Amplification of Mercury Concentrations in the Marine Food Chain of the East Coast of Thailand

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Abstract

Three hundred and ninety samples of marine organisms were collected from the East Coast of Thailand for total mercury analysis. The results indicated that mercury levels of fish and other marine organisms from the East Coast of Thailand are within the safety limit. However, biological magnification of mercury residue in the marine food chain was observed. Organisms of higher trophic levels have higher mercury residue than those in the lower trophic levels. Statistical analysis showed positive linear regression between the size of the marine organisms and mercury contents of some species of marine organisms.

1. Introduction

Mercury coumpounds are utilized on a wide scale both in industry and agriculture. Mercury from industrial and agricultural wastes accumulate in soil and water, and is partially transported to the aquatic environment, which in turn becomes a source of contamination of fish and other organisms. The ability of some microorganisms to methylate inorganic mercury to the more biological stable alkyl forms and the more toxic forms further increases the danger of contamination [1]. The concern about mercury pollution in the marine environments started in the 1950s with the case of Minamata in Japan where several people died or became terminally sick after consuming fish and shell fish containing relatively high concentrations of methyl mercury [2]. High levels of mercury were also found in fish from Swedish lakes and streams. The principal mercury contamination of these fish was reported to be an organic form of methyl mercury [3].

Many studies on a wide range of marine fish have reported positive correlations between mercury concentration and a measure of age, weight, or length of fish [4,5,6,7,8,9]. This may, however, reflect the increased interest in mercury as a potential threat to human health. Despite this tendency for mercury to increase in concentration with increasing size/age of some fish, muscle mercury levels tend to be less than 1 ppm with kidney and liver levels slightly higher [10,11,12,13].

In 1975, the total mercury contents of fish in the Gulf of Thailand ranged from 0 to 0.58 ppm [14]. In the same year, traces of total mercury were found in the marine food chain of Bang Pra coastal area of Chonburi province [1] which tend to increase at higher trophic levels and according to the size of organisms . Since Thailand is one of the countries where the nationwide fish consumption is comparatively high, further study on the contamination of mercury in fish and other marine organisms is essential.

2. Materials and Methods

2.1 Sample collection and treatment

Samples for mercury analysis were collected from Station A (Angsila) Station B (Laem Chabang) subdivision of Chonburi province and Station C (Ban Pae) subdivision of Rayong province(Fig. 1). Fish samples were collected from the catch by otter trawl in January 1999. The species of fish and other organisms from which samples were taken ranged from the lower trophic level to the higher trophic levels. Plankton samples were collected by a plankton net. All of the samples were preserved in a freezer at approximately -20 °C. For fish assay the samples were thawed and dissected with a stainless steel knife, and a portion of muscle under the dorsal fin, kidney, liver, gill, and stomach were dried in the freeze dryer and used for mercury determination.

2.2 Mercury analysis

Total mercury levels in fish and other organisms were determined by means of Cold Vapor analysis techniques. One gram of tissue was digested in 20 ml of 1:1 concentrated redistilled HNO_3 and concentrated H_2SO_4 , and further oxidized with 10 mL of saturated $K_2S_2O_8$ solution. Excess oxidizing agents and mercury ions were reduced by 10 mL of reducing solution (3%$NaBH_4$ in 1% NaOH) in hydride generator apparatus, and then mercury was vaporized and measured in the flamelesss atomic absorption spectrophotometer.

A Perkin-Elmer 3300 atomic absorption spectrophotometer (The Perkin-Elmer Corporation, Norwalk, CT) equipped with a MHS-10 mercury hydride system was used to determine the total mercury concentration of each sample. The accuracy of these determination was verified with a standard reference material DOLT-1 (dogfish liver : 0.225 ± 0.057 ppm Hg) of the National Research Council of Canada. Results of analysis are within the range of $\pm$ 10 %.

