associated with prenatal mercury exposure in the Faroe Islands study, for example, were attributed to the regular consumption of whale meat, which typically has selenium to mercury molar ratios of less than one. The notable absence of such effects in the Seychelles study was ascribed to a fish diet composed exclusively of ocean fish, which have selenium to mercury molar ratios greater than one. These and other supportive findings have led to widespread speculation among the scientific community that no matter how high the mercury levels are in a particular fish, if the selenium levels are higher there is no significant health risk. Further, the more selenium fish contain the safer they are to eat (Kanko and Ralston 2007). Clearly this is an area that warrants further investigation.

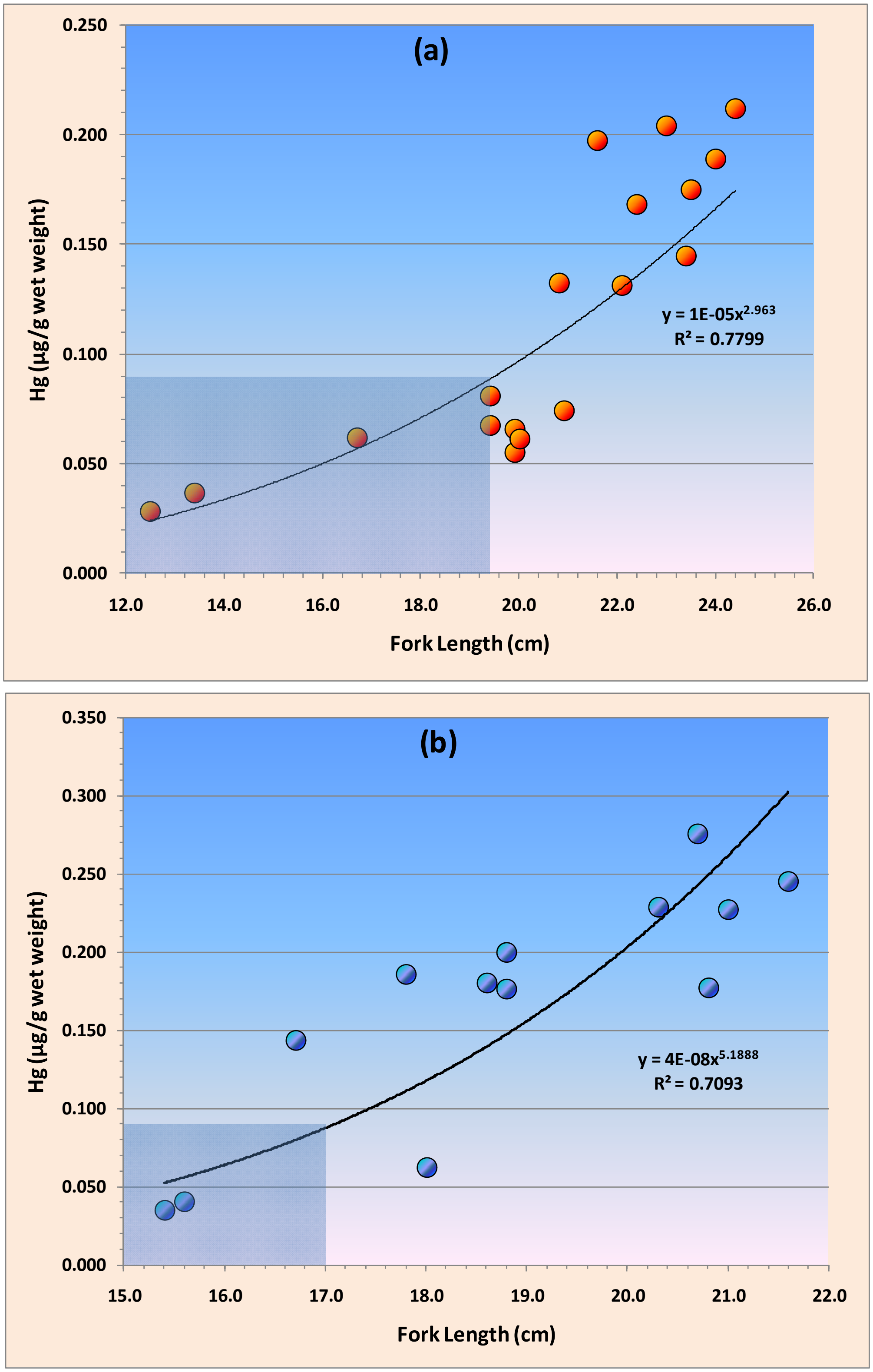
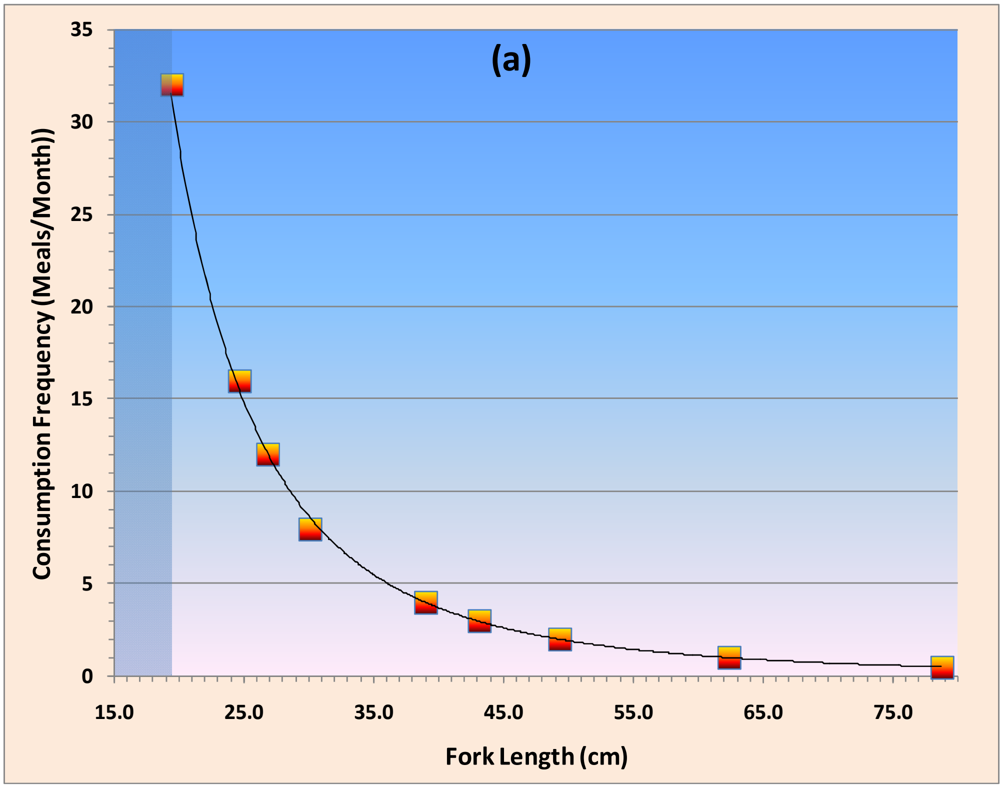


Figure 33: Regression analyses of axial muscle mercury data-sets for (a) *Lethrinus harak* and (b) *Lethrinus atkinsoni* from sites 10-11 in Saipan Lagoon. Shaded areas represent size ranges that may be consumed on an unrestricted basis when weighed against the 0.088 µg/g wet weight mercury benchmark for the general population (see Table 14).



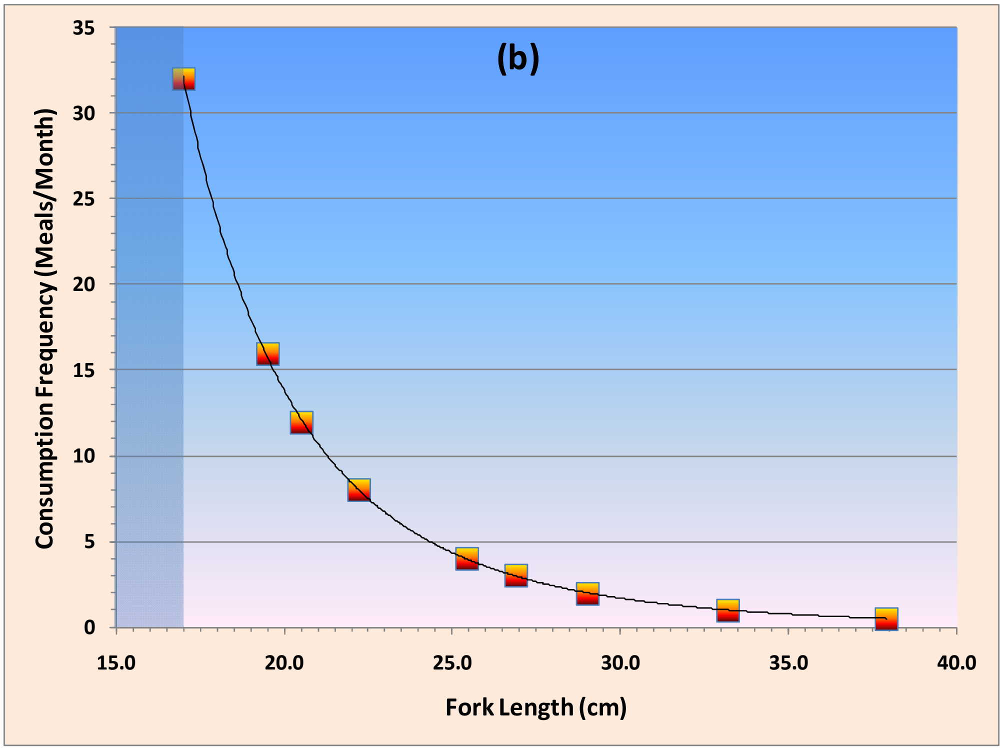


Figure 34: Preliminary consumption frequencies based on fish size for (a) *Lethrinus harak* and (b) *Lethrinus atkinsoni* from sites 10-11. Shaded areas represent size ranges that may be consumed on an unrestricted basis when weighed against the 0.088 µg/g wet weight mercury benchmark for the general population (see Table 14).

PCBs

The general population is exposed to PCBs primarily through the consumption of contaminated foods, particularly fish, meat and poultry (ATSDR 2000). Acute exposure to PCBs can result in dermatological (chloracne) and hepatic (increased microsomal enzyme induction) effects while reproductive and developmental effects can occur in the longer term. Neurobehavioral and developmental deficits in newborns exposed to PCBs in utero have been reported, and epidemiologic studies have raised concerns about the potential carcinogenicity of these compounds. Additional reported adverse effects of PCBs involve the cardiovascular, immune, endocrine, musculoskeletal, and gastrointestinal systems (ATSDR 2000).

The sum of the 20 PCB congeners (Σ_{20}PCB) determined in fish from Saipan Lagoon during the present study ranged from 0.04-145 ng/g dry weight with an overall mean of 5.43 ng/g. This equates to wet weight values of 0.01-33.4 ng/g with a mean of 1.24 ng/g assuming fish axial muscle averages around 77% water (Denton *et al.* 2006c). Total PCBs in fish can be approximated by applying a multiplier of 2 to the Σ_{20}PCB data (NOAA 1989). By this means, the highest total PCB concentration recorded during the present study was 67 ng/g wet weight found in *Myripristis violacea* from Site 1. Only two other specimens had total concentrations above 50 ng/g wet weight, *Lethrinus harak* (55 ng/g wet weight) from Site 11, and *Naso lituratus* (53 ng/g wet weight) from Site 6. All other fish had total PCB concentrations of less than 40 ng/g wet weight.

The U.S. Food and Drug Administration action level for PCBs in commercially bought fish is 2 µg/g wet weight (USFDA 1998), which is well above the maximum value determined here. According to the FDA's original doctrine, the general population can consume fish with the presence of PCBs at up to these levels with no adverse health effect. In light of more recent research and concerns over the toxicological impact of dioxin-like PCBs (dl-PCBs) in commercial mixtures and environmental samples, this now seems unlikely. Nevertheless, some State public health authorities still model their fish advisories on this value. For example, the Iowa Department of Public Health has determined that all fish containing PCBs at concentrations below 0.2 µg/g wet weight are safe to consume with no meal restriction. Consumption of up to 1 meal per week of fish containing 0.2-2.0 µg/g wet weight was safe and fish containing over 2.0 µg/g wet weight should not be eaten at all (which is consistent with the FDA action level).

Tissue guidance levels for PCBs developed by the USEPA (2000) from non-cancer and cancer health endpoints are shown in Table 15 below. Guidance levels based on the former indicate that total PCBs in fish consumed on a daily basis (8-oz meal size) should not exceed 0.006 µg/g wet weight (6 ng/g). Approximately 75% of fish examined here yielded values below this benchmark. Even when evaluated against the more stringent cancer health endpoints 34% of fish analyzed fell into the unrestricted consumption category while 56% could be eaten up to four times a week without any long-term adverse health effects. These findings are particularly encouraging and clearly indicate that the recently remediated PCB hot-spot in Tanapag village had little if any impact on levels of these contaminants in fisheries resource within the lagoon.

Based on the evidence presented, it would appear that PCB levels in fish from Saipan Lagoon do not currently pose a significant health risk to regular consumers. That said, risk assessment methods used to derive fish consumption limits for these compounds continue to change as new information comes to light on the toxicological significance to consumers of dioxin-like PCBs (dl-PCBs) present in edible fish tissues (Giesy and Kannan 1998). A brief description of the toxicological properties of these congeners and their abundance in fish tissue is given below, together with suggested consumption guidelines based on their dioxin toxic equivalency factors.

Table 15: Risk-Based Consumption Limits for PCBs (total Aroclor) in Fish (USEPA 2000)

Risk Based Consumption Limit[a]	Fish Tissue Concentrations (µg/g wet weight)	
Fish Meals/Month	**Noncancer Health Endpoints[b]**	**Cancer Health Endpoints[c]**
Unrestricted (>16)	0 - 0.006	0 - 0.0015
16	>0.006 - 0.012	>0.0015 - 0.0029
12	>0.012 - 0.016	>0.0029 - 0.0039
8	>0.016 - 0.023	>0.0039 - 0.0059
4	>0.023 - 0.047	>0.0059 - 0.012
3	>0.047 - 0.063	>0.012 - 0.016
2	>0.063 - 0.094	>0.016 - 0.023
1	>0.094 - 0.19	>0.023 - 0.047
0.5	>0.19 - 0.38	>0.047 - 0.094
none (<0.5)	>0.38	>0.094

[a]PCBs are considered to be carcinogens. Consumption limits calculated by USEPA were thus derived from both non-cancer and cancer health endpoints using a chronic reference dose (RfD) for PCBs of 2×10^{-5} mg/kg BW/day and a cancer slope factor (CSF) of 2 $(mg/kg/day)^{-1}$ respectively. Total PCB non cancer reference doses adopted by other contries range from a *Provisional Tolerable Daily Intake* of 1×10^{-4} mg/kg BW/day for Australia and New Zealand, to a *Maximum Daily Intake* of 1.3×10^{-4} mg/kg BW/day for Canada. The UK currently has no *Tolerable Daily Intake* reference dose for total PCBs. For the purpose of this table, it was assumed that fish provide 100% of all dietary PCBs and that all ingested PCBs are absorbed by the GI tract.

[b]Non-cancer based fish consumption limits were calculated as: $Tissue_{PCB}$ = RfD x BW x TAP/FM_{size} x FM_{month}, where BW = body weight of consumer (70 kg default); $Tissue_{PCB}$ = PCB concentration in fish (µg/g wet weight); TAP = time averaging period (365.25 days/12 months = 30.44 days/month); FM_{size} = fish meal size (227 g default); FM_{month} = number of fish meals consumed per month.

[c]Cancer based consumption limits were calculated as: $Tissue_{PCB}$ = ARL x BW x AT/$Fish_{size}$ x CSV x FM_{year} x D, where ARL = maximum acceptible individual lifetime risk level (unitless) (1 in 100,000 risk level = 1×10^{-5}); AT = human lifespan (70 years default) expressed in days (25567.5 days); FM_{year} = number of fish meals consumed per year; D = duration of exposure (70 years default).

Notes:

1. USEPA (1997) defines the *reference dose* (RfD) as an estimate (with uncertainy spanning perhaps an order of magnitude) of a daily exposure level (mg/kg BW/day) for the human population, including sensitive subpopulations, that is likely to be without appreciable risk of deliterious effects during a lifetime. The value of the RfD is chemical and toxicological endpoint specific. The lower the value of the RfD the more toxic the substance.

2. The *Cancer Slope Factor* (CSF) is derived, usually but not always, as the 95th percent upper confidence limit of the low-dose linear slope of the dose response curve, and is expressed in units of $(mg/kg/day)^{-1}$. The CSF is most often derived from studies of laboratory animals, traditionally by application of dose-response models that assume no threshold for carcinogenic effects (i.e., any dose, no matter how small, will result in some risk) and allow for linearity in response at low dose. The value of the CSF is chemical specific. The greater the value of the CSF, the greater the carcinogenic potency of the substance (USEPA 1997).

Dioxin-like PCBs posses two substituent chlorine atoms in the *para* position, at least one in the *meta* position, and no more than one in the *ortho* position. By assuming a coplanar configuration they act through the aryl hydrocarbon receptor and cause the full range of toxic responses (including cancer) elicited by the most potent member of the dioxin family, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD). Dioxin-like PCBs generally rank among the most toxic PCB congeners found in commercial mixtures and environmental samples (Schantz and Widholm 2001).

There are twelve dl-PCBs in all and they collectively account for 5-11% of total PCBs in fish (Bhavsar *et al.* 2007a,b). A strong positive correlation was shown to exist between the Σdl-PCBs 77, 105, 118 and 126 and total PCB levels (Σ_{20}PCB x 2) in fish examined during the current study (Fig. 35). From the regression equation, it was determined that these four congeners account for 5-8% of the total PCB concentrations, depending on whether or not the regression line was forced through zero. These estimates compare well with the range of 4-9% reported earlier by Bhavsar *et al.* (2007a,b) who applied similar regression techniques to a considerable PCB data-base for marine fish. The collective average abundance for all four congeners in Table 9 also comes out to ~8% if based on total PCBs rather than Σ_{20}PCB.

