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Concentrations of Heavy Metals in Various Organs of Four Fish Species and Their Use as Pollution Indicators.

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❒ ABSTRACT ❒

Feeding habits, dry/wet weight ratio and the concentration of Cd, Pb, Cu and Zn were determined in muscle, gill, liver, gonad and stomach contents of 4 fish species; King George Whiting (Sillaginodes punctatus), Yellow-Fin Whiting (Sillaginodes punctatus), Yellow-eye Mullet (Aldrichetta forsteri) and Gar Fish (Hyporhamphus melanochir) caught from Barker Inlet, South Australia during the period Oct.1994 - Jul.1995. Regarding their ability to accumulate heavy metal, in the first instance, the usage possibility of the above mentioned organs as representatives of the species as pollution indicators was considered. In general, the higher Cd concentration was in the liver & muscle, followed by the gill then by gonad and the muscle tissue was the best organ as a representative of Mullet and K.G.Whiting as Cd indicators. It was found that the highest Pb concentration was in the liver and in the gill (for Mullet) but the lowest one was in the gonad. The best organs as a species representative of Pb pollution were the gill (for Mullet) and liver (for K.G.Whiting and Y.F.Whiting). Copper concentration in the liver was higher than that in the gill of all fish species studied. Liver tissue is regarded as a representative of the fish as Cu indicator. The highest Zn concentration was in the gonad then in the gill & liver and the lowest concentration was in the muscle. The gills of all species studied were the best representative organ as Zn indicator in that the gonads do not satisfy the requirements since it changes by quality and quantity over the year.

The discussion presented in this study reveals that the metal concentration in the muscle tissue is related to many biological and environmental factors. The conclusion drawn from this study necessitates the use of bioidindicators, such as the fish, to survey metal concentration in the marine ecosystem.

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تراكيز المعادن الثقيلة في الأعضاء المختلفة لأربعة أنواع من الأسماك واستخداماتها كمؤشرات للتلوث

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(ورد إلى المجلة في 1998/9/29، قبل للنشر في 1999/1/26)

□ الملخص □

تمت دراسة عادات التغذية ونسبة الوزن الجاف/الوزن الرطب وتراكيز كل من الكادميوم والرصاص والنحاس والزنك في العضلات والغلاصم والكبد والغدد الجنسية ومحتويات المعدة لأسماك قد الملك جورج (*Sillaginodes punctatus*) والقد ذو الزعنفة الصفراء (*Sillago schomburgkii*) والبوري ذو العين الصفراء (*Aldrichetta forsteri*) والأرفيذة (*Hyporhamphus melanochir*) صيدت من شواطيء جنوب استراليا خلال الفترة من تشرين الاول *1994* حتى تموز *1995* . وتمت دراسة إمكانية استخدام هذه الأسماك كمؤشرات حيوية للتلوث بطريقة دراسة تراكيز المعادن الثقيلة أعضائها المختلفة. يمكن القول أن أعلى تراكيز للكادميوم كانت في الكبد وأنسجة العضلات ثم في الغلاصم ومن ثم في الغدد الجنسية ، وان الأنسجة العضلية للبوري وقد الملك جورج يمكن أن تخدم كأعضاء مؤشرة للتلوث بالكادميوم. و أعلى تراكيز للرصاص كانت في الكبد والغلاصم (عند البوري) وأقلها في الغدد الجنسية. وتشير النتائج أن افضل أعضاء الأسماك المؤشرة للتلوث بالرصاص هي الغلاصم عند البوري والكبد عند نوعي القد. وقد كانت تراكيز عنصر النحاس أعلى في الكبد مقارنة منها في الغلاصم عند كل الأسماك المدروسة، وتعتبر أنسجة الكبد معيارا مقبولا كمؤشر للتلوث بالنحاس. وتبين النتائج أن أعلى تراكيز للزنك كانت في الغدد الجنسية ثم في الغلاصم والكبد. وتعتبر الغلاصم عند كل الأنواع المدروسة أفضل عضو مؤشر للتلوث بالزنك لأن الغدد الجنسية ذاتها لا تحقق الشروط المطلوب توفرها لأن نموها يختلف تبعا للفصل التكاثري. وقد تمت مناقشة النتائج اعتمادا على الخصائص الفيزيائية والكيميائية لمكان الدراسة وعلى ما هو منشور حول نفس الموضوع. وتخلص مناقشة نتائج هذا البحث إلى ضرورة الاعتماد على المؤشرات الحيوية، كالأسماك وتراكيز المعادن الثقيلة في بعض أعضائها لمراقبة تراكيز هذه المعادن في النظام البيئي البحري عوضا عن الطرق التقليدية الخاصة بذلك، وبينت إيجابيات استعمال المؤشرات الحيوية في هذا المجال.