3. Results and Discussion

One hundred and seventy samples of 5 species of fish, one hundred and eight samples of 2 species of crustacean, fifty-four samples of 1 species of shellfish, fifty-four samples of 1 species of squid and four samples of plankton from the East Coast of Thailand were analysed for total mercury. Results showed that total mercury concentrations ranged from 0.002 - 0.714 ppm (dry weight) with the mean value of 0.118 ppm. While those found in 1975 in the adjacent area ranged from 0-0.58 ppm [4]. Of the total of 390 samples analysed, 20 % contained less than 0.05 ppm of total mercury, 79 % had a total mercury content between 0.05 - 0.5 ppm and 1 % contained over 0.5 ppm. According to Menasveta [1] , these concentration can be regarded as a natural background of mercury for fish in general. It should be noted that only 3 samples were found having total mercury levels above the United States Food and Drug Administration tolerance limit of 0.5 ppm.

Table 1 gives the mean and standard deviation of total mercury concentrations in the four trophic levels. The mean values of total mercury for the first and second trophic levels (composited species of plankton) from station A (Angsila) and B (Laem Chabang) were 0.004 and 0.007 ppm, respectively. The mercury residue concentration in the third trophic level was higher than the first and second trophic levels. The mean values were 0.068, 0.112, and 0.053 ppm for station A, B, and C respectively. The mean values of the fourth trophic level have higher mercury residue than those in third trophic level as shown in Table1. Student 't' test showed significant difference in total mercury concentrations between trophic levels I + II and trophic level III and between trophic levels III and IV ($p < 0.5$). The lowest mercury residue (0.002 ppm) was detected in the composite species of plankton while the highest mercury residue (0.714 ppm) was detected in *Loligo formosana* (Splendid squid). This species was categorized in trophic level IV.

Table 1: Total mercury contents (ppm) in different trophic levels from three sampling stations (Angsila, Laem Chabang, and Rayong)

A) Angsila station

Trophic levels	No. of samples	mean	standard deviation
I, II	2	0.004	0.002
III	36	0.068	0.032
IV	90	0.150	0.094

B) Laem Chabang station

Trophic levels	No. of samples	mean	standard deviation
I, II	2	0.007	0.002
III	36	0.112	0.070
IV	94	0.144	0.120

C) Rayong station

Trophic levels	No. of samples	mean	standard deviation
III	36	0.053	0.022
IV	94	0.113	0.099

Based on the above analysis, it can be concluded that there is a biological magnification of mercury residue in the marine food chain of the East Coast of Thailand. Fish of higher trophic levels contain higher mercury residue than those in the lower trophic levels (Fig. 2). This suggests that mercury may be concentrated in the same manner as an organic compound such as organochlorine compounds, i.e., passed through and amplified by the food chain. The concept also conforms to the the data presented by Johnels *et al.* [3] , Scott [15] , and Menasveta [1].

Statistical analysis showed positive linear regression between the size of the marine organisms (weight) and mercury contents of some species of marine organisms. Figure 3 gives the example of the linear regression in *Peneaus merguiensis* (White shrimp), *Portunus pelagicus* (Blue swimming crab), *Mytilus edulis* (Green mussel), *Sillago maculata* (Trumpeter sillago), and *Atule mate* (Banded crevalle) collected from stationB. (Laem Chabang). However, the results showed different correlation between size and mercury contents in different sampling stations for other organisms. The positive linear regression between age/or weight and mercury contents of fish is well documented by Scott [15].

Figure 4. showed the mean values of mercury content in various marine organisms collected from 3 sampling stations. The results indicated that *Portunus pelagicus* (Blue swimming crab)(0.240 ppm), *Loligo formosana* (Splendid squid)(0.325 ppm) and *Atule mate* (Banded crevalle) (0.387 ppm) have the highest mercury content among other marine organisms collected from Angsila, Laem Chabang, and Rayong respectively. However, the average mercury content of these marine organisms from the East Coast of Thailand were lower than the United States Food and Drug Administration tolerance limit of 0.5 ppm.

