# PROCEEDINGS, FIRST ANNUAL PACIFIC ECOZONE WORKSHOP
# SIDNEY, B.C., FEBRUARY 1-3, 1994

Lee Harding
Janet Landucci
Robert C.H. Wilson

## TECHNICAL REPORT SERIES NO. 222

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Canadian Wildlife Service

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## ABSTRACT

Environment Canada and the Department of Fisheries and Oceans have begun design of a marine environmental quality monitoring network. The purpose of the network is to provide a forum for agencies monitoring aspects of marine environmental quality and marine ecosystem health to share results of time series monitoring, to enhance opportunities for collaboration, and to disseminate information more widely within and outside of the scientific community.

The network design has proceeded in phases: Phase I, 1992-3, was completion of a marine ecosystem classification system to provide a geographic basis for stratified sampling and prioritization of collection sites, and to develop an ecological context for more detailed design. Phase II, 1992-93, was consultation across Canada on design of the network, including the objectives and scientific questions to be asked, and indicators of marine ecosystem health. Phase III, 1993-94, was a field trial of the network concept in the Pacific coast of Canada. At a workshop held in Sidney, B.C. in February, 1994, 26 custodians of data sets from three federal departments, two provincial ministries and two regional districts presented results of monitoring in two ecodistricts: the Strait of Georgia, and the Vancouver Island Shelf. Speakers also participated in panel discussions to draw conclusions from the results presented, and to evaluate the success of these measures and their associated data sets in assessing trends in the health of marine ecosystems.

### Contaminants

The contaminants panel presented trend data on contaminants in sediments and benthic animal tissues at ocean disposal sites, in Boundary Bay and the Fraser River Estuary, in Vancouver Harbour, in other harbours and inlets monitored by B.C. Environment, in the central basin of the Strait of Georgia and in marine mammals, fish, and the eggs of seabirds, great blue herons and cormorants. Most data were from the Strait of Georgia; none were from the Vancouver Island Shelf. Therefore, a comparison of contaminants in these two marine ecodistricts is likely not possible based on ongoing trend data. To pursue this objective would require comparing new data with a snapshot of conditions from the literature. Furthermore, in most cases, the trend data presented were sufficiently inconsistent in methods, timing and frequency of collection and methods of analysis as to raise doubts about statistical comparison of data sets. Of the tissue data, only the seabird, cormorant and heron series are methodologically consistent enough to establish trends.

The Panel concluded that some persistent compounds are dispersed widely throughout the Strait of Georgia, and are biomagnifying in marine food webs. These contaminants include dioxins and furans, PCBs and chlorinated pesticides. Less bioaccumulative contaminants, including PAHs, arsenic, mercury and lead, are also detectable in sediments and tissues exposed to anthropogenic sources. Although these contaminants are present and are taken up by organisms, the levels in sediments and net bioaccumulation (as inferred from the levels in tissues) have declined in some ecosystem compartments in the Strait of Georgia, apparently as a result of

regulatory controls. PCB levels in seabirds feeding in the open ocean declined in the late 1960s or early 1970s but have levelled off since then, and are similar to levels in comparable populations off the Atlantic coast of Canada. The workshop found evidence that only tributyl tin (TBT) is currently a pollutant in the sense defined by GESAMP as a substance which does result in harm to living resources. Surveys in the mid 1980s showed that tributyl tin was causing widespread reproductive effects in marine gastropod molluscs throughout the Strait. The effect, a morphological disorder called imposex, causes female snails to grow male sex organs and become sterile. Unfortunately, these surveys have not been repeated since regulatory controls restricted some, but not all, uses of TBT. Evidence was also presented that dioxins and furans caused a variety of effects in heron, but that the concentrations bioaccumulated were declining in response to controls in the pulp and paper industry and to a decrease in atmospheric inputs.

**Pathogens and Disease Prevalence**

This Panel presented results of monitoring of hepatic lesions in English sole (*Parophrys vetulus*), fecal coliforms (an indicator of human pathogens), and the incidence and severity of toxic algal blooms and their implications to human consumption of shellfish. Data were presented for shellfish biotoxins and toxic algae for both the Strait of Georgia and the Vancouver Island Shelf.

The panel concluded that:

- Contamination of shellfish with human pathogens from sewage is widespread along the coast of the Strait of Georgia and is increasing. New closures of shellfish growing areas occur in the strait annually. Illegal harvesting of shellfish from closed areas is growing, raising the risk of disease outbreaks among shellfish consumers. Closures also occur on the Vancouver Island Shelf, but trend data suggest that the new closures are more related to increased survey coverage than increased contamination. As well, some of the fecal coliform contamination is from hinterland drainage where human sewage sources are absent.

- The Paralytic Shellfish Poisoning Index seems to be declining or steady in recent years in both Ecodistricts; however, only in the last dozen years has this data set become standardized enough to permit rigorous trend analysis, and long term trends are not detectable. Domoic acid, the cause of amnesic shellfish poisoning, was detected for the first time on the Pacific coast in the fall of 1992, after several years of negative testing. There is some suggestion that the species responsible for producing domoic acid have been moving northwards over the last few years.

- Toxic algal blooms (diatoms or dinoflagellates that produce toxins naturally) are widespread in both ecodistricts and cause annual losses to salmon farmers in the millions of dollars. These blooms are a natural feature of west coast marine biology, but monitoring has not been able to determine whether the frequency of outbreaks has been increased by anthropogenic nutrient sources.

- In the Strait of Georgia, neoplastic liver lesions have been found in flatfish at all pulp mill and industrial harbour areas surveyed, but not in reference stations in the Strait, nor in central coast inlets. In Vancouver Harbour, trend data suggest the beginnings of a decline in prevalence following pollution control.

**Species Diversity and Size Spectrum**

Panellists presented trend data on zooplankton communities on the Vancouver Island Shelf Ecodistrict, intertidal invertebrate communities in the Strait of Georgia, marine mammal abundance in both ecodistricts and nesting marine bird populations in both Ecodistricts, commercial fish populations in the Strait of Georgia and in the Pacific Shelf/Fjord Ecoregion (but not in the Vancouver Island Shelf Ecodistrict, except for one species). Since the two ecodistricts have different stocks or populations of sometimes different species and different harvesting and other pressures, it is hard to make broad comparisons. Nevertheless, the data do allow conclusions about changes in each ecodistrict. It should be noted that while information on total numbers of species in various taxa, rare and endangered species and introduced species for the B.C. coast is available, ongoing monitoring efforts are focused on a few specific taxa or communities. The panel concluded:

- Zooplankton populations fluctuate dramatically, both seasonally and interannually, in species dominance and in size spectra. The main cause of fluctuations is natural variations in physical and chemical factors (temperature, nutrients) which affect primary productivity. No trends are apparent on the Vancouver Island Shelf, despite the availability of a reliable, two-decade time series. Native zooplankton still dominate the biomass over the Vancouver Island Shelf.