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INTRODUCTION:

Studies on heavy metal accumulation in fish and other aquatic organisms are of utmost importance, because of the potential transportation of such toxic substances to human body through food chain (Forstner & Wittmann, 1983). Therefore, a number of studies has been conducted to assess the level of metal concentration in marine ecosystem and specifically in marine organisms. However, studying metal concentration in biota reflects the bioavailability of the pollutants and consequently marks the effective degree of pollution in the environment.

Organisms accumulate trace metals from ambient waters either through absorption or through their feeds and metal accumulated by primary producers may be concentrated to toxic proportion in organisms higher at trophic levels. The use of environmental indicators has, thus, been recommended to describe the pollution-state of environment and in this context heavy metal concentration in stationary fish can act as environmental indicators (OECD, 1991), especially in areas affected by human activity.

Heavy metals are known to be potentially toxic because of their ability to be concentrated in the organs of marine organisms (Watling, 1983). However, metal concentration in animals is metal, species and tissue specific, depending on the biology and physiology of a species. Workers have demonstrated that the accumulation of heavy metals occurs mainly in the nonedible parts of fish such as liver, kidney, gills, brain.... etc. (Winger *et al.*, 1990).

Cadmium and lead are among the most toxic heavy metals, and to a lesser extent are copper and zinc (Furness and Rainbow, 1990) and, even so, on the other hand, there are very few references about such metal contamination of biota from Barker Inlet ecosystem. Thus, it would be relevant to establish a baseline of contaminant information to evaluate the level and extent of the present pollution state in the area and for comparison with future monitoring. Therefore, various organs of the dominant fish species of Barker Inlet were studied for the accumulation of Cd,Pb,Cu and Zn. The data should be useful for better water quality planning and resources management. This study might also contribute to the development of bioindicators, for metal distribution in the ecosystem. Some biological parameters such as feeding habits and dry/wet weight ratio were also considered.

MATERIAL AND METHODS:

Fish samples were collected from 3 sites in Barker Inlet (part of the St. Vincent gulf system), Adelaide-South Australia. These sites differ in their characteristics and in the extent of exposure to pollution: **Site 1** (Kings Beach) is more open to the gulf and is a recipient of creek water carrying waste and saline discharges from nearby salt crystallization & chemical works. A large amount of effluent from a sewage treatment works is discharged to the north-east of this site. **Site 2** (Angas Inlet) is affected by warm water discharged from a nearby power generating station. **Site 3** (North Arm) is a major receiving point of most urban & industrial runoff from northern Adelaide city. all of these sites are estuarine areas supporting extensive mangroves (*Avicinia marina*). A full description of these sites is cited in (Ibrahim, 1998).

Samples included 4 different fish species, including King George Whiting (*Sillaginodes punctatus*), Yellow-Fin Whiting (*Sillago schomburgkii*), Yellow-eye Mullet (*Aldrichetta forsteri*) and Sea Gar-Fish (*Hyporhamphus melanochir*); referred to as K.G. Whiting, Y.F. Whiting, Mullet and Gar Fish respectively. These fish are thought to be suitable for this study because they differ in their feeding habits, are dominant and spend a significant time of their lives in the area -hatching, nursing and feeding (Jones, 1984). In addition, these species are popular for Australian people and studying toxic metal concentration is significant from human health point of view.

Samples were collected at 4 occasions: 20th October 1994, 22nd November 1994, 1-2nd March 1995 and 13-14th July 1995. Fish were caught using seine net operated from a boat. At each date and site, about 25 fish (generally 16-20cm. standard length) of each species were collected and sorted into plastic bags. Very small and very large fish were not included in this study to minimize any size dependent variability of heavy metals. The species make up depending upon availability at that time. In the laboratory, fish were cleaned from mud by distilled water and about 5 cm. of dorso-lateral skinless fillets were then taken from about 10 fish and put in a small plastic vial. The first 2 gill arks were also separated into vials. The fish were then opened and the stomachs were dissected, the percentage of fullness was estimated and present food types were classified and removed into plastic vials. Samples of liver were also taken where about 75% of the liver of each fish were separated into vials. The Whole gonad of each fish was also taken in a similar way.

