CEER–M-42
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A STUDY OF THE MERCURY CONCENTRATIONS OF FISH OFF THE SOUTH AND WEST COASTS OF PUERTO RICO

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ABSTRACT

Commercially important fish and invertebrates were collected on the south and west coasts of Puerto Rico, primarily in and around Mayaguez Bay. The edible flesh was analyzed for mercury. The concentrations of total mercury ranged from a low of .007 ppm (ug/g) in *Strombus gigas* ("conch" or "carrucho") to 1.47 ppm in *Centropomus undecimalis* ("snook" or "robalo"). There appeared to be a positive relationship between the size of the organism and the amount of mercury present: the larger the organism, the higher the mercury concentration. Some of the organisms, in particular *Centropomus undecimalis*, showed higher concentrations of mercury than the safety limit of 0.5 ppm recommended by the N.A.S.-N.A.E. and the U.S.F.D.A. and higher than the action limit of 1.0 ppm established by the U.S.F.D.A.

INTRODUCTION

Since the Minamata Bay poisonings in Japan (N.A.S.-N.A.E., 1973) public concern about mercury poisoning has sparked research and quality controls on the mercury levels of edible fish. Sources of mercury pollution are a concern in areas where commercial fishing takes place, and it is to identify these sources and measure the effects of human pollution on fish populations that studies like ours are begun.

Our contemporary, José A. Ramírez Barbot, (1979) spent a year sampling the fish populations of Guayanilla Bay on the south coast of Puerto Rico where a power plant and other industries are known to contribute trace metals to the environment. Our study was undertaken in an attempt to supplement his research and to look at another part of the island's ecosystem for comparison purposes.

Our sampling area included Mayaguez Bay on the west coast of Puerto Rico which, although not known to be as polluted as Guayanilla Bay, is a commercial harbor and has several industrial attractions such as a tuna processing facility on its northern shore. We also sampled frequently on a clean and much fished reef about eight miles off shore and took sampling trips to the south coast and to Desecheo Island, where we fished on clear off-shore reefs. With this study and the previous work done in Guayanilla we hope to formulate a more complete picture of the mercury concentration of fish in south and west coasts of Puerto Rico, with an eye to controlling human consumption of possible toxic materials.

LITERATURE REVIEW

Mercury occurs naturally in aquatic environments. Its natural concentration in sea water has been estimated to be 0.1 ug/l (ppb) (N.A.S.-N.A.E., 1973). It is a non-essential non-beneficial element and is potentially toxic. It is accumulated by organisms far more rapidly than it can be eliminated, and a fish may contain a concentration of mercury 10,000 times that of the surrounding water (McKim 1974). This toxic magnification can be carried to man, who must limit his intake of fish with high concentrations of mercury. The National Academy of Science and National Academy of Engineering suggested in the publication Water Quality Criteria, 1972 (N.A.S.-N.A.E. 1973) that the concentration of mercury in fish for human consumption should not exceed 0.5 ppm (ug/g). This limit was adopted by U.S. Food and Drug Administration. There is still an active concern in the literature that this is not low enough for human safety. Recently, however, U.S. F.D.A. released a "Revised Action List for Poisons or Deleterious Substances" where the action level for mercury was established at 1.0 ppm (NFI 1978). Clearly, not enough is known about the dangers of mercury in lower concentrations.

Mercury occurs in several forms. Microorganisms have the ability to convert inorganic and organic forms of mercury to highly toxic methyl or dimethyl mercury, making any form of mercury a potential hazard to the environment. The methylation process takes place in and on the sediment where benthic organisms are most active. From the ingestion of sediment, detritus, or the benthos, fish and other larger organisms accumulate the highly toxic methylmercury (N.A.S.-N.A.E., 1973).

Recent studies have suggested relationships between mercury concentration and environmental factors. In particular, that the water temperature may have a significant effect on the mercury concentration in fish (Cember, Curtis, Blaylock, 1978). This was not considered in our study and may be of interest. Also, it has been shown that controls on mercury discharges have effected a decrease of the mercury content of fish in an area (Armstrong and Scott, 1979).

The problem of trace metals (in particular, mercury) being contributed to the environment by man may be dealt with only by identification of dangerous levels in the environment, pinpointing the source, and elimination of contaminants. It is only the first step of this procedure that this study deals with, with hopes that further work will be done if indicated by our results.

PROCEDURES

Field Method

Sampling trips were made throughout June, July, and the beginning of August, 1979. Within Mayaguez Bay trawl nets were used, both in the day and at night. At Tourmaline reef off-shore and on trips further afield collection was made by spearfishing and hook and line. All samples were stored on ice, transported to the lab, and frozen.

Laboratory Method

After transportation to the lab the samples were separated and identified with the help of the Cornelia Hill staff, in particular, Leida Luz Cruz. Randall (1968) and Bohlke and Chaplin (1968) were used as references for identification. The specimens were counted, measured and weighed and separated by species and size. Fish were grouped by 3.0 cm increments, and crabs were separated into 10 gram groups. The edible flesh and muscles were removed for analysis of total mercury content. When prominent, the eggs were also removed for analysis. For each size group duplicates of two gram samples (wet weight) were used for the mercury analysis.

The two gram samples were weighed into BOD bottles, then digested with concentrated sulfuric and nitric acid in a 80°C water bath. Excess potassium permanganate was added to oxidize the mercury present to the mercuric form (Hg^{+2}) and the sample was further heated at 80°C for an hour before cooling. Hydroxylamine hydrochloride was added to clear excess permanganate, and stannous chloride was added to reduce the mercury to the metallic form just before analysis.

The instrument used was a Mercury Analyzer System, Model MAS 50, from Perkin Elmer Corporation, Coleman Instruments Division. It is sensitive to 0.01 micrograms of mercury. The percent transmittance (%T) was given for each sample.

Calculations

The absorbance can be calculated from the percent transmittance by using Beer's Law: $A=\log 1/T$. The samples were analyzed together with a series of standards of mercury. These were graphed with a Linear Regression that was used to determine the final concentration of the element in the different samples. The final concentration of mercury was determined by the formula:

$$\text{Final conc.} = \frac{\text{(conc.-blank) x volume of sample}}{\text{grams of sample}}$$

The final concentration was given in micrograms of mercury per gram of sample, or ppm.

Graphs comparing fish size to mercury concentration were made for the more common species using linear regression analysis and a t-test was used to compare results from different stations.

RESULTS

In 1,122 organisms sampled of 45 different species, the mean mercury concentrations found varied from .007 ppm (ug/g) to 1.47 ppm. The only fish found to exceed the U.S. Food and Drug Administration action limit of 1.0 ppm were *Scarus coeruleus* (a large parrotfish) from Tourmaline, and several *Centropomus undecimalis* from the Guanajibo river mouth, with concentrations to 1.9 ppm in some fish. The *Centropomus* (or snook) are a concern because they are considered excellent for eating and were acquired from fisherman who were selling them for food. *Centropomus ensiferus* from the Añasco River area also surpassed the 0.5 ppm safety limit recommended by the National Academy of Science and the National Academy of Engineering. Other than these fish, all samples were below the limit established by the U.S.F.D.A., but variations among species, sampling areas, and size occurred at lower mercury concentrations.

Unfortunately, not all the samples were readily comparable between sampling sites. Stations on a reef did not yield the same type of fish that were collected in bay stations, and different collection techniques such as trawl nets vs. spearfishing in these different areas made direct comparisons between species and size groups impossible in many cases. A t-test was done for comparison of the following: Añasco vs. Mayaguez, Tourmaline and Punta Ostiones reefs vs. Desecheo Island, Añasco and Mayaguez vs. Desecheo, Añasco and Mayaguez vs. Tourmaline and Punta Ostiones, and Desecheo, Tourmaline and Punta Ostiones vs. Añasco and Mayaguez. It was found that $p < 0.05$ for the two bay stations and the bay stations vs. the island. For the other three comparisons it was found that $p > 0.01$. It can therefore be assumed that there is less mercury found in the fish at Añasco than the fish in Mayaguez Bay; and less mercury in the fish around Desecheo Island than in the bay stations. For the others compared there is no significant difference in the mercury content.

It is well known that mercury is accumulated by most organisms faster than it can be eliminated. Most species, for which three or more size groups could be established, showed an increase in mercury levels with an increase in size. These were *Balistes vetula*, *Bothus* sp., *Callinectes* sp., *Centropomus undecimalis*, *Cephalopholis fulva*, *Cynoscion* *jamaicensis*, *Diapterus* sp., *Larimus breviceps*, *Lutjanus synagris*, *Ophioscion adustus*, *Panulirus argus*, *Peneaus* sp., *Selene vomer*, *Symphurus arawak*, and *Trichirus lepturus*. Some of the species tested showed a decrease in mercury levels with an increase in size. These were *Epinephelus guttatus*, *Epinephelus striatus*, *Petrometopon cruentatum*, and *Polydactylus* sp. (see graphs). The other species analyzed were not graphed as there were not enough size groups for each.

The minimum number of points used for graphing was three which may allow for too great an error. The fact that the points used were mean concentrations regardless of station, there may be some fluctuations in the graphs that are not attributable to size increase only. (The graphs were done by means of linear regression analysis and best fit line.)

Only the large fish had concentrations approaching or exceeding potentially dangerous levels. We also observed a correlation between diet and mercury concentration. Grazers and other organisms lower on the food chain (such as conchs, lobsters, or shrimp) generally exhibited lower mercury concentrations than carnivorous or predator species.

In some specimens we were able to analyze the gonads as well as the edible flesh and found less mercury in the gonads. The gonads were not free from mercury, however, and especially in very large fish (in particular, *Centropomus*) the mercury concentration of the gonads was high enough (see table) to warrant concern about future generations of fish continually exposed to high levels of mercury.

CONCLUSIONS AND RECOMMENDATIONS

There is a positive relationship between size and mercury concentration with a few exceptions, since larger fish demonstrated significantly higher levels of mercury. This has been found by other researchers in the field. There is also an apparent correlation between an organism's niche in the food web and the level of mercury accumulated in that lower levels of mercury are found in organisms lower in the food web.

Some commercial, edible, and valuable fish were shown to have mercury concentrations not only above the 0.5 ppm safety limit recommended by the National Academy of Science and the National Academy of Engineering and originally established the U.S.F.D.A., but also exceeded the action limit of 1.0 ppm recently set by the U.S.F.D.A. These fish were being sold for human consumption and an effort should be made to effect some control and educate the public about the dangers of mercury poisoning from fish.

Stations closer to centers of human population yielded more mercury in the fish populations, indicating that pollution from a human source could cause higher mercury levels in fish in these areas. The tuna canneries on the north shore of Mayaguez Bay are possible mercury sources. Since the areas closer to shore are often where the highest amount of commercial and private fishing takes place, it is desirable to control sources of mercury pollution and to educate the public, once again, of the dangers involved.

Our results were generally similar to those of the research done in Guayanilla Bay by José A. Ramírez Barbot (1979). The same relationship between fish size and mercury concentrations was observed. Similar results were found for the same species in both studies. *Centropomus undecimalis*, for example, exhibited very high levels of mercury in both studies.

Anyone wishing to make further studies in this area may want to analyze for mercury in other components of the environment surrounding the fish sampled. Not only water and sediment, and food sources, but also temperature records may be both interesting and beneficial to a study of this kind.