- Although benthic macroinvertebrate community monitoring has been initiated recently in the Strait of Georgia, no trends are yet available. These organisms are important in food chains leading to fish and birds, and may also be sensitive indicators of climate change. Problems of monitoring include a loss of taxonomic expertise from the region, and large variability and patchiness that are formidable challenges to designing and resourcing monitoring programs with sufficient resolution to detect modest changes.

- Finfish populations are variable in space and time, but reliable time series data are available for most commercial species. Present populations are within historic ranges and most stocks are in good shape. Chinook salmon and lingcod in the Strait of Georgia have declined significantly, coho salmon somewhat less so, but pink, chum and sockeye salmon stocks are at high levels not seen since the 1930s. The extent to which these changes reflect natural phenomena, fishing pressure and stock enhancement efforts is not clear in all cases. The decline in lingcod is thought to be due to fishing pressure, whereas the decline in chinook may be due more to shifts in characteristics of the physical environment and a consequent increase in natural predation. While Fraser River sockeye are the focus of a major enforcement effort, the present stock strength coincides with historically high salmon production (actually, survival) over the whole northeast Pacific ocean. This high salmon survival in the open seas is thought to be related to high levels of primary and secondary productivity as a result of decadal-scale fluctuations in natural phenomena. Based on long term trend data, a decline in survival as a result of natural changes can also be expected, with serious implications for the fishery.

- Increases in numbers and number of species of nesting marine birds seem to be levelling off, indicating a possible approach to carrying capacity limits. Numbers and species composition reflect changes in food supply, controlled by physical factors (temperature and nutrients). Changes in Vancouver Island Shelf habitats are thought to be of natural origin, whereas human disturbance and toxic contaminants (in the cases mentioned above) may affect populations in the Strait of Georgia.

- Marine mammals populations have been increasing, but some seem to be levelling off, possibly indicating an approach to carrying capacity of these marine ecosystems. The expansion of sea otter range on the west coast of B.C. is an especially notable example of the result of conservation efforts. Another positive sign of ecosystem health is the doubling of bald eagle populations in the Gulf Islands over the last fifteen years.

**Primary Productivity and Nutrients**

This Panel presented papers on remote sensing of algal blooms, primary and secondary production trends in the Vancouver Island Shelf Ecodistrict, long term biological and physical oceanographic monitoring throughout the Pacific Shelf/Fjords Ecoprovince, and nutrients, chlorophyll and primary productivity in the Fraser River Estuary. The panel concluded that:

- Strong temporal and spatial variability is observed in primary productivity of both ecodistricts. Factors controlling primary productivity are wind mixing, upwelling, grazing of zooplankton, river discharge and temperature. While long term trends are unknown, it is clear that anthropogenic sources of nutrients are not important, except perhaps in small, poorly flushed areas. Plankton patchiness and its intimate relation to small scale processes governing the availability of nutrients led this panel to conclude that efforts to monitor primary production in the Strait of Georgia using present technology would be impractical. Data and modelling suggest that primary production off the west coast of Vancouver Island jumped upwards in 1976 and then increased steadily for about 10 years. There is some suggestion of a decline in productivity in this ecodistrict beginning in the late 1980s.

**Instability**

The Instability panel examined some diverse measures of physical stability to assess their utility in trend monitoring. They presented data on potential changes in carrying capacity of the Strait of Georgia resulting from water column changes; and trends in sea-surface properties in all ecoregions. They found:

- Fraser River runoff seems to be increasing over time. Catches of Fraser River coho, chinook and chum seem to decrease when Fraser River runoff is high. A 60-year trend shows mild warming and a strong trend toward lower salinity in the sea-surface off B.C. The resulting reduced density in the surface mixed layer is very marked, and will reduce mixing and nutrient inputs from offshore areas. These trends are not observed as yet in shorter data records from inshore areas.

- With the possible exception of these temperature and salinity trends in offshore surface waters, for most sets of data available it is impossible to differentiate short-term state changes from long-term trends from long-period cycles. Further, in many cases, it is difficult or impossible to differentiate anthropogenic from naturally-induced changes due to climate, hydrology or biological processes. This is especially true where human influence indirectly affects natural processes (e.g., climate change).

- In selected situations, for example, in the case of certain contaminants, it has been possible to identify specific anthropogenic effects and to implement effective control measures.

**Conclusions**

Overall, data were adequate to detect high variability and decadal-scale changes in most variables monitored. Ecosystems in both the Vancouver Island Shelf and the Strait of Georgia ecodistricts were productive and diverse. The Vancouver Island Shelf ecodistrict was affected by meso-scale changes and events in the northeast Pacific ocean, and there were no signs of anthropogenic stress. The Strait of Georgia was affected by both meso-scale phenomena in the northeast Pacific Ocean, and decadal-scale changes in runoff from the Fraser River, which drives estuarine circulation. Signs of anthropogenic stress observed in the Strait of Georgia included effects of fish harvest, localized areas of bacterial and chemical contamintation, uptake of persistent contaminants in fish, birds and marine mammals, and biological effects of certain contaminants at the organism (bottomfish: liver lesions) and population (gastropods: imposex) levels. There were no ecosystem-level effects of any identified anthropogenic stressors.

**RESUME**

Environnement Canada ainsi que Pêches et Océans Canada ont commencé à mettre au point un réseau de surveillance pour la qualité de l'environnement marin. L'objet de ce réseau est de constituer un forum pour tous les aspects de la qualité de l'environnement marin et de la santé de l'écosystème marin, afin de pouvoir partager les résultats de la surveillance chronologique, d'améliorer les possibilités de collaboration et de pouvoir diffuser l'information plus largement à l'intérieur et à l'extérieur de la communauté scientifique.

Le réseau a été conçu en différentes phases. La phase I, 1992-93, comprenait l'achèvement d'un système de classification de l'écosystème marin fournissant une base géographique pour l'échantillonnage stratifié et permettant l'établissement de priorités pour les sites de prélèvement et l'élaboration d'un contexte écologique pour une conception plus détaillée. La phase II, 1992-93, a consisté en consultations dans tout le Canada au sujet de la conception du réseau, y compris les objectifs et les questions scientifiques à poser, ainsi que les indicateurs de la santé de l'écosystème. La phase III, 1993-94, était un essai sur le terrain du concept de réseau sur la côte canadienne du Pacifique. Lors d'un atelier tenu en février 1994 à Sydney, en C.-B., 26 dépositaires de données provenant de trois ministères fédéraux, deux ministères provinciaux et deux districts régionaux ont présenté les résultats de la surveillance dans deux écodistricts : le détroit de Géorgie et la plate-forme de l'île de Vancouver (Vancouver Island Shelf). Des participants aux discussions en groupes ont tiré des conclusions à partir des résultats présentés, et évalué l'efficacité de ces mesures et des séries de données connexes pour juger de la santé des écosystèmes marins.