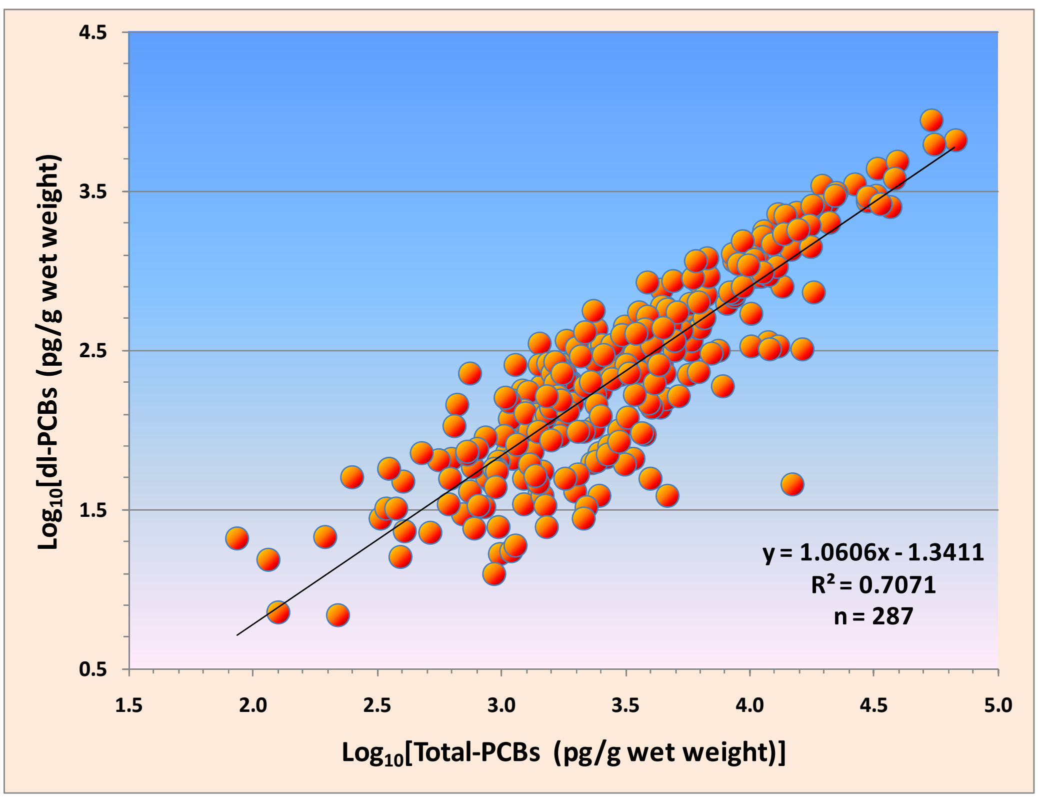


Figure 35: Regression analysis of Σdl-PCBs 77, 105, 118 and 126 against total PCBs (Σ_{20}PCB x 2) in axial muscle of fish from Saipan Lagoon. Data sets used have quantifiable levels of one or more of the above dl-PCBs and represent 88% of fish examined. Non quantifiable congener levels set as zero. Regression equation of line forced through zero = 0.6835x (r^2: 0.6158).

All 12 dl-PCBs are listed in Table 16 together with their respective toxic equivalency factors (TEFs), defined as the toxicity of any dioxin-like compound relative to that of 2,3,7,8-TCDD.

Also shown are their relative abundances (25-75% percentiles) in fish tissue as determined by Bhavsar *et al.* (2007a,b) using the regression techniques referred to earlier.

Table 16: Toxic Equivalency Factors (TEFs) for Dioxin-Like PCBs (WHO)

Chemical Structure	IUPAC[a] Number	TEF[b]	%[c]
non-*ortho* dl-PCBs			
3,3',4,4'-tetrachlorobiphenyl	PCB-77	0.0001	0.018 - 0.093
3,4,4',5-tetrachlorobiphenyl	PCB-81	0.0003	0.002 - 0.007
3,3',4,4',5-pentachlorobiphenyl	PCB-126	0.1	0.015 - 0.036
3,3',4,4',5,5'-hexachlorobiphenyl	PCB-169	0.03	0.001 - 0.006
mono-*ortho* dl-PCBs			
2,3,3',4,4'-pentachlorobiphenyl	PCB-105	0.00003	1.1 - 2.4
2,3,4,4',5-pentachlorobiphenyl	PCB-114	0.00003	0.08 - 0.18
2,3',4,4',5-pentachlorobiphenyl	PCB-118	0.00003	3.0 - 6.2
2',3,4,4',5-pentachlorobiphenyl	PCB-123	0.00003	0.11 - 0.26
2,3,3',4,4',5-hexachlorobiphenyl	PCB-156	0.00003	0.39 - 0.75
2,3,3',4,4',5'-hexachlorobiphenyl	PCB-157	0.00003	0.09 - 0.19
2,3',4,4',5,5'-hexachlorobiphenyl	PCB-167	0.00003	0.2 - 0.43
2,3,3',4,4',5,5'-heptachlorobiphenyl	PCB-189	0.00003	0.045 - 0.094

grey highlights or those congeners analyzed during the present study

[a]International Union of Pure & Applied Chemistry.

[b]Original TEF values established by WHO in 1997 were update by WHO in 2005 (Van den Berg *et al.* 2006)

[c]dioxin like PCB congeners expressed as percentage (25-75 quartile ranges) of total PCBs in fish (Bhavsar *et al.* 2007a,

The toxicological hazard associated with a dl-PCBs in fish is conventionally assessed using a 2,3,7,8-TCDD toxic equivalent (TEQ) concentration of the mixture and is estimated as:

$$TEQ_{\text{dl-PCB}} = \sum_{i=1}^{12}(TEF_i \times C_{\text{dl-PCB},i})$$

where $C_{\text{dl-PCB},i}$ is the fish tissues concentration of the dl-PCB congener '*i*'.

An overall TEQ for all dioxin-like contaminants that interact with organisms by the same mechanism as 2,3,7,8-TCDD is calculated by summing their individual TEQs. Among these contaminants, dl-PCBs generally are the greatest contributors (>70%) to overall TEQs (i.e., from dioxins, furans and PCBs) in fish (Bhavsar 2007).

While the USEPA has yet to establish fish advisories for PCBs based on TEQs, the World Health Organization (WHO) advocates a tolerable weekly TEQ intake (TWI) from food of 14 pg dioxin equivalents per kg body weight per week (conventionally written as 14 pg TEQ/kg BW/week). This is equivalent to 2 pg TEQ/kg BW/day of which 50% is estimated to come from foodstuffs other than fish (UKFSA/COT 2001).

TEQ based fish advisories are formulated here (Table 17) for comparative purposes with the USEPA risk-based consumption limits for PCBs based on total Aroclor (Table 15). The computed total PCB ranges for standard sized fish meal consumed at intervals ranging from one per day to one per month are presented in µg/g fish wet weight, again for direct comparison with the earlier table, and are formulated to maintain the maximum TEQ intake by consumers at no more than 30 pg TEQ/kg BW/month (equivalent to 1 pg TEQ/kg BW/day).

Table 17: Consumption Limits for PCBs in Fish Based on WHO Toxic Equivalents (TEQs)

8-oz Fish Meals per Month[a]	Total PCBs (Σ_{20}PCBs x 2)[b] (µg/g fish wet wt.)	$TEQ_{dl\text{-}PCBs}$ (pg/g fish wet wt.)	TEQ_{Total}[c] (pg/g fish wet wt.)	Monthly TEQ_{Total} Intake from Fish Consumed (pg/kg BW/meal)
Unresticted (>16)	<0.065	<0.2	<0.3	<1
16	0.065 - 0.130	0.2 - 0.4	0.3 - 0.6	1.9
12	0.130 - 0.170	0.4 - 0.6	0.6 - 0.8	2.5
8	0.170 - 0.255	0.6 - 0.8	0.8 - 1.2	3.8
4	0.255- 0.515	0.8 - 1.6	1.2 - 2.4	7.5
3	0.515 - 0.685	1.6 - 2.2	2.4 - 3.1	10
2	0.685 - 1.030	2.2 - 3.3	3.1- 4.7	15
1	1.030 - 2.055	3.7 - 6.7	4.7 - 9.4	30
None	>2.055	>6.7	>9.4	None

[a]Consumption limits are based on the World Health Organization (WHO) tolerable weekly intake (TWI) of dioxins and dioxin-like compounds (i.e., furans and dl-PCBs) of 14 pg toxic equivalents (WHO-TEQ)/kg body weight (BW) per week and assumes that contributions from fish account for 50% of this value (UKFSA/COT 2001).

[b]Maximum acceptable tissue concentrations of total PCBs, for any given number of fish meals/month, were computed using the following equation:

$$TEQ_{Total} = \left[TEQ_{dl\text{-}PCBs} = \sum_{i=1}^{12} {}_{dl\text{-}PCBs} \left(\frac{\text{Total } PCB_{Fish} \text{ x } RA_{dl\text{-}PCB,\, i} \text{ x } TEF_{dl\text{-}PCB,\, i} \text{ x } FM_{Size} \text{ x } FM_{Month}}{BW \text{ x } TAP} \right) \right] \text{ x M}$$

where: TEQ_{Total} = 1 pg/kg BW/day and represents the collective TEQ of all dioxins and dioxin-like compounds; $TEQ_{dl\text{-}PCBS}$ = Collective TEQ of all twelve dl-PCB congeners in fish; Total PCB_{Fish} = maximum acceptable total PCB concentration in fish (pg/g fish wet weight) for any given number of standard sized meals consumed; $RA_{dl\text{-}PCB,\, i}$ = the relative abundance of each dl-PCB congener expressed as a percentage of total PCBs in fish (employed upper value of 25-75 quartile range reported by Bhavsar *et al.* 2005a, see Table 17) and converted to pg/g fish wet weight relative to the Total PCB_{Fish} concentration entered into the equation; $TEF_{dl\text{-}PCB}$ = the Toxic Equivalency Factor (TEF) for each dl-PCB congener (Van den Berg *et al.* 2006, see Table 17); FM_{Size} = fish meal size (227 g default); FM_{Month} = number of fish meals consumed per month; BW = consumer body weight (70 kg default); TAP = time averaging period (365.25 days/year = 30.44 days/month); M = multiplyer (1.42857) converts $TEQ_{dl\text{-}PCBs}$ to TEQ_{Total} based on assumption that $TEQ_{dl\text{-}PCBs}$ accounts for approximately 70% of TEQ_{Total} in marine fish (Bhavsar 2007). The maximum Total PCB_{Fish} that can be safely ingested for any given number of fish meals consumed per month was obtained by adjusting the value for Total PCB_{Fish} on the computer spread-sheet until a TEQ_{Total} of 1 pg/kg BW was reached (but not exceeded).

[c]The WHO recommended maximum TEQ in consumed fish is 12 pg/g wet weight for eels and 8 pg/g wet weight for all other fish.

It can be seen that fish with total PCB concentrations in edible tissue of less than 0.065 µg/g wet weight may be consumed on an unrestricted basis. In contrast, fish with total PCB levels of 1-2 µg/g wet weight should not be consumed more than once a month while fish exceeding 2 µg/g wet weight (FDA action level) should not be eaten at all. Fortunately, such high levels were not encountered during the present study. In fact, over 97% of all fish analyzed yielded total PCB estimates that fit within the unrestricted consumption category when evaluated in terms of their dioxin toxicity equivalence.

Interestingly, the TEQ-based tissue guidance levels listed above are about an order of magnitude less sensitive than their Aroclor-based counterparts developed by the USEPA using non-cancer health endpoints (Table 15). Some might say that the existing USEPA consumption guidelines for PCBs in fish are adequately protective from a TEQ standpoint and in no need of revision, particularly since so little is known about the toxicity of the non dl-PCBs. In fact, given the complexity of PCB mixtures in fish, risk estimates based solely on 12 dl-PCBs may seriously underestimate the total PCB risk to consumers especially since non dl-PCB comprise the bulk of the mixture. Others might counter argue that the guidelines are overly protective based on the fact that the dl-PCBs are generally far more potent and exert their toxic effects at much lower concentrations than non dl-PCBs. By this reasoning, the assessment of risk based on the dl-PCBs could be considered protective against potentially deleterious effects from the non dl-PCB (Giesy and Kannan, 1998, Henry and De Vito 2003).

We conclude that future risk assessment practices for setting fish advisories for PCBs in the USA will likely have to consider the toxicological significance of dl-PCBs and non dl-PCBs separately and break away from traditional Aroclor based methodologies. Such dual-track assessments have already been suggested (Rice *et al.* 2002), but, in the marked absence of more definitive information regarding the potential effects of the non dioxin-like congeners to humans, have yet to be formulated. Nevertheless, as more information becomes available about the toxicity mechanisms and relative potencies of these widely distributed compounds, alternative methods for assessing their risk will likely emerge.

FUTURE DIRECTIVES

The following recommendations for future research emerge from the studies described herein:

- Additional studies are needed to identify and delineate the mercury source(s) impacting the Hafa Adai Beach nearshore environment and locations further south.
- Conduct public surveys of fish consumption rates on Saipan and other nearby islands in the CNMI in order to formulate appropriate action levels (especially for mercury) and consumption guidelines.
- Determine molar ratios of selenium and mercury for species identified in this study as being of potential risk.
- Extend the monitoring program to the southern half of Saipan Lagoon where extensive network of stormwater drainage system discharge large volumes of freshwater runoff into the ocean along much of its length. Catchments of many of these drainage systems include commercial and light industrial premises.
- Particular attention should be paid to fisheries at the southern end of the lagoon where extensive lead contamination associated with an old dumpsite has recently been discovered, and a primary wastewater treatment plant discharges close to shore
- Future investigations should also include a preliminary assessment of fisheries resources in nearshore environments inundated with freshwater runoff from formerly used defense sites (FUDS) and Brownfield sites. There are a number of these old, abandoned facilities scattered about the islands of the CNMI, and very little information is known about their contents and pollution potential, especially to adjacent wetlands and coastal environs.
- Finally, little information exists on contaminant levels in larger pelagic species captured further offshore and offered for sale locally from make-shift roadside stands.

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APPENDICES

Raw Data Sets and Supplemental Information

APPENDIX A

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon

Total Arsenic and Mercury in Fish from the Northern Half of Saipan Lagoon (2004-2005)

Site and Species Identity	Date	Trophic Level	Range	Body F/Length	Body Weight	Gender	Gonad Stage	Tissue	µg/g wet weight As	µg/g wet weight Hg
Site 1: Pau Pau Shoals										
Acanthurus lineatus	14-Jan-05	H	S	13.8	72.0	M	I	M	0.15	0.002
								L	0.97	0.078
Acanthurus lineatus	21-Jan-05	H	S	12.9	56.0	U	I	M	0.16	0.002
								L	0.59	0.065
Acanthurus triostegus	14-Jan-05	H/P	R	12.2	54.9	F	M	M	0.37	0.006
								L	0.54	0.121
Ctenochaetus striatus	14-Jan-05	H	R	11.0	32.9	U	I	M	0.24	0.037
Gnathodentax aurolineatus	21-Jan-05	C	R	16.7	96.0	F	M	M	5.00	0.008
								L	8.77	0.042
Lethrinus harak	14-Jan-05	C	R	19.1	132.0	M	I	M	0.95	0.146
								L	2.43	0.167
Lethrinus xanthochilus	21-Jan-05	C	R	11.8	32.0	F	I	M	0.42	0.020
								L	1.05	0.025
Lethrinus xanthochilus	21-Jan-05	C	R	10.3	20.0	U	I	M	0.71	0.015
								L	1.21	0.046
Myripristis amaena	21-Jan-05	P/C	S	13.9	74.0	U	I	M	11.3	0.060
								L	10.0	0.338
Myripristis amaena	21-Jan-05	P/C	S	12.8	56.0	F	I	M	10.2	0.023
								L	16.3	0.045
Myripristis amaena	21-Jan-05	P/C	S	11.3	36.0	F	I	M	15.8	0.014
								L	20.1	0.065
Myripristis amaena	21-Jan-05	P/C	S	12.3	54.0	U	I	M	13.7	0.021
								L	6.86	0.054
Myripristis amaena	14-Jan-05	P/C	S	13.2	66.0	F	D	M	11.9	0.029
								L	19.9	0.090
Myripristis amaena	21-Jan-05	P/C	S	11.7	46.0	U	I	M	11.5	0.022
								L	13.2	0.082
Myripristis amaena	21-Jan-05	P/C	S	11.1	40.0	M	I	M	9.91	0.016
								L	11.6	0.054
Myripristis berndti	21-Jan-05	P/C	S	10.7	34.0	U	I	M	18.8	0.014
								L	3.37	0.029

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	µg/g wet weight	
				F/Length	Weight				As	Hg
<u>Site 1: Pau Pau Shoals (cont.)</u>										
Myripristis violacea	21-Jan-05	P/C	S	10.2	30.0	U	I	M	19.9	0.011
								L	6.17	0.030
Myripristis violacea	21-Jan-05	P/C	S	8.9	24.0	M	D	M	13.5	0.009
								L	10.1	0.026
Myripristis violacea	21-Jan-05	P/C	S	10.3	32.0	U	I	M	27.7	0.012
								L	8.21	0.027
Myripristis violacea	21-Jan-05	P/C	S	12.1	52.0	M	I	M	21.7	0.021
								L	15.4	0.033
Myripristis violacea	21-Jan-05	P/C	S	12.6	68.0	M	I	M	22.9	0.022
								L	36.2	0.037
Myripristis violacea	21-Jan-05	P/C	S	11.9	49.2	F	I	M	12.7	0.022
								L	16.6	0.045
Myripristis violacea	21-Jan-05	P/C	S	13.3	53.2	F	I	M	20.5	0.024
								L	19.8	0.043
Myripristis violacea	21-Jan-05	P/C	S	11.3	40.3	U	I	M	18.3	0.017
								L	7.39	0.030
Myripristis violacea	21-Jan-05	P/C	S	10.2	29.7	U	I	M	15.3	0.012
								L	15.8	0.027
Myripristis violacea	21-Jan-05	P/C	S	8.8	18.0	U	I	M	5.99	0.017
Naso lituratus	21-Jan-05	H	R	14.5	70.3	U	I	M	0.20	0.002
								L	0.52	0.039
Naso lituratus	21-Jan-05	H	R	14.0	61.5	U	I	M	0.22	0.002
								L	0.67	0.031
Naso lituratus	21-Jan-05	H	R	13.8	63.9	U	I	M	0.24	0.003
								L	0.61	0.044
Naso lituratus	21-Jan-05	H	R	12.7	49.5	U	I	M	0.22	0.002
								L	0.53	0.043
Naso lituratus	21-Jan-05	H	R	13.5	51.8	U	I	M	0.22	0.002
								L	0.44	0.025
Naso lituratus	14-Jan-05	H	R	15.9	92.0	U	I	M	0.20	0.002
								L	1.18	0.087

