

Total Mercury in water, sediments, and animals along the Indian Coast

India has a coastline of ~ 7000 km; rivers discharge ~ 1645 km³ of fresh water annually, of which 75% enters the Bay of Bengal (E coast) and 25% the Arabian Sea (W coast). About 25% of the 700 million population live in or near coastal areas and are, directly or indirectly, dependent on the sea for their living. The total addition of domestic sewage to coastal waters is estimated to be of the order of 4.1 km³ yr⁻¹, and industries discharge about 0.41 km³ yr⁻¹ of waste. The Hg data presented here include values reported by Singbal *et al.*, 1978; Sanzgiry *et al.*, 1979; Kureishy *et al.*, 1979, 1983.

Water samples were collected on several cruises of RV *Gaveshani*. Sampling was done at the surface (10 m) and at several depths. Wherever possible near bottom samples have been collected. Samples (2 l aliquots) were acidified on board with 9N H₂SO₄ and stored at pH < 2 in glass bottles. Determinations of Hg were done in the laboratory by cold vapour AAS, after a pre-concentration step (Gardner & Riley, 1974). The coefficient of variation of the analyses was within ±5% and the detection limit was 0.01 µg l⁻¹. Recoveries of 97–99% Hg were observed on analysing spiked standards using the above method. Fish meal, used in the 1975 ICES intercalibration exercise, was obtained from DAFS Marine Laboratory, Aberdeen, and was used as standard material and gave 80–90% recovery. Standard titrisol ampoules supplied by Merck, Darmstadt, Germany, were used for preparing the standards.

Zooplankton samples were collected by Indian Ocean Standard Net and Heron Tranter nets of 500 mesh size. Fish samples were collected by trolling lines, scoop nets, and at landing sites wherever possible. The fish were dissected for various tissues using stainless steel apparatus. The zooplankton and fish tissue samples were then frozen to -5 to -10°C until analysed. In the laboratory the samples were thawed to room temperature and analysed by methods described elsewhere (Kureishy *et al.*, 1979).

Sediment samples were collected by La Fondietz snapper and carefully transferred to polyethylene bags and stored at -5°C until analysis. In the laboratory, the sediments were dried at ~50°C (no loss of Hg was found to occur at this temperature) and analysed as described by Windom & Cutshall (1976) by cold vapour AAS using USGS international rock standards for reference which gave values within ±10–15% of their specified concentrations.

Blank determinations were carried out for all the analyses and these corresponded to ~7 ng l⁻¹ for water samples, <0.004 ppm for biological material and non detectable (0 absorbance values) in the case of sediments.

Water

Surface as well as average values for Hg in the water column increase nearshore, indicating that the source of Hg is from the land. Hg values in Arabian Sea waters range 0.03–0.13 µg l⁻¹ with an average of 0.061 µg l⁻¹. The regions off Bombay, Karwar and the coastal strip between Mangalore to Calicut are discussed individually as the ranges of values observed in these regions do not reflect the prevailing average concentrations in the Arabian Sea.

In the region off Bombay, the surface as well as near bottom waters contain higher concentrations of Hg than at other sites in the Arabian Sea. The values range between 0.12 and 1.4 µg l⁻¹. The highest value of 1.4 µg l⁻¹ is off the mouth of the Ulhas river. No effect of these high concentrations is observed at stations further away and sediments and fish in the area do not reflect enhanced Hg value.

In the region off Karwar, Kureishy *et al.* (1986) observed high surface Hg (2.68 µg l⁻¹) and a simultaneous occurrence of a low value (0.26 µg l⁻¹) in a near bottom sample; off Bhatkal, close to bottom samples have values an order of magnitude higher than the surface samples (Kureishy *et al.*, 1986). High surface value was observed off Karwar near the discharge of a chlor alkali factory. Waters off Mangalore to Calicut contained 0.12–0.4 µg l⁻¹ of total Hg. Values as high as 0.4 µg l⁻¹ have been observed by Singbal *et al.* (1978), which are attributed to leaching from the cinnabar deposits in the crustal rocks of the hinterland between Calicut and Karwar (Siddiquie, pers. comm.).