Samples of each tissue and fish types were mixed to form a composite sample and kept in a deep freezer (-30°c) until analyzed. Later, samples were weighed for wet weight and freeze-dried for about 15 hours. They were then ground using agate mortar and pestles. Digestion was made using 10 ml high purity nitric acid (70%) for each 1g. dried materials and heated at 70°c for 1 h. then another 10ml hydrogen peroxide (100% vol.) were added and heating continued until complete gas emission from the sample. The acid digestate was then brought to volume and used for analysis of Cd, Pb, Cu and Zn by Anodic Stripping Voltammetry (chemtronics

PDV2000) following the method of standard addition (Batley & Florence, 1974). To achieve the highest possible accuracy of the results, samples were done in three replicates and reagent blanks were always carried out. Recovery of standard addition was always 10% or less below. All the equipment and containers used in this work were previously soaked in nitric acid (1:1)for several days and thoroughly rinsed in double-distilled water for several times and dried before use, as has been suggested for trace and ultratrace metal analysis (Guerrero & Kesten, 1993). After obtaining the appropriate samples for heavy metal analysis, samples from various tissues were taken to estimate the dry/wet weight ratios, on each sampling date, by drying at 105°c until the constant weight was reached.

DATA PRESENTATION & STATISTICAL ANALYSIS:

The results of heavy metal analysis were presented in a form of μg/g dry material to minimize the effect of moisture variation in various tissues. Prior to statistical comparisons, data were analyzed using Bartletts test for homogeneity of variance and the difference between the variances was significant (heterogeneous) in most cases. Thus, the null hypothesis that heavy metal concentration would not differ from a fish species or tissue to another was analyzed by Kruskal-Wallis nonparametric ANOVA (Siegel, 1956). A probability of 0.05 or less was regarded as significant.

RESULTS:

a. Feeding habits of the fish:

All fish used in this study were active feeders, having 50-100% of the food in their stomachs; only Mullet have always 80-100% of the food in their stomachs. No empty stomachs were encountered.

During the study period, K.G. Whiting and Y.F.Whiting of Barker Inlet had primarily fed on Polychaeta and, to a lesser extent, on Crustacea (Decapods & Isopods) while the Mullet had fed on *Ulva australis*, Polychaeta and Crustacea (Isopod & Amphipod). By contrast, GarFish had fed on zooplankton only. Unidentified material were always found in the stomachs of the four fish species studied.

b. Dry/wet weight ratio:

Dry/wet weight ratio values are presented in Table (1). This ratio for fish muscle was similar between fish samples (0.225-0.238) throughout the sampling periods (no significant difference was found; $P>0.05$). Similarly, this value did not differ significantly between fish species ($P>0.05$). Among various tissues, liver tissues seem to have the highest values of dry/wet weight ratio (up to 0.407); this was more obvious (the difference was highly significant, $P < 0.001$ in all cases) in the case of Y.F.Whiting. By contrast, that ratio of gill tissue was low comparing to other organs especially in Mullet. Stomach contents had, in most cases, lower values comparing to the organ tissues of the fish. Gonad tissue values of Y.F.Whiting was higher than those of other tissues.

Table (1): Dry/wet weight ratio (±SD) of samples collected for heavy metal analyses. Number of samples = 5 in all cases. (-= No sample was available).