The mercury contents in various tissues such as kidney, stomach, gill, muscle, and liver of *Epinephelus corallicola* (Grouper) collected from station b. (Laem Chabang) were analysed. Highest mercury residues were found in kidney and liver respectively (Fig. 5). This is probably due to their high affinity for sulphur containing ligands such as sulhydryl (-SH) group in metallothionine in fish's kidney and liver as described by De [16]. Similar results were reported by Thongra-ar [17] in 1988.

The results of this study indicated that the average mercury content of fish and other marine organisms from the Eastern Coast of Thailand was lower than the United States Food and Drug Administraton tolerance limit of 0.5 ppm. The mean value of 0.118 ppm for total mercury is only one-fourth of this tolerance limit. However it is probably not practical to consider this recommended level without correlating it to the frequency of consumption. It was estimated that the fish/sea food consumption rate among Thai people is 20 kg/person/year [18]. This level is equal to 55 g/person/day. If the mean total mercury content of fish and other marine organisms is 0.118 ppm, it can be calculated that the daily intake of mercury through fish/seafood consumption is 6.49 μg/person/day for Thai people. This value is greater than 4 μg/person/day as reported from Sweden [19]. The Joint FAO/WHO Expert Committee on Food Additives proposed that the provisional tolerate-weekly intake (PTWI) of mercury for man be set at 0.0033 mg/kg body-weight for methyl mercury. This value is equal to to PTWI of 0.2 mg. mercury as methyl mercury, for an average body-weight of 60 kg. The daily mercury intake of 6.49 μg/person/day which we derived from this study, would contribute to weekly intake of 0.045 mg/person. This level is only one-fourth of PTWI of mercury (assuming that all mercury contributed by fish and other marine organisms is in the form of methyl mercury). It is therefore, the mercury levels of fish and other marine organisms from the East Coast of Thailand are within the safety limit for consumption.

4. Conclusions

The result of this study indicates that the mercury levels of fish and other marine organisms from the East Coast of Thailand are within the safety limit. However, the situation may change in the future, because at present our country is still at developing stage. Modern agricultural techniques, including extensive use of pesticides, coupled with industrial development, will probably increase the amount of mercury in the environment in the future. Hence, the plan for monitoring, proper protection and control of mercury residue in Thailand's environment should be formulated and implemented without delay.

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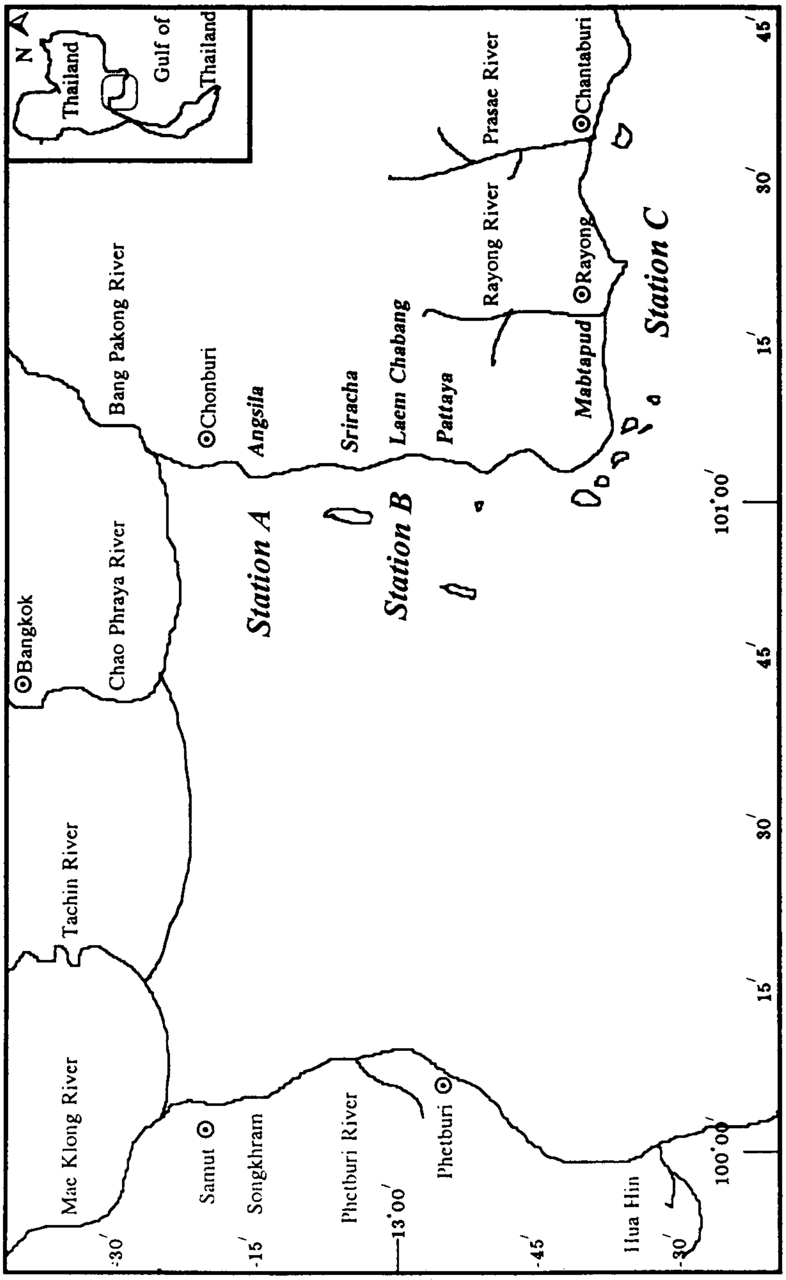