Most importantly, however, we need to pinpoint the sources of mercury pollution and implement some form of control. Traditionally, it has been known that tuna have particularly high mercury concentrations. The presence of the tuna canneries on the northern shore of Mayaguez Bay that have been releasing their effluent into the bay for years is certainly suspect as a mercury pollutant. Before we actually endanger the fish populations and the people who eat them, we should take care to regulate the amount and kinds of waste we contribute to our environment. In this area, mercury may be of particular concern as it so directly affects the fish that are necessary to the economy.

TABLE 1

SUMMARY OF MERCURY CONTENT OF FISH AND INVERTEBRATE ORGANISMS

SPECIES	SIZE	STATION	MEAN CONC. (ug/g)	STA. DEV.	n
Acanthostracion quadricornis	15-18 cm	Tourmaline Reef	.0303	.0011	1
Acanthostracion polygonius	21-24 cm	Tourmaline Reef	.0126	.0015	1
Anchoa lyolepis	3-6 cm	Añasco	.0612	0.0	10
Anistremus surinamensis	27-30 cm	Tourmaline	.1721	.0356	1
Balistes vetula			.0480	.0076	4
	21-24 cm	Tourmaline	.0346	.0041	1
	24-27 cm	Tourmaline	.0387	0.0	1
	27-30 cm	Tourmaline	.0382	.0008	1
	33-36 cm	Tourmaline	.0802	.0027	1
Bothus sp.			.0998	.0177	42
	3-6 cm	Añasco	.0513	.0047	9
		Mayaguez	.0450	.0015	11
	3-6 cm	-	.0482	.0062	20
	6-9 cm	Añasco	.0948	.0037	18
	9-12 cm	Añasco	.1782	.0027	3
	12-15 cm	Mayaguez	.1298	.0051	1
Callinectes sp.			.1130	.0872	86
	0-10 g	Añasco	.0244	.0007	52
		Mayaguez	.0189	.0006	5
	0-10 g	-	.0217	.0013	57
	10-20 g	Añasco	.0318	.0010	7
	30-40 g	Añasco	.0921	.0189	4
		Mayaguez	.0543	.0037	2
	30-40 g	-	.0732	.0226	6
	40-50 g	Añasco	.1064	.0157	7
		Mayaguez	.0560	0.0	1
	40-50 g	-	.0817	.0157	8
	50-60 g	Añasco	.1008	.0073	3
	60-70 g	Añasco	.3052	.0169	1
	70-80 g	Añasco	.1263	.0210	2
	80-90 g	Añasco	.0822	.0024	2

SPECIES	SIZE	STATION	MEAN CONC. (ug/g)	STA. DEV.	n
Centropomus undecimalis		-	1.4702	.7132	4
gonads		-	.3015	.0145	2
	9.53 kg	Guanajibo	1.0520	.1635	1
	11.79 kg	Guanajibo	1.6106	.4158	1
	13.61 kg	Guanajibo	1.3124	.0048	1
	gonads	Guanajibo	0.2119	.0093	1
	15.88 kg	Guanajibo	1.9048	.0391	1
	gonads	Guanajibo	0.3910	.0052	1
Centropomus ensiferus			.7413	.0362	2
	30-33 cm	Añasco	.7173	.0308	1
	33-36 cm	Añasco	.7653	.0054	1
Cantherhines macrocerus	35.2 cm	Desecheo	.0305	.0040	1
Cephalopholis fulva			.1013	.0595	10
	15-18 cm	Tourmaline	.0424	.0008	1
	18-21 cm	Tourmaline	.1829	.0137	1
		Desecheo	.0912	.0055	1
	18-24 cm	-	.1371	.0192	2
	21-24 cm	Tourmaline	.1446	.0091	1
		Desecheo	.0629	.0022	5
	21-24 cm	-	.1038	.0113	6
	24-27 cm	Desecheo	.0835	.0054	1
Chaetodipterus faber	21-24 cm	Tourmaline	.0678	.0010	2
Chloroscombrus chrysurus	3-6 cm	Mayaguez	.0324	0.0	6
Clepticus parrae	18-21 cm	Tourmaline	.0564	.0006	1
Cynoscion jamaicensis			.1527	.0034	10
	6-9 cm	Añasco	.0551	.0018	4
	9-12 cm	Mayaguez	.1171	.0016	4
	12-15 cm	Mayaguez	.1658	0.0	1
	15-18 cm	Mayaguez	.2726	0.0	1
Diapterus sp.			.0328	.0051	14
	3-6 cm	Mayaguez	.0299	.0009	7
	6-9 cm	Mayaguez	.0269	.0033	1
	9-12 cm	Mayaguez	.0325	0.0	5
	12-15 cm	Mayaguez	.0399	.0009	1

SPECIES	SIZE	STATION	MEAN CONC. (ug/g)	STA. DEV.	n
Diodon holacanthus			.0166	0.0	5
	6-9 cm	Joyuda	.0159	0.0	4
	9-12 cm	Joyuda	.0172	0.0	1
Diplectrum radiale	6-9 cm	Joyuda	.0322	.0002	1
Epinephelus guttatus			.0526	.0205	14
	15-18 cm	Pta. Ostiones	.0470	.0027	1
		La Parguera	.0802	.0004	1
	15-18 cm	-	.0636	.0031	2
	18-21 cm	Tourmaline	.0464	.0066	3
		Pta. Ostiones	.0458	.0024	5
	18-21 cm	-	.0461	.0100	8
	21-24 cm	Pta. Ostiones	.0514	.0047	4
Epinephelus striatus			.0736	.0278	4
	21-24 cm	Pta. Ostiones	.0656	.0002	1
	24-27 cm	Pta. Ostiones	.1223	.0039	2
	36-39 cm	Pta. Ostiones	.0408	.0237	1
Eucinostomus sp.			.0459	0.0	4
	3-6 cm	Guanajibo	.0380	0.0	3
	6-9 cm	Guanajibo	.0538	0.0	1
Euthynnus sp.	30-33 cm	Tourmaline	.1369	.0191	1
Haemulon sp.			.0623	.0025	5
	3-6 cm	Añasco	.0548	0.0	2
	6-9 cm	Mayaguez	.0757	.0025	3
Harengula sp.			.2129	.0113	17
	6-9 cm	Mayaguez	.1305	.0045	13
	9-12 cm	Añasco	.2953	.0068	4
Lactophrys bicaudalis	18-21 cm	Desecheo	.0226	.0025	1
Lactophrys trigonus	15-18 cm	Tourmaline	.0563	.0017	1
Larimus breviceps			.1572	.0815	48
	0-3 cm	Añasco	.0230	0.0	10
	3-6 cm	Añasco	.0353	0.0	13
	6-9 cm	Añasco	.0745	.0183	12
		Mayaguez	.1240	.0028	2
	6-9 cm	-	.0993	.0211	14
	9-12 cm	Añasco	.0551	.0135	5
		Mayaguez	.1576	0.0	3

SPECIES	SIZE	STATION	MEAN CONC (ug/g)	STA. DEV.	n
Larimus breviceps	9-12 cm	-	.1064	.0135	8
	15-18 cm	Añasco	.3361	.0552	1
	18-21 cm	Añasco	.4517	.0111	1
Lutjanus analis	15-18 cm	Pta. Ostiones	.0389	.0013	1
Lutjanus jocu	21-24 cm	Pta. Ostiones	.1220	.0091	1
Lutjanus synagris			.0535	.0098	17
	3-6 cm	Mayaguez	.0282	.0014	9
	6-9 cm	Joyuda	.0422	.0047	2
		Mayaguez	.0677	.0037	5
	6-9 cm	-	.0550	.0074	7
	9-12 cm	Mayaguez	.0760	.0010	1
Ophioscion adustus			.0614	.0335	11
	9-12 cm	Mayaguez	.0537	.0033	2
	9-12 cm	Añasco	.0310	.0127	1
	9-12 cm	-	.0424	.0160	3
	12-15 cm	Mayaguez	.0315	.0014	2
	15-18 cm	Mayaguez	.0416	.0014	1
	18-21 cm	Mayaguez	.0580	.0015	1
	21-24 cm	Mayaguez	.0546	.0024	1
	24-27 cm	Mayaguez	.0811	0.0	2
	30-33 cm	Añasco	.1387	.0075	1
Panulirus argus			.0322	.0172	16
	21-24 cm	Tourmaline	.0373	.0003	1
	24-27 cm	Tourmaline	.0212	.0009	1
	27-30 cm	Tourmaline	.0366	.0100	7
	30-33 cm	Tourmaline	.0346	.0020	2
	33-36 cm	Tourmaline	.0335	.0034	3
		Pta. Ostiones	.0299	.0006	2
	33-36 cm	-	.0317	.0040	5
Peneaus sp.			.0512	.0370	550
	0-3 cm	Añasco	.0148	.0050	200
	3-6 cm	Añasco	.0228	.0056	50
	6-9 cm	Añasco	.0751	.0046	236
		Mayaguez	.0259	.0018	26
	6-9 cm	-	.0505	.0064	262

SPECIES	SIZE	STATION	MEAN CONC (ug/g)	STA. DEV.	n
Peaneaus sp.	9-12 cm	Añasco	.1129	.0031	12
		Mayaguez	.0506	0.0	23
	9-12 cm	-	.0818	.0031	35
	12-15 cm	Mayaguez	.0564	.0169	3
Petrometopon cruentatum			.1234	.0233	9
	18-21 cm	Tourmaline	.1211	.0025	1
	18-21 cm	La Parguera	.1479	.0048	1
	18-21 cm	-	.1345	.0078	2
	21-24 cm	Tourmaline	.1231	.0032	1
	21-24 cm	Desecheo	.0951	.0111	3
	21-24 cm	-	.1091	.0143	4
	24-27 cm	La Parguera	.1300	.0012	3
Polydactylus sp.			.1275	.1070	28
	3-6 cm	Añasco	.3312	0.0	2
		Mayaguez	.0071	.0009	21
	3-6 cm	-	.1692	.0009	23
	6-9 cm	Añasco	.0921	.001	1
	9-12 cm	Añasco	.0721	.0925	1
		Mayaguez	.1350	.0126	3
	9-12 cm	-	.1036	.1051	4
Pomacanthus arcuatus	27-30 cm	Tourmaline	.0424	.0392	1
Rypticus saponaceus			.1041	.0042	4
	9-12 cm	Mayaguez	.0757	.0025	3
	12-15 cm	Mayaguez	.1325	.0017	1
Scarus coeruleus	49.4 cm	Tourmaline	1.226	.0064	1
Scomberomorus regalis	42.2 cm	Pta. Ostiones	.0963	.0175	1
Selene vomer			.1063	.0028	12
	3-6 cm	Mayaguez	.0250	0.0	7
	6-9 cm	Mayaguez	.1106	0.0	2
	9-12 cm	Mayaguez	.1832	.0028	3
Serranus flavivertris	3-6 cm	Joyuda	.0626	0.0	2
Sphaeroides testudineus	3-6 cm	Añasco	.0296	0.0	2
Steliffer sp.			.1486	.0147	77
	6-9 cm	Añasco	.1262	.0055	16
	9-12 cm	Añasco	.1709	.0092	61