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Site and Species Identity	Date	Trophic Level	Range	Body F/Length	Body Weight	Gender	Gonad Stage	Tissue	µg/g wet weight As	µg/g wet weight Hg
Site 1: Pau Pau Shoals (cont.)										
Naso lituratus	14-Jan-05	H	R	14.0	66.0	M	D	M	0.18	0.013
								L	0.97	0.142
Naso lituratus	14-Jan-05	H	R	13.9	60.0	U	I	M	0.30	0.013
								L	1.11	0.098
Naso lituratus	14-Jan-05	H	R	14.3	70.0	M	U	M	0.16	0.008
								L	1.32	0.251
Naso lituratus	14-Jan-05	H	R	12.5	48.0	U	I	M	0.16	0.002
								L	1.93	0.199
Naso lituratus	14-Jan-05	H	R	12.6	44.0	F	I	M	0.16	0.013
								L	1.05	0.100
Naso lituratus	14-Jan-05	H	R	14.0	58.0	U	I	M	0.36	0.009
								L	1.18	0.081
Naso lituratus	21-Jan-05	H	R	14.3	66.0	U	I	M	0.16	0.002
								L	0.81	0.087
Naso lituratus	21-Jan-05	H	R	12.6	40.0	U	I	M	0.14	0.002
								L	1.16	0.117
Naso lituratus	21-Jan-05	H	R	13.9	54.0	U	I	M	0.17	0.002
								L	0.54	0.109
Naso unicornis	14-Jan-05	H	R	16.0	50.0	U	I	M	0.43	0.007
								L	1.57	0.060
Neoniphon sammara	21-Jan-05	C	S	13.5	50.9	U	I	M	2.27	0.063
								L	1.20	0.042
Neoniphon sammara	21-Jan-05	C	S	12.2	43.2	M	I	M	4.81	0.027
								L	6.68	0.025
Neoniphon sammara	21-Jan-05	C	S	10.7	24.7	U	I	M	3.05	0.027
								L	1.81	0.018
Parupeneus barberinus	14-Jan-05	C	R	14.3	54.0	U	I	M	4.42	0.023
								L	11.9	0.033
Parupeneus barberinus	21-Jan-05	C	R	13.1	38.0	U	I	M	4.03	0.015
								L	7.91	0.033
Sargocentron spiniferum	21-Jan-05	C	S	14.6	76.0	M	I	M	0.97	0.037
								L	0.42	0.117

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	µg/g wet weight	
				F/Length	Weight				As	Hg
Site 1: Pau Pau Shoals (cont.)										
Sargocentron spiniferum	21-Jan-05	C	S	17.5	120.9	U	I	M	0.68	0.051
								L	0.49	0.079
Sargocentron spiniferum	14-Jan-05	C	S	14.0	72.0	F	I	M	1.62	0.044
								L	0.75	0.109
Sargocentron spiniferum	14-Jan-05	C	S	15.0	98.0	M	I	M	0.53	0.056
								L	0.43	0.121
Sargocentron spiniferum	14-Jan-05	C	S	15.6	88.0	U	I	M	0.54	0.042
								L	0.51	0.118
Sargocentron spiniferum	21-Jan-05	C	S	22.4	286.0	M	M	M	0.45	0.050
								L	1.22	0.099
Siganus spinus	21-Jan-05	H	R	11.9	30.0	U	I	M	0.09	0.001
								L	3.30	0.017
Site 2: Outer Lagoon 1 (Dankulo Rock)										
Acanthurus lineatus	27-Oct-04	H	S	13.0	55.7	U	I	M	0.19	0.002
								L	1.50	0.417
Acanthurus lineatus	23-Feb-05	H	S	16.7	122.0	M	M	M	0.17	0.002
Acanthurus lineatus	23-Feb-05	H	S	14.2	67.2	U	I	M	0.16	0.002
								L	1.88	0.067
Acanthurus olivaceous	27-Oct-04	O	R	16.6	129.2	F	I	M	1.43	0.004
								L	0.93	0.103
Acanthurus triostegus	27-Oct-04	H/P	R	13.5	77.8	U	I	M	0.51	0.003
								L	1.74	0.544
Cheilinus chlorous	18-Feb-05	C	R	17.6	106.9	M	D	M	2.07	0.011
									0.53	0.050
Cheilo inermis	18-Feb-05	C	R	32.4	222.3	M	D	M	1.09	0.025
								L	4.50	0.302
Chlorurus frontalis	27-Oct-04	H	R	22.5	27.1	M	I	M	0.79	0.002
								L	19.3	1.217
Ctenochaetus striatus	23-Feb-05	H	S	14.4	73.6	U	I	M	0.32	0.003
								L	0.38	0.173

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	µg/g wet weight	
				F/Length	Weight				As	Hg
Site 2: Outer Lagoon 1 (cont.)										
Ctenochaetus striatus	23-Feb-05	H	S	11.7	38.4	U	I	M	0.58	0.003
								L	0.70	0.084
Epinephelus maculatus	27-Oct-04	C	S	21.4	138.9	M	I	M	0.48	0.015
								L	1.41	0.226
Epinephelus merra	23-Feb-05	C	S	36.5	290.1	M	I	M	0.08	0.021
								L	0.25	0.042
Gnathodentex aurolineatus	27-Oct-04	C	R	15.1	69.7	M	D	M	8.77	0.021
								L	9.31	0.358
Halichoeres trimaculatus	23-Feb-05	C	R	14.6	51.7	F	D	M	0.58	0.006
								L	0.61	0.035
Kyphosus biggibus	23-Feb-05	H	R	21.7	242.3	M	D	M	1.10	0.006
								L	2.15	0.129
Lethrinus atkinsoni	11-Feb-05	C	R	18.9	121.6	F	D	M	6.65	0.051
								L	5.12	0.080
Lethrinus erycanthus	23-Feb-05	C	R	14.6	69.0	U	I	M	4.07	0.024
								L	2.64	0.037
Lethrinus harak	11-Feb-05	C	R	22.2	207.4	F	D	M	0.42	0.116
								L	0.79	0.207
Lethrinus olivaceous	23-Feb-05	C	R	35.4	682.0	F	D	M	0.89	0.027
								L	5.38	0.050
Lethrinus olivaceous	11-Feb-05	C	R	22.4	170.8	U	I	M	0.54	0.010
								L	1.17	0.030
Lethrinus xanthochilus	18-Feb-05	C	R	29.9	418.5	F	D	M	1.53	0.033
								L	8.66	0.081
Lethrinus xanthochilus	23-Feb-05	C	R	42.5	1416.0	F	M	M	5.09	0.072
								L	19.2	0.125
Lethrinus xanthochilus	11-Feb-05	C	R	17.5	95.1	U	I	M	0.58	0.040
								L	0.19	0.062
Lutjanus fulvus	23-Feb-05	C	R	20.9	155.9	M	D	M	1.53	0.075
								L	2.13	0.178
Lutjanus kasmira	23-Feb-05	C	R	19.6	143.3	F	M	M	13.0	0.025
								L	10.4	0.054

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	µg/g wet weight	
				F/Length	Weight				As	Hg
Site 2: Outer Lagoon 1 (cont.)										
Myripristis amaena	23-Feb-05	P/C	S	12.7	62.2	F	I	M	14.4	0.021
								L	10.8	0.037
Myripristis berndti	27-Oct-04	P	S	11.0	32.3	U	I	M	23.4	0.020
Myripristis berndti	23-Feb-05	P	S	12.0	52.8	U	I	M	19.9	0.019
								L	5.92	0.030
Myripristis berndti	23-Feb-05	P	S	11.6	45.6	F	I	M	10.3	0.016
								L	4.82	0.031
Myripristis berndti	23-Feb-05	P	S	11.8	45.6	U	I	M	16.3	0.021
								L	7.81	0.028
Myripristis berndti	23-Feb-05	P	S	11.3	39.7	F	D	M	8.47	0.023
								L	6.13	0.044
Myripristis berndti	23-Feb-05	P	S	9.4	32.9	F	S	M	27.3	0.012
Myripristis berndti	23-Feb-05	P	S	10.0	32.6	F	D	M	13.0	0.016
								L	7.92	0.030
Naso annulatus	18-Feb-05	H	R	31.5	544.6	F	D	M	0.41	0.002
								L	1.05	0.015
Naso lituratus	23-Feb-05	H	R	14.8	64.2	U	I	M	0.27	0.003
								L	0.70	0.042
Neoniphon argenteus	23-Feb-05	C	S	15.3	61.9	F	M	M	1.07	0.029
								L	1.40	0.044
Parupeneus multifasciatus	18-Feb-05	C	R	15.4	61.4	M	D	M	15.5	0.016
								L	17.3	0.077
Pseudobalistes fuscus	27-Oct-04	C	S	21.0	302.3	U	I	M	8.06	0.014
								L	5.02	0.037
Pseudobalistes fuscus	27-Oct-04	C	S	18.2	200.7	F	I	M	10.6	0.016
								L	2.36	0.027
Sargocentron spiniferum	27-Oct-04	C	S	17.7	155.7	F	I	M	1.12	0.078
								L	1.95	0.088
Scarus psittacus	27-Oct-04	H	R	20.0	186.1	F	D	M	0.25	0.004
								L	0.97	0.033
Scarus sordidus	23-Feb-05	H	R	14.6	69.2	F	U	M	0.34	0.001
								L	0.86	0.004

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	µg/g wet weight	
				F/Length	Weight				As	Hg
Site 2: Outer Lagoon 1 (cont.)										
Scarus sordidus	23-Feb-05	H	R	14.9	73.2	F	U	M	0.59	0.002
								L	0.69	0.008
Scarus sordidus	23-Feb-05	H	R	14.7	71.0	F	U	M	0.48	0.002
								L	1.08	0.006
Scarus sordidus	23-Feb-05	H	R	13.5	52.4	F	U	M	0.95	0.002
								L	0.62	0.008
Sufflamen chrysoptera	23-Feb-05	C	S	14.7	74.7	F	D	M	11.6	0.018
								L	12.5	0.145
Thalassoma trilobatum	27-Oct-04	C	R	16.1	89.2	M	I	M	22.4	0.026
								L	75.3	0.204
Site 3: Outer Lagoon 2										
Acanthurus nigrofuscus	Dec-04	H	S	13.5	62.0	M	I	M	0.78	0.007
								L	1.22	0.151
Cheilinus trilobatus	Dec-04	C	R	23.9	318.0	M	I	M	1.31	0.025
								L	11.7	0.135
Hemigymnus melapterus	Dec-04	C	R	18.4	148.0	F	D	M	13.8	0.039
								L	45.6	0.111
Hemigymnus melapterus	Dec-04	C	R	18.5	126.0	F	D	M	12.9	0.034
								L	20.0	0.140
Lethrinus obsoletus	Dec-04	C	R	21.3	190.0	F	D	M	1.81	0.052
								L	2.07	0.064
Naso unicornis	Dec-04	H	R	20.0	136.0	U	I	M	0.70	0.005
Parupeneus barberinus	Dec-04	C	R	23.8	244.0	U	I	M	9.86	0.021
								L	10.6	0.019
Scarus ghobban	Dec-04	H	R	25.9	322.0	F	I	M	0.67	0.008
								L	0.68	0.038
Scarus ghobban	Dec-04	H	R	25.6	308.0	F	I	M	0.31	0.009
								L	1.07	0.025
Scarus ghobban	Dec-04	H	R	23.0	244.0	F	I	M	0.34	0.028
								L	0.92	0.035

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	μg/g wet weight	
				F/Length	Weight				As	Hg
Site 3: Outer Lagoon 2 (cont.)										
Scarus globiceps	Dec-04	H	R	20.0	182.0	F	M	M	0.66	0.003
								L	1.48	0.023
Scarus globiceps	Dec-04	H	R	21.3	226.0	M	M	M	0.23	0.004
								L	1.54	0.042
Site 4: Tanapag Reef Shoals										
Acanthurus nigricans	29-Oct-04	H	R	16.5	124.0	U	U	M	0.30	0.022
Acanthurus nigricauda	23-Feb-05	H	R	9.8	21.6	U	I	M	0.94	0.003
Chelinus trilobatus	23-Feb-05	C	R	16.0	88.5	U	I	M	1.43	0.015
								L	0.78	0.033
Ctenochaetus striatus	23-Feb-05	H	S	12.3	46.6	U	I	M	0.20	0.002
								L	0.48	0.085
Ctenochaetus striatus	23-Feb-05	H	S	11.3	37.9	U	I	M	0.26	0.002
								L	0.44	0.139
Ctenochaetus striatus	29-Oct-04	H	S	17.0	116.0	U	U	M	0.61	0.007
								L	8.59	1.390
Ctenochaetus striatus	29-Oct-04	H	S	16.9	92.0	U	U	M	0.21	0.010
Gnathodentex aurolineatus	29-Oct-04	C	R	18.0	160.0	U	U	M	6.60	0.161
								L	19.8	0.496
Lethrinus harak	29-Oct-04	C	R	19.1	136.0	U	U	M	1.63	0.037
								L	3.49	0.068
Lethrinus harak	29-Oct-04	C	R	15.7	76.0	U	U	M	1.46	0.096
Lethrinus harak	29-Oct-04	C	R	17.5	110.0	U	U	M	2.36	0.064
								L	9.06	0.167
Lethrinus harak	29-Oct-04	C	R	18.5	100.0	U	U	M	2.21	0.073
								L	7.16	0.215
Lutjanus kasmira	29-Oct-04	C	R	16.8	90.0	U	U	M	5.95	0.028
								L	1.97	0.045
Lutjanus kasmira	29-Oct-04	C	R	14.5	46.0	U	U	M	6.66	0.023
Myripristis berndti	23-Feb-05	P	S	13.8	84.7	F	I	M	14.6	0.021
								L	16.6	0.029

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Site and Species Identity	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	µg/g wet weight	
				F/Length	Weight				As	Hg
Site 4: Tanapag Reef Shoals (cont.)										
Myripristis pralina	23-Feb-05	P/C	S	12.7	57.1	U	I	M	25.2	0.019
								L	5.44	0.022
Myripristis pralina	23-Feb-05	P/C	S	11.9	50.6	F	M	M	25.8	0.016
								L	15.7	0.040
Myripristis pralina	23-Feb-05	P/C	S	12.4	57.3	M	D	M	22.0	0.014
								L	8.75	0.021
Myripristis pralina	23-Feb-05	P/C	S	11.9	51.2	U	I	M	31.6	0.016
								L	5.54	0.021
Myripristis sp.	29-Oct-04	P/C	S	14.2	82.0	U	U	M	19.3	0.050
								L	16.2	0.117
Naso lituratus	23-Feb-05	H	R	17.9	112.3	M	D	M	0.10	0.002
								L	0.42	0.024
Naso lituratus	23-Feb-05	H	R	16.4	94.2	M	I	M	0.26	0.003
								L	0.99	0.040
Naso lituratus	23-Feb-05	H	R	12.4	38.5	M	I	M	0.18	0.002
								L	0.54	0.053
Naso lituratus	23-Feb-05	H	R	11.9	34.9	M	I	M	0.25	0.002
								L	1.23	0.039
Naso lituratus	29-Oct-04	H	R	15.6	98.0	U	U	M	0.24	0.007
								L	0.67	0.091
Naso unicornis	29-Oct-04	H	R	19.3	168.0	U	U	M	0.42	0.005
								L	0.73	0.035
Naso vlamingii	23-Feb-05	H	S	17.2	108.9	U	I	M	1.08	0.003
								L	1.97	0.015
Parupeneus barberinus	23-Feb-05	C	R	17.4	98.7	U	I	M	5.33	0.010
								L	5.68	0.011
Plectropomis laevis	23-Feb-05	C	R	25.0	304.2	F	I	M	3.74	0.037
								L	1.84	0.100
Rhinecanthus aculeatus	23-Feb-05	O	S	15.0	101.7	M	I	M	11.9	0.015
								L	14.8	0.069
Rhinecanthus aculeatus	23-Feb-05	O	S	15.4	92.9	F	D	M	13.4	0.033
								L	10.3	0.116

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Site and Species Identity	Date	Trophic Level	Range	Body F/Length	Body Weight	Gender	Gonad Stage	Tissue	µg/g wet weight As	µg/g wet weight Hg
Site 4: Tanapag Reef Shoals (cont.)										
Rhinecanthus aculeatus	23-Feb-05	O	S	11.7	42.3	M	I	M	14.7	0.010
								L	8.22	0.055
Rhinecanthus aculeatus	23-Feb-05	O	S	10.0	32.8	U	I	M	36.2	0.010
								L	13.8	0.067
Scarus sordidus	23-Feb-05	H	R	25.4	354.8	M	I	M	0.95	0.005
								L	2.60	0.019
Scarus sordidus	23-Feb-05	H	R	18.8	124.8	M	I	M	0.36	0.009
								L	2.43	0.027
Scarus sordidus	23-Feb-05	H	R	16.5	82.4	M	I	M	0.35	0.010
								L	0.18	0.053
Siganus spinus	29-Oct-04	H	R	16.2	84.0	U	U	M	0.19	0.003
								L	1.82	0.058
Trigger Fish (unknown sp.)	23-Feb-05	C	S	15.8	87.0	U	I	M	4.30	0.007
								L	8.80	0.047
Site 5: Seaplane Reefs										
Acanthurus lineatus	26-Oct-04	H	S	18.6	71.6	M	I	M	0.50	0.003
								L	0.61	0.619
Acanthurus lineatus	27-Oct-04	H	S	15.0	97.7	M	I	M	0.33	0.114
								L	1.07	0.209
Acanthurus lineatus	27-Oct-04	H	S	15.6	111.6	M	I	M	0.03	0.003
								L	0.81	0.128
Acanthurus lineatus	27-Oct-04	H	S	15.9	114.2	M	I	M	0.44	0.016
								L	0.85	0.125
Acanthurus lineatus	27-Oct-04	H	S	13.3	79.9	F	I	M	0.24	0.031
								L	0.86	0.124
Acanthurus lineatus	27-Oct-04	H	S	15.4	112.0	F	I	M	0.49	0.004
								L	0.28	0.230
Acanthurus lineatus	27-Oct-04	H	S	15.6	112.8	M	I	M	0.13	0.004
								L	0.19	0.239
Acanthurus lineatus	27-Oct-04	H	S	16.7	140.7	M	I	M	0.09	0.003
								L	0.49	0.136