Sample Type	OCT.94	NOV.94	MAR.95	JUL.95
K.G.Whiting:				
Muscle	0.224(0.001)	0.228(0.005)	0.230(0.001)	0.225(0.008)
Liver	0.246(0.006)	0.279(0.004)	0.262(0.007)	0.234(0.006)
Gill	0.182(0.011)	0.240(0.001)	0.198(0.001)	0.186(0.002)
St. contents	0.162(0.007)	0.185(0.021)	0.201(0.001)	0.180(0.003)
Y.F.Whiting:				
Muscle	0.228(0.001)	0.229(0.004)	0.231(0.001)	0.229(0.008)
Liver	0.407(0.023)	0.371(0.009)	0.356(0.008)	0.302(0.009)
Gill	0.202(0.006)	0.234(0.011)	0.218(0.009)	0.210(0.009)
Gonad	0.270(0.005)	0.286(0.008)	0.260(0.011)	0.243(0.012)
St. contents	0.210(0.001)	0.242(0.021)	0.182(0.005)	0.195(0.008)
Mullet:				
Muscle	0.233(0.006)	0.228(0.004)	0.253(0.003)	0.229(0.015)
Liver	0.320(0.009)	0.265(0.014)	0.297(0.001)	0.253(0.021)
Gill	0.192(0.020)	0.257(0.063)	0.180(0.011)	0.177(0.016)
Gonad	0.215(0.014)	0.205(0.009)	0.187(0.022)	0.190(0.016)
St. contents	0.172(0.008)	0.144(0.031)	0.257(0.014)	0.319(0.105)
Gar Fish:				
Muscle	-	0.240(0.012)	0.239(0.018)	0.236(0.004)
Liver	-	0.280(0.011)	0.292(0.002)	0.328(0.032)
Gill	-	0.233(0.007)	0.230(0.009)	0.218(0.010)
Gonad	-	0.267(0.006)	0.258(0.006)	0.202(0.001)
St. contents	-	0.153(0.007)	0.185(0.010)	0.197(0.017)

c. Heavy Metal Concentrations:

Cadmium:

Table 2 shows that metal concentrations in muscle tissues of the studied fish were generally low; only the muscle of K.G. Whiting and, to a lesser extent, those of Mullet show elevated levels of Cd exceeding the maximum legal limit (0.2µg/g wet weight-; Anon. 1994- Dry/wet weight ratio is between 0.224-0.253 -Table 1). K.G.Whiting caught from Angas Inlet had higher Cd concentration comparing to the fish caught from the other 2 sites. Generally, liver tissues of all fish species have higher Cd concentrations comparing to gill or gonad tissues ($P<0.05$ or less).

Unexpectedly, gills of most fish species had low Cd concentrations; falling below the detection limit of the apparatus used for the analysis, and so had the tissue of the gonad. Stomach contents of all fish species had higher Cd concentrations comparing to various tissues ($P<0.05$ or less), especially at N.Arm and Angas sites in comparison with K.Beach site.

Table (2): Cadmium concentration (µg/g dry weight) in muscle, liver, gill, gonad and stomach contents of fish sampled during the study period.(ND= not detected, - = no sample was available).
Standard deviation was always less than 20% and is omitted here for the ease of presentation.

Sample Type	OCT.94		NOV.94			MAR.95		JUL.95		
	Ang.	N.Arm	K.Beach	Ang.	N.Arm	Ang.	N.Arm	K.Beach	Ang.	N.Arm
K.G.Whiting:										
Muscle	2.12	0.44	0.43	2.62	1.40	1.56	1.36	0.51	1.88	1.61
Liver	0.50	0.26	1.40	0.40	0.20	1.90	1.83	1.72	2.01	1.93
Gill	ND	ND	ND	0.70	0.33	0.82	0.72	0.33	0.52	0.63
Gonad	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
St. Contents	1.73	1.92	2.26	2.72	3.86	2.32	2.70	2.20	2.63	2.90
Y.F.Whiting:										
Muscle	0.69	-	-	1.05	-	0.67	-	0.73	0.98	0.90
Liver	1.02	-	-	1.42	-	0.94	-	1.01	1.42	1.52
Gill	ND	-	-	ND	-	0.28	-	ND	0.22	0.30
Gonad	ND	-	-	ND	-	ND	-	ND	ND	ND
St. Contents	1.88	-	-	1.40	-	1.90	-	1.62	1.70	1.81
Mullet:										
Muscle	0.98	0.59	0.60	0.96	1.20	0.86	1.38	1.14	0.84	2.14
Liver	-	1.04	1.21	1.64	1.32	0.49	0.25	3.76	3.11	3.86
Gill	0.86	0.77	0.23	0.47	0.28	1.34	0.30	2.99	3.21	3.01
Gonad	ND	ND	0.92	1.26	1.24	0.02	0.45	ND	ND	ND
St. Contents	1.73	1.58	1.50	1.82	1.94	1.02	0.32	2.99	2.62	2.01
Gar Fish:										
Muscle	-	-	-	0.84	-	0.63	0.98	-	1.32	0.81
Liver	-	-	-	0.91	-	2.71	2.30	-	2.92	2.00
Gill	-	-	-	0.94	-	0.43	0.33	-	2.21	3.92
Gonad	-	-	-	ND	-	0.18	0.20	-	ND	ND
St. Contents	-	-	-	1.96	-	2.21	2.03	-	4.49	4.95