SPECIES	SIZE	STATION	MEAN CONC. (ug/g)	STA. DEV.	n
Strombus gigas	1.36 kg	Pta. Ostiones	.0074	.0049	18
Symphurus arawak			.0529	.0260	47
	3-6 cm	Añasco	.0303	0.0	7
	6-9 cm	Añasco	.0520	.0072	9
		Mayaguez	.0392	0.0	1
	6-9 cm	-	.0456	.0072	10
	9-12 cm	Añasco	.0747	.0088	19
		Mayaguez	.0335	.0035	2
	9-12 cm	-	.0541	.0123	21
	12-15 cm	Añasco	.0506	.0041	6
		Mayaguez	.0610	.0009	2
	12-15 cm	-	.0558	.0050	8
	15-18 cm	Mayaguez	.0822	.0015	1
Trichiurus lepturus			.0654	.0103	6
	18-21 cm	Añasco	.0356	.0010	1
	21-24 cm	Añasco	.0283	0.0	1
	24-27 cm	Añasco	.0314	.0110	1
		Mayaguez	.0224	0.0	1
	24-27 cm	-	.0269	.0110	2
	27-30 cm	Añasco	.1124	.0016	1
	48.8 cm	Mayaguez	.1949	.0055	1

Fig. 1

SAMPLING SITES ON THE WEST COAST OF PUERTO RICO

GRAPHS SHOWING CORRELATIONS BETWEEN ORGANISM SIZE AND MERCURY CONCENTRATION

Fig. 2

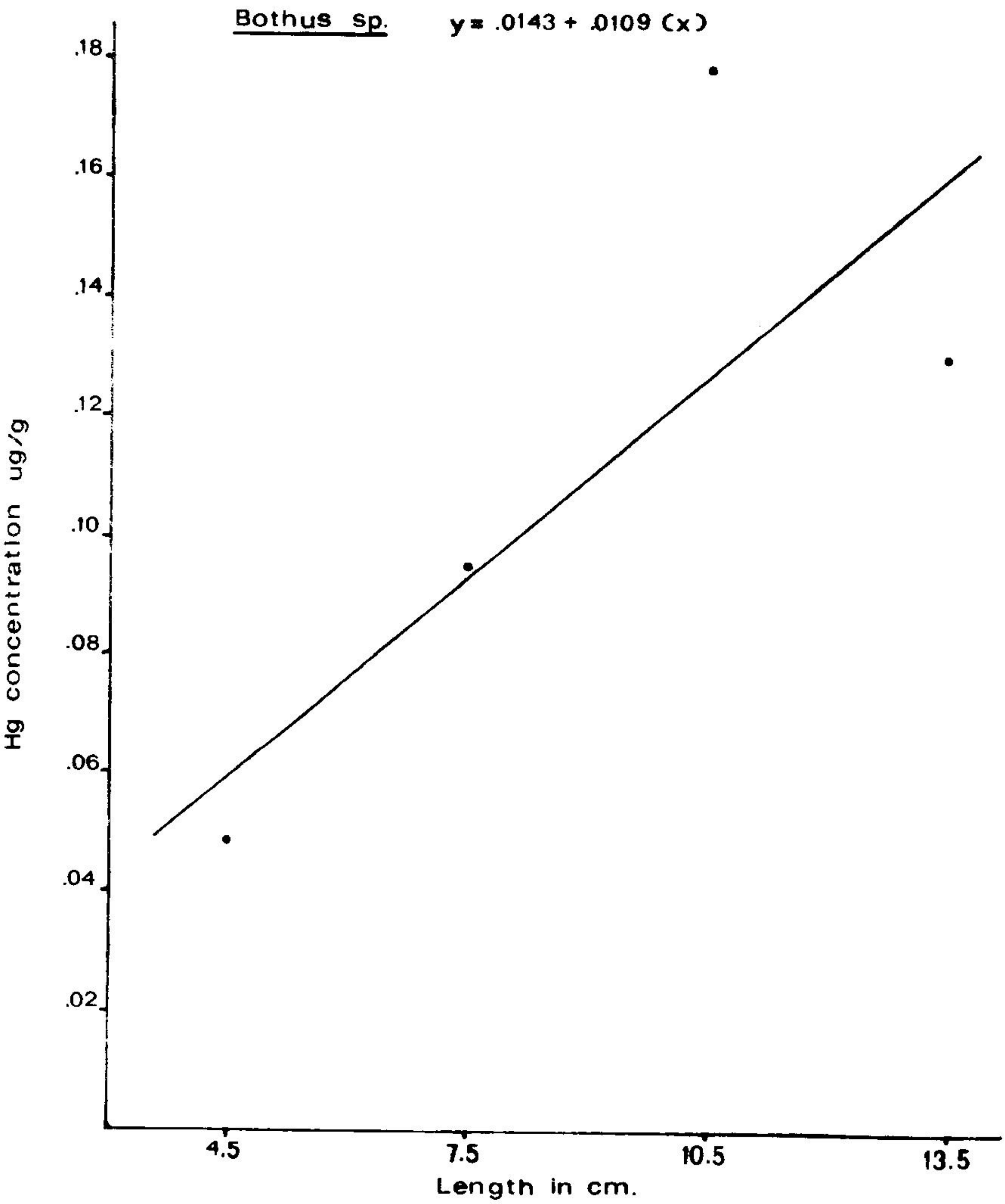
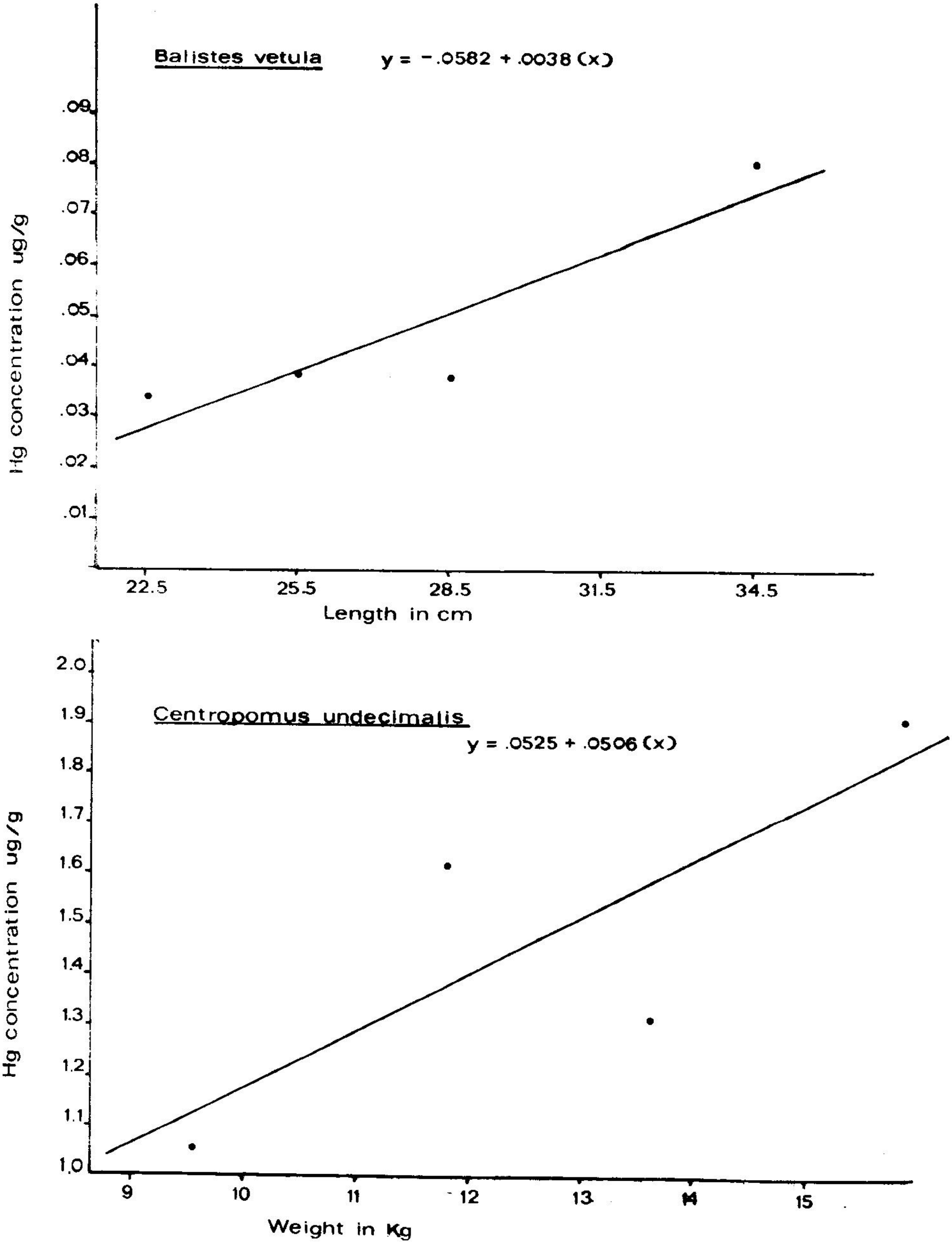

Bothus sp.
y= .0143 + .0109 (x)
.18
.16
.14
.12
.10
.08
.06
.04
.02
Hg concentration ug/g
4.5
7.5
10.5
13.5
Length in cm.

Fig. 3



Balistes vetula
y = −.0582 + .0038 (x)
Hg concentration ug/g
.09
.08
.07
.06
.05
.04
.03
.02
.01
22.5
25.5
28.5
31.5
34.5
Length in cm
Centropomus undecimalis
y = .0525 + .0506 (x)
Hg concentration ug/g
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
9
10
11
12
13
14
15
Weight in Kg