**Contaminants**

Le groupe des contaminants a présenté les données sur les tendances régissant les contaminants dans les sédiments et les tissus d'animaux benthiques à des sites de déversement de la baie Boundary et de l'estuaire du Fraser, du port de Vancouver et d'autres ports et de bras surveillés par Environnement C.-B., du bassin central du détroit de Géorgie, et chez les mammifères marins, les poissons et les oeufs d'oiseaux marins, comme les grands hérons et les cormorans. La plupart des données provenaient du détroit de Géorgie; il n'y en avait aucune de la plate-forme de l'île de Vancouver. Par conséquent, il n'est probablement pas possible de comparer les contaminants de ces deux écodistricts marins en se fondant sur des données permanentes de tendance. Pour cela, il faudrait comparer les nouvelles données avec un instantané des conditions tiré de la documentation. De plus, comme, dans la plupart des cas, les données de tendance présentées étaient assez irrégulières du point de vue des méthodes, de la chronologie et de la fréquence de prélèvement, et des méthodes d'analyse, la comparaison statistique des diverses séries de données devenait plutôt douteuse. De toutes les valeurs obtenues pour les tissus, seule la série des cormorans et des hérons présentait assez de cohérence du point de vue méthodologique pour pouvoir établir certaines tendances.

Le groupe en a conclu que certains composés persistants sont largement dispersés dans tout le détroit de Géorgie et qu'il y a biomultiplication de ces composés dans les réseaux alimentaires

marins. Parmi ces contaminants figurent les dioxines, les furanes, les BPC et les pesticides chlorés. Des contaminants moins biocumulatifs, comme les HAP, l'arsenic, le mercure et le plomb, ont eux aussi été décelés dans les sédiments et les tissus exposés à des sources anthropogènes. Bien que ces contaminants soient présents et soient absorbés par divers organismes, leurs concentrations dans les sédiments et leur bioaccumulation nette (obtenue à partir de leurs concentrations dans les tissus) ont baissé dans certains compartiments de l'écosystème du détroit de Géorgie, apparemment à la suite de la mise en oeuvre de mesures de réglementation. Les concentrations de BPC chez les oiseaux marins se nourrissant en pleine mer ont diminué à la fin des années 1960 ou au début des années 1970, mais depuis lors elles ont atteint un pallier et sont semblables à celles décelées chez des populations comparables vivant au large de la côte atlantique du Canada. Le groupe a constaté que seul le tributylétain (TBE) est actuellement un polluant au sens défini par le GESAMP, à savoir une substance qui n'est pas nocive pour les ressources vivantes. Des études effectuées au milieu des années 1980 ont montré que le tributylétain causait des effets très étendus sur la reproduction des mollusques gastropodes dans tout le détroit. L'effet, un trouble morphologique appelé imposex, provoque chez les escargots femelles la croissance d'organes sexuels mâles qui les rend stériles. Malheureusement, ces études n'ont pas été répétées du fait que des mesures de réglementation ont restreint certaines des utilisations de TBE, mais pas toutes. Certaines données ont également été présentées, qui montraient que les dioxines et les furanes provoquaient divers effets chez les hérons, mais que les concentrations bioaccumulées baissaient grâce à des mesures de décontamination dans l'industrie des pâtes et papiers et à la diminution des rejets dans l'atmosphère.

**Incidence d'agents pathogènes et de maladies**

Le présent groupe a présenté les résultats de l'observation de lésions hépatiques chez la sole anglaise (*Parophrys vetulus*), de coliformes fécaux (indicateurs d'agents pathogènes d'origine humaine), ainsi que de l'incidence et de la gravité des proliférations d'algues toxiques et de leurs effets sur la consommation de mollusques par l'homme. Les données ont été présentées pour les biotoxines des mollusques et les algues toxiques aussi bien du détroit de Géorgie que de la plate-forme de l'île de Vancouver. Le groupe en est arrivé aux conclusions suivantes :

- La contamination des mollusques par les agents pathogènes provenant de déchets d'origine humaine est largement répandue le long de la côte du détroit de Géorgie et elle est en progression. Chaque année, on ferme de nouvelles aires de croissance de mollusques dans le détroit. La récolte illégale de mollusques de zones ainsi condamnées augmente le risque d'épidémie chez les consommateurs de ces fruits de mer. Il y a également des fermetures sur la plate-forme de l'île de Vancouver, mais les données de tendance montrent que les nouvelles fermetures sont davantage liées à une surveillance plus étroite qu'à une contamination plus importante. De même, une partie de la contamination par les coliformes fécaux est attribuable au drainage provenant de l'arrière-pays où il n'y a pas de sources de déchets d'origine humaine.

- Ces dernières années, l'indice d'intoxication paralysante par les mollusques semble reculer ou demeurer stationnaire dans les deux écodistricts; cependant, ce n'est que dans les douze dernières années que cet ensemble de données est devenu assez normalisé pour permettre une analyse rigoureuse de la tendance, et il n'a pas été possible de déceler une évolution à long terme. L'acide domoïque, cause de l'intoxication amnésique par les mollusques, a été décelée la première fois sur la côte du Pacifique à l'automne de 1992 après plusieurs années d'essais négatifs. Il semblerait que, ces dernières années, les espèces responsables de la production d'acide domoïque se soient déplacées vers le nord.

- Les proliférations d'algues toxiques (diatomées ou dinoflagellés qui produisent naturellement des toxines) sont nombreuses dans les deux écodistricts et entraînent des pertes annuelles de plusieurs millions de dollars pour les producteurs de saumons. Ces proliférations constituent une caractéristique naturelle de la biologie marine de la côte ouest, mais la surveillance n'a pas permis de déterminer si les sources de nutriments anthropogènes avaient augmenté la fréquence des épidémies.

- Dans le détroit de Géorgie, des lésions néoplasiques hépatiques ont été décelées chez les poissons plats près de toutes les usines de pâtes et dans les zones portuaires industrielles, mais non dans les stations de référence du détroit, ni dans les bras de la côte centrale. Dans le port de Vancouver, les données de tendance laissent supposer le début d'une baisse de l'incidence de ces lésions après la mise en oeuvre de mesures de décontamination.

