Mercury Content of Biota in Coastal Waters in Hawaii

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A survey of mercury and pesticide residue content of biota collected from four coastal areas of Hawaii was undertaken as part of a multi-disciplinary project in Quality of Coastal Waters (LAU 1972, 1973) supported by the Sea Grant Program of the University of Hawaii. Information collected from this survey is presented for evidence of biological concentration of mercury and of any influence of agricultural or urban waste discharges on mercury concentrations in coastal biota.

MATERIALS AND METHODS

The four coastal areas involved were located adjacent to Kilauea and McBryde sugar plantations along the northeast and south shores of Kauai, and the Kahana and Maunalua Bay areas along the northeast and southeast shores of Oahu. At the outset of the study in 1971, the two areas off Kauai were undergoing some alteration by changes in waste discharges from the plantations. McBryde plantation had curtailed liquid and waste discharges during the previous two-year period and sugar mill operations at Kilauea had ceased permanently at the time the study began. Kahana Bay represented a relatively pristine area remote from agriculture or urban development. Maunalua Bay, including an extensive marina, represented a domestic urban, drainage area of Honolulu.

The survey continued from 1971 through 1974. Sampling stations located in each of the areas were periodically visited during each year to obtain quantitative and qualitative information on biota present. All biological specimens collected were packed in ice and later frozen until analytical determinations could be made. Species identification and categorization followed established taxonomy and practice (EDMONSON 1946; GOSLINE and BROCK 1971; HOSAKA 1965; TINKER 1965).

Measurements of total mercury were made by the method of RIVERS et al. (1972). Homogenized samples were digested with nitric acid over low heat and further oxidized with potassium permanganate. Excess oxidizing agents were reduced with hydroxylamine after which mercury ions were reduced to elemental mercury with stannous chloride and vaporized into the flameless atomic absorption apparatus. Where biota specimens were sufficiently large for ready dissection, muscle tissue was the preferred and usual type of tissue analyzed. Where idssection was not feasible, composite tissues were analyzed.

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RESULTS AND DISCUSSION

The 223 biological specimens collected represented 58 different animal species. Species identification and mean mercury concentrations measured are given in Table 1. Vertebrates and invertebrates are grouped according to primary food material as herbivores, omnivores, primary benthic carnivores and secondary benthic carnivores. All but a few of the species collected were benthic in habitat.

Mercury concentrations found ranged from undetectable (<0.01 ppm) in 26% of the samples analyzed to a high of 1.0 ppm in one sample. The overall mean value found was 0.08 ppm.

As noted in Table 1, there was considerable variation in mercury concentrations found among different species. One-way analysis of variance of the measurement data showed highly significant differences ($P<0.001$) to exist between mean values of mercury for different trophic levels. Variation between mean values for families of organisms within different trophic levels was not significant except for that occurring among families categorized as primary benthic carnivores ($P<0.001$). Thus, the increase in mean mercury value with each elevation in trophic level is strongly suggestive of successive biological concentration and transport of this element.

Separate analysis of variance of mercury measurements from the Kilauea, Kahana Bay and Moanalua Bay areas of the survey all showed the same highly significant differences between mean values of mercury at different trophic levels. The fourth area of the survey, McBryde, was omitted from the analysis because of insufficient species representation at each trophic level.

Earlier results of mercury measurements made on samples collected from the Kilauea area of this survey had shown that higher concentrations of mercury were found in organisms feeding on benthic organic material than in organisms feeding above the sediment-water interface (KLEMMER and LUOMA 1973). However, results now complete for a similar categorization of species show that highest concentrations of mercury were found in organisms feeding above the sediment-water interface, as indicated in Table 2. Analysis of variance showed the differences in mean values in this table to be significant at all trophic levels ($P<.05$). Thus, it would appear that mercury transport does occur through one or more linear food chains from algae to herbivore, omnivore and carnivore.

Additional one-way analysis of variance were made to determine any differences in mercury concentrations found