Figure 1 Sampling stations

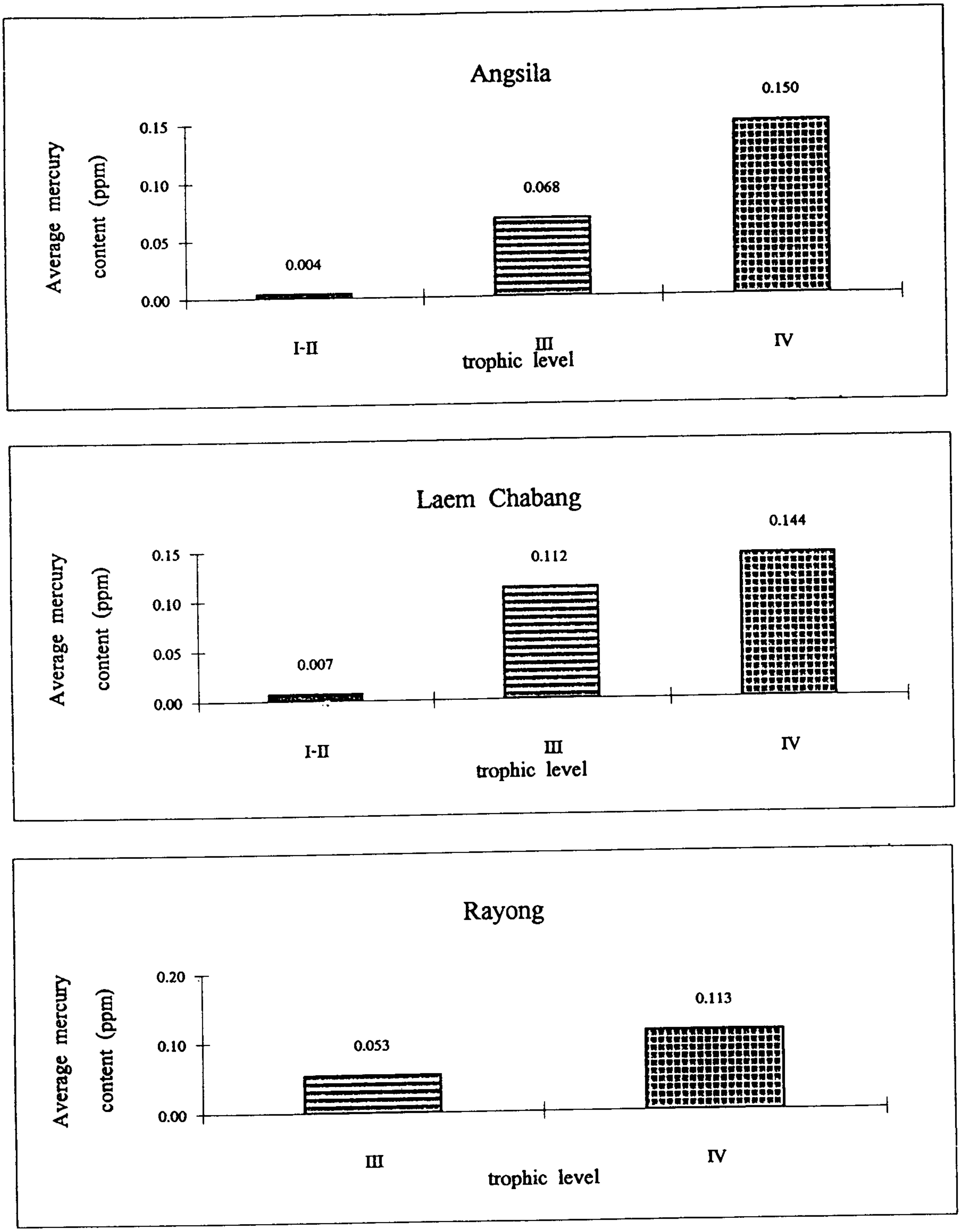

Figure 2 Average mercury content (ppm) in the four trophic levels