**Diversité des espèces et éventail démographique**

Les participants ont présenté les données de tendance sur : les communautés de zooplancton de l'écodistrict de la plate-forme de l'île de Vancouver; les communautés d'invertébrés intertidaux du détroit de Géorgie; l'abondance des mammifères marins et des populations d'oiseaux marins nicheurs dans les deux écodistricts; les populations de poissons commerciaux dans le détroit de Géorgie et dans l'écorégion plate-forme/fjord du Pacifique (mais non dans l'écodistrict de la plate-forme de l'île de Vancouver, excepté pour une seule espèce). Étant donné que les deux écodistricts renferment différents stocks ou populations d'espèces parfois distinctes, et qu'ils sont soumis à des récoltes variables et à d'autres contraintes, il est difficile de procéder à des comparaisons élargies. Cependant, les données permettent de tirer des conclusions sur les changements dans chaque écodistrict. À noter que, bien que l'on dispose pour la côte de C. B. de données sur le nombre total d'espèces faisant partie des divers taxons, sur les espèces rares et menacées, ainsi que sur les espèces introduites, les travaux d'observation régulière sont concentrés uniquement sur quelques taxons et communautés spécifiques. Le groupe a abouti aux conclusions suivantes :

- Il y a d'énormes fluctuations saisonnières et annuelles chez les populations de zooplancton, qu'il s'agisse de la nature des espèces dominantes ou bien de la répartition démographique. Les principales causes des fluctuations sont les variations naturelles dans les facteurs physiques et chimiques (température, nutriments), qui influent sur la productivité primaire. Aucune tendance ne se dégage pour la plate-forme de l'île de Vancouver, en dépit de l'existence d'une série temporelle fiable, couvrant deux décennies. Le zooplancton indigène est toujours dominant dans la biomasse de cette plate-forme.

- On a entrepris récemment l'observation de la communauté de macro-invertébrés benthiques dans le détroit de Géorgie, mais aucune tendance n'a pour l'instant été décelée. Ces organismes sont importants dans les chaînes alimentaires conduisant aux poissons et aux oiseaux, et ils peuvent également servir d'indicateurs pour les changements climatiques. Parmi les problèmes que pose la surveillance, on peut citer une certaine perte d'expertise taxonomique dans la région, ainsi qu'une forte variabilité et un grand manque d'homogénéité, qui représentent des défis majeurs pour la conception et la mise en oeuvre de programmes de surveillance permettant de déceler de faibles variations.

- Les populations de poissons sont variables dans l'espace et le temps, mais on dispose de données temporelles fiables pour la plupart des espèces commerciales. Les populations actuelles se situent dans leurs limites historiques et la plupart des stocks sont en bonne santé. Dans le détroit de Géorgie, le saumon quinnat et la morue-lingue ont reculé de façon significative, le saumon coho un peu moins, mais le saumon rose, le saumon kéta et le saumon rouge ont grimpé à des niveaux que l'on a pas vus depuis les années 1930. Le degré auquel ces changements reflètent des phénomènes naturels, la pression de la pêche ou les efforts pour améliorer les stocks, n'est pas clairement établi dans tous les cas. La diminution de la population de morue-lingue serait attribuable à la pêche, alors que celle du saumon quinnat pourrait plutôt s'expliquer par des variations dans les caractéristiques de l'environnement physique et de l'amplification de la prédation naturelle qui en résulte. Alors que la population de saumon rouge du Fraser fait l'objet d'activités majeures de protection, l'importance du stock actuel coïncide avec une production historique élevée de saumon (correspondant, en fait, à un taux élevé de survie) dans toute la zone nord-est de l'océan Pacifique. Ce fort taux de survie du saumon en pleine mer serait lié à des taux élevés de productivité primaire et secondaire, résultant de fluctuations dans les phénomènes naturels à l'échelle décennale. D'après les données de tendance à long terme, on peut également prévoir une baisse du taux de survie résultant de variations naturelles, avec de graves conséquences pour l'industrie de la pêche.

- Les augmentations du nombre d'espèces d'oiseaux marins nicheurs et de leurs populations semblent se stabiliser, ce qui indiquerait qu'on est pas loin des limites de capacité d'accueil. La composition en espèces et le nombre d'oiseaux reflètent les variations de l'approvisionnement en nourriture, régi par des facteurs physiques (température et nutriments). On estime que les changements dans les habitats de la plate-forme de l'île de Vancouver sont d'origine naturelle, alors que les populations du détroit de Géorgie seraient plutôt touchées par des perturbations d'origine humaine et la présence de contaminants toxiques (dans les cas mentionnés ci-dessus).

- Les populations de mammifères marins ont augmenté, mais certaines semblent se stabiliser, ce qui indique que l'on s'approche peut-être de la capacité d'accueil limite de ces écosystèmes marins. L'expansion du territoire de la loutre de mer sur la côte ouest de C.-B. est un très bon exemple des résultats d'activités de conservation. Autre signe positif de la santé de l'écosystème : la population du pygargue à tête blanche des îles Gulf a doublé ces quinze dernières années.

**Productivité primaire et nutriments**

Le groupe a présenté des communications sur les sujets suivants : télédétection de proliférations algales; tendances de la production primaire et secondaire dans l'écodistrict de la plate-forme de l'île de Vancouver; surveillance océanographique, biologique et physique, à long terme, dans toute l'écoprovince plate-forme/fjords du Pacifique; nutriments, chlorophylle et productivité primaire dans l'estuaire du Fraser. Le groupe en est arrivé aux conclusions suivantes :

- Dans les deux écodistricts, on peut observer une forte variabilité temporelle et spatiale de la productivité primaire. Les facteurs régissant la productivité primaire sont les suivants : brassage éolien, remontée des eaux, pacage du zooplancton, déversement des rivières et température. Bien que l'on ne connaisse pas les tendances à long terme, il est clair que les sources anthropogènes de nutriments ne sont pas très importantes, excepté peut-être dans de petites zones, faiblement arrosées. L'irrégularité du plancton et son étroite relation avec les processus à petite échelle régissant la disponibilité de nutriments a amené le présent groupe à conclure que, dans la pratique, il serait difficile de surveiller la production primaire dans le détroit de Géorgie à l'aide de la technologie actuelle. Les données et la modélisation laissent supposer que la production primaire au large de la côte ouest de l'île de Vancouver a fortement augmenté en 1976, pour progresser ensuite régulièrement pendant environ 10 ans. Il y aurait eu baisse de la productivité dans cet écodistrict à partir de la fin des années 1980.

**Instabilité**

Le groupe de l'instabilité a examiné diverses mesures de la stabilité physique afin de déterminer leur utilité pour la surveillance des tendances. Le groupe a présenté des données sur les possibles variations de la capacité de transport du détroit de Géorgie résultant de modifications de la colonne d'eau, ainsi que sur les tendances des propriétés de la surface marine dans toutes les écorégions. Ils ont constaté ce qui suit :

- L'écoulement du Fraser semble augmenter avec le temps. Les prises de coho, de quinnat et de kéta semblent diminuer lorsque l'écoulement du Fraser est élevé. Une tendance sur 60 ans montre qu'il y a un léger réchauffement et une forte tendance vers une baisse de la salinité de l'eau de surface au large de la C.-B. Il en résulte une diminution marquée de la masse spécifique de la couche superficielle mixte, ce qui a comme effet de réduire le mélange et l'apport de nutriments provenant de zones situées au large. Ces tendances n'ont pas encore été observées dans les données à plus court terme provenant de zones littorales.