Lead:

As shown in table 3, lead levels in Y.F.Whiting, Mullet and Garfish muscle tissues are generally low ranging from 0.80 to 1.68 µg/g dry weight. By contrast, muscle tissue of K.G. Whiting had elevated lead concentration, reaching 4.13 µg/g dry weight; with October sample having lower Pb concentration compared with sampling dates. On the other hand, fish from Angas site have higher Pb concentration comparing to the other two sites. The planktivorous Garfish showed higher concentration of lead in their muscles compared with Y.F.Whiting ($P<0.02$) & Mullet ($P<0.001$) but not to K.G.Whiting which have much higher lead concentration ($P<0.001$).

Generally, liver tissues of all fish species (except those of Mullet) have the highest Pb concentration followed by gill then by gonad tissues, with K. Beach samples having lower concentration comparing to the other sites. On contrast to muscle tissue, Liver tissue of GarFish had the lowest lead concentration comparing to those of other fish species ($P<0.01$ and $P<0.001$ for Mullet & K.G.Whiting and $P<0.05$ for Y.F.Whiting). Mullet, on the other hand, had concentrated lead in its gills more in any other organ.

Stomach contents have Pb concentration several times higher than that of the muscle tissues itself; this was true for the four fish species studied ($P<0.001$ in all cases) with exceptionally high values of GarFish (45.33 & 46.26 µg/g for Angas & N.Arm respectively).

Table (3): Lead concentration (µg/g dry weight) in muscle, liver, gill, gonad and stomach contents of fish sampled during the study period.(- = No sample was available). Standard deviation was always less than 20% and is omitted here for the ease of presentation.

Sample Type	OCT. 94		NOV. 94			MAR. 95		JUL. 95		
	Ang.	N.Arm	K.Beach	Ang.	N.Arm	Ang.	N.Arm	K.B.	Ang.	N.Arm
K.G.Whiting:										
Muscle	1.02	1.28	3.77	4.13	1.36	3.36	2.37	2.18	4.01	3.25
Liver	7.04	9.58	12.52	7.60	7.80	8.08	10.12	8.68	13.26	13.02
Gill	4.30	4.37	1.84	7.72	3.18	4.40	5.32	3.81	4.01	3.92
St. Contents	8.52	8.32	8.96	41.00	10.36	15.82	10.36	6.03	12.23	9.22
Y.F.Whiting:										
Muscle	1.21	-	-	1.26	-	1.21	-	1.01	1.53	1.16
Liver	9.22	-	-	5.96	-	3.50	-	10.11	9.28	9.20
Gill	4.00	-	-	3.48	-	3.26	-	9.39	7.23	7.92
Gonad	1.32	-	-	0.80	-	0.98	-	1.01	1.29	1.62
St. Contents	6.52	-	-	11.00	-	4.21	-	5.56	7.21	7.88
Mullet:										
Muscle	1.19	1.38	1.32	1.68	1.51	1.32	1.37	1.24	0.80	1.68
Liver	5.52	4.39	5.30	5.06	4.56	2.44	6.32	5.05	5.83	6.22
Gill	9.63	9.62	7.21	8.26	14.26	6.96	14.42	7.92	8.03	8.64
Gonad	0.87	1.21	1.08	2.03	2.54	1.26	2.22	1.23	2.21	1.92
St. Contents	5.02	6.30	4.41	3.80	9.80	29.10	34.24	8.80	23.04	20.04
Gar Fish:										
Muscle	-	-	-	1.78	-	1.52	1.70	-	1.34	1.59
Liver	-	-	-	4.75	-	3.28	4.47	-	2.67	6.08
Gill	-	-	-	3.22	-	6.23	5.05	-	2.16	6.40
Gonad	-	-	-	0.80	-	1.32	1.62	-	-	-
St. Contents	-	-	-	2.78	-	45.33	46.26	-	6.31	9.31

Copper:

For technical reason, copper was not analyzed in the muscle tissues of the fish. Table 4 shows that copper concentration tends to be higher in liver tissue compared with gill or gonad tissues. Liver tissue of Mullet seems to have the highest Cu concentration compared with other fish species, and so does the gonad tissue. The highest value of Cu concentration in the gill tissue was recorded in Mullet during March 1995 at N.Arm site (3.56 µg/g dry weight) and the highest concentration of gonad tissue was also recorded in the same species and location (41.7 µg/g dry weight). Generally, stomach contents of the fish have higher Cu concentration compared with other fish tissues and in some cases, such as those of K.G.Whiting (at Angas during Nov.94) and Mullet (at N.Arm during Nov.94), these values were remarkably high (900.80 and 261.08 µg/g dry weight respectively).