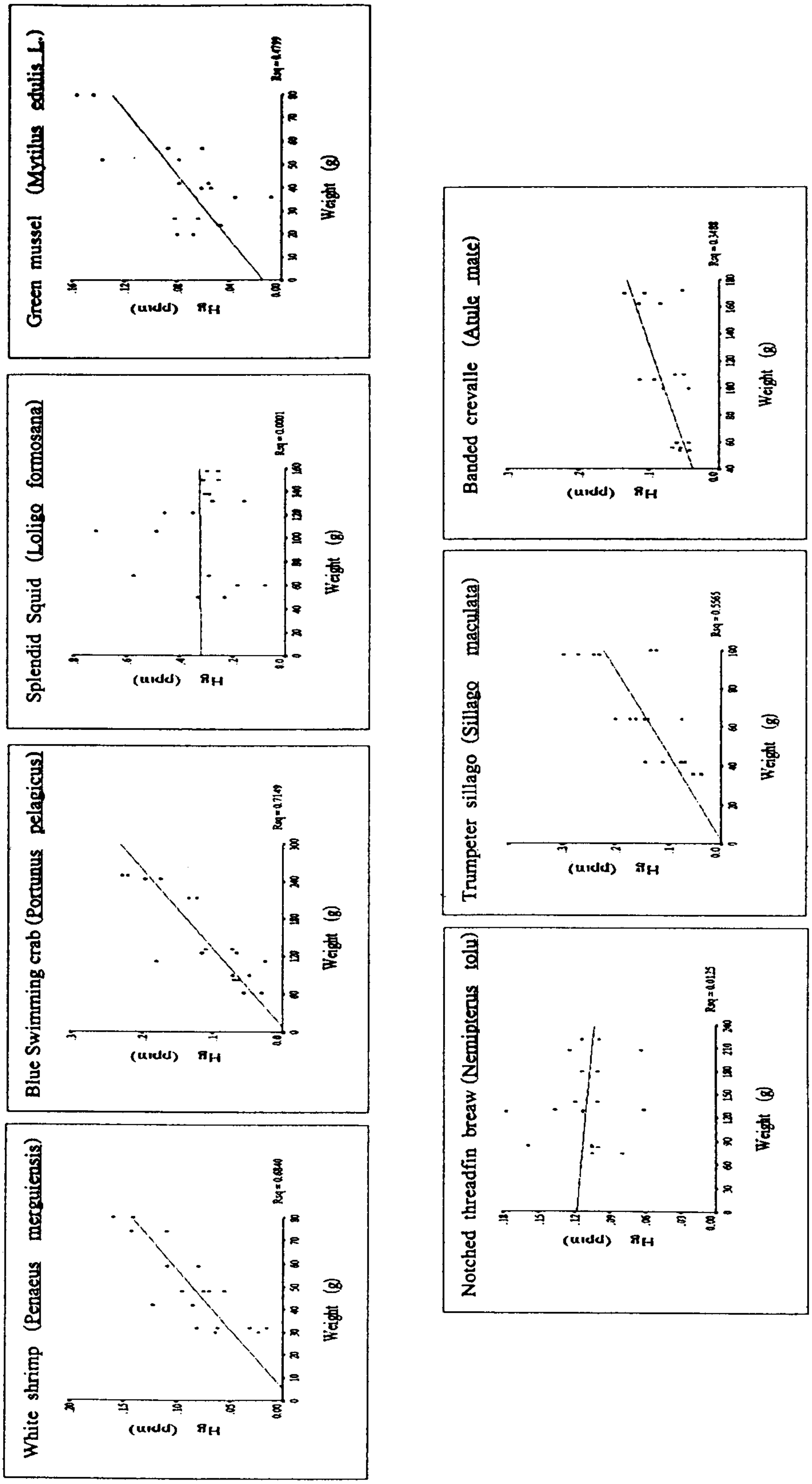

Figure 3 The relationship of total mercury to the weight of various marine organsims