- À l'exception peut-être de ces températures et des tendances de la salinité dans les eaux de surface au large, il est impossible, pour la plupart des ensembles de données disponibles, de différencier les changements d'état à court terme des tendances à plus long terme et des cycle à longue période. De plus, dans beaucoup de cas, il est difficile ou impossible de faire la différence entre les changements anthropogènes et les changements d'origine naturelle, dus par exemple à des processus climatiques, hydrologiques ou biologiques. Cela est particulièrement vrai lorsqu'une influence humaine s'exerce indirectement sur les processus naturels (exemple : le changement climatique).

- Dans certaines situations, notamment pour certains contaminants, on a pu caractériser des effets anthropogènes spécifiques et mettre en oeuvre des mesures de décontamination efficaces.

**Conclusions**

Dans l'ensemble, les données étaient suffisantes pour déceler une forte variabilité et des changements décennaux dans la plupart des variables observées. Les écosystèmes aussi bien dans l'écodistrict de la plate-forme de l'île de Vancouver que dans celui du détroit de Géorgie étaient productifs et variés. L'écodistrict de la plate-forme de l'île de Vancouver a été touché par des phénomènes et des variations à l'échelle moyenne dans le nord-est de l'océan Pacifique, et il n'y avait aucun signe de contrainte d'origine anthropogène. Le détroit de Géorgie a subi aussi bien les effets de phénomènes à échelle moyenne dans le nord-est de l'océan Pacifique que des variations à l'échelle décennale de l'écoulement du Fraser, qui active la circulation estuarienne. Parmi les signes de contrainte d'origine anthropogène, observés dans le détroit de Géorgie, on peut citer les suivants : effets sur la récolte de poissons; zones ponctuelles de contamination bactérienne et chimique; absorption de contaminants persistants par les poissons, les oiseaux et les mammifères marins; effets biologiques de certains contaminants au niveau des organismes (poissons de fond : lésions hépatiques) et des populations (gastropodes : imposex). On n'a observé aucun effet à l'échelle de l'écosystème, quel que soit l'agent d'aggression anthropogène.

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# INTRODUCTION

## INTRODUCTORY REMARKS TO THE PACIFIC MARINE ECOZONE WORKSHOP

*R. Wilson*

Like many of you, I was at the symposium two weeks ago on the Georgia Basin, the Strait of Georgia - Puget Sound - Juan de Fuca system. I found myself sitting there asking one of the questions that is central to our meeting over the next two days: "How well did the symposium do at describing the state of that ecosystem, the stresses on it and the way it might be going?" That meeting, with its emphasis on sustainability, is an appropriate stepping stone into this workshop.

As Lee has said, this is a meeting about time series and a monitoring network. (Is it presumptuous to talk about establishing a monitoring network?). The speakers over the next two days represent probably the best foundation for government's ability to describe conditions in the southern British Columbia marine environment. Oceanographers think of their science as a continuum beginning with descriptive studies, followed by process studies, followed by modelling that leads to prediction. Time series measurements - monitoring programs - are essential to our understanding of state and process, and in areas other than oceanography.

We often hear criticism of monitoring programs. They cost too much money. They are not appropriate work for scientists to undertake. They do not use the best measurement methodology. They are not designed to address a hypothesis.

Some of these criticisms may be true of some or all of the programs we will hear about in the next couple of days. I would challenge the speakers, if you can, to tell us about the questions your time series were designed to answer, or about why you are continuing the work.

Nevertheless, I have a hard time thinking that some of our longest time series, the Shorestation temperature program for example, were motivated at the outset by anything more than curiosity and scientific discipline. I doubt that the originators of the shorestation program in the 1930's thought of the way it would be used to address global warming questions and predict salmon migration 60 years later.

Not all monitoring needs to address a hypothesis. I refer particularly to compliance monitoring, which is the kind of monitoring undertaken to fulfill a statutory responsibility, but we are not discussing this type of information here.

What are some of the reasons people undertake or continue time series today? The following is a short list.

## NEEDS FOR MONITORING IN THE 90'S

- Monitoring provides the information needed to evaluate pollution abatement actions.

- Monitoring information can provide an early warning system and a scientific basis for lower cost solutions to environmental problems.

- Monitoring information meets a need in government for a factual basis for policy development on environmental issues.

- Monitoring contributes to the knowledge of marine ecosystems and how they are affected by human activity. Such knowledge allows for the establishment of priorities for environmental protection and resource conservation, and for public education.

- Monitoring information helps answer such questions as "Is it safe to swim or eat fish and shellfish?"

- Monitoring information is the best basis for the calibration of predictive numerical models.

What do the organisers want out of this workshop? There's a second part to the meeting, which takes place on Thursday. We will be looking to see if the presentations were able to tell us about the condition and significant changes - at the risk of upstaging Bruce McCain, I would say status and trends - of these two parts of the west coast marine ecosystem.

That second part of the meeting will also be looking to see if we have learned something about the sources of change. If change can be described, can we separate human effects from effects due to natural variability? This is a difficult problem in coastal regions and one which argues for careful and critical experimental design, periodic evaluation, and that counterpoint to evaluation, a constancy of commitment.

In a department where northern Atlantic cod serves as a dark example, DFO is now very focused on understanding the non-fishing, as well as the fishing, influences on stock abundance. Nobody wants another fishery to go down as an example of ignoring environmental influences in making stock forecasts and of second guessing the quality of scientific advice. Advice that was hampered, I might add, by the lack of an appropriate oceanographic time series as well as knowledge of how oceanographic factors influence the biology of northern Atlantic cod.

Will all these west coast time series tell us something useful about the quality of the marine environment? These are times of growing pressure on resources at all levels of government in

Canada. By their very nature time series involve measurements, and measurements are expensive. They require people, travel. And they may not hold the promise of answering many of today's questions today.

Our time series programs will be scrutinized to see if they provide value for the money. The managers who do this will not necessarily be sympathetic or believe that their continuance is part of the heritage we pass on to the next generation of scientists, to help them wrestle with sustainability or whatever the environmental issue of the day is.

This meeting is a chance to look at some of the scientific issues around time series. How big a change is any particular program capable of detecting? What is the magnitude of interannual variability compared to geographic variability? Are we taking enough measurements? Are we taking too many measurements? Is the frequency right? What questions are both meaningful to ourselves and our clients and provide a basis for scientific investigation? Is enough attention being paid to the management, synthesis and interpretation of our data? Are we communicating the results to the people who would benefit by being aware of them?

There is no way that the activities we discuss here will completely cover marine ecosystems in southwest B.C.. The number of biological and ecological variables and processes which could be monitored is far too large for that. But we hope that we are addressing critical parts of the marine ecosystem. Lee and I are interested to know how well this happenstance assemblage of people with time series information does that. Please tell us any time over the next three days if you think we are missing an important element - and it would be very surprising if we were not.

Finally, here is a challenge for all of us as we look towards the future. A US NRC committee on marine environmental monitoring concluded in their book "Managing Troubled Waters" that most environmental time series programs failed to provide the necessary information to understand the condition of the marine environment or to assess the effects of human activity on it. Can we build on discussions in this workshop to improve on that assessment in our corner of the world?