The overall range of Hg values in the Bay of Bengal is <0.01–0.1 µg l⁻¹, but off the mouth of the Hooghly river concentrations vary between 0.2–0.27 µg l⁻¹ which is consistent with the suspended load of this river and the established close association of Hg with particulates.

Zooplankton and Fish (Fig. 2)

Zooplankton contained non-detectable (<0.004 µg g⁻¹) levels of Hg; prawns, crabs and bivalves had concentrations below the WHO maximum limit of 0.5 ppm in fish products for human consumption. Small fish from 3–20 cm long and total concentrations of Hg in muscle <0.004–0.1 µg g⁻¹ wet weight with an average of 0.018 µg g⁻¹. In larger fish Hg concentrations varied between 0.008–0.023 µg g⁻¹ in gills, <0.004–0.04 µg g⁻¹ in kidneys and <0.004–0.2 µg g⁻¹ in liver (Tables 1, 2). In general the Hg values followed a pattern of the type muscle > gills > kidney > liver. Earlier observations (Kureishy *et al.*, 1983) in the Arabian Sea gave values between not detected to 0.2 µg g⁻¹ in the seerfish (*Acanthocybium solandri*) muscle, not detected to 0.034 µg g⁻¹ in gills and non detectable to 0.042 µg g⁻¹ in liver. In general, Hg was the lowest in liver. Topping *et al.* (1975) found lower concentrations of total Hg in liver than in muscle while Doi & Ui