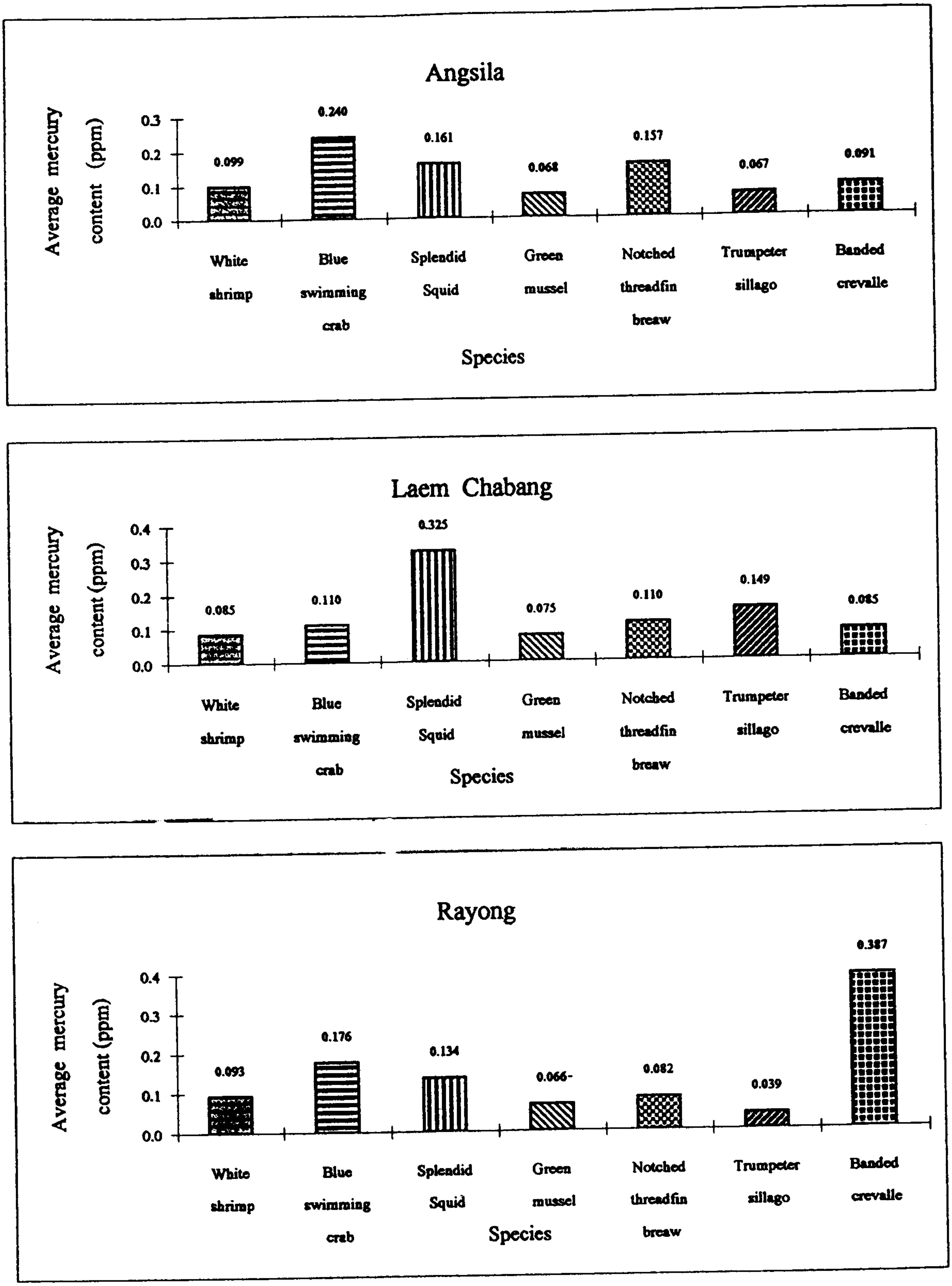

Figure 4 Average mercury content of various marine organisms