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	µg/g wet weight	
				F/Length	Weight				As	Hg
Site 5: Seaplane Reefs (cont.)										
Acanthurus lineatus	27-Oct-04	H	S	16.0	117.5	F	I	M	0.18	0.026
								L	0.83	0.147
Acanthurus lineatus	27-Oct-04	H	S	15.9	120.9	F	D	M	0.06	0.007
								L	0.18	0.230
Acanthurus lineatus	27-Oct-04	H	S	15.8	124.8	F	D	M	0.04	0.003
								L	0.23	0.100
Acanthurus lineatus	27-Oct-04	H	S	15.0	100.5	F	I	M	0.07	0.005
								L	0.07	0.228
Calotomus carolinus	27-Oct-04	H	R	21.0	218.3	M	D	M	0.38	0.010
								L	0.67	0.099
Caranx melampygus	26-Oct-04	C	R	23.4	265.1	U	I	M	0.82	0.129
								L	2.61	0.124
Caranx melampygus	27-Oct-04	C	R	23.5	250.5	U	I	M	0.42	0.089
								L	1.47	0.103
Chaetodon ornatissimus	27-Oct-04	C	S	13.9	97.8	U	I	M	2.90	0.026
								L	2.30	0.127
Cheilinus trilobatus	26-Oct-04	C	R	21.0	230.2	M	D	M	2.00	0.027
								L	2.86	0.254
Cheilinus trilobatus	27-Oct-04	C	R	17.7	109.5	M	D	M	0.76	0.026
								L	2.03	0.185
Coris aygula	27-Oct-04	C	R	30.3	488.8	F	D	M	6.27	0.016
								L	5.84	0.054
Epinephelus howlandi	26-Oct-04	C	S	23.4	217.9	M	I	M	2.23	0.091
								L	2.41	0.065
Epinephelus howlandi	27-Oct-04	C	S	23.3	200.2	F	I	M	0.16	0.065
								L	0.37	0.167
Epinephelus merra	26-Oct-04	C	S	28.2	343.7	U	I	M	1.12	0.616
								L	1.35	1.436
Lethrinus harak	26-Oct-04	C	R	18.0	109.7	M	D	M	1.87	0.113
								L	4.77	0.151
Lethrinus harak	26-Oct-04	C	R	24.0	276.1	F	M	M	0.91	0.396
								L	4.53	0.216

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body F/Length	Body Weight	Gender	Gonad Stage	Tissue	µg/g wet weight As	µg/g wet weight Hg
Site 5: Seaplane Reefs (cont.)										
Lethrinus harak	26-Oct-04	C	R	21.8	156.5	F	D	M	1.52	0.054
								L	5.24	0.105
Lethrinus harak	26-Oct-04	C	R	27.0	412.1	F	M	M	2.55	0.123
								L	4.22	0.315
Lethrinus harak	27-Oct-04	C	R	15.9	76.6	M	S	M	3.95	0.087
								L	7.87	0.182
Lutjanus kasmira	26-Oct-04	C	R	18.8	102.0	M	D	M	6.73	0.032
								L	7.75	0.453
Myripristis berndti	27-Oct-04	P/C	S	11.2	48.6	M	I	M	17.3	0.153
								L	104	9.131
Myripristis berndti	27-Oct-04	P	S	10.1	32.1	U	I	M	11.4	0.054
								L	7.49	0.434
Naso lituratus	26-Oct-04	H	R	16.8	102.6	U	I	M	0.36	0.004
								L	0.35	0.032
Naso lituratus	26-Oct-04	H	R	14.8	71.4	U	I	M	0.88	0.018
								L	1.34	0.150
Naso lituratus	27-Oct-04	H	R	18.3	144.7	F	I	M	0.03	0.003
								L	0.70	0.764
Naso lituratus	27-Oct-04	H	R	20.2	178.8	U	I	M	0.03	0.004
								L	0.30	0.171
Naso lituratus	27-Oct-04	H	R	14.8	77.1	U	I	M	0.03	0.026
								L	0.18	0.044
Naso lituratus	27-Oct-04	H	R	16.0	106.7	M	M	M	0.07	0.003
								L	0.11	0.106
Naso lituratus	27-Oct-04	H	R	14.5	71.4	F	D	M	0.03	0.013
								L	0.17	0.694
Naso lituratus	27-Oct-04	H	R	14.8	75.5	F	I	M	0.12	0.019
								L	0.49	0.042
Naso lituratus	27-Oct-04	H	R	16.1	106.4	F	I	M	0.10	0.013
								L	0.73	0.135
Naso lituratus	27-Oct-04	H	R	14.3	70.5	U	I	M	0.10	0.016
								L	1.04	0.046

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body F/Length	Body Weight	Gender	Gonad Stage	Tissue	µg/g wet weight As	µg/g wet weight Hg
Site 5: Seaplane Reefs (cont.)										
Naso lituratus	27-Oct-04	H	R	13.8	62.0	U	I	M	0.29	0.023
								L	0.81	0.119
Naso lituratus	27-Oct-04	H	R	19.0	163.4	M	I	M	0.24	0.087
								L	0.90	0.168
Naso lituratus	27-Oct-04	H	R	18.4	150.3	M	I	M	0.18	0.002
								L	0.40	0.186
Naso lituratus	27-Oct-04	H	R	13.0	56.7	U	I	M	0.15	0.002
								L	1.46	0.100
Naso lituratus	27-Oct-04	H	R	15.1	87.9	M	I	M	0.38	0.002
								L	0.56	0.042
Rhinecanthus rectangulus	26-Oct-04	O	S	15.8	106.4	M	D	M	19.3	0.066
								L	7.23	0.100
Sargocentron spiniferum	27-Oct-04	C	S	13.4	63.9	M	I	M	1.98	0.106
								L	2.95	0.246
Scarus ghobban	27-Oct-04	H	R	21.2	214.9	F	I	M	0.49	0.007
								L	1.97	0.071
Scarus ghobban	27-Oct-04	H	R	26.9	415.7	F	I	M	1.19	0.013
								L	3.44	0.021
Scarus psittacus	26-Oct-04	H	R	23.5	307.1	M	D	M	0.52	0.008
								L	1.60	0.063
Scarus psittacus	26-Oct-04	H	R	19.2	189.3	F	D	M	0.21	0.248
								L	0.74	0.064
Scarus sp.	26-Oct-04	H	R	22.7	245.2	M	D	M	1.60	0.004
								L	1.60	0.050
Sphyraena flavicauda	26-Oct-04	C	R	34.0	216.0	M	D	M	0.90	0.051
								L	1.37	0.073
Sphyraena flavicauda	26-Oct-04	C	R	36.0	256.0	F	D	M	0.55	0.081
								L	2.46	0.071
Triaenodon obesus	26-Oct-04	C	R	58.5	1376.0	M	I	M	7.59	0.135
								L	18.34	0.058
Zanclus cornutus	27-Oct-04	O	R	14.1	97.2	U	I	M	4.39	0.005

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	µg/g wet weight	
				F/Length	Weight				As	Hg
Site 6: Puerto Rico Dump										
Acanthurus lineatus	30-Oct-04	H	S	10.3	30.0	U	U	M	0.08	0.003
Acanthurus nigricauda	30-Oct-04	H	R	14.8	84.0	U	U	M	0.44	0.011
Acanthurus nigrofuscus	30-Oct-04	H	S	15.2	90.0	U	U	M	0.42	0.009
Acanthurus nigrofuscus	30-Oct-04	H	S	16.0	98.0	U	U	M	0.40	0.006
Balistiodes viridescens	30-Oct-04	C	S	16.8	140.0	U	U	M	8.13	0.076
Lethrinus harak	30-Oct-04	C	R	14.5	70.0	U	U	M	7.41	0.100
Lethrinus harak	30-Oct-04	C	R	14.6	56.0	U	U	M	1.47	0.079
Lethrinus harak	30-Oct-04	C	R	12.5	42.0	U	U	M	5.18	0.069
Myripristis berndti	30-Oct-04	P/C	S	12.8	66.0	U	U	M	4.47	0.039
Myripristis berndti	30-Oct-04	P/C	S	11.8	54.0	U	U	M	10.3	0.037
Myripristis berndti	30-Oct-04	P/C	S	11.8	60.0	U	U	M	12.5	0.045
Myripristis berndti	30-Oct-04	P/C	S	12.2	54.0	U	U	M	8.37	0.047
Myripristis berndti	30-Oct-04	P/C	S	11.5	46.0	U	U	M	6.85	0.039
Myripristis berndti	30-Oct-04	P/C	S	10.5	38.0	U	U	M	6.98	0.033
Myripristis berndti	30-Oct-04	P/C	S	10.9	40.0	U	U	M	6.00	0.030
Myripristis berndti	30-Oct-04	P/C	S	10.0	34.0	U	U	M	7.20	0.031
Myripristis berndti	30-Oct-04	P/C	S	10.2	40.0	U	U	M	7.84	0.034
Myripristis berndti	30-Oct-04	P/C	S	10.2	34.0	U	U	M	6.94	0.046
Myripristis violacea	30-Oct-04	P/C	S	10.5	46.0	U	U	M	9.32	0.037
Myripristis violacea	30-Oct-04	P/C	S	12.4	62.0	U	U	M	7.14	0.052
Myripristis violacea	30-Oct-04	P/C	S	12.0	62.0	U	U	M	11.8	0.049
Myripristis violacea	30-Oct-04	P/C	S	12.5	66.0	U	U	M	14.1	0.041
Naso lituratus	30-Oct-04	H	R	15.7	84.0	U	U	M	0.22	0.008
								L	2.39	0.118
Naso lituratus	30-Oct-04	H	R	14.5	70.0	U	U	M	0.55	0.009
Naso lituratus	30-Oct-04	H	R	16.5	88.0	U	U	M	0.43	0.005
Naso lituratus	30-Oct-04	H	R	15.0	68.0	U	U	M	0.65	0.005
Naso lituratus	30-Oct-04	H	R	15.5	78.0	U	U	M	0.48	0.006
Naso lituratus	30-Oct-04	H	R	16.0	80.0	U	U	M	0.11	0.002
Naso lituratus	30-Oct-04	H	R	14.6	64.0	U	U	M	0.24	0.004
Naso lituratus	30-Oct-04	H	R	14.6	64.0	U	U	M	0.61	0.006

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	µg/g wet weight	
				F/Length	Weight				As	Hg
Site 6: Puerto Rico Dump										
Naso lituratus	30-Oct-04	H	R	14.9	74.0	U	U	M	0.44	0.003
Naso lituratus	30-Oct-04	H	R	15.1	70.0	U	U	M	0.35	0.007
Naso lituratus	30-Oct-04	H	R	16.9	98.0	U	U	M	0.55	0.005
Naso lituratus	30-Oct-04	H	R	14.8	64.0	U	U	M	0.09	0.005
Naso lituratus	30-Oct-04	H	R	16.5	92.0	U	U	M	0.30	0.003
Naso lituratus	30-Oct-04	H	R	14.8	64.0	U	U	M	0.03	0.002
Naso unicornis	30-Oct-04	H	R	18.4	118.0	U	U	M	0.12	0.014
Neoniphon opercularis	30-Oct-04	C	S	14.6	60.0	U	U	M	26.9	0.297
Parupeneus multifasciatus	30-Oct-04	C	R	16.5	84.0	U	U	M	10.2	0.110
Parupeneus multifasciatus	30-Oct-04	C	R	13.0	50.0	U	U	M	8.98	0.073
Sargocentron spiniferum	30-Oct-04	C	S	17.5	120.0	U	U	M	0.62	0.178
								L	1.10	0.331
Siganus spinus	30-Oct-04	H	R	14.8	56.0	U	U	M	0.20	0.002
Site 7: Micro Beach Point										
Acanthurus blochii	19-Jan-05	H	R	13.1	60.0	U	I	M	0.51	0.013
								L	0.54	0.153
Lethrinus harak	19-Jan-05	C	R	13.9	46.0	M	I	M	1.58	0.144
								L	2.19	0.234
Lutjanus monostigmus	19-Jan-05	C	R	12.5	32.0	U	I	M	0.54	0.027
								L	2.53	0.043
Naso lituratus	19-Jan-05	H	R	20.4	188.0	M	D	M	0.30	0.004
								L	0.75	0.271
Rhinocanthus aculeatus	19-Jan-05	O	S	12.7	50.0	F	I	M	10.3	0.017
								L	10.4	0.059
Site 8: Micro Reef Complex										
Acanthurus lineatus	19-Jan-05	H	S	19.1	201.6	M	M	M	0.14	0.013
Acanthurus lineatus	19-Jan-05	H	S	17.0	171.1	M	M	M	0.03	0.019
Acanthurus lineatus	19-Jan-05	H	S	18.2	150.0	F	D	M	0.24	0.015
Acanthurus lineatus	19-Jan-05	H	S	18.4	145.8	F	I	M	0.23	0.004

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	μg/g wet weight	
				F/Length	Weight				As	Hg
Site 8: Micro Reef Complex (cont.)										
Acanthurus lineatus	19-Jan-05	H	S	18.5	151.8	F	D	M	0.05	0.013
Acanthurus lineatus	19-Jan-05	H	S	18.5	160.6	M	M	M	0.27	0.109
Acanthurus lineatus	19-Jan-05	H	S	18.0	167.8	M	I	M	0.21	0.051
Acanthurus lineatus	19-Jan-05	H	S	17.9	154.9	F	D	M	0.09	0.018
Acanthurus lineatus	19-Jan-05	H	S	18.5	181.3	M	M	M	0.10	0.022
Acanthurus lineatus	19-Jan-05	H	S	17.2	153.5	M	I	M	0.17	0.034
Acanthurus lineatus	19-Jan-05	H	S	18.4	162.4	M	M	M	0.05	0.014
Acanthurus lineatus	19-Jan-05	H	S	19.0	175.9	F	D	M	0.43	0.018
Acanthurus lineatus	19-Jan-05	H	S	18.0	142.3	M	D	M	0.07	0.005
Acanthurus lineatus	19-Jan-05	H	S	17.5	122.1	M	I	M	0.29	0.063
Acanthurus lineatus	19-Jan-05	H	S	17.0	137.1	M	I	M	0.18	0.009
Acanthurus lineatus	19-Jan-05	H	S	17.5	138.6	F	I	M	0.28	0.010
Acanthurus lineatus	19-Jan-05	H	S	18.9	145.9	F	I	M	0.20	0.028
Acanthurus lineatus	19-Jan-05	H	S	16.2	128.3	F	M	M	0.23	0.015
Acanthurus lineatus	19-Jan-05	H	S	16.0	121.1	F	I	M	0.25	0.068
Acanthurus lineatus	19-Jan-05	H	S	16.5	115.6	M	I	M	0.18	0.010
Site 9: Hafa Adai Beach										
Acanthurus lineatus	26-Oct-04	H	S	18.8	171.0	M	D	M	0.46	0.007
								L	0.24	0.221
Acanthurus nigricans	26-Oct-04	H	R	15.4	113.0	F	M	M	0.11	0.012
								L	0.27	0.488
Calotomus carolinus	26-Oct-04	H	R	20.4	197.0	F	M	M	0.29	0.011
Calotomus carolinus	26-Oct-04	H	R	21.0	223.0	F	D	M	0.16	0.021
								L	0.60	0.081
Ctenochaetus striatus	26-Oct-04	H	S	16.9	120.0	M	I	M	0.12	0.059
								L	1.43	0.714
Gnathodentex aurolineatus	26-Oct-04	C	R	16.4	97.0	M	I	M	11.2	0.142
								L	11.7	0.143
Heteropriacanthus cruentatus	26-Oct-04	C	S	20.1	123.0	M	D	M	1.60	0.029
								L	3.34	0.177

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body F/Length	Body Weight	Gender	Gonad Stage	Tissue	µg/g wet weight As	µg/g wet weight Hg
Site 9: Hafa Adai Beach (cont.)										
Lutjanus fulvus	26-Oct-04	C	R	16.9	90.0	U	I	M	3.16	0.194
								L	6.61	0.310
Myripristis amaena	26-Oct-04	P/C	S	15.8	95.0	F	I	M	14.0	0.182
								L	24.6	0.535
Myripristis amaena	26-Oct-04	P/C	S	15.3	88.0	U	I	M	17.4	0.184
Myripristis berndti	26-Oct-04	P/C	S	13.1	61.0	F	I	M	17.6	0.207
Myripristis kuntee	26-Oct-04	P/C	S	13.4	67.0	U	I	M	14.6	0.157
Myripristis murdjan	26-Oct-04	P/C	S	14.0	77.0	F	S	M	10.1	0.171
								L	14.3	1.657
Myripristis pralina	26-Oct-04	P/C	S	13.8	78.0	F	D	M	17.8	0.123
								L	8.06	0.677
Myripristis pralina	26-Oct-04	P/C	S	14.8	97.0	F	I	M	25.9	0.145
								L	7.43	0.671
Myripristis violacea	26-Oct-04	P/C	S	13.4	72.0	F	I	M	15.2	0.104
								L	12.4	0.365
Myripristis violacea	26-Oct-04	P/C	S	14.1	80.0	M	D	M	32.6	0.087
								L	8.74	0.450
Myripristis violacea	26-Oct-04	P/C	S	12.7	57.0	F	I	M	15.7	0.175
								L	17.3	0.341
Myripristis violacea	26-Oct-04	P/C	S	14.8	77.0	M	S	M	8.93	0.139
								L	20.3	1.589
Myripristis violacea	26-Oct-04	P/C	S	13.7	77.0	M	D	M	17.4	0.124
								L	14.0	2.443
Myripristis violacea	26-Oct-04	P/C	S	16.5	104.0	F	D	M	13.6	0.196
								L	33.7	2.348
Myripristis violacea	26-Oct-04	P/C	S	13.3	69.0	F	D	M	36.1	0.070
								L	7.89	0.445
Naso lituratus	26-Oct-04	H	R	20.4	198.0	F	I	M	0.20	0.020
								L	0.42	0.070
Naso lituratus	26-Oct-04	H	R	19.8	178.0	F	D	M	0.14	0.015
								L	0.56	0.128
Naso lituratus	26-Oct-04	H	R	17.8	135.0	F	D	M	0.15	0.048
								L	1.51	0.171