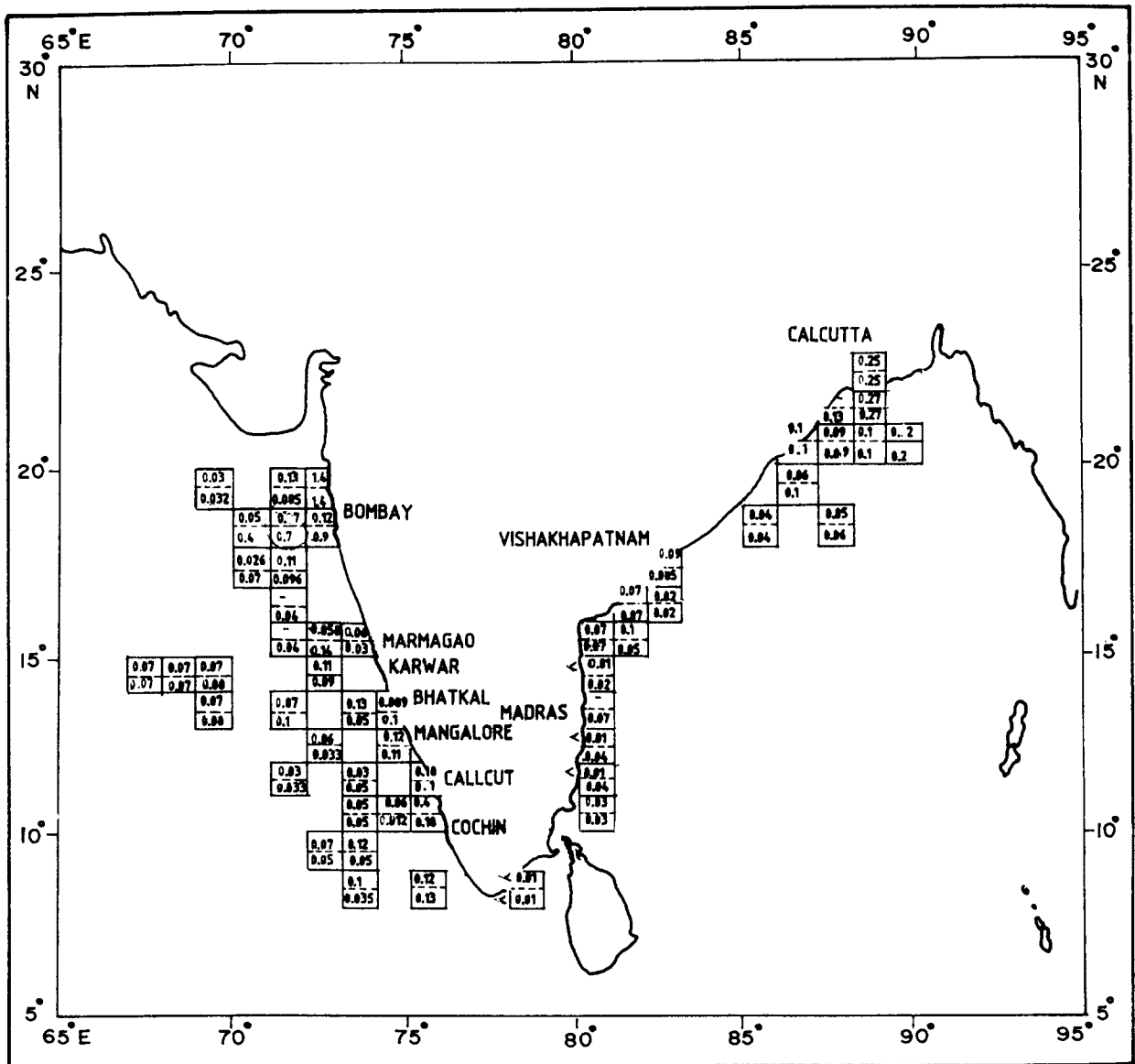


Fig. 1 Distribution of total Hg ($\mu\text{g l}^{-1}$) in water in one degree squares (top value in each square represents the surface value and the lower value represents the average). — = Not analysed.

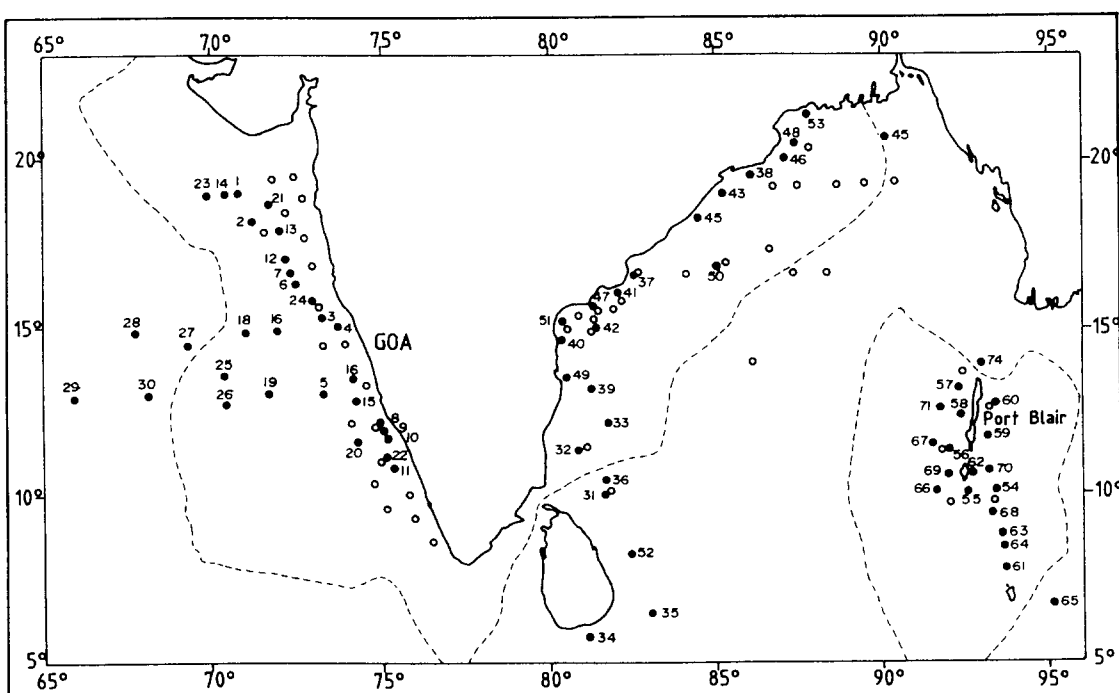


Fig. 2 Station positions from where zooplankton and fish samples were collected. ○ = Zooplankton samples. ● = Fish samples.