## DEVELOPMENT OF A MARINE ECOSYSTEM MONITORING NETWORK

*L. Harding*

### Why Monitor?

At this stage in the development of a marine environmental quality monitoring network we should not have to ask, why monitor? Still, our purpose is worth repeating: We need to monitor conditions in the environment because environmental and resource managers and the public want to know the answers to two questions:

1. How bad is it?

2. Is it getting better or worse?

These questions have linkages to other initiatives and programs. The question of how bad it is is directed at the state of the environment. It relates to the conditions of the environment relative to intended uses, such as can we drink it? fish it? swim in it? Each of these are subsidiary, that is, they take the first question and refine it to a higher resolution. Questions at this level can relate to environmental quality guidelines that have been established. Yet a higher resolution might be to ask if we can swim in it at this particular beach. If site specific water contact recreation objectives have been set for several variables, such as concentrations of bacteria, we could have a binary (yes/no) answer; otherwise we are left with a qualitative answer. An example might be, you can swim in it if you are willing to risk the measured concentration of bacteria. The task of monitoring is only to provide the levels of bacteria (and other relevant variables). Development of guidelines and objectives is another task, related to monitoring, that is being undertaken as part of Environment Canada's Marine Environmental Quality Action Plan (MacDonald *et al.*, 1992).

The second question is more directly the domain of monitoring. Time series environmental monitoring data must answer this question.

Ancillary questions are, why is it changing? and what can we do about it? These are not the domain of monitoring. The question of cause is a research question; it is linked to monitoring because monitoring may demonstrate trends which then need to be explained by research, and because many research questions require trend data. But monitoring should not be expected to find the cause in all cases, only the effect. Likewise, the question, what can we do about it? has to be answered by environmental and resource managers - those in positions to change the ways we use and abuse marine environments. However, monitoring data can often be used to evaluate the effectiveness of various control options, and hence provide important feedback to the regulatory apparatus.

## Why a Network?

At a 1988 conference on marine environmental quality (Wells and Gratwick, 1988) one of the conclusions was that all options for managing the quality of the marine environment depended on a much improved base of knowledge of status and trends in condition of the marine environment. Work began on design of a national marine monitoring program, with examination of models adopted by other jurisdictions, appraisal of specific approaches and review of methods (Harding, 1990). New funding was not available, however, and in 1992 direction was received to proceed with design of a network of agencies to share and better use existing monitoring information, and then to develop specific proposals for selective enhancements. Components of this design include the development of a marine ecosystem classification system for Canada, which will be presented at this workshop; and a review of existing marine monitoring programs across Canada, from which we might select to include in an MEQ monitoring network (LGL Ltd., 1993). This work led us to a conceptual design for a field trial during 1993, the results of which are the subject of this workshop.

## What is a Network?

A marine monitoring network is a strategic, operational and scientific linkage of monitoring programs. Its purposes are to make better use of existing monitoring information by disseminating it more widely, and to improve the usefulness of monitoring data for secondary and subsequent uses by providing increased opportunities for collaborative design. A network is strategic when agencies agree to marshall their resources towards joint objectives, for example, by collaborating on design, sharing of information and resources (such as ship time, computer facilities, lab space), and, more importantly, maintaining continuity of key data sets that have been accepted as essential to long term monitoring of marine environmental quality. Linkages are scientific when similar scientific standards are shared, such as common field and analytical protocols, metadata standards, and interdisciplinary design of field programs. Linkages are operational if they include joint planning of ship time, regular sharing of results, joint publication of proceedings, and other "network" infrastructure.

## Workshop Objectives

What do we want out of this workshop? I see three objectives:

1. Assemble summaries of results of our monitoring during the past year. This will enable us to present, in a proceedings, trends in the key variables of the condition of ocean ecosystems that resource and environmental managers and the public need to know to understand how our activities affect the functioning of marine ecosystems against the background of natural change.

2. Consider adjustments for next year. Which indicators are the key ones that, 20 years from now, someone will be glad we started monitoring on a methodical and consistent basis? Of the ones we would like to measure, which ones can we measure, given existing knowledge and

levels of funding? What further actions can we take to ensure continuity of data sets, and the need for selective enhancements?

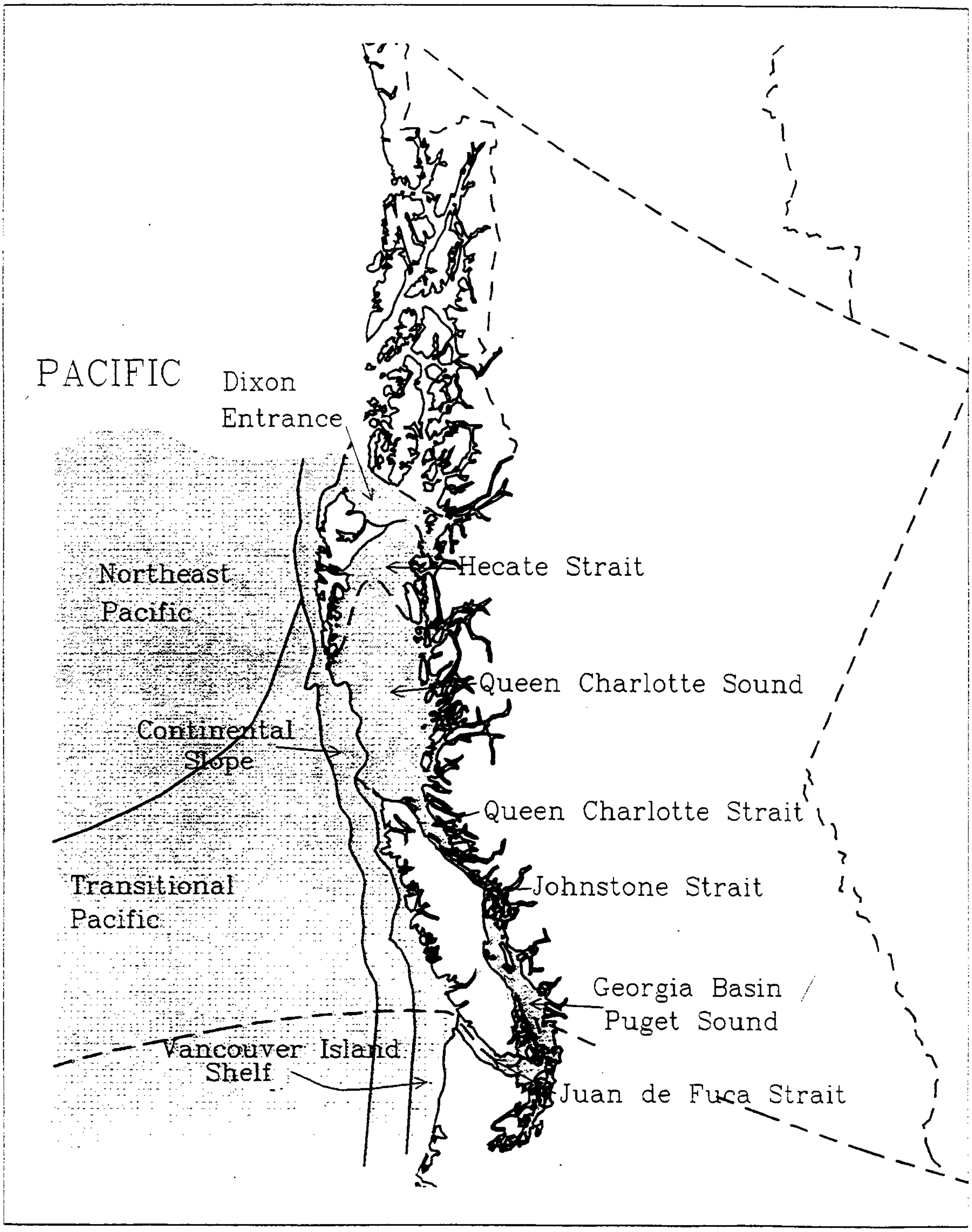
3. Expand the concept of a coordinated network of custodians of data sets to other regions. What are the process, timing and funding constraints? Will there be (do we need?) national coordination?