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body F/Length	Body Weight	Gender	Gonad Stage	Tissue	µg/g wet weight As	µg/g wet weight Hg
Site 9: Hafa Adai Beach (cont.)										
Neoniphon sammara	26-Oct-04	C	S	16.2	75.0	F	D	M	2.24	0.243
								L	1.92	1.467
Neoniphon sammara	26-Oct-04	C	S	15.8	73.0	M	I	M	3.90	0.318
Neoniphon sammara	26-Oct-04	C	S	14.5	62.6	M	M	M	2.69	0.165
Parupeneus multifasciatus	26-Oct-04	C	R	17.0	101.0	M	I	M	28.6	0.125
								L	23.6	0.289
Scarus ghobban	26-Oct-04	H	R	20.6	163.0	F	I	M	0.29	0.133
								L	1.16	0.058
Site 10: Hafa Adai Beach to Fisherman's Base										
Lethrinus atkinsoni	13-Jan-05	C	R	18.0	130.5	F	I	M	6.01	0.063
Lethrinus atkinsoni	13-Jan-05	C	R	15.4	79.5	U	I	M	5.69	0.036
								L	3.09	0.058
Lethrinua harak	13-Jan-05	C	R	24.0	255.5	M	S	M	0.78	0.189
								L	1.92	0.246
Lethrinus harak	13-Jan-05	C	R	21.6	200.8	F	M	M	3.43	0.197
								L	4.65	0.198
Lethrinus harak	13-Jan-05	C	R	24.4	308.4	F	M	M	3.39	0.212
								L	8.52	0.165
Lethrinus harak	13-Jan-05	C	R	23.0	243.1	F	M	M	5.46	0.204
								L	11.4	0.218
Lethrinus harak	13-Jan-05	C	R	23.4	257.8	M	M	M	0.85	0.145
								L	2.52	0.146
Lethrinus harak	13-Jan-05	C	R	19.9	170.5	F	M	M	0.46	0.066
								L	0.85	0.078
Lethrinus harak	13-Jan-05	C	R	19.4	146.5	F	M	M	0.63	0.068
Lethrinus harak	13-Jan-05	C	R	19.4	146.5	F	M	L	0.81	0.057
Lethrinus harak	13-Jan-05	C	R	16.7	86.2	F	I	M	1.18	0.062
								L	1.42	0.049
Lethrinus harak	13-Jan-05	C	R	22.4	235.7	F	M	M	0.85	0.169
	13-Jan-05							L	3.44	0.109

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	µg/g wet weight	
				F/Length	Weight				As	Hg
Site 10: Hafa Adai Beach to Fisherman's Base (cont.)										
Lethrinus harak	13-Jan-05	C	R	20.8	178.6	F	M	M	1.48	0.132
								L	2.99	0.124
Lethrinus harak	6-Apr-05	C	R	19.9	165.2	F	I	M	0.66	0.055
								L	1.60	0.047
Lethrinus harak	6-Apr-05	C	R	13.4	46.0	U	I	M	0.79	0.037
Lethrinus harak	6-Apr-05	C	R	12.5	37.5	F	I	M	0.79	0.029
Lethrinus obsoletus	13-Jan-05	C	R	21.3	201.1	U	I	M	3.41	0.058
								L	2.69	0.042
Lethrinus obsoletus	13-Jan-05	C	R	15.4	70.0	U	I	M	0.44	0.040
								L	0.60	0.034
Lethrinus xanthochilus	13-Jan-05	C	R	19.4	133.2	U	I	M	0.88	0.038
								L	0.48	0.075
Lethrinus xanthochilus	13-Jan-05	C	R	19.5	138.6	F	I	M	0.85	0.033
								L	1.15	0.059
Lethrinus xanthochilus	13-Jan-05	C	R	19.0	113.8	U	I	M	0.64	0.029
								L	1.17	0.046
Site 11: Lighthouse to Micro Toyota										
Lethrinus atkinsoni	19-Apr-05	C	R	20.8	200.1	M	D	M	3.86	0.178
								L	5.11	1.712
Lethrinus atkinsoni	19-Apr-05	C	R	18.8	148.3	F	D	M	7.05	0.177
								L	8.18	0.791
Lethrinus atkinsoni	19-Apr-05	C	R	20.7	163.0	M	S	M	3.00	0.276
								L	5.36	1.394
Lethrinus atkinsoni	19-Apr-05	C	R	18.6	138.0	F	D	M	2.81	0.181
								L	4.39	4.383
Lethrinus atkinsoni	19-Apr-05	C	R	21.0	198.4	M	D	M	0.97	0.227
								L	2.68	0.964
Lethrinus atkinsoni	19-Apr-05	C	R	18.8	149.1	M	M	M	0.33	0.200
								L	2.09	0.409
Lethrinus atkinsoni	19-Apr-05	C	R	21.6	211.3	F	D	M	2.43	0.245
								L	7.41	1.146

Total Arsenic and Mercury in Axial Muscle and Liver Tissue of Fish from Saipan Lagoon (2004-2005)

Sample	Date	Trophic Level	Range	Body		Gender	Gonad Stage	Tissue	μg/g wet weight	
				F/Length	Weight				As	Hg
Site 11: Lighthouse to Micro Toyota (cont.)										
Lethrinus atkinsoni	19-Apr-05	C	R	20.3	182.2	M	D	M	3.15	0.229
								L	4.66	0.705
Lethrinus atkinsoni	19-Apr-05	C	R	16.7	118.3	F	D	M	5.17	0.144
								L	9.86	0.582
Lethrinus atkinsoni	19-Apr-05	C	R	17.8	120.2	F	D	M	4.70	0.186
								L	6.89	0.531
Lethrinus atkinsoni	7-Apr-05	C	R	15.6	87.2	F	I	M	2.44	0.041
								L	1.13	0.034
Lethrinus harak	7-Apr-05	C	R	22.1	205.1	M	M	M	0.28	0.131
								L	0.55	0.103
Lethrinus harak	7-Apr-05	C	R	20.0	157.0	F	D	M	1.13	0.061
								L	1.24	0.056
Lethrinus harak	7-Apr-05	C	R	23.5	240.5	F	M	M	0.63	0.175
								L	1.41	0.328
Lethrinus harak	7-Apr-05	C	R	20.9	178.4	M	M	M	0.15	0.074
								L	0.87	0.072
Lethrinus harak	7-Apr-05	C	R	19.4	143.0	F	M	M	0.56	0.081
								L	2.94	0.109

Trophic Level: H = herbivore benthic, P = planktivore, C = carnivore, O = omnivore; Range: R = roving/large home range, S = sedentary/small home range
Gender: M = male, F= female, U = undetermined; Gonad Stage: M = mature, I = immature, D = developing, U = undetermined; Tissue: M = axial muscle, L = liver

APPENDIX B

PCBs in Axial Muscle of Fish from Saipan Lagoon

PCB Congeners in Axial Muscle of Fish from Saipan Lagoon (2004-2005)

Site and Species Identity	Fork Length	Weight	PCB Congener Concentrations (ng/g dry weight)																				Σ_{20}PCB	
			8	18	28	44	52	66	77	101	105	118	126	128	138	153	170	180	187	195	206	209		
	(cm)	(g)	(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})	(dry)	(wet)
Site 1: Pau Pau Shoals																								
Acanthurus lineatus	14	72	0	0	0	1.65	0.35	0.0	0.95	4.49	0.06	0	0	0	0.27	0	0	0	0	0	0	0	7.77	1.79
Acanthurus lineatus	13	56	0	0	0	2.05	3.16	0	4.72	0.81	1.58	0.14	0.40	0.38	0	0	0.21	0	0	0	0	0	13.45	3.09
Acanthurus triostegus	12	54	0	0	0	0	0.30	0	0.36	4.50	0	0.29	0	0	0	0	0.04	0.14	0.32	0.10	0.21	2.24	8.51	1.96
Ctenochaetus striatus	11	33	0	0	0	0	1.51	0	0.3	11.0	3.1	10.1	0	2.87	8.0	7.4	1.21	1.96	0.76	0	0	0	48.2	11.1
Gnathodentex aurolineatus	17	96	0	0	0	1.58	1.77	0	2.49	0.98	0.69	0.12	0.20	0.22	0	0	0.15	0	0	0	0	0	8.20	1.89
Lethrinus harak	19	132	0	0	0	1.62	0.73	0	0.43	9.93	2.52	7.33	0	1.23	3.93	4.11	0.45	0.85	0.34	0.03	0	0	33.5	7.71
Lethrinus xanthocheilus	12	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0.36	0	0.07	0	0	0	0	0.43	0.10
Lethrinus xanthocheilus	10	20	0	0	0	0	0	4.19	1.33	0	0	1.39	0	0.09	0	0.53	1.05	0.81	2.08	0.50	0.52	0.90	13.4	3.08
Myripristis amaena	13	56	0	0	0.04	3.84	3.71	0	9.03	0	3.52	1.01	1.18	1.40	0	0	0.93	0.81	0.80	0.72	0.94	0	27.9	6.42
Myripristis amaena	11	36	0	0	0	6.37	6.32	0	13.4	1.68	5.27	1.07	1.91	2.76	0	1.51	1.58	0.66	0.85	0.75	1.16	0	45.3	10.4
Myripristis amaena	11	40	0	0	0	4.09	3.92	0	9.58	2.03	3.46	0.56	1.01	1.09	0	0	0.71	0	0.19	0	0	0	26.6	6.13
Myripristis amaena	12	46	0	0	0	0	0.08	0.94	0	0.87	0	0.27	0.90	0	0	0.27	0	0.13	0.12	0	0	0	3.58	0.82
Myripristis amaena	14	74	0	0	0	0	0	0.89	0.04	0	0	0.21	0.04	0.05	0	0.13	0	0	0	0	0	0	1.36	0.31
Myripristis amaena	12	54	0	0	0	0	0	0.68	0	0	0	0.47	0	0	0	0.18	0	0.07	0	0	0	0	1.40	0.32
Myripristis anaema	13	66	0	0	0	0.00	0.24	0	0.10	2.42	0.16	0.38	0	0	0	0.16	0	0	0	0	0	0	3.45	0.79
Myripristis berndti	11	34	0	0	0	0	0.05	1.40	0	0	0	0.23	0	0	0	0.25	0.02	0.09	0	0	0.20	2.17	4.41	1.01
Myripristis violacea	10	30	0	0	0	0	0	1.93	0	1.04	0	0.11	0	0	0	0.20	0	0	0	0	0	0	3.29	0.76
Myripristis violacea	10	30	0	0	0	0	0	8.12	0	0	0	0.22	0	0	0	0.21	0	0	0	0	0	0	8.55	1.97
Myripristis violacea	13	68	0	0	0.02	0	0.05	0.86	0.14	0.76	0.02	0.27	0	0.08	0	0.26	0	0.13	0.24	0	0	0	2.82	0.65
Myripristis violacea	12	52	0	0	0.05	0	0	1.02	0.13	0.88	0	0.20	0	0	0	0.21	0	0.14	0.26	0	0	0	2.89	0.66
Myripristis violacea	12	49	0	0	0.02	0	0.20	1.33	0	0	0	0.55	0	0.11	0.13	0.03	0	0.64	0	0	0	0	3.01	0.69
Myripristis violacea	9	24	0	0	0	19.3	22.1	0	8.27	47.9	4.63	16.3	0	2.99	6.05	4.28	2.42	2.24	3.22	2.22	3.32	0.0	145	33.4
Myripristis violacea	10	32	0	0	0	3.11	2.95	0	7.70	1.44	2.61	0.42	0.76	0	0	0	0.461	0	0	0	0	0	19.4	4.47
Myripristis violacea	13	53	0	0	0	6.10	6.59	0	12.5	3.16	4.40	0.90	0.95	1.23	0	0.37	0.67	0.31	0.13	0	0.20	0	37.6	8.64
Myripristis violacea	11	40	0	0	0	4.18	0	0	11.0	3.13	0	0	0	0	0	0.38	0	0	0	0	0	0	18.7	4.30
Naso lituratus	14	52	0	0.12	0	0	0.25	1.03	0	0	0	0.25	0	0	0	0	0	0	0	0	0	0	1.65	0.38
Naso lituratus	13	50	0	0	0.08	0	1.44	1.26	0	0	0.09	0.55	0	0	0.13	0	0	0	0	0	0	0	3.56	0.82
Naso lituratus	15	70	0	0	0.06	0	1.63	1.05	0	0	0.07	0.38	0.48	0.13	0.10	0	0	0	0	0	0	0	3.90	0.90
Naso lituratus	14	66	0	0	0	0.25	0	0	0	0	0	0.10	0	0	0	0.39	0	0.15	0	0	0	0	0.88	0.20
Naso lituratus	13	45	0	0	0	0	0.14	0	0.25	1.60	0	0	0	0	0	0.07	0	0	0	0	0	0	2.06	0.47
Naso lituratus	13	49	0	0	0	0	1.05	0	1.79	12.7	0.47	0.97	0	0	0.91	0.28	0	0	0.20	0	0	0	18.4	4.23
Naso lituratus	14	59	0	0	0	0	0.46	0	0.39	2.78	0.15	1.38	0	0	0	0.27	0	1.56	0.28	0	0	1.21	8.48	1.95
Naso lituratus	14	61	0	0	0	0	0.57	0	0.64	7.39	1.59	0	0	0.72	1.22	1.92	0.03	0	0.19	0	0	0	14.3	3.28
Naso lituratus	16	93	0	0	0	1.64	0.68	0	0.53	4.47	1.53	3.58	0	0.75	2.43	1.93	0.21	0.49	0.08	0.02	0	0	18.3	4.22
Naso lituratus	14	67	0	0	0	0	0.21	0	0.62	2.50	0.03	0	0	0	0.13	0	0	0	0.01	0	0.18	0.49	4.17	0.96
Naso lituratus	14	71	0	0	0	2.56	2.50	0	0.66	13.7	2.66	7.91	0	0.99	3.12	3.08	0.18	0.45	0.18	0.12	0.21	0.39	38.7	8.90
Naso lituratus	13	40	0	0	0.04	2.59	4.33	5.11	7.55	1.09	2.48	0.10	0.53	0.73	0	0	0.42	0.74	0	0	0	0	25.7	5.91
Naso lituratus	14	54	0	0	0.12	1.43	2.01	1.92	0	0.94	1.05	0.04	0.28	0.31	0	0	0.22	0.09	0	0	0	0	8.41	1.94
Naso lituratus	14	62	0	0	0	6.95	5.69	0	13.7	1.46	0	0	0	0	0	0.29	0	0	0	0	0	0	28.0	6.45
Naso lituratus	14	64	0	0	0	8.37	0	0	16.3	1.41	0	0	0	0	0	0	0	0	0	0	0	0	26.1	5.99
Naso unicornis	16	51	0	0	0	0	0.06	0	0	2.03	0	0.27	0	0.27	0	0.13	0	0	0.06	0	0	0	2.81	0.65
Neoniphon sammara	14	51	0	0.15	0.04	0	0.14	1.33	0	0	0.03	0.32	0.21	0	0.08	0.01	0.16	0.25	0	0	0	0	2.71	0.62
Neoniphon sammara	12	43	0	0	0	5.43	0	0	27.4	3.19	0	0	0	0	0	3.21	0	0	0	0	0	0	39.2	9.02

PCB Congeners in Axial Muscle of Fish from Saipan Lagoon (2004-2005)