TABLE 1

Range of total -Hg Concentrations (ppm wet wt) in zooplankton, crustaceans, bivalves and muscles of fish from the Northern Indian Ocean.

Common Name	Station No.*	Species	Tissue analysed	Range Total Hg ppm
Zooplankton	O	Copepods, euphausiids, ostracods etc.	Whole biomass	<0.004
Prawns	GJ	1. <i>Metapenaeus dobsoni</i> [†]	Soft tissues	<0.004
	GJ	2. <i>M. affinis</i> [†]	Soft tissues	<0.004
	KJ	3. <i>M. burkenroadi</i> [†]	Soft tissues	0.007
	GJ	4. <i>M. monoceros</i> [†]	Soft tissues	<0.004-0.17
	GJ	5. <i>Parapenaeopsis styliifera</i> [†]	Soft tissues	0.008
	GJ, KJ	6. <i>Penaeus merguensis</i> [†]	Soft tissues	0.005-0.01
	KJ	7. <i>P. indicus</i> [†]	Soft tissues	<0.004-0.008
	KJ	8. <i>P. monodon</i> [†]	Soft tissues	0.008
	5-4	9. Unidentified (deep sea) [†]	Whole	0.009
Crabs	GJ	<i>Scylla serrata</i> [†]	Muscle	0.004-0.009
	33	<i>Megalopa</i> [†]	Whole	0.01
	KJ	<i>Portunus pelagicus</i> [†]	Muscle	<0.004-0.012
	KJ	<i>P. Sanguinolentus</i> [†]	Muscle	0.021
Clams	GJ	<i>Villorita Cyprinoides</i> [†]	Whole soft parts	0.065
Oyster	GJ	<i>Crassostrea cucullata</i> [†]	Whole soft parts	0.02
Muscle	GJ	<i>Perna viridis</i> [†]	Whole soft parts	0.092
Flying fish	5, 34, 35, 36, 62	<i>Cyselurus comatus</i> [†]	Muscle	<0.004-0.01
Silver bellies	GJ	<i>Leiognathus splendens</i> [†]	Whole	<0.004-0.01
Malabar anchovies	GJ	<i>Thrissocles malabarica</i> [†]	Whole	0.007-0.01
Sardines	GJ, PBJ, KJ	<i>Sardinella longiceps</i> [†]	Muscle	<0.004-0.01
Mackerel	GJ, PBJ	<i>Rastrelliger kanagurta</i> [†]	Muscle	0.01-0.022
	17	<i>Indocybium guttatum</i>	Muscle	0.007
Jew fish	PBJ	<i>Johnius osseus</i>	Muscle	0.006-0.007
Perch	PBJ	<i>Pelates quadrilineatus</i>	Muscle	0.026
	GJ, PBJ	Unidentified	Muscle	0.007-0.11
Pilot fish	3, 4, 56	<i>Naucratos ductor</i>	Muscle	<0.004-0.02
Sucker fish	4, 8	<i>Remora remora</i>	Whole	0.007
Blow fish	4	<i>Arothron nigropunctatus</i>	Muscle	<0.004
Sciaenid	GJ	<i>Otolithus ruber</i> [†]	Muscle	<0.004-0.2
Sole	KJ	<i>Solea indica</i> [†]	Muscle	0.01-0.021
	GJ	<i>Sinoglossus semifasciatusa</i>	Muscle	0.008-0.02
Pomfret	GJ	<i>Pampus argentus</i>	Muscle	0.005-0.009
Catfish	GJ	<i>Paphia malabarica</i>	Muscle	0.062
Trevally	62	<i>Carangoides malabaricus</i>	Muscle	0.02-0.08
	62	Unidentified	Muscle	0.02
Grunter	37	<i>Theraponidae</i> unidentified	Muscle	0.24
Talang	38	<i>Chorenemus lysan</i>	Muscle	0.36
Tuna	45, 46	<i>Euthynnus affinis</i> [†]	Muscle	0.11-0.13
	19, 20, 45, 47	<i>Kishinoella tonggol</i>	Muscle	0.12-0.14
	GJ, 21-28, 33, 48, 49, 50, 73, 74	<i>Katsuwonus pelamis</i> [†]	Muscle	0.004-0.16
	18, 63, 64	<i>Neothunnus macropterus</i>	Muscle	0.023-0.04
Dolphin fish	12-16, 40-44, 59, 60	<i>Coryphaena hippurus</i> [†]	Muscle	0.01-0.14
Seer fish	GJ, 7, 8, 9, 11, 19, 39, 63	<i>Acanthocybium solandri</i> [†]	Muscle	0.09-0.11
Barracuda	65, 66, 67	<i>Sphyræna picuda</i>	Muscle	0.062-0.2
Sea pike	68	<i>Sphyræna jello</i>	Muscle	0.11
Sharks	PBJ	<i>Scoliodon palasorrah</i>	Muscle	0.036
	51	<i>Sphyma blochii</i>	Muscle	0.21
	29, 30, 52, 59, 69, 70, 71	<i>Eulamia ellioti</i> [†]	Muscle	0.02-0.2