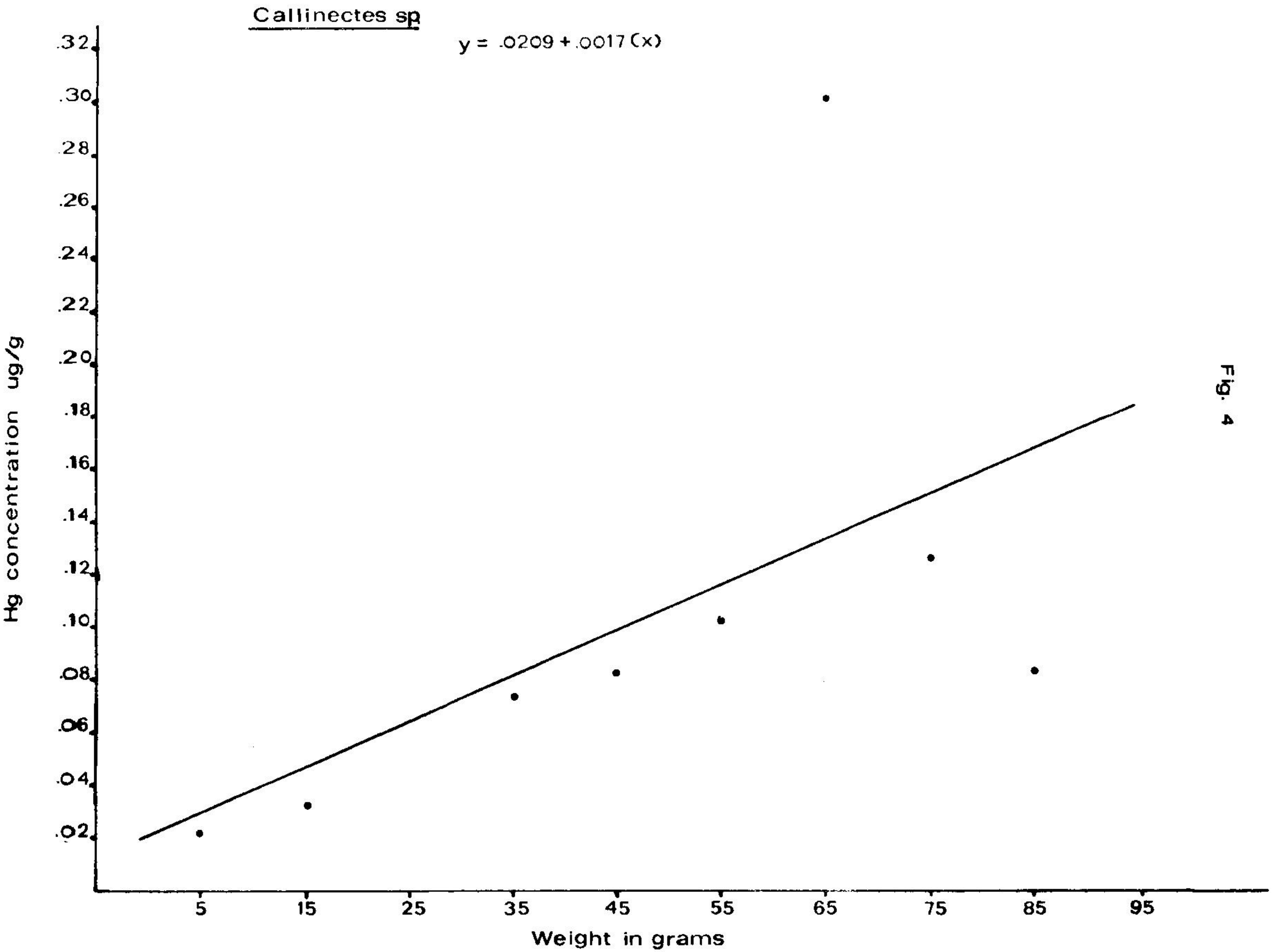


Fig. 4

Callinectes sp

$y = .0209 + .0017(x)$

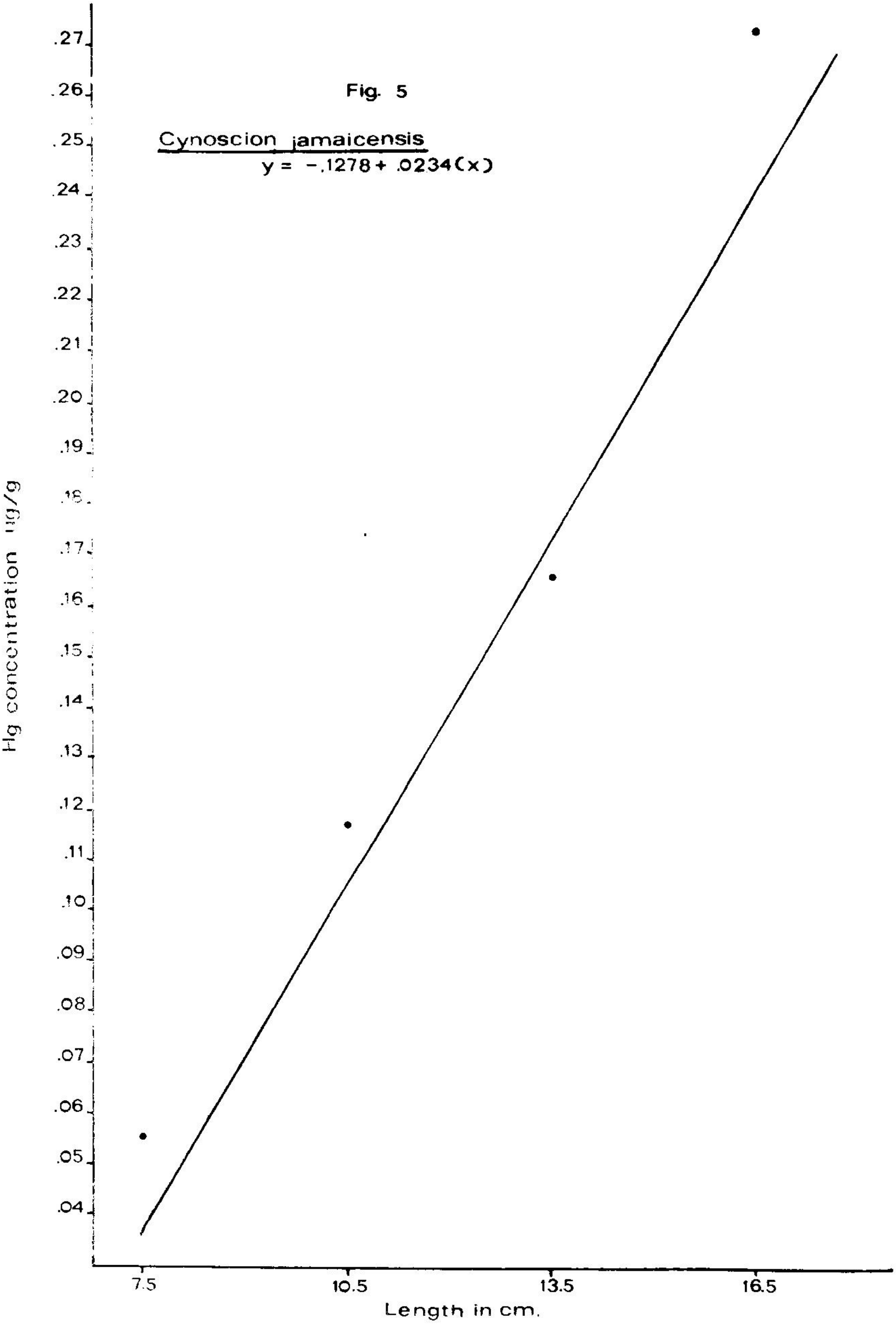


Fig. 5

Cynoscion jamaicensis

$y = -.1278 + .0234(x)$

Fig. 6

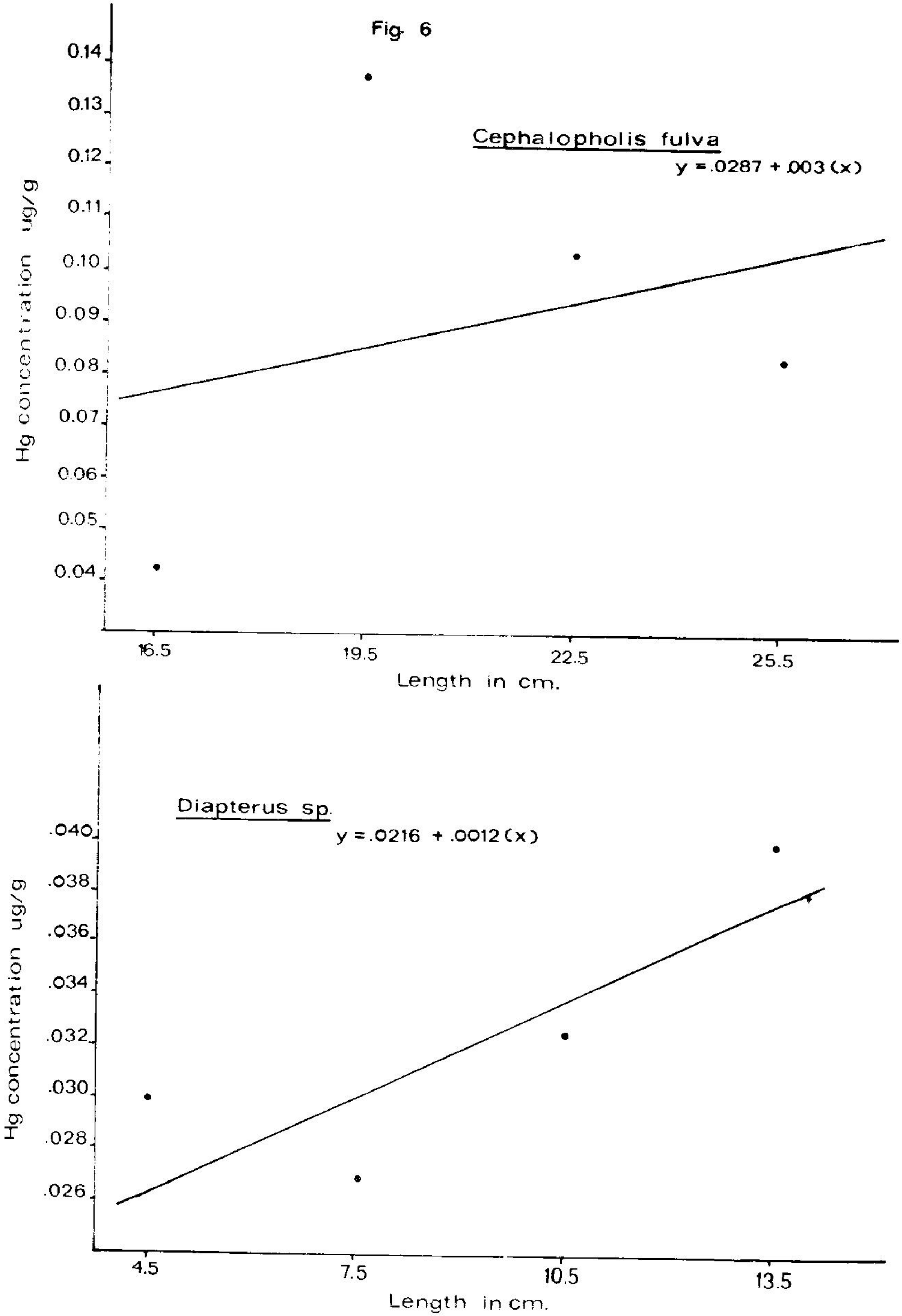

Cephalopholis fulva
y = .0287 + .003 (x)
Hg concentration ug/g
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
16.5
19.5
22.5
25.5
Length in cm.
Diapterus sp.
y = .0216 + .0012 (x)
Hg concentration ug/g
.040
.038
.036
.034
.032
.030
.028
.026
4.5
7.5
10.5
13.5
Length in cm.