Site and Species Identity	Fork Length	Weight	PCB Congener Concentrations (ng/g dry weight)																				Σ_{20}PCB	
			8	18	28	44	52	66	77	101	105	118	126	128	138	153	170	180	187	195	206	209		
	(cm)	(g)	(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})	(dry)	(wet)
Site 1: Pau Pau Shoals (cont.)																								
Neoniphon sammara	11	25	0	0	0	2.01	0	0	6.49	0	0	0	0	0	0	0	0	0	0	0	0	0	8.5	1.96
Parpeneus barberinus	13	38	0	0	0	0.49	0	4.59	1.45	0	0	0.40	0	0	0	0.64	0.34	0.56	2.39	0.35	0.33	0	11.6	2.66
Parupeneus barberinus	14	54	0	0	0	0	0.32	0	0.53	5.17	0.03	0.58	0	0.10	0	0.04	0	0	0.12	0	0	0	6.88	1.58
Sargocentron spiniferum	18	121	0	0	0.02	0	0.04	0	0	0	0	0.09	0	0	0.03	0	0	0	0	0	0	0	0.19	0.04
Sargocentron spiniferum	15	76	0	0	0	0	0.22	0.54	0	0.91	0.04	0.21	0	0.05	0.05	0	0	0	0	0	0	0	2.02	0.47
Sargocentron spiniferum	22	286	0	0	0	0	0	0.35	0	0	0	0.25	0	0	0	0	0	0	0.17	0	0	0	0.76	0.18
Sargocentron spiniferum	15	98	0	0	0.01	0	0.08	0	0.09	2.23	0.04	0.30	0	0	0.26	0.10	0	0	0	0	0	0	3.12	0.72
Sargocentron spiniferum	14	72	0	0	0	0	0.15	0	0.24	1.63	0	0	0	0.06	0	0	0	0	0	0	0	0	2.07	0.48
Sargocentron spiniferum	16	88	0	0	0	0.35	0.14	0	0.59	3.53	0.28	1.10	0	0.18	0.32	0.27	0	0	0	0	0	0	6.77	1.56
Siganus spinus	12	30	0	0	0	4.42	5.14	4.54	10.1	2.30	2.96	0.14	0.75	0.89	0	0	0.49	0	0	0	0	0	31.7	7.29
Site 2: Outer Lagoon 1 (Dankulo Rock)																								
Acanthurus lineatus	13	56	0.20	0	0	0	0	1.62	0	0.21	0.24	0.42	0.31	0.41	0.08	0.36	0.47	0.50	0.80	0.45	0.47	0.44	6.99	1.61
Acanthurus lineatus	14	67	0	0	0	0	0	1.46	0	0.18	0	0	0	0	0	0.07	0	0	0	0	0	0	1.71	0.39
Acanthurus lineatus	17	122	0	0	0	0	0	1.41	0	0.17	0	0.14	0	0	0	0.12	0	0	0	0	0	0	1.84	0.42
Acanthurus olivaceous	17	129	0	0	0	0	0	0.68	0	0.75	0	0.16	0.02	0	0	0	0	0	0	0	0	0	1.62	0.37
Acanthurus triostegus	14	78	0	0	0	0	0	0.67	0	0.64	0	0.13	0	0	0	0.06	0	0	0	0	0	0	1.50	0.35
Cheilio inermis	32	222	0.27	0	0	0	0	1.10	0	0.23	0.19	0.64	0	0.12	0	0.33	0.09	0.09	0.05	0	0	0	3.11	0.72
Chelinus chlorous	18	107	0.18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.18	0.04
Chlorurus fontalis	23	27	0	0	0.11	0	0	0.64	0	0.68	0.11	0.66	0	0.11	0.21	0.18	0.02	0.02	0	0	0	0	2.74	0.63
Ctenochaetus striatus	14	74	0	0	0	0	0.43	0	0	0.53	0	0	0	0	0	0	0	0	0	0	0	0	0.96	0.22
Ctenochaetus striatus	12	38	0	0	0	0	0.81	0	0	1.59	0	0	0	0	0	0	0	0	0	0	0	0	2.40	0.55
Epinephelus maculatus	21	139	0	0	0.11	0	0	0	0.58	1.33	0.27	1.01	0.03	0.46	0	0.44	0.28	0.18	0.25	0	0.26	0	5.20	1.20
Epinephelus merra	37	290	0	0	0	0	0	0.75	0	0	0	0.57	0.06	0.06	0	0	0	0	0	0	0	0	1.44	0.33
Gnathodentex aurolineatus	15	70	0	0	0.11	0	0	1.23	0	0	0	1.13	0	0	0	0	0	0	0	0	0	0	2.47	0.57
Halichoeres trimaculatus	15	52	0	0	0	0	0	1.54	0	1.24	0	0.24	0	0	0	0.12	0	0	0	0	0	0	3.15	0.72
Kyphosus bigibbus	22	242	0	0	0	0	0	1.01	0	0	0	0.12	0.03	0	0	0.04	0	0	0.12	0	0	0	1.33	0.31
Lethrinus atkinsoni	19	122	0	0	0.07	0	0	1.32	0	0.52	0	0	0	0	0	0.02	0	0	0	0	0	0	1.93	0.44
Lethrinus erycanthus	15	69	0	0	0	3.37	0	1.53	0	0	0	0.30	0	0	0	0.13	0.03	0	0.30	0.05	0	0	5.71	1.31
Lethrinus harak	22	207	0	0.03	0	0.30	0.07	0	0	0.71	0.19	0.58	0	0.11	0.16	0.23	0.07	0.10	0.07	0	0	0	2.62	0.60
Lethrinus olivaceous	35	682	0	0	0	0	0	1.02	0	0	0.17	0.46	0.04	0.08	0.17	0.25	0.03	0.06	0.11	0	0	0	2.38	0.55
Lethrinus olivaceous	22	171	0	0	0.09	0	0	0	0	0.92	0.26	0.36	0.04	0.11	0.28	0.34	0.17	0.19	0.24	0	0	0	3.00	0.69
Lethrinus xanthocheilus	43	1416	0	0	0	0	0	1.39	0	0.03	0.22	0.55	0	0.08	0.06	0.33	0	0.09	0	0	0	0	2.75	0.63
Lethrinus xanthocheilus	30	419	0.11	0	0	0.53	0	0	0	0.49	0.41	1.20	0	0.22	0.11	0.53	0.12	0.11	0.16	0	0	0	3.97	0.91
Lethrinus xanthocheilus	18	95	0	0	0.00	0.43	0	0.80	0	0.54	0	0	0	0	0	0.03	0.03	0.04	0	0	0	0	1.88	0.43
Lutjanus fulvus	21	156	0	0	0	0	0	1.09	0	0.15	0	0.17	0.05	0.08	0	0.54	0.16	0.36	0.05	0.03	0	0	2.67	0.61
Lutjanus kasmira	20	143	0.30	0	0	0	0	1.13	0	0.25	0.06	0.34	0.08	0	0	0.22	0	0.10	0.20	0	0	0	2.67	0.61
Myripristis berndti	11	32	0	0	0	0	0	0	0	1.44	0	1.53	0	0	0	0.12	0	0	0	0	0	0	3.09	0.71
Myripristis berndti	11	40	0	0	0.05	3.32	0	1.69	0	0	0	0.17	0	0	0	0.13	0	0	0	0	0	0	5.36	1.23
Myripristis berndti	10	33	0.58	0	0	4.27	0	1.37	0	1.37	0	0.41	0	0	0	0.20	0	0	0	0	0	0	8.20	1.89
Myripristis berndti	9	33	0	0	0	4.31	0	1.49	0	0	0	0.43	0	0	0	0.24	0	0	0	0	0	0	6.47	1.49
Myripristis berndti	12	46	0.24	0	0.03	3.31	0	1.20	0	0	0.03	0.28	0	0	0	0.14	0	0.09	0	0	0	0	5.32	1.22
Myripristis berndti	12	46	0	0	0.02	4.66	0	1.15	0	0	0.05	0.40	0.08	0	0	0.28	0	0.10	0.24	0	0	0	6.99	1.61

PCB Congeners in Axial Muscle of Fish from Saipan Lagoon (2004-2005)

Site and Species Identity	Fork Length	Weight	PCB Congener Concentrations (ng/g dry weight) 8	18	28	44	52	66	77	101	105	118	126	128	138	153	170	180	187	195	206	209	Σ_{20}PCB	
	(cm)	(g)	(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})	(dry)	(wet)
Site 2: Outer Lagoon 1 (cont.)																								
Myripristis berndti	12	53	0	0	0.04	6.19	0	1.41	0	0	0.11	0.49	0	0.15	0	0.36	0.11	0.21	0.16	0.10	0.15	0	9.48	2.18
Naso annulatus	32	545	0.12	0	0	0	0	1.26	0	0.04	0.10	0.49	0	0.10	0	0.20	0.12	0.06	0.18	0	0	0	2.66	0.61
Naso lituratus	15	64	0	0	3.59	0	0.43	0	0	0.31	0	0	0	0	0	0	0	0	0	0	0	0	4.33	1.00
Neoniphon argenteus	15	62	0	0	0.02	3.61	0	0.91	0	0	0.02	0.25	0	0.03	0	0.10	0	0	0.06	0	0	0	5.00	1.15
Parupeneus multifasciatus	15	61	0.28	0	0	0	0	1.23	0	0.19	0	0.11	0	0	0	0.10	0	0.08	0.05	0	0.06	0	2.10	0.48
Sargocentron spiniferum	18	156	0	0	0	0	0.09	0	0	1.28	0.26	2.13	0.06	0.46	0.17	0.26	0.08	0	0	0	0.28	0	5.07	1.17
Scarus psittacus	20	186	0	0	0	0	0	0.64	0	0.79	0.07	1.02	0.04	0.09	0.09	0.10	0	0	0	0	0.22	0	3.07	0.71
Scarus sordidus	15	69	0	0	0.02	2.94	0	0.99	0	0	0	0.18	0	0	0	0.06	0	0	0.07	0	0	0	4.27	0.98
Scarus sordidus	15	71	0	0	0.03	4.27	0	1.16	0.07	1.35	0	0.22	0	0	0	0	0	0	0.21	0	0	0	7.31	1.68
Scarus sordidus	15	73	0	0	0.02	3.24	0	1.03	0	0	0	0.14	0	0	0	0.06	0	0	0.24	0	0	0	4.74	1.09
Scarus sordidus	14	52	0	0	0	4.87	0	1.47	0	0	0	0.25	0.04	0	0	0	0	0	0.54	0	0	0	7.18	1.65
Sufflamen chrysoptera	15	75	0	0	0	3.12	0	1.64	0	0	0	0.28	0	0	0	0.14	0	0	0	0	0	0	5.18	1.19
Thalassoma trilobatum	16	89	0	0	0	0	0	0.89	0	1.05	0	0.32	0	0	0	0	0	0	0	0	0	0	2.26	0.52
Pseudobalistes fuscus	18	201	0	0	0.04	0	0	0.53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.58	0.13
Pseudobalistes fuscus	21	302	0	0	0.03	0	0	0.58	0	0	0	0.16	0.04	0.05	0	0	0	0	0	0	0	0	0.87	0.20
Site 3: Outer Lagoon 2																								
Acanthurus nigrofuscus	14	62	2.72	0.80	0	2.19	1.66	0	0.81	14.7	2.73	7.72	0	1.42	2.58	3.73	0.23	0.48	0	0	0	0	41.8	9.62
Cheilinus trilobatus	24	318	0	0.56	0	2.00	0.99	0	0	8.08	1.73	5.45	0	0.89	1.71	2.48	0.16	0.33	0	0	0	0	24.4	5.61
Hemigymnus melapterus	19	126	3.00	0.91	0	3.40	1.80	0	0	8.66	0.42	1.96	0	0	0.28	1.17	0.13	0.22	0	0	0	0	22.0	5.05
Hemigymnus melapterus	18	148	2.51	0.91	2.62	0.29	0.56	0	0	3.11	0	0.69	0.13	0.08	0.59	3.26	0.26	0.66	1.11	0	0	0	16.8	3.86
Lethrinus obsoletus	21	190	0	0.67	0	0	0.31	0	0	2.98	0	0.73	0	0	0	0.46	0	0	0	0	0	0	5.15	1.18
Naso unicornis	20	136	3.00	5.24	0	2.85	2.20	0	0	14.4	3.97	11.0	0.23	2.48	4.51	4.83	0.67	1.07	0.54	0	0	0	57.0	13.1
Parupeneus barberinus	24	244	1.78	1.20	2.21	0	0.44	0	0	2.09	0	0.61	0	0	0	0.43	0	0	0	0	0	0	8.76	2.01
Scarus ghobban	26	322	2.17	0.93	2.24	1.28	1.23	0	0.70	6.45	1.15	3.25	0	0.68	0.81	1.68	0	0.53	0.36	0	0	0	23.5	5.40
Scarus ghobban	26	308	1.63	0.86	0.13	1.26	1.00	0	0	4.0	0.09	0.91	0	0	0	0	0	0	0	0	0	0	9.85	2.26
Sacrus globiceps	20	182	0	0	0.01	0.71	0	0	0	3.5	1.04	2.76	0	0.48	1.18	0.68	0.10	0.13	0	0	0	0	10.6	2.43
Scarus globiceps	21	226	2.20	1.38	0	1.10	0.64	0	0	4.2	0	0.71	0	0.07	0	0.82	0	0.07	0	0	0	0	11.2	2.58
Site 4: Tanapag Reef Shoals																								
Acanthurus nigricans	17	124	0	0	0	0	0.08	0.16	0	0	0	0.09	0	0.03	0.03	0.02	0	0	0	0	0	0	0.42	0.10
Chelinus trilobatus	16	89	0	0	0	0.76	0	0	1.79	0	0.72	0	0	0	0	0	0	0	0	0	0	0	3.27	0.75
Ctenochaetus striatus	17	116	0	0	0	0	0	0.48	0	0	0	0.12	0	0.10	0	0	0	0	0	0	0	0	0.71	0.16
Ctenochaetus striatus	17	92	0	0	0	0	0.06	2.06	0	0	0	0.22	0	0.11	0	0	0	0	0	0	0.42	1.03	3.90	0.90
Ctenochaetus striatus	12	47	0	0	0	0	0	1.98	1.46	0	0.43	0	0	0	0	0.55	0	0	0	0	0	0	4.42	1.02
Ctenochaetus striatus	11	38	0	0	0	0	0	1.50	1.08	0	0.38	0	0	0	0	0.46	0	0	0	0	0	0	3.42	0.79
Gnathodentex aurolineatus	18	160	0	0	0	3.82	4.15	0	7.62	1.29	1.87	0.39	0.36	0.51	0	0	0.15	0.09	0	0	0	0	20.2	4.66
Lethrinus harak	19	136	0	0.02	0.01	0	0.03	0	0	0.48	0.02	0.13	0	0	0.02	0.01	0	0.01	0.03	0	0	0	0.76	0.17
Lethrinus harak	19	100	0	0	0.02	0	0.05	0.10	0	0	0.08	0.24	0	0.10	0.30	0.22	0.11	0.19	0	0.08	0.10	0	1.57	0.36
Lethrinus harak	16	76	0	0	0	3.37	3.21	0	6.06	1.05	1.83	0.50	0.35	0.29	0	0.57	0.21	0.38	0.08	0	0.17	0	18.1	4.16
Lethrinus harak	18	110	0	0	0	1.82	2.27	0	3.15	0.70	1.02	0.14	0.21	0.30	0	0	0.110	0	0	0	0	0	9.72	2.24
Lutjanus kasmira	17	90	0	0	0.01	0	0.09	0	0	0	0.23	0.34	0	0.21	0	0.34	0.26	0.56	0.32	0.17	1.46	0	3.99	0.92
Lutjanus kasmira	15	46	0	0	0	0	5.14	0	10.1	1.08	3.30	0.57	0.75	0.97	0	0	0.48	0.13	0	0	0	0	22.5	5.18

PCB Congeners in Axial Muscle of Fish from Saipan Lagoon (2004-2005)

Site and Species Identity	Fork Length	Weight	PCB Congener Concentrations (ng/g dry weight)																				Σ_{20}PCB	
			8	18	28	44	52	66	77	101	105	118	126	128	138	153	170	180	187	195	206	209		
	(cm)	(g)	(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})	(dry)	(wet)
Site 4: Tanapag Reef Shoals (cont.)																								
Myripristis berndti	14	85	0	0	0	10.4	9.95	0	25.6	4.10	7.25	1.66	1.50	2.11	0	0.74	0.65	0.32	0	0	0	0	64.2	14.8
Myripristis pralina	13	57	0	0	0	0	7.25	0	13.0	3.07	3.64	0	0.78	1.06	0	0.46	0.31	0.13	0	0	0	0	29.7	6.84
Myripristis pralina	12	51	0	0	0	5.26	5.54	0	11.8	3.09	3.89	0.76	0.91	1.23	0	0.85	0.44	0.15	0	0	0	0	33.9	7.79
Myripristis pralina	12	57	0	0	0	12.3	11.3	0	28.8	0	9.31	2.15	2.16	2.38	0	1.27	0.75	0	0.40	0.38	1.25	0	72.4	16.7
Myripristis pralina	12	51	0	0	0	0.21	0	3.44	0	0	0.48	0.03	0.06	0	0	0	0.52	0.22	0	0	0.44	0	5.41	1.24
Myripristis sp.	14	82	0	0	0	8.83	0	0	23.1	6.2367	0	0	0	0	0	0	0	0	0	0	0	0	38.2	8.79
Naso lituratus	18	112	0	0	0	0	0.05	0.23	0	0.67	0	0.10	0	0.07	0	0	0	0	0	0	0	0	1.12	0.26
Naso lituratus	16	98	0	0	0.01	0.04	0.19	0.07	0	0	0.03	0.16	0	0.09	0	0.02	0	0.07	0.07	0	0.65	0.66	2.06	0.47
Naso lituratus	12	39	0	0	0	1.64	5.49	5.26	6.74	1.47	2.40	0.04	0.40	0.50	0	0	0.37	0	0	0	0	0	24.3	5.59
Naso lituratus	12	35	0	0	0	0.29	0	2.80	0	0	0.67	0	0	0	0	0	0	0	0	0	0	0	3.77	0.87
Naso unicornis	19	168	0	0	0	0	0.03	0	0	0	0	0.03	0	0	0	0	0	0.04	0.17	0	0	0	0.27	0.06
Naso vlamingii	17	109	0	0	0.02	1.09	0	0	3.73	0	0	0	0	0	0	0	0	0	0	0	0	0	4.84	1.11
Parupeneus barberinus	17	99	0	0	0.03	0.01	0	0.33	0	0.21	0.10	0	0	0.05	0	0	0.06	0.06	0.04	0.04	0.10	0	1.03	0.24
Rhinecanthus aculeatus	15	102	0	0	0.01	0	0.08	0.68	0	0.65	0	0.10	0	0.14	0	0	0	0	0	0	0	0	1.67	0.38
Rhinecanthus aculeatus	15	93	0	0	0	0	0	0.45	0	0	0	0.14	0	0.08	0	0.02	0	0.12	0	0	0	0	0.81	0.19
Rhinecanthus aculeatus	12	42	0	0	0	13.3	10.5	0	35.7	0	13.3	1.49	3.43	3.55	0	0	1.66	0	0	0	0	0	83.0	19.1
Scarus sordidus	25	355	0	0	0.13	0.15	1.25	0	0	0.50	0.35	4.45	0.14	0.13	0	0	0	0	0	0	0	0	7.10	1.63
Scarus sordidus	19	125	0	0	0	0.71	1.08	0	1.91	0.55	0.58	0.08	0.18	0.32	0	0.08	0.05	0	0	0	0	0	5.55	1.28
Scarus sordidus	17	82	0	0	0	0.94	1.77	0	2.48	0.69	0.83	0.15	0.26	0.37	0	0	0.08	0	0	0	0	0	7.58	1.74
Siganus spinus	16	84	0	0	0	0	0.05	0.13	0	0	0.31	0.32	0	0.48	0.34	0.04	0.54	0.48	0.50	0.56	0.76	0.72	5.22	1.20
Trigger fish unknown	16	89	0	0	0	3.14	4.30	0	7.03	1.63	2.32	0.22	0.78	1.06	0	0.32	0.38	0	0	0	0	0	21.2	4.88
Site 5: Seaplane Reefs																								
Acanthurus lineatus	16	114	0	0	0	0	0	0.71	0	0	0	0.29	0	0	0.05	0.17	0	0	0	0	0	0	1.22	0.28
Acanthurus lineatus	16	118	0	0	0	0	0.18	0	0	2.20	0	0	0.08	0	0	0	0	0	0	0	0	0	2.46	0.57
Acanthurus lineatus	16	121	0	0	0	0	0	0	0	1.37	0	0	0	0	0	0.03	0	0	0.021	0	0	0	1.42	0.33
Acanthurus lineatus	16	113	0	0	0.04	0	0.03	0	0	0	0.15	0.57	0.28	0.11	0.18	0.22	0	0.03	0	0	0	0	1.61	0.37
Acanthurus lineatus	15	112	0	0	0.01	1.28	0	0.95	0.23	0	0.15	0.62	0	0.11	0.02	0.31	0.03	0.08	0	0	0	0	3.79	0.87
Calatomus carolnus	21	218	0	0	0	1.82	1.69	0	2.81	0.07	0.52	0.09	0.14	0.13	0	0	0.07	0.03	0	0	0.09	0	7.5	1.72
Carax malampygus	24	251	0	0	0	0.53	0.32	0	0	0.57	0	0.43	0	0.03	0.12	0.69	0.00	0.28	0.07	0	0	0	3.04	0.70
Chaetodon ornatissimus	14	98	0	0	0	0	0	0	0	0.37	0	0.34	0	0	0	0.68	0	0.24	0.09	0	0	0	1.72	0.39
Cheilinus trilobatus	21	230	0	0	0	0.98	0.25	0	0.31	0	0	0	0	0	0	0	0	0.03	0	0	0	0	1.56	0.36
Cheilinus trilobatus	18	110	0	0	0	2.12	1.86	0	3.58	0	0.87	0.16	0.25	0.25	0	0	0	0.10	0	0.062	0	0	9.26	2.13
Coris aygula	30	489	0	0	0	0	3.41	0	0	2.07	1.85	0.23	0.48	0.70	0.64	0	0.66	0.93	0.97	1.08	0	0	13.0	2.99
Epinephelus houlandi	23	200	0	0	0	0.43	0.06	0	0	0.12	0	0.22	0	0	0	0.38	0	0.15	0	0	0	0	1.35	0.31
Epinephelus houlandi	23	218	0.81	0	0	0.81	0.66	0	0.14	0	0.23	0.81	0.02	0.13	0.35	0.39	0.14	0.28	0.19	0.05	0.14	0	5.15	1.18
Epinephelus merra	28	344	0	0	0	1.77	0.67	0	0.55	5.46	0.52	1.95	0	0.22	1.28	2.56	0.74	1.74	0.61	0.10	0.25	0.36	18.8	4.32
Lethrinus harak	24	276	0	0	0	1.05	0.18	0	0	0.99	0	0	0	0	0	0	0	0	0	0	0	0	2.21	0.51
Lethrinus harak	18	110	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0	0.04	0.01
Lethrinus harak	16	77	0	0	0	0	2.98	0	5.12	0	1.26	0.23	0.33	0.36	0	0	0.17	0.14	0.10	0.08	0	0	10.8	2.48
Lutjanus kasmira	19	102	0	0	0	0	0	0	0	1.84	0	0	0	0	0.19	0	0	0	0	0	0	0	2.03	0.47
Myripristis berndti	11	49	0	0	0	0	0	0	0	0.60	0	0.61	0	0	0	1.29	0.14	0.57	0.24	0	0	0	3.44	0.79
Myripristis berndti	10	32	0	0	0	10.7	11.3	0	31.09	3.19	8.30	1.07	1.50	2.09	0	0	0.81	0	0	0	0	0	70.0	16.1