Table (4) Copper concentration (µg/g dry weight) in liver, gill, gonad and stomach contents of fish sampled during the study period.(- = No sample was available). Standard deviation was always less than 20% and is omitted here for the ease of presentation.

Sample Type	OCT. 94		NOV. 94			MAR. 95		JUL.95		
	Ang.	N.Arm	K.Beach	Ang.	N.Arm	Ang.	N.Arm	K.Beach	Ang.	N.Arm
K.G.Whiting:										
Liver	6.36	13.64	22.14	29.80	19.08	25.06	20.80	15.61	18.20	17.32
Gill	0.52	0.49	0.52	0.64	2.14	1.25	1.82	0.72	0.90	0.78
St. Contents	38.23	35.72	10.46	900.80	42.46	92.20	73.23	31.01	39.92	35.08
Y.F.Whiting:										
Liver	6.36	-	-	7.04	-	5.76	-	8.01	10.35	9.92
Gill	0.36	-	-	2.10	-	1.62	-	2.25	4.32	4.01
Gonad	1.45	-	-	3.20	-	5.23	-	2.42	3.42	3.23
St. Contents	15.54	-	-	20.42	-	18.81	-	14.92	17.21	18.82
Mullet:										
Liver	20.32	29.18	28.42	33.40	30.46	25.10	48.34	27.77	23.37	22.47
Gill	2.98	3.56	1.22	1.71	1.31	1.93	1.30	ND	ND	ND
Gonad	20.21	22.37	20.32	32.86	25.46	12.82	41.70	-	-	-
St. Contents	25.35	28.21	5.38	6.20	261.08	23.68	49.90	8.81	16.83	18.98
Gar Fish:										
Liver	-	-	-	10.08	-	9.82	12.21	-	4.98	13.10
Gill	-	-	-	0.78	-	0.75	0.92	-	ND	0.52
St. Contents	-	-	-	8.04	-	12.25	17.35	-	41.64	57.23

Zinc:

As presented in table 5, zinc concentration in muscle tissues (except during Oct.94) ranges from 14.83-37.36 µg/g dry weight. However, during Oct. 94, this concentration tends to increase up to a maximum of 73.69 µg/g dry weight. Muscle tissue of Y.F. Whiting showed the highest zinc concentration followed by K.G.Whiting and then by mullet muscle tissues. Gonad tissue Zn concentration (which in many cases exceeds 500 µg/g dry weight) is the highest among various tissues under study ($P<0.001$ in all cases) followed by liver and gill tissues. Stomach contents, on the other hand, have fairly high concentration (up to 4 times of the concentration found in the muscle tissue of the fish). Zn concentrations show no general trend of variation between fish species or sites.

Table (5): Zinc concentration (µg/g dry weight) in muscle, liver, gill, gonad and stomach contents of fish sampled during the study period.(- = No sample was available). Standard deviation was always less than 20% and is omitted here for the ease of presentation.

Sample Type	OCT. 94		NOV. 94			MAR. 95		JUL. 95		
	Ang.	N.Arm	K.Beach	Ang.	N.Arm	Ang.	N.Arm	K.Beach.	Ang.	N.Arm
K. G. Whiting:										
Muscle	70.18	66.45	20.39	14.83	22.65	19.47	16.96	15.97	21.08	20.12
Liver	52.80	55.74	56.20	39.00	47.40	40.82	45.32	58.71	55.02	50.34
Gill	62.30	62.06	59.32	88.52	65.16	70.86	75.93	63.31	67.45	65.33
St. Contents	80.81	76.62	94.01	68.32	46.20	94.24	93.32	64.34	69.46	67.38
Y.F. Whiting:										
Muscle	73.69	-	-	21.49	-	36.33	-	22.91	32.30	27.50
Liver	36.41	-	-	33.76	-	23.04	-	28.32	30.36	33.34
Gill	51.40	-	-	106.00	-	207.03	-	83.38	85.42	86.46
Gonad	-	-	-	563.01	-	588.06	-	483.33	501.12	495.22
St. Contents	-	-	-	33.80	-	40.82	-	22.81	20.82	20.08
Mullet:										
Muscle	66.78	25.39	19.69	31.37	26.33	31.65	23.38	14.96	16.18	15.03
Liver	-	50.64	40.90	41.30	48.50	27.00	13.02	40.85	59.44	47.63
Gill	31.80	27.42	75.49	79.41	77.40	78.22	56.06	51.47	65.09	58.88
Gonad	442.80	452.50	550.21	546.64	567.31	379.40	597.50	-	-	-
St. Contents	60.21	65.51	39.87	45.34	40.49	45.09	101.74	49.61	61.53	60.58
Gar Fish:										
Muscle	-	-	-	17.540	-	28.87	20.82	-	37.36	31.97
Liver	-	-	-	34.540	-	38.02	40.24	-	40.56	65.65
Gill	-	-	-	112.020	-	92.22	94.47	-	89.10	161.30
Gonad	-	-	-	152.740	-	180.83	175.85	-	-	-
St. Contents	-	-	-	37.120	-	47.11	40.17	-	45.19	20.86