*Marked in Fig. 3, †composite sample of 10 individuals of same size. GJ—Goa Jetty, PBJ—Port Blair Jetty, KJ—Karwar Jetty.

TABLE 2

Ranges and average concentrations of total Hg (ppm wet wt) in different parts of fish from the Northern Indian Ocean.

Body parts	Range	Average
Muscle	<0.005-0.36	0.07
Liver	<0.005-0.04	0.01
Gill	<0.005-0.03	0.016
Heart	<0.005-0.08	0.026
Kidney	<0.005-0.04	0.015
Gonads	<0.005-0.03	0.015

(1975), Denton & Breck (1981) and Stoeppler & Nurenberg (1979) found equal or higher levels of Hg in liver than in the muscle of several fish.

Tejam & Haldar (1975) have reported 0.217-0.512 $\mu\text{g g}^{-1}$ Hg (wet weight) in muscle of fish from Thana creek (Bombay). Zingde & Desai (1981) have observed bioaccumulation of Hg in the creek region. Although we observed high Hg values in waters off the Bombay coast, we did not find any particularly high values in

fish from that area. We therefore conclude that the effect of Hg on the biota remains confined to the creek region.

An attempt was made to correlate the total Hg concentrations and the size of various species of fish. A positive correlation was observed between concentrations in muscles and the size of flying fishes, dolphin fishes, and all other species combined, which corroborates the observations of Stoeppler et al., (1979). We did not observe a significant correlation between Total Hg and size in tuna, *Kishinoella pelamis*.

Sediments

Sediment samples were collected and analysed at stations shown in Fig. 3. At Stations 50–59 off Bombay, values range from 0.038–0.08 $\mu\text{g g}^{-1}$ (dry weight). For stations 1–49, values of $<0.05 \mu\text{g g}^{-1}$ Hg, are reported because we had only small samples. Recent studies carried out on sediments off the Karwar coast, show a range of values between 0.05–1.32 $\mu\text{g g}^{-1}$ (dry weight) (Kureishy et al., 1986), which are in fair agreement with those presented here.

The Hg concentrations observed in various constituents of the Indian coastal region, are well within the safe limits except for certain identified 'hot spots' off Bombay, Karwar, and between Mangalore to Calicut. Thus there seems to be no apparent 'Hg pollution risk' in the seas around India, but a close watch of the localized 'hot spots' should be maintained.

This paper is dedicated to Dr. S. Z. Qasim, our former Director for his keen interest in our work.