PCB Congeners in Axial Muscle of Fish from Saipan Lagoon (2004-2005)

Site and Species Identity	Fork Length	Weight	PCB Congener Concentrations (ng/g dry weight)																				Σ_{20}PCB	
			8	18	28	44	52	66	77	101	105	118	126	128	138	153	170	180	187	195	206	209		
	(cm)	(g)	(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})	(dry)	(wet)
Site 5: Seaplane Reefs (cont.)																								
Naso lituratus	20	179	0	0	0	0	0	0	0	2.33	0	0	0	0	0	0	0	0	0	0	0	0	2.33	0.54
Naso lituratus	15	77	0	0	0	0	0	0	0	2.70	0	0	0	0	0	0	0	0	0	0	0	0	2.70	0.62
Naso lituratus	14	62	0	0	0	0	0.23	0	3.70	3.83	0	0	0	0	0.12	0.468	0	0	0	0	0	0	8.33	1.92
Naso lituratus	19	163	0	0	0	1.64	2.13	0	0	4.72	0.105	1.29	0	0	0.23	0.699	0	0	0	0	0	0	10.8	2.49
Naso lituratus	16	107	0	0	0	0	0	0	0	1.96	0	0	0	0	0.43	0	0	0	0	0	0	0	2.39	0.55
Naso lituratus	18	150	0	0.02	0	1.13	1.37	0	0.18	3.85	0.09	1.22	0	0	0.11	0.68	0	0	0.00	0	0	0	8.67	1.99
Naso lituratus	14	71	0	0	0	0.59	0.30	0	0	1.29	0	0.72	0	0	0.18	0.50	0	0	0.06	0	0	0	3.63	0.84
Naso lituratus	15	88	0	0	0	0.85	0	0	0	2.74	0.234	1.50	0	0.06	0	0.91	0	0	0.34	0	0	0	6.64	1.53
Naso lituratus	13	57	0	0	0	0.55	0.34	0	0.19	1.43	0.15	0.94	0	0.13	0.22	0.53	0	0	0	0	0	0	4.48	1.03
Naso lituratus	16	102	0	0	0	0.55	0.39	0	0	1.49	0	0.68	0	0	0.13	0.50	0	0.00	0	0	0	0	3.75	0.86
Naso lituratus	18	145	0	0	0	0	0	0	0	4.31	0	0.12	0	0	0	0	0	0.16	0	0	0	0	4.60	1.06
Naso lituratus	15	71	0	0	0	0	0	0	0	4.06	0	0	0	0	0	0	0	1.34	0	0	0	0	5.40	1.24
Naso lituratus	15	76	0	0	0	0	0	0.05	0	0	0	0.07	0	0	0	0.08	0	0	0.02	0	0.03	0	0.25	0.06
Naso lituratus	15	71	0	0	0	0	0.32	0	0.54	3.00	1.64	3.13	0	1.02	2.09	1.53	0.42	0.59	0.22	0	0	0	14.5	3.34
Rhinecanthus rectangulus	16	106	0	0	0	1.83	0.81	0	0.33	4.91	0.47	1.18	0	0.07	0.26	0.40	0	0.10	0	0	0	0	10.4	2.38
Sargocentron spiniferum	13	64	0	0	0	3.60	4.05	0	9.86	0	3.26	0.37	0.75	1.41	0	0	0.50	0.25	0	0	0	0	24.0	5.53
Scarus ghobban	27	416	0	0	0	1.33	1.01	0	0	1.70	0	0.43	0	0	0	0.15	0	0	0	0	0	0	4.62	1.06
Scarus ghobban	21	215	0	0.04	0	1.12	0.78	0	0.16	1.80	0.07	0.65	0	0.03	0	0.28	0	0	0	0	0	0	4.92	1.13
Scarus psittacus	19	189	0	0	0	0.90	0.31	0	0.21	1.50	0	0	0	0	0	0	0	0	0	0	0	0	2.93	0.67
Scarus sp.	23	245	0	0	0	1.32	0.48	0	0.49	4.09	0.51	1.51	0	0.21	0.66	0.67	0.05	0	0	0.03	0.08	0	10.1	2.33
Sphyraena flavicauda	36	256	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.24	5.24	1.20
Triaenodon obesus	59	1376	21.1	11.1	0	0	0	0	0	1.72	0	0	1.40	0	0	0	0	0	0	0	0	0	35.4	8.14
Triaenodon obesus	duplicate		0	0	0	0	0	0.30	0	0	0	0.07	0	0	0	0.34	0	0.07	0.06	0	0	0	0.85	0.19
Zanclus cornutus	14	97	0	0	0	11.4	12.7	0	25.1	3.59	6.87	1.09	1.43	1.89	0	0	0.57	0.20	0	0	0	0	64.9	14.92
Site 6: Puerto Rico Dump																								
Acanthurus lineatus	10	30	0	0	0	0	0	0	0	1.89	0	0	0	0	0	0	0	0	0	0	0	0	1.89	0.43
Acanthurus nigricauda	15	84	0	0	0	0	0.15	0	0.10	2.17	0.29	1.07	0	0.18	0.43	0.53	0.07	0.21	0.15	0	0	0	5.35	1.23
Acanthurus nigrofuscus	16	98	0.12	0	0	0.24	0.04	0	0.14	1.27	0.04	0.34	0	0	0	0.09	0	0	0.04	0	0	0	2.32	0.53
Acanthurus nigrofuscus	15	90	0	0	0	1.23	0.74	0	0.19	4.51	0.96	2.63	0	0.41	1.20	1.05	0.12	0.20	0.13	0	0	0	13.4	3.07
Balistoides viridescens	17	140	2.04	0.62	0	1.22	0.41	0	0	5.40	0.09	0.89	0	0	0	1.05	0	0.49	0	0	0	0	12.2	2.81
Lethrinus harak	13	42	3.71	1.36	0	1.29	0.60	0	0	6.21	1.08	2.92	0	0.89	1.45	4.10	0.61	1.49	1.15	0.12	0	0	27.0	6.21
Lethrinus harak	15	56	2.54	1.77	4.99	2.04	0.69	0	0	5.76	0	1.56	0	0.22	0	3.02	0	1.90	1.21	0	0	0	25.7	5.91
Lethrinus harak	15	70	0	0	0.02	0.46	0	0	0.21	2.17	0.31	1.08	0.20	0.31	0.57	1.25	0.39	0.57	0.53	0.29	0.42	0.47	9.24	2.12
Myripristis berndti	11	38	0.44	0	0.41	0	0.17	1.85	0	2.94	0.12	1.14	0	0.15	0	0.62	0	0.20	0.53	0	0	0	8.56	1.97
Myripristis berndti	10	34	0	0	0	0	0	0	0.07	2.88	0.67	2.60	0	0.46	0.98	1.23	0.13	0.29	0.18	0	0	0	9.51	2.19
Myripristis berndti	10	34	0	0	0	0	0	0	0.10	2.22	0.13	1.27	0	0.17	0.12	0.75	0.14	0.36	0.21	0	0	0	5.48	1.26
Myripristis berndti	12	46	0	0	0.17	0	0.15	0	0	3.00	0.40	1.58	0	0.41	0.81	1.46	0.16	0.43	0.63	0	0	0	9.22	2.12
Myripristis berndti	12	54	0	0	0	1.30	1.10	0	0.10	7.62	1.98	5.75	0	0.88	2.13	2.28	0.24	0.52	0.27	0	0	0.62	24.8	5.71
Myripristis berndti	12	54	0	0	0.24	0	0.04	0	0.05	1.76	0.17	1.04	0.15	0.27	0.54	0.93	0.20	0.45	0.28	0.08	0.12	1.98	8.31	1.91
Myripristis berndti	11	40	0	0	0.04	0	0.11	0	0.08	1.95	0.07	1.01	0	0.19	0.34	1.02	0.20	0.49	0.36	0.06	0.12	0	6.05	1.39
Myripristis violacea	11	46	0	0	0	0	0.08	0	0	1.22	0.08	0.57	0	0.04	0	0.27	0	0	0.06	0	0	0	2.33	0.54
Myripristis violacea	12	62	0.18	0	0	0	0.11	0	0.16	2.35	0.43	1.70	0	0.41	1.16	1.94	0.18	0.50	0.25	0	0	0	9.38	2.16

PCB Congeners in Axial Muscle of Fish from Saipan Lagoon (2004-2005)

Site and Species Identity	Fork Length	Weight	PCB Congener Concentrations (ng/g dry weight)																				$\sum_{20}$PCB	
			8	18	28	44	52	66	77	101	105	118	126	128	138	153	170	180	187	195	206	209		
	(cm)	(g)	(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})	(dry)	(wet)
Site 6: Puerto Rico Dump (cont.)																								
Myripristis violacea	12	62	0	0	0.15	0.34	0.96	0	0.14	4.89	1.24	3.71	0	0.75	2.01	2.67	0.34	0.79	0.52	0.03	0.11	0.12	18.8	4.32
Myripristis violacea	13	66	0	0	0.11	0	0.18	0	0.10	0	0.46	2.01	0	0.52	0.82	2.33	0.55	1.22	0.75	0.05	0.22	0.63	9.96	2.29
Naso lituratus	15	64	0.48	1.04	2.92	0	0.43	0	0	0	0	0.27	0	0.08	0	0	0	0.26	0.29	0.37	0	0.68	6.81	1.57
Naso lituratus	15	64	2.61	0.90	0	0	0.26	5.84	0	0	0	0.17	0	0.12	0	0	0.06	0.09	0	0	0	0	10.1	2.31
Naso lituratus	15	74	0	0.87	0	0	1.10	0	0	5.17	1.63	3.76	0	1.09	2.08	1.53	0.29	0.81	0.59	0	0	0.34	19.2	4.43
Naso lituratus	15	64	2.33	1.67	3.70	0	0	0	0	2.89	0	1.01	0	0.18	0	1.68	0	0.07	0	0	0	0	13.5	3.11
Naso lituratus	15	70	1.27	0.70	0.83	0	0.32	0	0	2.08	0	0.35	0	0.20	0	0	0	0.14	0	0	0	0	5.88	1.35
Naso lituratus	15	64	2.13	1.57	3.48	0	0	0	0	3.36	0.11	1.33	0.15	0.16	0	0	0	0.33	0	0	0	0	12.6	2.90
Naso lituratus	17	88	3.08	1.03	0	0	0.28	0	0	4.28	0.20	1.18	0	0.18	0	1.81	0	0.41	0.16	0	0	0	12.6	2.90
Naso lituratus	15	70	2.96	1.47	0.26	0	0.74	0	0	7.41	1.43	4.05	0.58	0.82	0.72	2.37	0	0.51	0	0	0	0	23.3	5.36
Naso lituratus	16	84	2.63	1.28	0	0	1.20	0	0.89	5.47	0	1.01	0	0.18	0	0	0	0.51	0.34	0	0	0	13.5	3.11
Naso lituratus	16	80	2.04	2.51	0	0	0	0	0	8.42	2.57	5.58	0	1.34	1.60	4.83	0	0.75	0.41	0	0	0	30.1	6.91
Naso lituratus	15	68	3.51	2.38	6.30	1.66	2.39	0	0	19.3	6.11	13.1	0.16	3.07	4.65	6.92	0	1.15	0.47	0	0	0	71.1	16.4
Naso lituratus	16	78	2.67	1.94	0.35	0	0	0	0	5.40	0.25	1.15	0.87	0	0	0.15	0	0	0	0	0	0	12.8	2.94
Naso lituratus	17	98	0.93	0.57	2.17	0.50	2.27	0	0	11.0	3.45	8.28	0	2.02	3.96	6.22	0.85	1.48	0.65	0	0.17	0	44.5	10.2
Naso lituratus	17	92	0	0	0.16	3.53	2.68	0	0	27.8	10.2	24.3	4.41	5.94	13.3	14.3	2.41	3.71	1.23	0	0.72	1.14	116	26.7
Naso unicornis	18	118	1.49	0	0.09	0.37	0.08	0	0	0.66	0.04	0.14	0	0	0	0.19	0	0	0	0	0	0	3.07	0.71
Neoniphon opercularis	15	60	0	0	0	0	0	0	0.08	1.10	0.12	0.68	0	0.12	0.35	0.68	0.12	0.33	0.25	0	0.08	0.16	4.10	0.94
Parupeneus multifasciatus	17	84	10.5	6.68	0.83	0	2.67	0	0	12.3	3.20	7.81		2.54	3.82	16.1	2.02	6.95	4.43	0	0	0	79.9	18.4
Parupeneus multifasciatus	13	50	2.53	2.35	0	0	1.02	0	0	10.6	0.50	3.01	0	0.42	0.56	4.25	0.57	2.67	0	0	0.88	0	29.4	6.76
Sargocentron spiniferum	18	120	0	0	0.08	0	0.13	0	0.11	0.96	0.19	0.86	0	0.19	0.07	0.42	0.09	0.13	0.10	0	0	0	3.34	0.77
Siganus spinus	15	56	0	0	0	0	0	0	0	2.22	0.15	0.77	0.02	0.17	0	0.43	0.04	0	0.18	0	0	0	3.98	0.91
Site 7: Micro Beach Point																								
Acanthurus blochii	13	60	0	0	0.05	1.56	1.94	0	3.89	0.89	1.18	0.12	0.36	0.44	0	0.19	0.18	0	0.08	0	0.16	0	11.0	2.54
Lethrinus harak	14	46	0	0	0	0	0	0	0	0.45	0	0.39	0	0	0	0.66	0	0.30	0.08	0	0	0	1.87	0.37
Lutjanus monostigmus	13	32	0	0	0	0	0	2.46	0	0	0	0.63	0	0	0	0.25	0	0	0	0	0	0	3.34	0.67
Rhinecanthus aculeatus	13	50	0	0	0	0	0	1.06	0	0	0	0	0	0	0	0.16	0	0	0	0	0	0	1.22	0.24
Site 8: Micro Reef Complex																								
Acanthurus lineatus	19	202	0	0.22	0	0	1.29	0	0	3.36	0.82	2.78	0	0.74	1.77	1.71	0.26	0.71	0.17	0	0	0	13.8	2.76
Acanthurus lineatus	17	171	0	0	0	0	1.29	0	0	2.27	0.37	1.30	0	0.34	0.93	0.96	0	0.13	0	0	0	0	7.59	1.52
Acanthurus lineatus	duplicate		0	0	0.11	0.13	0.12	1.52	0	1.59	0.36	1.13	0	0.37	0.53	0.72	0	0.17	0	0	0	0	6.76	1.35
Acanthurus lineatus	18	150	0	0	0	0	0.81	1.64	0	0	0	0.15	0	0	0		0	0.07	0	0	0	0	2.67	0.53
Acanthurus lineatus	18	146	0	0	0	0	1.10	0	0	0	0.07	0.33	0	0.13	0.30	0.15	0	0	0.12	0	0	0	2.21	0.44
Acanthurus lineatus	19	152	27.5	0.34	0	0	1.11	0	0	2.66	0	0.20	0	0	0	0.14	0	0	0.15	0	0	0	32.1	6.42
Acanthurus lineatus	18	162	0	0	0.14	0	0.27	0	0	1.66	0	0.08	0	0	0	0.21	0	0	0	0	0	0	2.35	0.47
Acanthurus lineatus	19	161	0	0.84	0	0	2.02	0	0.17	0	0	0	0	0.10	0	0	0	0.05	0	0	0	0	3.17	0.63
Acanthurus lineatus	duplicate		0	0	0	0.36	0.08	0	0	1.10	0	0.20	0	0	0	0.22	0	0	0	0	0	0	1.97	0.39
Acanthurus lineatus	18	168	0	0	0	0	0	1.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.17	0.23
Acanthurus lineatus	duplicate		0	0	0	0	0.05	1.42	0	0	0	0	0.07	0	0	0.14	0	0.19	0.27	0	0	0	2.14	0.43
Acanthurus lineatus	18	155	0	0	0	0	0	0	0.96	0	1.50	2.61	0	0.73	2.19	0.85	0	0.58	0.24	0	0	4.79	14.4	2.89
Acanthurus lineatus	17	154	0	0	0	0	0.51	0	0	3.31	0.52	1.58	0	0	0	1.94	0	0	0	0	0	0	7.85	1.57