DISCUSSION:

Several of the fish species were studied in order to identify any possible heavy metal bioindicators species. The fish ranged from carnivorous (K.G.Whiting & Y.F.Whiting) to omnivorous (Mullet) and to planktivorous (GarFish) and had always sufficient food in their stomachs indicating their close association with the present food and consequently with the present pollutants in the area. In this respect, the organism must have certain characteristics in order to be a suitable bioindicator, i.e. it should accumulate pollutants without being killed with, be sedentary in order to be representative of the study area, be abundant, be sufficiently long lived, be easy to sample and finally, a simple correlation should exist between the level of a pollutant in the organism and in the surrounding (Phillips, 1980). Thus, the 4 fish species can be nominated for this purpose once the last condition has been met by.

Cadmium had high concentration especially in the muscle tissues (and to some extent in the liver tissues) of K.G. Whiting and Mullet during July samples. Moreover, the level of Cd concentration increases from K.Beach to Angas and to N.Arm reflecting the increasing level of pollution in that order (Ibrahim, 1998). This indicates that the above mentioned 2 fish species are likely to be suitable bioindicators of Cd contamination in marine waters. Cadmium is a nonessential metal and is metabolically regulated or accumulated and stored in a nontoxic form (metal binding sites) and thus it is unlikely to impose a threat to the fish life but is likely to do so for the fish population from economic and health point of view. Y.F.Whiting and Garfish, on contrast, did not show that trend of variation exhibited by those of K.G.Whiting or Mullet indicating their unsuitability as representative of the species as environmental indicators of Cd pollution. Similarly, the other organs of the fish such as Gill and Gonad (and to some extent liver) did not show the same trend of variation, again indicating their unsuitability as indicators of Cd level changes in the environment. Because Cd levels are normally low in the edible muscle tissue of Y.F.Whiting and Garfish, accumulation of such metal is not a threat to the fish resources. Mullet feeds primarily on *Ulva australis* and this type of food is known to concentrate heavy metals directly from ambient waters (Karez *et al.*, 1994). Thus it is likely that the food is the main source of transferring Cd to the muscle tissue of Mullet. Sorption of Cd in the fish tissue depends on water temperature (Edgren & Notter, 1980). Thus, it is likely that the increased Cd concentration in the tissue of K.G.Whiting in Angas is probably due to the rise of water temperature by the power station located nearby.

Generally, Cd concentrations in the gill were low, falling in many cases below the detection limit of the apparatus (table 2). However, assuming that the gill filaments (which are the active part of the respiratory system) which accumulate Cd, the actual metal concentration in the gill may be higher than that obtained in this study because the samples of the gill had included, in addition to gill filaments, the gill arks which may have diluted the sample.

Because of the inconsistency in Cd uptake by different fish species, biomonitoring programs involving fish have to be carefully handled in order to reflect correctly the ambient contamination level.

Different fish species have different ability to concentrate lead in their organs: the GarFish which is the only planktivorous fish species studied showed higher lead concentration in their muscle compared with either Mullet (omnivorous) or Y.F.Whiting (carnivorous). Zooplankton from the area has been shown to have exceptionally high levels of Pb during March 1995 (Ibrahim, 1998) and this seems to have been reflected in high Pb level in the diet (table 3) and in the muscle of GarFish. Mullet have the highest possible lead concentration in the gill, while the other fish species showed the highest one in the liver. However, regarding the tissue of the gonad, lead concentration was the lowest among other organs. Lead, as the case of Cd, has no biological function in the fish (Furness and Rainbow, 1990) and its movement across cell membrane is restricted by the fact that solubility of lead salts are low, making its concentration in the muscle tissue few times lower than it in the other organs. This makes such metal be concentrated in the most direct organs such as the gill (as in mullet) and the liver (as in the other species).