Fig. 7

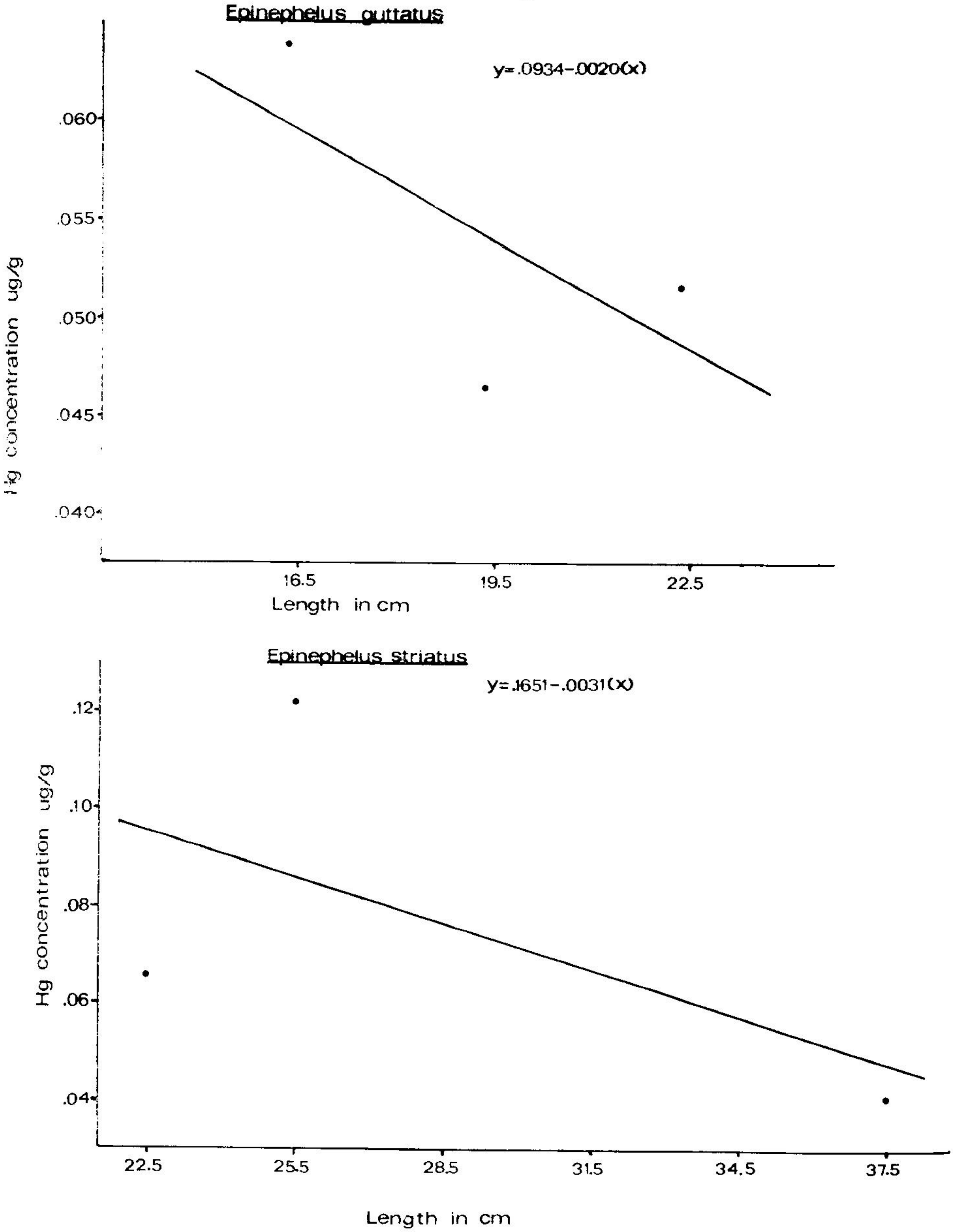

Epinephelus guttatus
y=.0934-.0020(x)
Hg concentration ug/g
.060
.055
.050
.045
.040
16.5
19.5
22.5
Length in cm
Epinephelus striatus
y=.1651-.0031(x)
Hg concentration ug/g
.12
.10
.08
.06
.04
22.5
25.5
28.5
31.5
34.5
37.5
Length in cm

Fig. 8

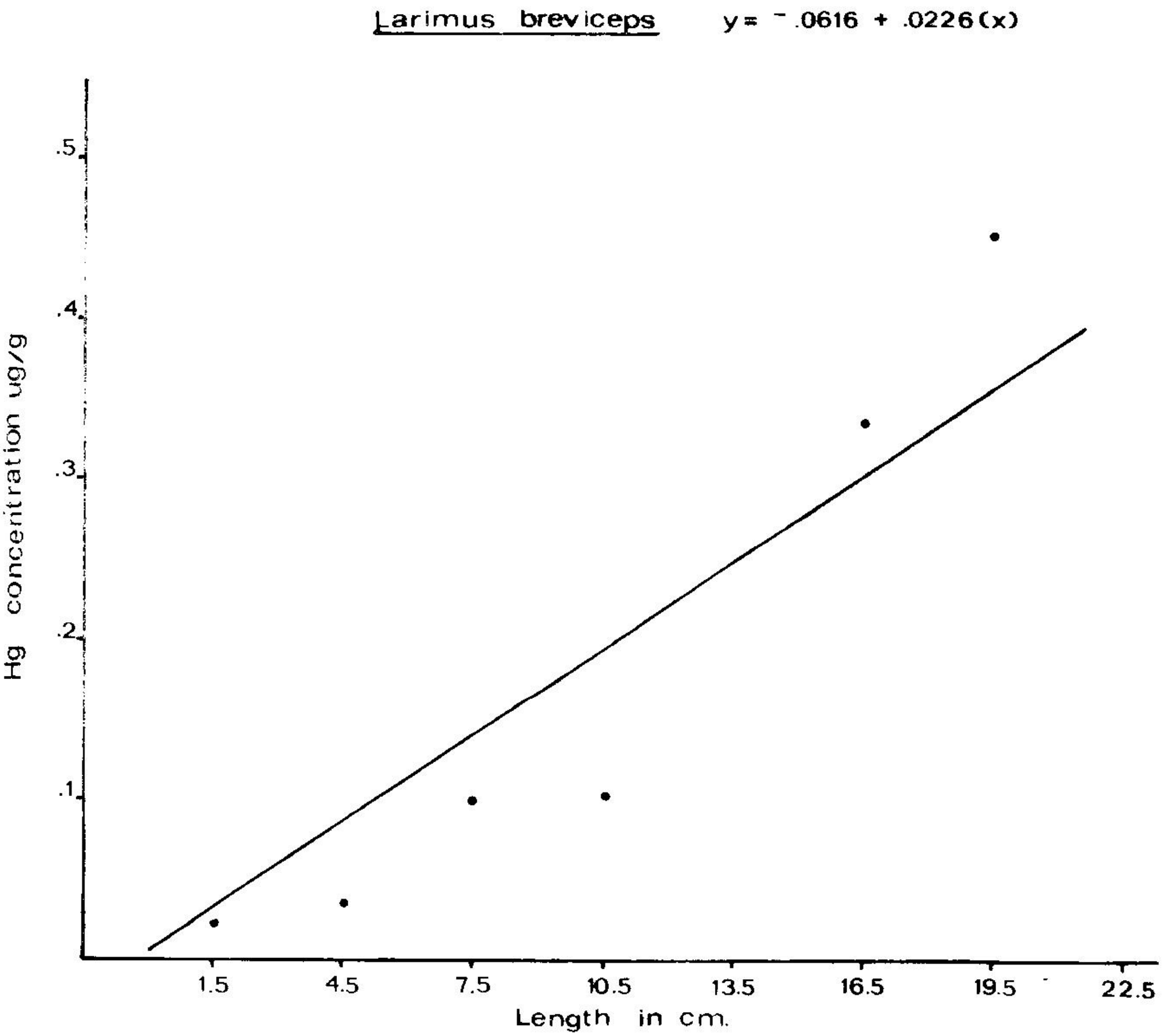

Larimus breviceps
y= ⁻.0616 + .0226(x)
Hg concentration ug/g
.5
.4
.3
.2
.1
1.5
4.5
7.5
10.5
13.5
16.5
19.5
22.5
Length in cm.

Fig. 9

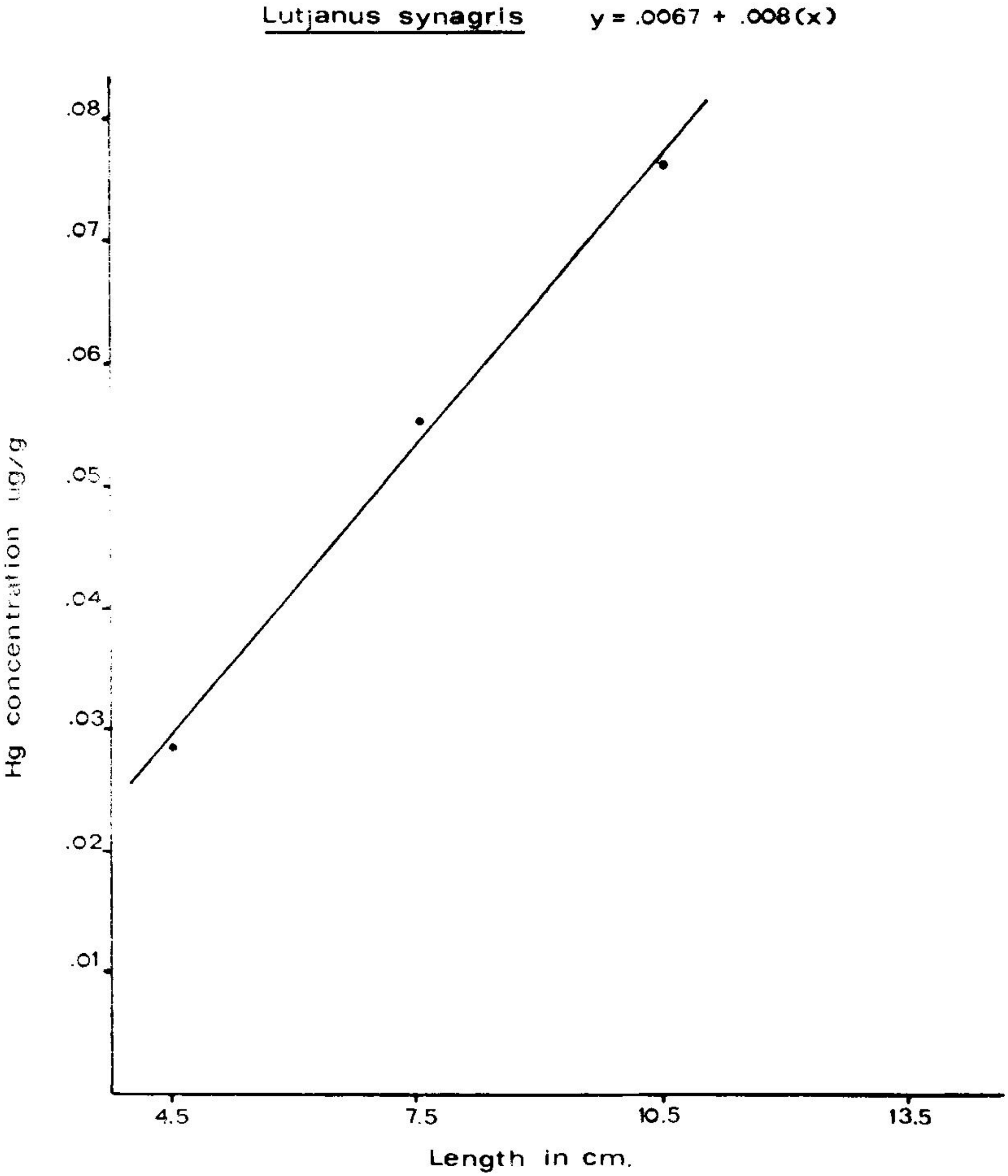
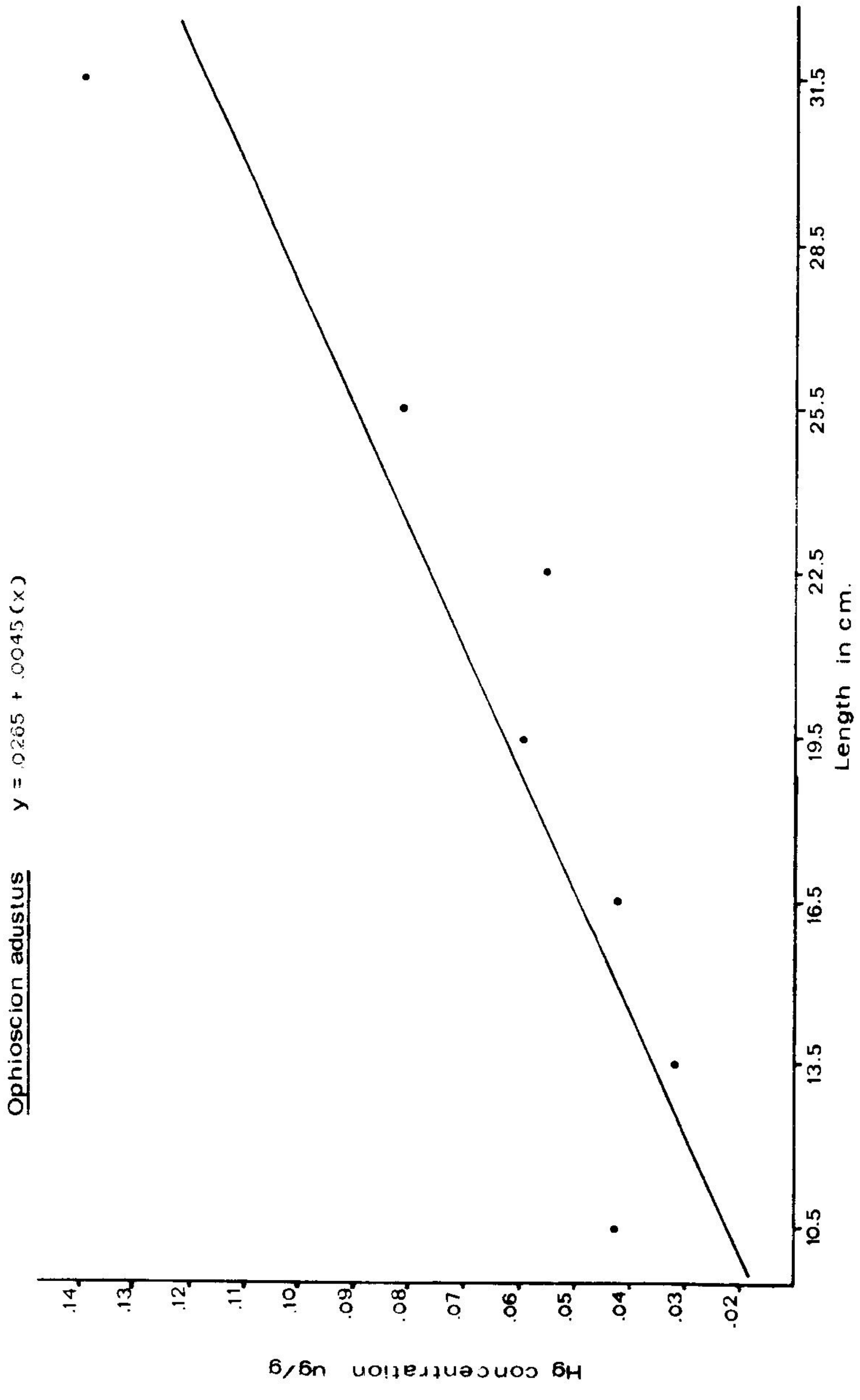