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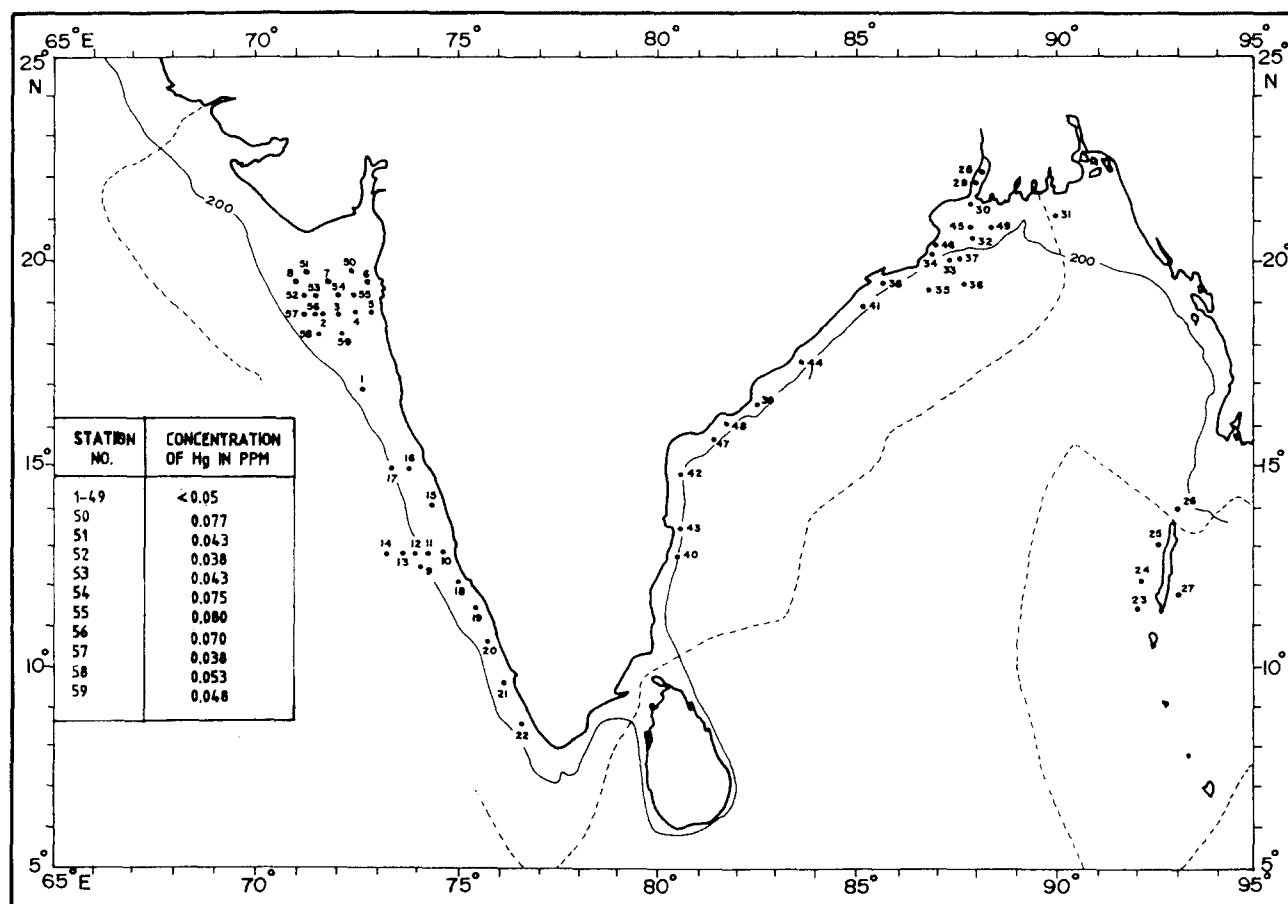


Fig. 3 Distribution of Hg in sediments (ppm dry wt).