Lead level in muscle tissue of the fish is generally low, falling below the legal limit (Ibrahim, 1998), the thing which does not form a threat to the population of the 4 species of the fish studied. According to this discussion, gill tissue of Mullet and liver tissues of K.G.Whiting & Y.F.Whiting may be good representative of the species as environmental indicators of lead pollution in the marine environment. However, no obvious trend of any particular tissue of GarFish was observed species representative of lead indicator.

Copper concentration in the fish is generally high, reflecting the increased availability of CuCl2 in the marine waters. Copper concentration in the gill is always low falling in many cases below the detection limit of the apparatus used in the analysis. This leads us to conclude that the food may be the main source of Cu in the fish tissues. This is supported by the finding of Ibrahim (1998) that copper is easily concentrated through the food chains of fish. In this study, stomach contents of the fish have in many cases substantially high copper concentration compared with the concentration in the fish tissues. Liver tissues of all fish species seem to be good indicators of copper pollution in the marine environment . Gonad tissue of Mullet also seems to reflect well the level of copper in the marine ecosystem but such tissue is not available year round which may restrict their use as representative indicators.

Zinc concentration had the highest values in the gonad tissues of the fish studied. This tendency of gonad to accumulate Zn, and not Cd or Pb, may reflect the metabolic requirement of this organ for Zinc. This element, (as the case of Cu) is essential for several Metalloproteins, particularly Metalloenzymes (Furness & Rainbow, 1990).

Zinc levels in fish tissue are generally low, reflecting the fish ability to closely regulate such metal metabolically and this metal is unlikely to cause serious pollution threat in general terms. Gill tissue of all fish species seem to reflect well the level of Zinc in the marine ecosystem and is likely to be a suitable species representative of Zn indicator. As the case of Cu, gonad tissues accumulate Zn but the use of such tissue as representative bioindicator is restricted by the fact that such tissues are not available year round and the accumulation is dependent on the maturity stage and on the biological requirement of the fish for Cu & Zn.

Generally, tissue of the fish sampled from N.Arm and Angas Inlet showed higher concentration of the 4 metals compared to the fish sampled from K.Beach, reflecting the increased pollution level in N.Arm and Angas Inlet (Ibrahim, 1998). N.Arm receives high levels of pollutants discharged into the area (Edyvane, 1996) and is a subject to the prevailing water current which flows towards this site carrying pollutants. Angas Inlet, on the other hand, has high water temperature (Ibrahim, 1998) which enhances the fish ability to accumulate heavy metals from the environment; fish will increase the respiration, metabolism and feeding rates.

The fish used in this study were immature and taking into account that most heavy metals (especially those which have no biological function such as Cd & Pb) increase in concentration with age and size of the fish, the level of such metals may be higher in the mature (older) and larger fish sizes.

Mullet (which is omnivorous and feed mostly on plant food such as *Ulva australis*) have in many cases elevated levels of heavy metals compared to the other fish which are carnivorous. This result is unexpected because of the low trophic level mullet occupy in Barker Inlet, considering that the top predators are usually known to be most important heavy metal accumulators.

Although the fish species studied showed a general trend of metal accumulation in various tissue, species to species, place to place and time to time differences in heavy metal concentration have existed, indicating that metal concentration is species, organ and environment specific.

The data presented in this study regarding dry/wet weight ratios of various organs of the fish are useful when conversion of heavy metal concentration to a form of wet weight is needed. They are also useful for fish biologists who need to know the percentage of dry weight in a specific organ and/or fish species and their changes over the time.

From the results and discussion presented in this study, it can be concluded that specific organs of the fish, rather than the 'whole fish', may be used as indicators to measure the rate and extent of metal pollution. The use of biological indicators to monitor metal pollution in the marine ecosystem is recommended since it is biologically & economically preferable to the traditional measure control; they measure directly the biological availability of the pollutants and avoid measuring and dealing with the very low metal concentrations in the environment, the thing which shortens the time and lowers the cost needed for the analysis.

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