Lutjanus synagris
y = .0067 + .008(x)
.08
.07
.06
.05
.04
.03
.02
.01
Hg concentration ug/g
4.5
7.5
10.5
13.5
Length in cm.

Fig. 10



Ophioscion adustus
y = .0265 + .0045 (x)
Hg concentration ug/g
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
Length in cm.
10.5
13.5
16.5
19.5
22.5
25.5
28.5
31.5

Fig. 11

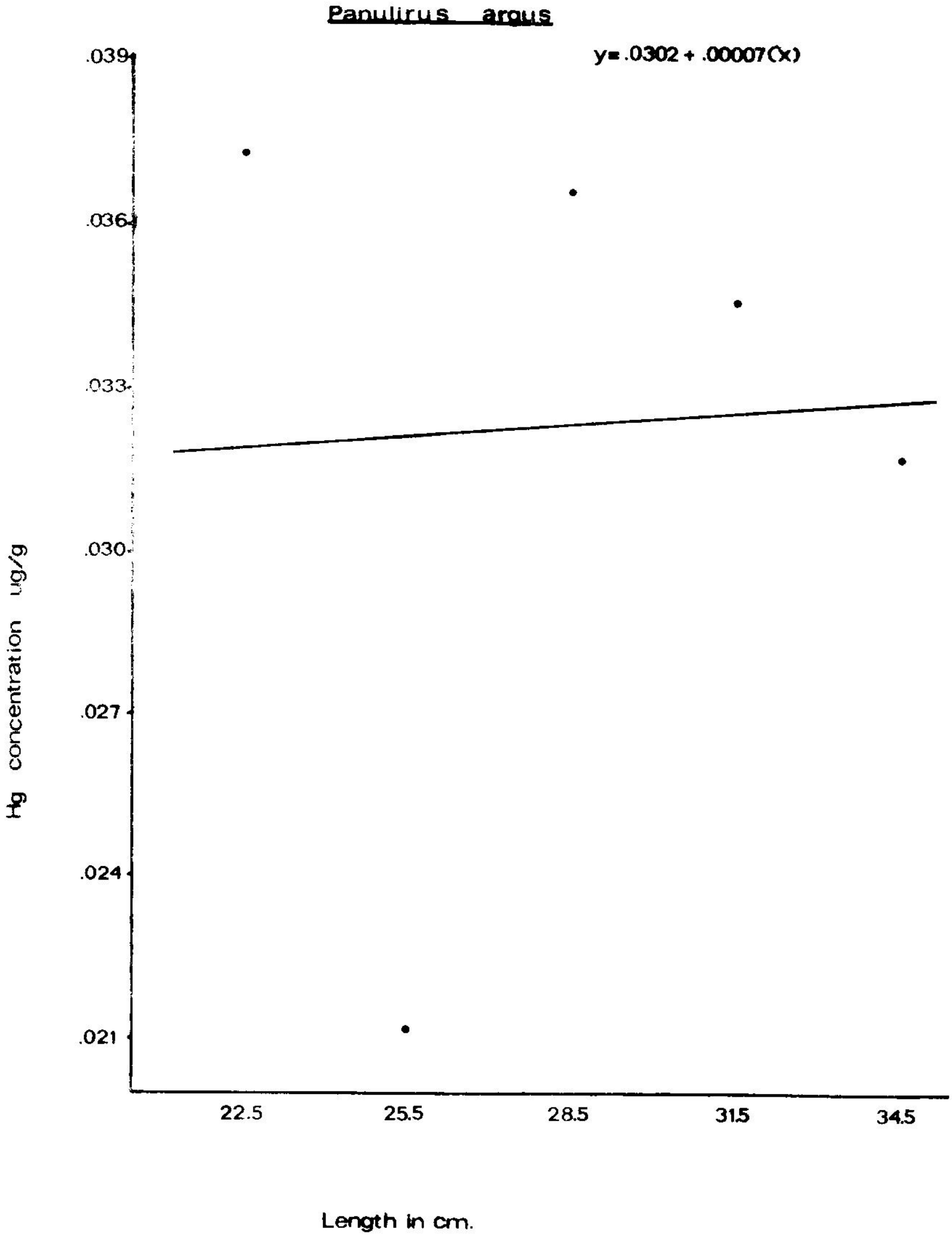
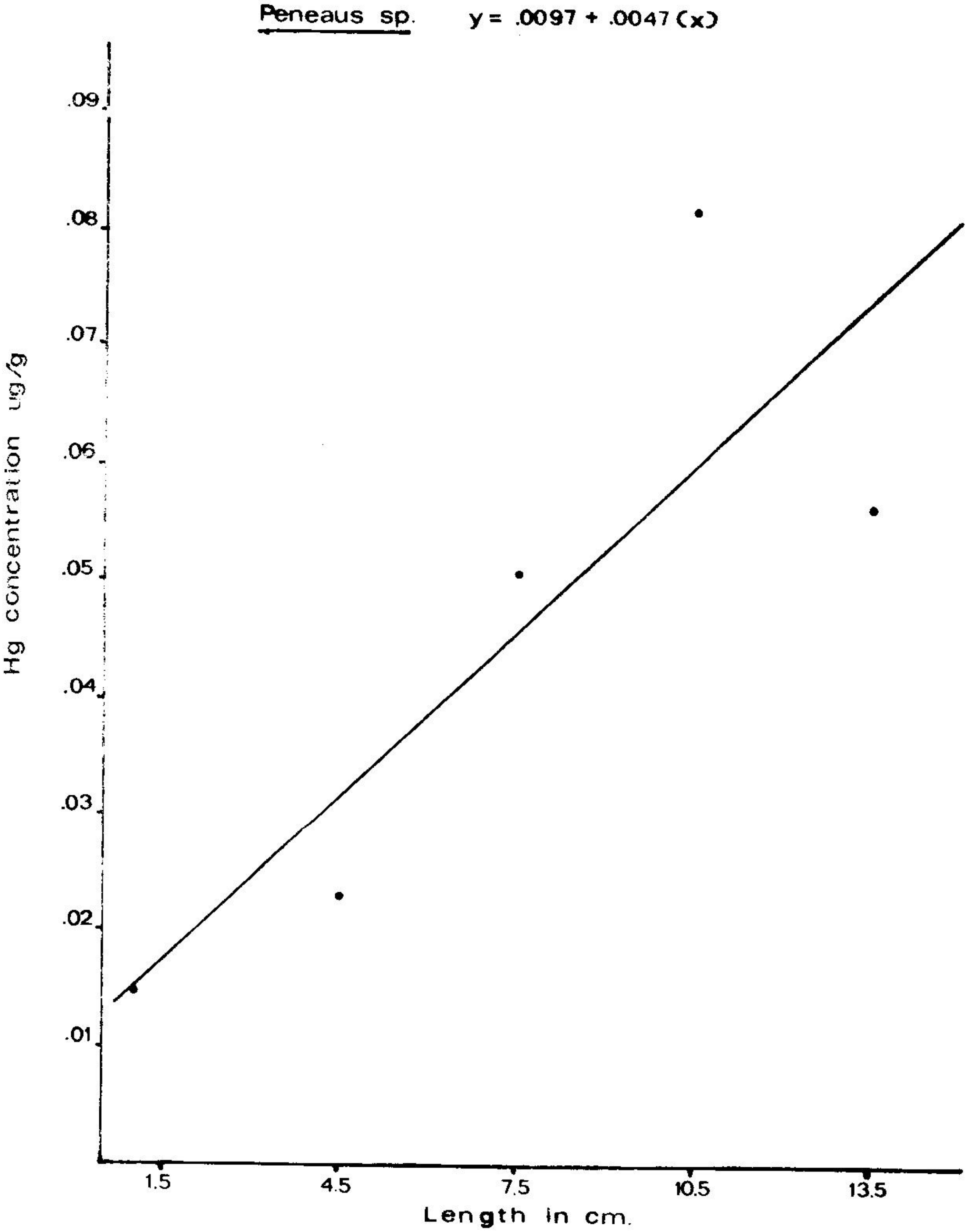
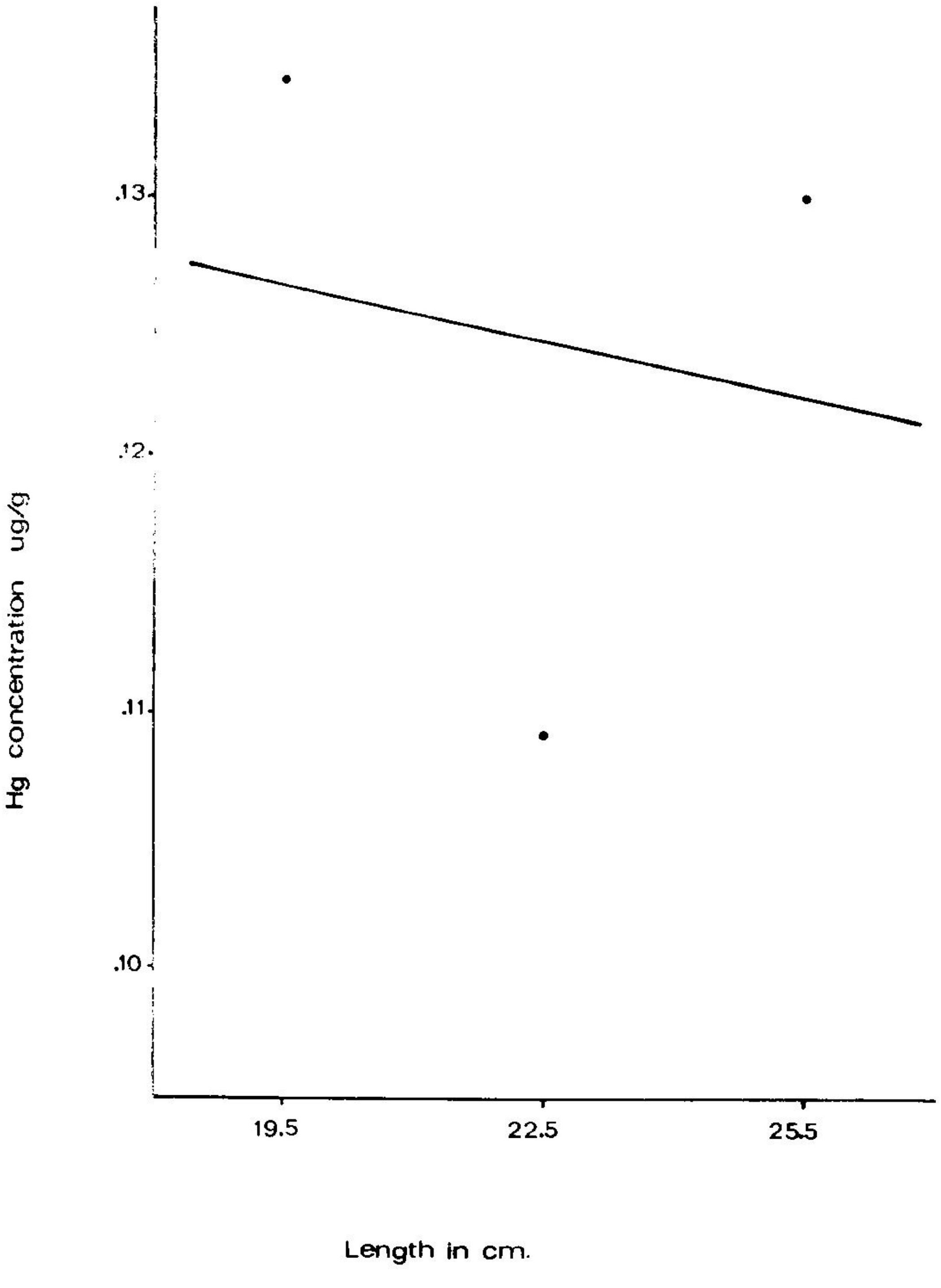