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THESIS RECORD

Edited by D. V. Ellis

Marine Pollution Bulletin will publish records of university theses relevant to marine pollution in the format shown below. Theses can be from any relevant discipline such as Biology, Chemistry, Engineering, Medicine, Economics, etc. Contributions should be 50–100 word descriptions of thesis content, with emphasis on the marine pollution aspects. They should be sent to the *Thesis Record* editor (Dr. D. V. Ellis, Biology Department, University of Victoria, Victoria, B.C., Canada V8W 2Y2), with a copy of the officially endorsed thesis title page and abstract. Copy of a title page alone may be submitted (by any interested person) in which case the record will consist of author, year, title, degree, university and supervisor. Contributions should be for theses accepted for M.Sc. or Ph.D. degrees during the past five years, although in exceptional circumstances a contribution recording an older thesis will be accepted for publication.

Cross, S. F. 1982. *Fucus*-Epifauna as a Marine Biological Monitoring Technique in Environmental and Rehabilitation Assessments: A Case Study, with Preliminary Examination and Discussion of its Applicability to Other Coastal Regions. M.Sc. University of Victoria (Supervisor: Dr. D. V. Ellis)

Fucus-epifauna, particularly the amphipod component, provided an effective community-based shoreline technique for monitoring pulp-mill pollution. As pollution controls were introduced, an amphipod peak of opportunists, and other indicators, moved closer in to the mill's discharging outfall. Natural variation within the *Fucus* epifaunal community was related to wave and current exposure and to salinity.

Correspondence to: S. F. Cross, Aquamatrix Research Ltd., 204–2527 Beacon Ave., Sidney, B.C., V8L 1Y1, Canada.

Day, M. E. 1984. Spatial and Temporal Variation of the Macrobenthos in East Sound, A Shallow Fjord in the San Juan Islands of Washington. M.Sc. University of Victoria (Supervisor: Dr. D. V. Ellis)

Annual samples were collected 1978–1981 and quarterly samples 1981–82. Community classification and ordination analyses showed that variation between sites was greater than temporal variation within them. Results were compared with the 1929 samples of Shelford and co-investigators. Unlike European areas investigated by repeat time-separated sampling long-term comparisons were substantially confounded by taxonomic changes. Nevertheless there are broad similarities

between the species assemblages present 50 years apart. Areas which are being investigated by such time-separated sampling need to pay particular attention to taxonomy of the species concerned.

Correspondence to: Ms. M. E. Day Striplin, 1220 Sixth Street, Kirkland, WA 98033, USA.

Kessler, T. A. 1986. Mixing-Primary Production in Holberg Inlet, a Tidally Energetic Fjord. Ph.D. University of British Columbia. (Supervisor: Dr. T. R. Parsons)

The effect of an inflowing tidal jet on primary production is indicated as secondary to wind/tide generated diffusion effects and planktonic grazing in a fjord receiving tailings discharge from a large copper mine. A numerical model based on a 7-year data set indicates that turbidity upwelling effects also do not control primary production, but that phytoplankton nutrition is involved.

Correspondence to: Dr. T. A. Kessler, Bedford Institute of Oceanography, Dartmouth, N.S., Canada

Coates, K. A. 1987. Phylogenetic Analysis of some Enchytraeidae (Annelida: Oligochaeta): Parsimony analysis of Structural Characters. Ph.D. University of Victoria (Supervisor: Dr. R. O. Brinkhurst)

This thesis is an important phylogenetic analysis, with updated comments on species descriptions, of this little known oligochaete Family. The author has previously shown that a number of marine enchytraeid species can be used as pollution indicators.

Correspondence to: Dr. K. A. Coates, Department of Invertebrate Zoology, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, Canada M5S 2C6

McHugh, D. 1987. The Life-History Patterns of Two Hydrothermal Vent Polychaetes, *Paralvinella pandorae* Desbruyères and Laubier and *Paralvinella palmiformis* Desbruyères and Laubier. M.Sc. University of Victoria (Supervisor: Dr. V. J. Tunnicliffe)

Two species of the genus *Paralvinella* (Order Terebellida, Family Alvinellidae) are endemic to hydrothermal vents of the Juan de Fuca and Explorer Ridges. Studies of the population structure and reproductive biology of these two worms indicate that *P. pandorae* undergoes