**Scale of Monitoring**

Figure 1 shows the Pacific marine ecosystem classification developed for this project. Presenters have been asked to provide summaries of their trend data for either the Strait of Georgia EcoDistrict or the Vancouver Island Shelf EcoDistrict, or both. These ecodistricts are part of the Georgia Basin/Puget Sound and Shelf/Fjords EcoRegions, respectively, and both of these ecoregions are part of the Pacific Shelf/Fjords EcoProvince. The scale of monitoring at the ecodistrict level is able to aggregate information from smaller scales (such as pollution site investigations or shellfish closure areas). Likewise, information from these ecodistricts could be aggregated to larger scale monitoring, such as long distance migratory species or meso-scale ocean phenomena. Each of these scales of monitoring have specific sets of management responses which may overlap, but are to some extent mutually exclusive. For example, you would not expect time series data on attributes of the Strait of Georgia as a whole to be sufficient to evaluate adequacy of a pulp mill or municipal effluent discharge permit. Nor could conditions in the Strait, in isolation, be used to explain or predict changes in adjacent ecodistricts, or the ecoprovince of which it is a part. However, conditions at the ecodistrict scale can show background variations (natural or otherwise) against which site-specific data can be assessed. Conditions in the ecodistrict could also be used to evaluate the success of pollution control programs applied basin-wide, or of specific legislation (such as pulp mill regulations) affecting an industrial sector distributed throughout the basin.

By linking these scales - for example, by using consistent design criteria for site-specific monitoring so that results can be aggregated upwards - it is possible to integrate top-down and bottom-up approaches to monitoring, and thereby provide more cohesive information needed by researchers to unravel cause-effect relationships. The bottom-up approach refers to stress-response-effect studies which give clear indications of effects of stresses on affected organisms, but are often difficult to interpret in terms of ecosystem level effects. The top-down approach applies to ecosystem-level effects that may be difficult to connected to a cause. Speakers at this workshop will be presenting both types of data. Since ecosystem-level effects are often felt beyond the site(s) of stress, and at different trophic levels representing different organisms studies by researchers in different disciplines, we hope that this kind of forum will provide the opportunity for cross-discipline exchange of information. These will surely increase opportunities for collaboration and lead to improved understanding of the response of marine ecosystems to anthropogenic stress against a background of natural change.

Figure 1


PACIFIC
Dixon
Entrance
Hecate Strait
Northeast
Pacific
Queen Charlotte Sound
Continental
Slope
Queen Charlotte Strait
Transitional
Pacific
Johnstone Strait
Georgia Basin /
Puget Sound
Vancouver Island
Shelf
Juan de Fuca Strait

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## U.S. NATIONAL STATUS AND TRENDS PROGRAM: NATIONAL BENTHIC SURVEILLANCE PROJECT

*B. B. McCain*

The National Benthic Surveillance Project (NBSP) is one major component of NOAA's National Status and Trends (NS&T) Program, which is a cooperative effort between the Coastal Monitoring and Bioeffects Division, Office of Ocean Resources Conservation and Assessment on NOAA's National Ocean Services and the National Marine Fisheries Service (NMFS). The NBSP has been conducted since its inception in 1984 by NMFS scientists from various regional laboratories. Since 1988, the NBSP has been conducted cooperatively by NMFS scientists from the Environmental Conservation Division of the Northwest Fisheries Science Center in Seattle, WA and the Beaufort (NC) Laboratory of the Southeast Fisheries Science Center.

The NBSP is a long-term monitoring program designed primarily to assess the occurrence of bioeffects, namely physiological/biochemical alterations (biomarkers) and pathological conditions, and their relationships to toxic chemicals, in fish from 150 U.S. coastal sites. The overall goal of the NBSP is to improve the scientific basis for quantifying the status of environmental quality and temporal trends in bioeffects and chemical concentrations both at individual sites and among selected regionwide and nationwide assemblages of sites. The bioeffects focus of NBSP complements the objectives of the NS&T Mussel Watch Project, which analyzes toxic chemicals in tissues of bivalve molluscs and in sediments from 200 sites nationwide mainly for chemical monitoring objectives, including detection of spatial patterns and analysis of temporal trends in the distributions of contaminants. Together, the NBSP and Mussel Watch Projects provide a basis for assessing the status and trends of contaminant distributions and associated effects on both site-specific and large regional or national scales.

With respect to the missions and objectives of NMFS, the NBSP provides information necessary to manage the living marine resources of our nation's coastal and estuarine waters and the necessary habitats. The information generated under NBSP is also useful for the planning and implementation of habitat remediation and restoration activities at coastal sites in the U.S.

The specific objectives of NBSP are:

* to measure contaminant-related effects in selected target species of fish and other resource species at coastal locations nationwide;

* to evaluate relationships between the occurrence of contaminant- associated bioeffects and indicators of contaminant exposure, including contaminant levels in sediments and tissues;

* to quantify levels of, and assess possible temporal trends in, certain toxic chemical contaminants in target marine fish species and in sediments associated with these species; and

* to identify areas where significant contaminant-related effects are occurring, and where more detailed surveys may be required.