TABLE 1

MERCURY CONCENTRATION (ppm) IN BIOTA COLLECTED FROM COASTAL WATERS OF HAWAII

FAMILY	SPECIES	COMMON NAME	NO. OF SAMPLES	MEAN	S.D.
Herbivore:					
Acanthuridae	*Ctenochaetus strigosus*	Surgeonfish	3	0.03	0.03
"	*Acanthurus sandvicensis*	"	17	0.04	0.04
"	" *nigroris*	"	6	0.05	0.05
"	" *leucopareius*	"	1	0.00	0.00
"	" *mata*	"	3	0.03	0.06
Mugilidae	*Neomyxus chaptelii*	Diamond Scale Mullet	2	0.03	0.04
"	*Mugil cephalus*	Sea Mullet	9	0.03	0.03
"	*Mugil engeli*	Silver Mullet	3	0.01	0.02
Chanidae	*Chanos chanos*	Milkfish	2	0.03	0.01
Scaridae	*Calotomus sandvicensis*	Parrotfish	4	0.05	0.04
Blennidae	*Cirripectus lineopunctates*	Blenny	1	0.00	0.00
Echinidae	*Tripneustes gratilla*	Sea urchin	6	0.03	0.06
Echinometridae	*Echinometra methei*	"	3	0.00	0.00
"	*Colobocentrotys mamillatus*	Flat sea urchin	2	0.08	0.11
Patellidae	*Cellana exarata*	Limpet	9	0.02	0.03
Neritidae	*Nerita picea*	Pitchy seasnail	4	0.03	0.01
Veneridae	*Tapes japonica*	Clam	4	0.02	0.01
Plakobranchidae	*Plakobranchus ocellata*	Sea slug	1	0.00	0.00
Holothuridae	*Holothuria atra*	Sea cucumber	9	0.04	0.05
Ophiothricidae	*Ophiothrix*	Brittle star	1	0.00	0.00
			90	0.03	0.04
Omnivore:					
Kyphosidae	*Kyphosus cinerascens*	Rudderfish	5	0.06	0.07
Pomacentridae	*Pomacentrus jenkinsi*	Damselfish	5	0.04	0.05
"	*Abundefduf abdominalis*	"	6	0.08	0.07
"	" *sindonis*	"	1	0.00	0.00
"	" *sordidus*	"	1	0.02	0.00
Labridae	*Thalossoma duperreyi*	Wrasse	4	0.10	0.06
Chaetodontidae	*Chaetodon multicinctus*	Butterflyfish	1	0.17	0.00
Balistidae	*Balistes fuscus*	Triggerfish	1	0.07	0.00
Eleotridae	*Electris sandwicensis*	Goby	1	0.08	0.00
Protunidae	*Podophthalma vigil*	Long-eyed swimming crab	4	0.03	0.01
"	*Thalamita crenata*	Crenate swimming crab	6	0.09	0.10
"	*Portunus sanguinolentus*	Blood-spotted swimming crab	1	0.09	0.00
"	" *deprossa*	Aama swimming crab	1	0.10	0.00
Grapsidae	*Grapsus grapsus*	Rock crab	3	0.10	0.09
Ocypodidae	*Ocypode ceratophthalma*	Ghost crab	9	0.12	0.08
Palaemonidae	*Macrobrachium grandimanus*	Prawn	1	0.08	0.00
			50	0.08	0.07
Primary Benthic Carnivore:					
Labridae	*Bodianus bilunulatus*	Spotted wrasse	6	0.05	0.03
Holocentridae	*Holocentrus diadema*	Squirrelfish	3	0.31	0.22
"	*Myripristis argyromus*	"	2	0.39	0.18
"	" *berndti*	"	1	0.18	0.00
Mullidae	*Mulloidichthys samoensis*	Goatfish	4	0.09	0.11
"	*Parupeneus chryserydros*	"	2	0.03	0.04
"	" *multifasciatus*	"	6	0.04	0.03
"	" *pleurostigma*	"	2	0.12	0.08
"	" *porphyreus*	"	18	0.09	0.08
Priacanthidae	*Priacanthus cruentatus*	Red big-eye	8	0.05	0.04
Kuhliidae	*Kuhlia sandvicensis*	White bass	9	0.12	0.09
Albulidae	*Albula vulpes*	Bonefish	1	0.08	0.00
Diodontidae	*Diodon hystrix*	Spiny puffer	2	0.19	0.05
Octopodidae	*Octopus octopus*	Octopus	4	0.09	0.02
			68	0.10	0.10
Secondary Benthic Carnivore:					
Lutjanidae	*Lutjanus kasmira*	Blue-line Perch	1	0.22	0.00
Synodontidae	*Synodus dermatogeny*	Lizardfish	2	0.07	0.10
Cirrhitidae	*Cirrhitus alternatus*	Hawkfish	8	0.32	0.37
Scorpaenidae	*Scorpaenopsis cacopsis*	Scorpionfish	1	0.05	0.00
Muraenidae	*Gymnothorax eurostus*	Moray eel	1	0.31	0.00
Congridae	*Conger marginatus*	Conger eel	1	0.32	0.00
Sphyraenidae	*Sphyraena barracuda*	Barracuda	1	0.34	0.00
			15	0.26	0.28

TABLE 2

MEAN MERCURY CONCENTRATIONS (ppm) IN BIOTA CATEGORIZED BY BENTHIC FEEDING HABIT AND TROPHIC LEVEL

	HERBIVORES	OMNIVORES	CARNIVORES
1. Feeding habit in direct contact with sediment	.022	.058	.075
2. Feeding habit above sediment-water interface	.036	.070	.080

in identical species collected from each of the four areas of the survey and over the 4 years during which the survey was conducted. No significant differences were found between either the sampling areas or the 4 years of sampling. This would suggest that mercury concentrations found in the organisms collected were not being influenced by urban, domestic drainage in the Maunalua Bay area, or by agricultural -rainage in the areas bordering Kilauea and McBryde sugar plantations. Further, reductions in the amounts of liquid and solid agricultural wastes added to the Kilauea and McBryde coastal areas over the 4 years, particularly with cessation of sugar mill operations at Kilauea, had no significant effect on mercury concentrations found in the biota from these areas.

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