Panulirus argus
y= .0302 + .00007(x)
.039
.036
.033
.030
.027
.024
.021
Hg concentration ug/g
22.5
25.5
28.5
31.5
34.5
Length in cm.

Fig. 12



Peneaus sp. y = .0097 + .0047 (x)

Fig. 13



Petrometopon cruentatum

y=.1414-.0008(X)

Fig. 14

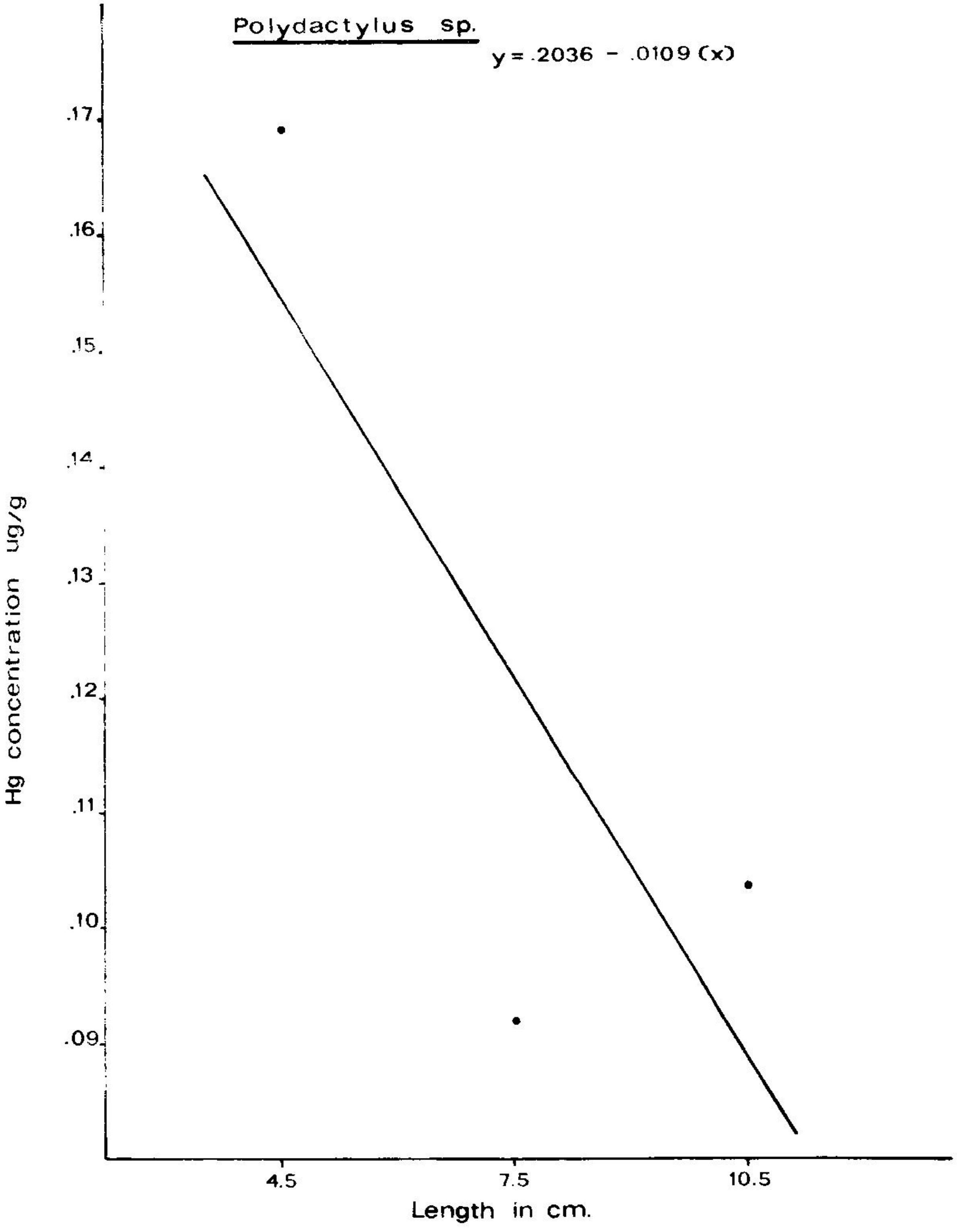

Polydactylus sp.
y = .2036 - .0109 (x)
.17
.16
.15
.14
.13
.12
.11
.10
.09
Hg concentration ug/g
4.5
7.5
10.5
Length in cm.

Fig. 15

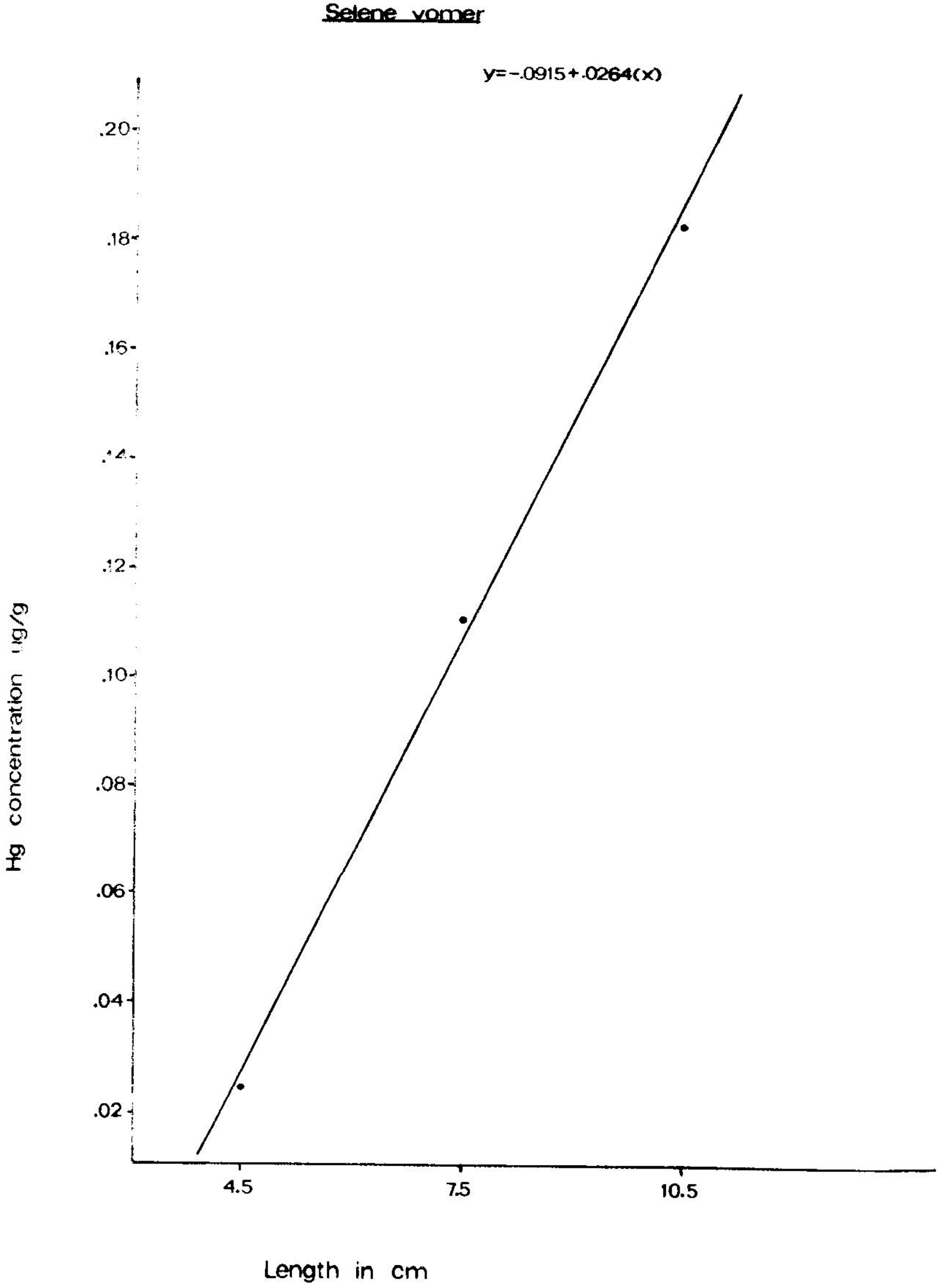

Selene vomer
y=-.0915+.0264(x)
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
Hg concentration ug/g
4.5
7.5
10.5
Length in cm