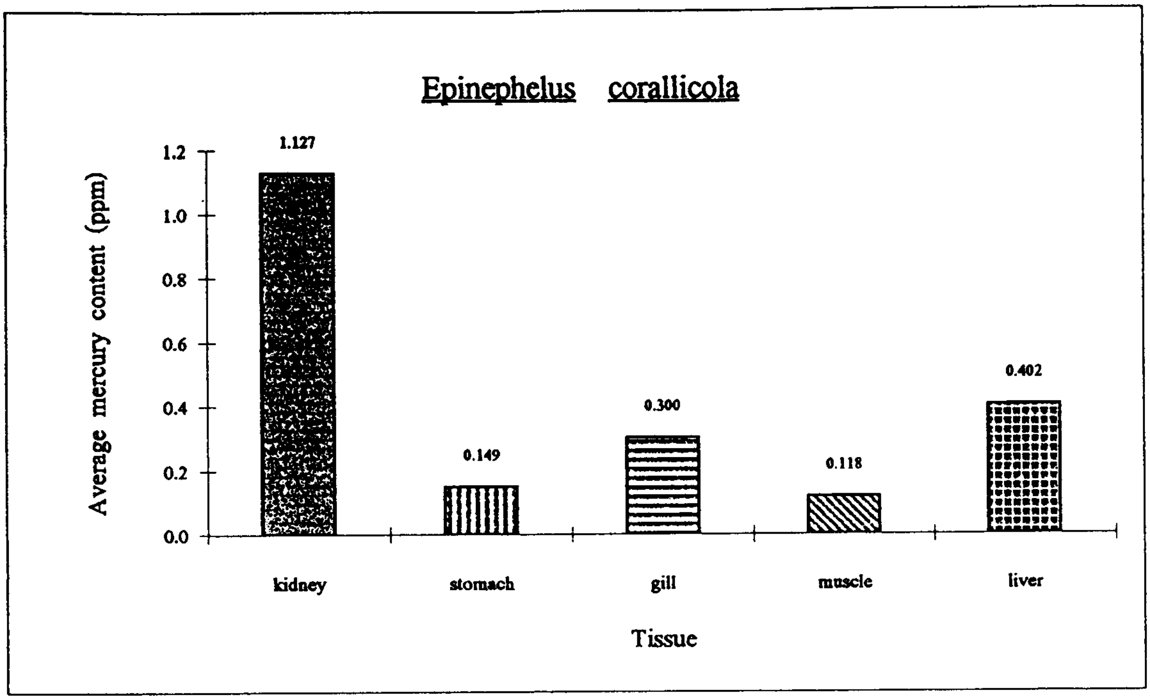

Figure 5 Average mercury content in various tissues of *Epinephelus corallicola* (Grouper)