PCB Congeners in Axial Muscle of Fish from Saipan Lagoon (2004-2005)

Site and Species Identity	Fork Length	Weight	PCB Congener Concentrations (ng/g dry weight)																				Σ_{20}PCB	
			8	18	28	44	52	66	77	101	105	118	126	128	138	153	170	180	187	195	206	209		
	(cm)	(g)	(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})	(dry)	(wet)
Site 8: Micro Reef Complex (cont.)																								
Acanthurus lineatus	19	181	0	0	0	0	0.60	0	0	5.25	0	0	0	0	0	0	0	0	0	0	0	0	5.85	1.17
Acanthurus lineatus	19	176	0	0	1.55	0	0	0	0.29	0	0	0.41	0	0	0	0	0	0	0	0	0	0	2.25	0.45
Acanthurus lineatus	18	142	0	0	0	0	0.14	0	0	0	0	0.22	0	0	0	0.18	0	0	0	0	0	0	0.54	0.11
Acanthurus lineatus	18	122	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09	0	0	0	0	0	0	0.09	0.02
Acanthurus lineatus	17	137	0	0.13	0	0.09	0.02	0.69	0.11	0	0	0	0.04	0.02	0	0	0.08	0.39	0.06	0.06	0.04	0	1.74	0.35
Acanthurus lineatus	18	139	0	0.07	0	0.39	0.09	0	0	0.87	0.23	0.77	0	0.08	0.34	0.37	0.09	0.10	0.07	0	0	0	3.47	0.69
Acanthurus lineatus	19	146	0.12	0.24	0	0.14	0	1.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.53	0.31
Acanthurus lineatus	16	128	0	0.00	0	0.45	0	0.74	0	0.44	0.01	0.28	0	0.00	0.03	0.22	0.07	0.08	0.06	0	0	0	2.39	0.48
Acanthurus lineatus	16	121	0	0.15	0	0.05	0	0.69	0	0	0	0	0	0	0	0	0	0.02	0.06	0	0	0.25	1.22	0.24
Acanthurus lineatus	17	116	0	0.03	0	0.31	0.20	0	0	1.04	0.27	0.86	0	0.11	0.29	0.47	0.09	0.12	0.05	0	0	0	3.85	0.77
Site 9: Hafa Adai Beach																								
Acanthurus lineatus	19	171	0	0.81	0	0	0.42	0	0	1.40	0	0.52	0	0.43	0	0	0	0.08	0.26	0	0	0	3.92	0.78
Acanthurus nigricans	15	113	4.47	4.11	0	0	0.31	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0	0.52	9.58	1.92
Calotomus carolinas	21	223	0	0.38	0	0.78	2.29	0	0	3.59	0.16	0.96	0	0.22	0.55	0.60	0	0.08	0	0	0	0	9.60	1.92
Calotomus carolinas	20	197	0.50	0.35	0	0	0.39	1.32	0	0	0	0	0	0	0	1.41	0	0	0	0	0	0	3.96	0.79
Calotomus carolinas	duplicate		0	0	0.05	0	0.02	0	0	0.31	0	0	0	0	0	0	0	0	0	0	0	0	0.38	0.08
Ctenochaetus striatus	17	120	0	0.95	1.06	0	0.73	0	0	3.72	1.02	3.06	0	0.70	1.19	0.81	0.16	0.33	0.18	0	0	0	13.9	2.78
Gnathodentex aurolineatus	16	97	2.37	1.88	4.18	2.57	3.52	0	1.53	12.3	5.99	12.8	1.16	5.10	8.39	7.08	3.27	3.64	2.45	1.85	2.09	2.56	84.7	16.9
Heteropriacanthus cruentatu	20	123	0.69	0.98	2.09	0	0.54	0	0	1.60	0	0.80	0	0.20	0.36	0	0	0.18	0.49	0	0	0.55	8.49	1.70
Lethrinus harak	21	179	0	0	0	0	0	0.81	0	0.43	0	0	0	0	0	0	0	0	0	0	0	0	1.24	0.25
Lethrinus harak	23	258	0	0	0	0	0	0.77	0	0.39	0.13	0.07	0.02	0.08	0	0.17	0.07	0.09	0.06	0.02	0	0	1.88	0.38
Lethrinus harak	23	243	0	0	0.01	0.42	0.15	1.55	0	1.09	0.71	1.47	0.07	0.49	0.50	0.91	0.26	0.27	0.15	0.08	0.07	0	8.20	1.64
Lethrinus harak	24	308	0	0	0	0.47	0	0.92	0	0.73	0.43	0.53	0.10	0.28	0.17	0.38	0.19	1.03	0.15	0.13	0.16	0.11	5.78	1.16
Lethrinus harak	19	147	0	0	0	0	0	1.28	0	0	0	0	0	0	0	0.01	0.06	0	0	0	0	0	1.35	0.27
Lethrinus harak	20	171	0	0	0.02	1.08	0.10	0	0	1.12	0.46	0.78	0	0.25	0.59	0.48	0.07	0.12	0.06	0	0	0	5.12	1.02
Lutjanus fulvus	17	90	0.66	0.48	0	0	0.92	0	0	2.54	0	1.10	0	0	0.58	0	0	0.70	0.48	0	0	0	7.45	1.49
Myripristis amaena	16	95	0	0.40	0	0.68	0.91	0	0.32	3.27	0.10	1.18	0	0.30	0.42	0.10	0.12	0.23	0.21	0.06	0	0.60	8.90	1.78
Myripristis amaena	15	88	0	0	0	1.25	0.36	1.92	0	0	0	0.46	0	0.10	0.09	0.21	0	0.69	0	0	0	0	5.07	1.01
Myripristis berndti	13	61	2.21	1.72	6.55	0	2.25	0	0	3.86	0	1.46	0	0.51	0.46	0	0	0.59	0.34	0	0	1.94	21.9	4.38
Myripristis kuntee	13	67	0.67	0.46	0	0	0.75	0	0	3.60		1.62	0	0.39	0.80	0.30	0.09	0.64	0.26		0.24	0.46	10.3	2.06
Myripristis murdjam	14	77	1.29	1.15	4.44	0.85	1.00	0	0.20	3.51	0	1.19	0	0.35	0.42	0	0	0.24	0.81	0.05	0.07	0.61	16.2	3.23
Myripristis pralina	15	97	0	0	0	0.68	0.41	2.08	0	1.71	0	0.31	0	0.09	0	0.36	0	0.17	0	0	0	0	5.79	1.16
Myripristis pralina	14	78	0	1.10	3.32	0.96	1.30	0	0	4.52	0.29	2.46	0	0.69	0.12	0.40	0.29	0.54	0.25	0	0	1.32	17.6	3.51
Myripristis violacea	17	105	0	0	0	0	0.63	2.32	0	0	0.26	0.77	0	0.28	0.47	0.60	0.08	0.19	0.34	0	0	0	5.93	1.19
Myripristis violacea	14	80	0	0	0	0.94	1.01	0	0	4.16	0.71	2.40	0	0.56	1.30	1.47	0.13	1.36	0.40	0	0	0	14.4	2.89
Myripristis violacea	13	72	0	0	0	0	0.41	3.31	0	0	0	0.78	0	0	0.10	0.51	0	0.30	0	0	0	0	5.41	1.08
Myripristis violacea	14	77	0	0	0	1.71	1.85	2.67	0	0	0	0.42	0	0.21	0	0.39	0	0.37	0	0	0	0.31	7.92	1.58
Myripristis violacea	13	69	0	0	0	0	0	2.31	0	0	0	0.15	0	0.09	0	0.15	0	0.53	0	0	0	0	3.24	0.65
Myripristis violacea	15	77	0	0	0	2.12	0.75	0	0	0	0	0.76	0	0.15	0	0.77	0	0.54	0	0	0	0	5.09	1.02
Myripristis violacea	13	57	0	0	0	1.58	1.37	4.60	0	3.53	0.16	1.18	0	0.19	0	0.39	0	2.22	0	0	0	0	15.2	3.04
Naso lituratus	18	135	5.10	6.91	0	0	1.74	0	0.23	8.94	2.87	7.04	0	0	0	2.93	1.97	1.42	1.43	0	0	0	40.6	8.11
Naso lituratus	20	178	2.46	4.77	0	0	0.71	0	0	0	0.07	0.62	0	0.13	0	0	0.15	0	0.87	0.11	0.11	0	9.99	2.00

PCB Congeners in Axial Muscle of Fish from Saipan Lagoon (2004-2005)

Site and Species Identity	Fork Length	Weight	PCB Congener Concentrations (ng/g dry weight)																				$\sum_{20}$PCB	
			8	18	28	44	52	66	77	101	105	118	126	128	138	153	170	180	187	195	206	209		
	(cm)	(g)	(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})	(dry)	(wet)
Site 9: Hafa Adai Beach (cont.)																								
Naso lituratus	20	198	0.28	0.24	0	1.78	2.26	0	0.72	12.0	4.28	10.0	0	2.53	0	5.04	0.90	1.37	0.49	0	0.12	0	42.1	8.41
Neoniphon sammara	15	63	1.32	0	0	0	1.11	0	0	0	0	0.37	0	0	0.56	1.18	0.23	1.25	0.39	0	0	0	6.40	1.28
Neoniphon sammara	16	75	0	0	0	0	0.58	0	0	3.16	0.13	1.19	0	0.39	0.67	0	0	0.42	0.39	0	0.48	0	7.42	1.48
Neoniphon sammara	16	73	1.42	1.11	4.00	0	1.12	0	0	4.12	0.51	3.56	0	1.07	2.10	1.10	0.36	0.73	0.41	0	0.48	0.79	22.9	4.58
Parupeneus multifasciatus	17	101	0.85	1.47	1.63	0	1.55	0	0	1.53		1.94	0	0.67	1.36	0.91	0	0.97	0.83	0	0	0	13.7	2.74
Scarus ghobban	21	163	0	0	1.05	0.57	0.80	0	0	3.63	0.76	3.28	0	0.83	2.02	0.84	0.30	0.46	0.25	0	0	0	14.8	2.96
Site 10: Hafa Adai Beach to Fisherman's Base																								
Lethrinus atkinsoni	15	80	0	0	0	0.24	0.03	0.88	0	0.40	0	0	0	0	0	0	0	0	0	0	0	0	1.55	0.31
Lethrinus atkinsoni	18	131	0	0	0	0.16	0.08	0.64	0	0.22	0	0	0	0	0.04	0.18	0.04	0.23	0.17	0	0	0	1.75	0.35
Lethrinus harak	17	86	0	0	0	0	0	0.51	0	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0.67	0.13
Lethrinus harak	24	256	0	0	0	0.15	0.03	0.71	0	0.29	0.15	0.12	0	0.10	0.18	0.21	0.04	0.07	0.04	0	0	0	2.10	0.42
Lethrinus harak	22	236	0.05	0.13	0	0.16	0.10	0	0	1.03	0.13	0.86	0	0.07	0.46	0.57	0.09	0.15	0.11	0	0	0	3.92	0.78
Lethrinus harak	22	201	0.06	0.09	0	0.59	0.11	0	0	1.24	0.29	0.78	0	0.13	0	0.31	0.11	0.06	0	0	0	0	3.77	0.75
Lethrinus obsoletus	21	201	0	0	0	0.12	0	0.57	0	0.09	0	0	0	0	0	0	0	0.03	0.05	0	0	0	0.87	0.17
Lethrinus xanthocheilus	19	133	0	0	0	0.24	0.01	0.75	0	0.34	0	0	0	0	0	0	0	0	0	0	0	0	1.34	0.27
Lethrinus xanthocheilus	19	114	0	0	0	0	0.22	0	0	1.69	0.58	1.24	0	0.24	0	0.70	0	0	0	0	0	0	4.67	0.93
Lethrinus xanthocheilus	20	139	0	0	0	0.21	0	0	0	1.27	0.45	0.99	0	0.21	0.45	0.50	0.09	0.12	0.06	0	0	0	4.34	0.87
Site 11: Lighthouse to Micro Toyota																								
Lethrinus atkinsoni	17	118	0	0	0	0.57	0.12	0	0	1.88	0	0.20	0	0	0	0.13	0	0	0.14	0	0	0	3.04	0.61
Lethrinus atkinsoni	18	120	0	0	0	0.81	0.12	0	0.19	1.98	0.05	0.16	0	0	0	0.12	0	0.14	0.14	0	0	0	3.72	0.74
Lethrinus atkinsoni	16	87	0	0	0	0.84	0.42	0	0.19	3.83	1.05	2.70	0	0.57	1.20	1.45	0.13	0.19	0.25	0	0	0	12.8	2.57
Lethrinus atkinsoni	22	211	0	0	0	1.06	0.19	0	0	2.64	0.70	1.94	0	0.45	0.62	1.09	0.22	0.43	0.28	0	0	0	9.60	1.92
Lethrinus atkinsoni	19	148	0	0	0	1.81	0.96	0	0.29	9.06	2.77	6.93	0	1.43	0	3.39	0.46	0.59	0.39	0	0	0	28.1	5.62
Lethrinus atkinsoni	20	182	0	0	0.43	1.27	2.85	0	0	11.1	3.34	9.78	0	1.83	6.61	7.52	0.94	1.49	0.59	0.06	0	0	47.8	9.56
Lethrinus atkinsoni	19	138	0	0	0	0.55	0.27	0	0.13	1.70	0.35	1.00	0	0.35	0.29	0.61	0.14	0.19	0.35	0.05	0.07	0	6.05	1.21
Lethrinus atkinsoni	21	198	0	0	0	0.36	0.06	0	0	0.64	0	0.05	0	0	0	0.14	0	0.16	0.17	0	0.11	0.31	2.01	0.40
Lethrinus atkinsoni	21	200	0	0	0	0.64	0.09	0	0.07	3.47	0.09	0.71	0	0.08	0	0.47	0.02	0.62	0.39	0.03	0.26	2.04	8.97	1.79
Lethrinus atkinsoni	19	149	0	0	0	0.39	0.17	0	0.16	1.06	0.11	0.50	0.14	0.15	0.19	0.64	0.32	0.89	0.69	0.17	0.27	0.17	6.03	1.21
Lethrinus atkinsoni	21	163	0.24	0	0	1.06	0.33	0	0.34	4.12	1.73	4.43	0.21	1.14	1.17	2.41	0.68	0.79	0.86	0.22	0.30	0.27	20.3	4.06
Lethrinus harak	13	38	0	0	0	0.00	0.24	0	0	2.26	0	0.55	0	0	0	0.26	0	0	0	0	0	0	3.30	0.66
Lethrinus harak	19	143	0	0	0	0.61	0.04	0	0.33	2.95	0.11	0.39	0	0	0.05	0.19	0	0	0	0	0	0	4.66	0.93
Lethrinus harak	21	178	0	0	0	0	0.08	0	0	0.10	0	0.03	0	0	0	0.10	0	0	0.17	0	0	0	0.47	0.09
Lethrinus harak	20	157	0	0.02	0	0	0.05	0	0.05	1.85	0.05	0.25	0	0.03	0	0.10	0	0	0.10	0	0	0	2.51	0.50
Lethrinus harak	24	241	0	0	0	0.99	0.20	0	0	1.77	0.71	1.71	0	0.37	0.70	0.92	0.11	0.14	0.11	0	0	0	7.73	1.55
Lethrinus harak	13	46	0	0	0	0.00	0.19	0	0.24	1.84	0.03	0.24	0	0	0	0.15	0.07	0.10	0.30	0.03	0	0	3.19	0.64
Lethrinus harak	22	205	0	0	0	2.62	5.65	0	0	30.0	5.85	21.4	0	3.57	17.2	24.3	2.22	4.59	2.07	0.11	0	0	120	23.9
Lethrinus harak	20	165	0	0	0	1.51	0.73	0	0.31	7.78	2.61	6.80	0	1.50	2.86	3.98	0.68	0.89	0.44	0.04	0.06	0	30.2	6.04
Lethrinus obsoletus	15	70	0	0	0	0.60	0.08	0	0.22	2.14	0.06	0.31	0	0	0	0.19	0	0	0.13	0	0	0	3.73	0.75

Method Detection limits (ng/g) for a 1 g sample were as follows: PCB 8 (0.015), PCB 18 (0.016), PCB 28 (0.004), PCB 44 (0.006), PCB 52 (0.019), PCB 66 (0.024), PCB 77 (0.016), PCB 101 (0.013), PCB 105 (0.015), PCB 118 (0.007), PCB 126 (0.007), PCB 128 (0.009), PCB 138 (0.012), PCB 153 (0.01), PCB 170 (0.013), PCB 180 (0.008), PCB 187 (0.008), PCB 195 (0.007), PCB 206 (0.016), PCB 209 (0.013). Congeners below analytical detection limits listed as zero.

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.

$\sum_{20}$PCB dry weight values converted to ng/g wet weight assuming an average water content on 77% (from Denton *et al.* 2006).

See raw data tables in Appendix A for trophic level status, foraging characteristic, gender and sexual development of species analyzed