Fig. 16

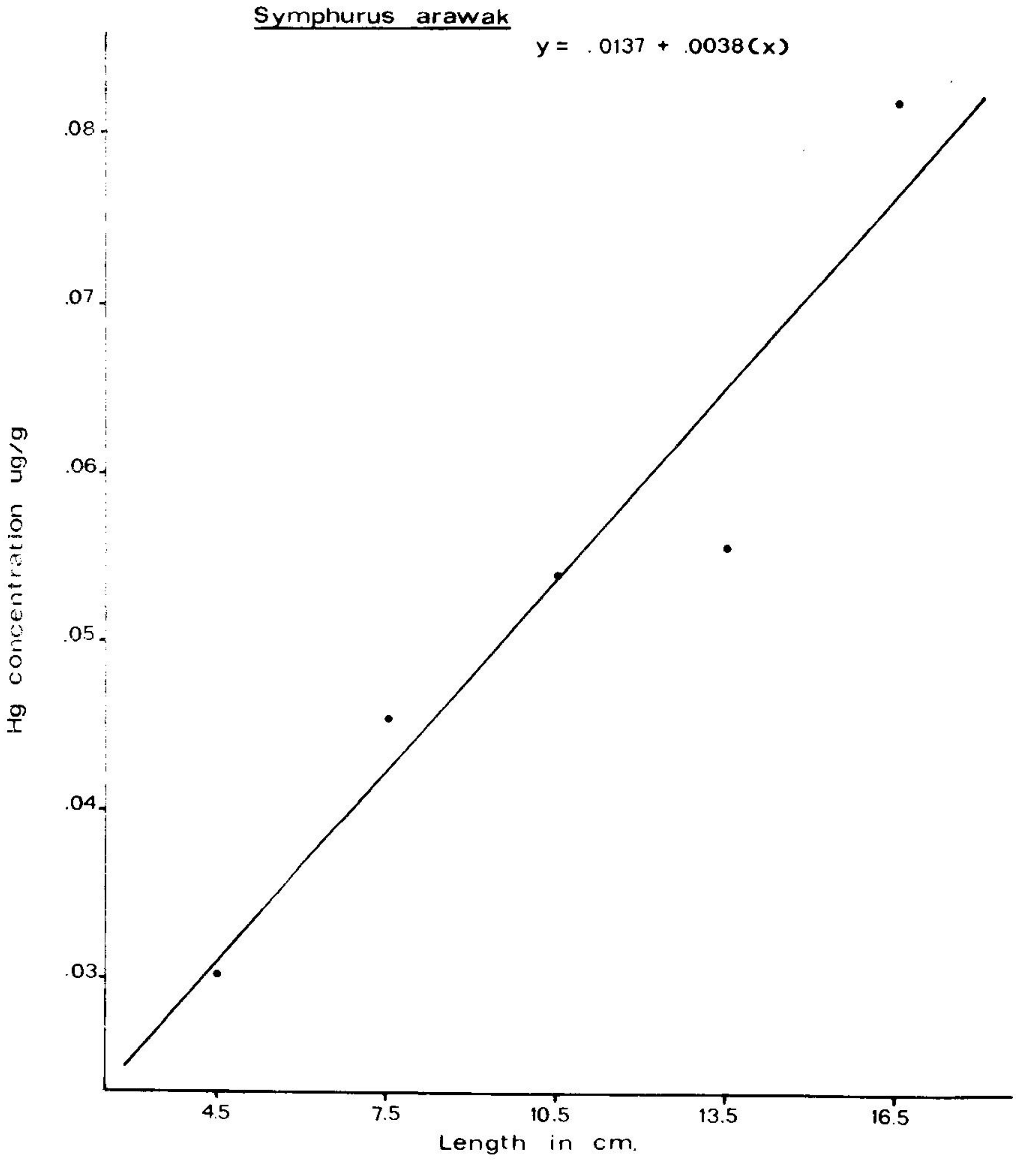
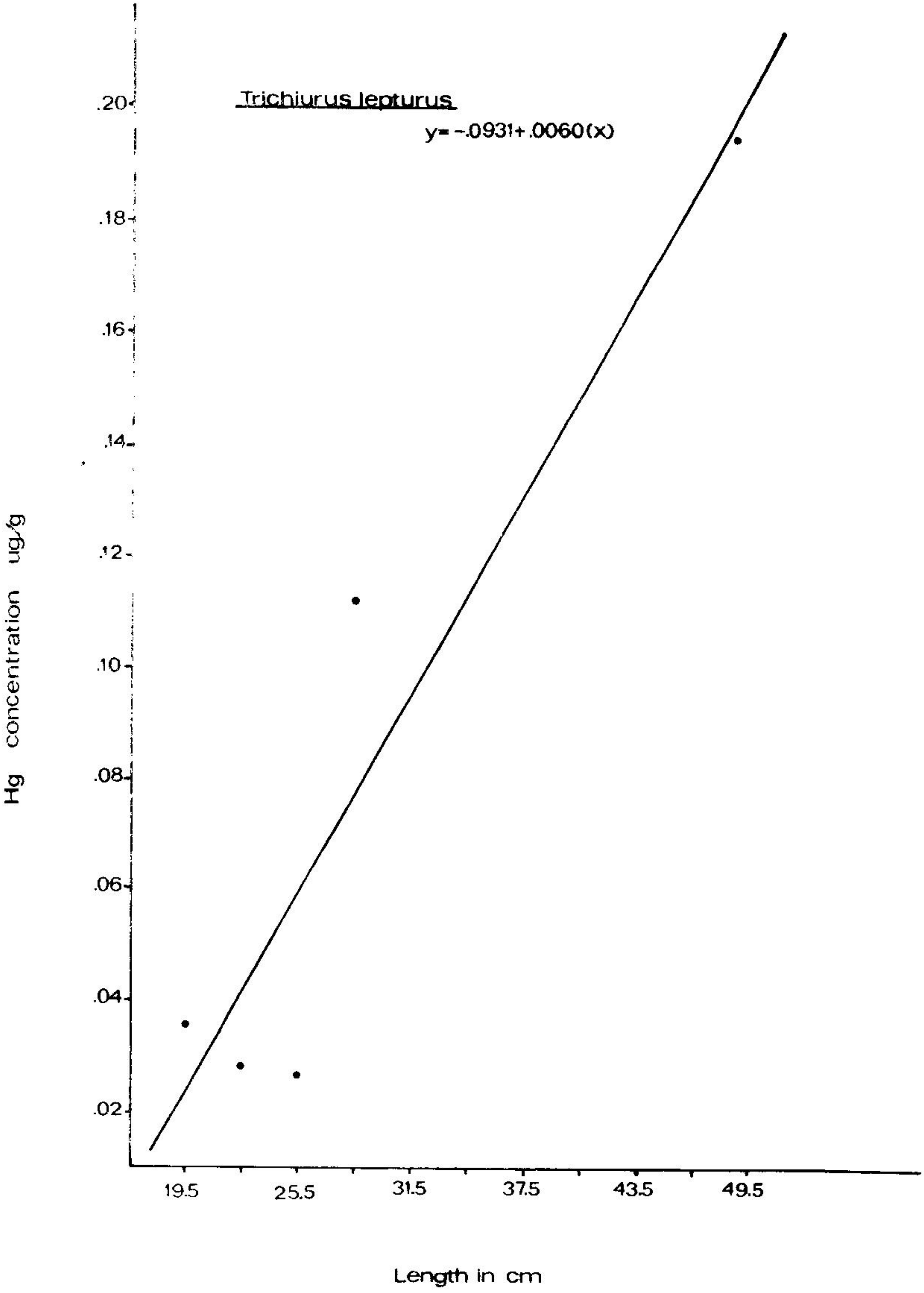

Symphurus arawak
y = .0137 + .0038(x)
Hg concentration ug/g
.08
.07
.06
.05
.04
.03
4.5
7.5
10.5
13.5
16.5
Length in cm.

Fig. 17


Trichiurus lepturus
y= -.0931+.0060(x)
Hg concentration ug/g
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
19.5
25.5
31.5
37.5
43.5
49.5
Length in cm

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LITERATURE CITED

Armstrong, F.A.J. and D.P. Scott. 1979. "Decrease in mercury content of fishes in Ball Lake, Ontario, since imposition of controls on mercury discharges." *Journal of the Fisheries Research Board of Canada*. 36(6):670-672.

Bohlke, J.E. and C.G. Chaplin. 1968. *Fishes of the Bahamas and adjacent tropical waters*. The Academy of Natural Sciences of Philadelphia. Livingston Publishing Co. Wynewood, Pa. 771 p.

Cember, H., E.H. Curtis and B.G. Blaylock. 1978. "Mercury bioconcentration in fish: temperature and concentration effects." *Environmental Pollution*. 17: 311-318.

Freund, John E. 1971. *Mathematical Statistics* 2nd ed. Prentice-Hill, Inc. Englewood Cliffs, New Jersey. 463 p.

National Academy of Science and National Academy of Engineering. 1973. *Quality criteria for water. U.S. Environmental Protection Agency,* Washington, D.C. 20460: 183-192.

Ramelow, G. and H. Hornung. 1978. "An investigation into possible mercury losses during lyophilization of marine biological samples." *Atomic Absorption Newsletter*. 17(3): 59-60.

Ramírez Barbot, J.A. 1979. *Biological availability of mercury to the fisheries of Guayanilla Bay, Puerto Rico*. M.S. thesis, U.P.R.

Randall, J.E. 1968. *Caribbean Reef Fishes*. Published by T.F.H. Publications Inc. Ltd. The British Crown Colony of Hong Kong. 318 p.

APPENDICES

APPENDIX TABLE 1

ADDITIONAL DATA

WATER SAMPLE ANALYSIS

SAMPLE	STATION	MEAN CONC. (ug/l)	STA. DEV.	NOTES
1A	Añasco	<0.001	-	
1B	Añasco	<0.001	-	
2A	Mayaguez	<0.001	-	
B	Mayaguez	<0.001	-	
3A	Punta Guanajibo	<0.001	-	
B	Punta Guanajibo	<0.001	-	
4A	Joyuda	<0.001	-	
B	Joyuda	<0.001	-	

APPENDIX TABLE 2

ADDITIONAL DATA

SEDIMENT SAMPLE ANALYSIS

SAMPLE	STATION	MEAN CONC. (ug/g)	STA. DEV.	NOTES
1A	Añasco	.0679	0.0	
1B	Añasco	.0677	.0243	
2A	Mayaguez	.1757	.0047	
2B	Mayaguez	.1719	.0004	
3A	Punta Guanajibo	.0423	.0126	
3B	Punta Guanajibo	.0745	0.0	
4A	Joyuda	.1036	.0714	
4B	Joyuda	.1018	0.0	
5	Punta Ostiones	.0936	.0123	
6	Punta Ostiones	.1005	.0124	
7	Punta Ostiones	<0.003	0.0	