Through yearly sampling and monitoring of various marine species at many coastal and estuarine sites throughout the country, NMFS scientists are establishing a comprehensive and temporal data bank on the distribution of chemical contaminants in marine biota and sediments. This work allows NOAA to determine baseline data on chemical pollutants and to follow changes in trends over time. The data generated from the NBSP are published in the form of annual reports, NOAA Technical Memoranda, and scientific articles. In a summary report on the status of chemical contamination on the West Coast covering the first three years (1984-86) of the NBSP, results indicated the presence of high concentrations of polycyclic aromatic hydrocarbons (PAHs), chlorinated hydrocarbons (CHs), and several metals (e.g., copper and lead) in sediments from many of the sites in major urban areas of California and Washington (e.g., San Diego Bay; San Pedro Bay, Long Beach/Los Angeles; and Elliott Bay, Seattle). High concentrations of CHs in the livers of bottomfish and high concentrations of fluorescent aromatic hydrocarbons, which reflect exposure to PAHs, in the bile of bottomfish were also found at these urban sites. Effects, including fin erosion and a variety of liver lesions, were detected in some of the fish spcies examined, with the highest prevalences generally found in fish from the urban sites.

In recent years, the NBSP has been expanded to include biochemical markers of contaminant exposure, hepatic aryl hydrocarbon hydroxylase (AHH) activity and DNA-xenobiotic adducts in fish, as part of the suite of measurements routinely performed. Increased activity of AHH is indicative of early physiological changes resulting from exposure of fish to certain contaminants. Measurement of DNA-xenobiotic adducts assess levels of genotoxic contaminants bound to hepatic DNA.

In conclusion, there are a number of advantages to the NBSP. The program provides an assessment of contaminant-related problems in indigenous marine species. The use of marine fish allows the utilization of a limited number of sites per embayment because fish tend to integrate relatively large areas. Although the long-term effects of pollution-associated liver lesions on marine fish are not fully understood, certain species of marine fish (e.g., English sole) with liver lesions are known to have abnormal serum chemistry, suggesting systemic effects. Moeover, these liver lesions serve as warning signs of other health effects, including reproductive impairment, and immunological dysfunction. With the recent addition of biomarkers, the NBSP has tools to detect contaminant-related changes in fish that are more sensitive than liver lesions.

## TRENDS IN CONTAMINANTS AT OCEAN DISPOSAL SITES

*D. Sullivan*

Environment Canada, under the authority of the Canadian Environmental Protection Act, Part VI, outlines terms and conditions for the disposal of approved dredged or excavated material in the ocean. These activities have been regulated since 1976.

Material proposed for ocean disposal must be sampled prior to loading and must meet the following screening and rejection limits:

| | |
|---|---|
| Cadmium | 0.06 ug/g |
| Mercury | 0.75 ug/g |
| Chlorophenols | 1.00 ug/g |
| PCB | 0.10 ug/g |
| PAH (total) | 2.50 ug/g |
| Dioxin/furan | quantifiable 2,3,7,8 TCDD |

Cadmium and mercury are prohibited in the Act at these levels. Interim guidelines for levels of organic compounds in sediments or excavated material were adopted nationally in 1989.

In the Pacific and Yukon Region, approved material is disposed of at designated ocean disposal sites. There are 36 disposal sites in the region, 15 of which are located in the Georgia Basin. About half the designated sites are active (used within the last five years) (Figure 1).

Environment Canada has conducted compliance monitoring since 1976 at most of the designated disposal sites on the British Columbia coast, as well as a background survey in most of the major inlets between Howe Sound and Prince Rupert.

The monitoring programs developed prior to 1989 were based on the prohibited substances in CEPA and therefore were focused on trace metal concentrations in sediments.

Following the development of interim guidelines, organics were added to the sampling requirements at load and dredge sites and have now been included in disposal site monitoring programs.

The largest multi-user disposal site in the Georgia Basin is the Point Grey disposal site (Figure 2).

Approximately 500 000 cubic metres of material is disposed of annually at the site. (10% of the volume is excavation material).

FIGURE 1

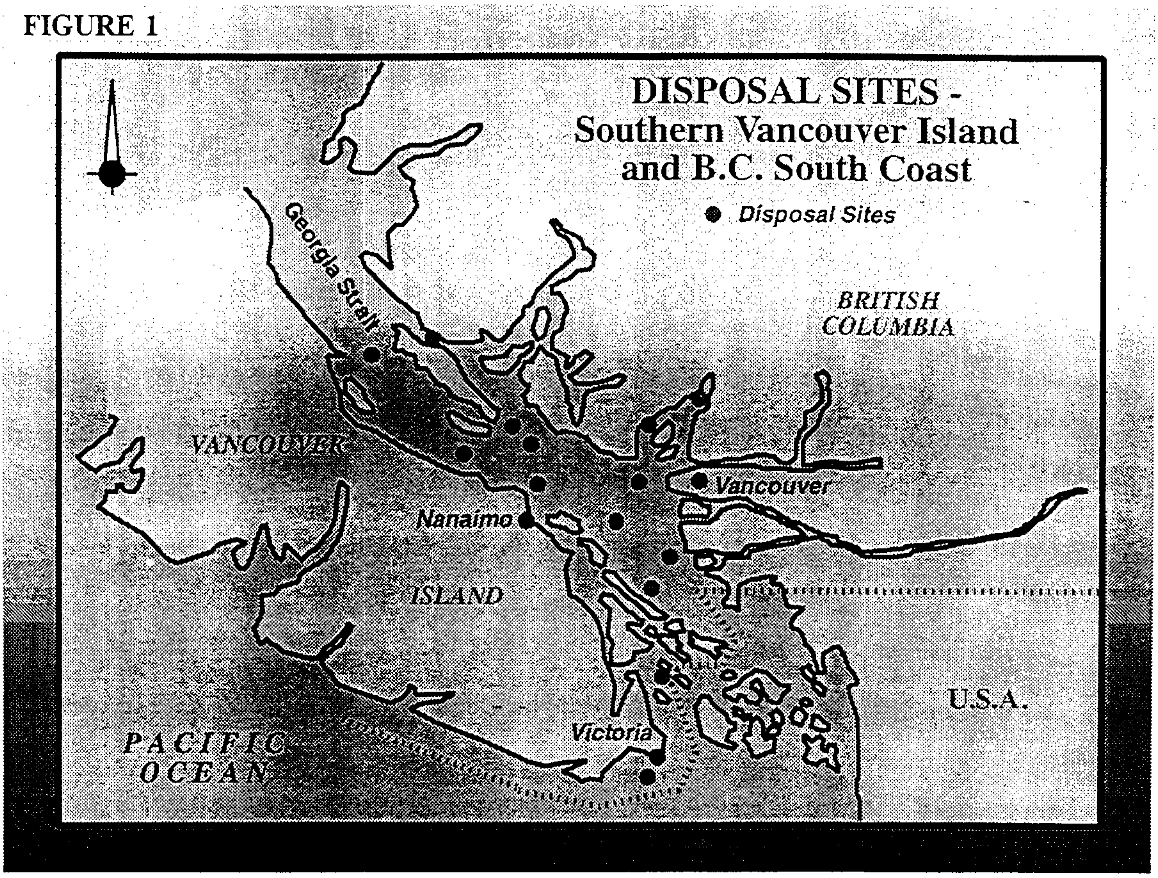
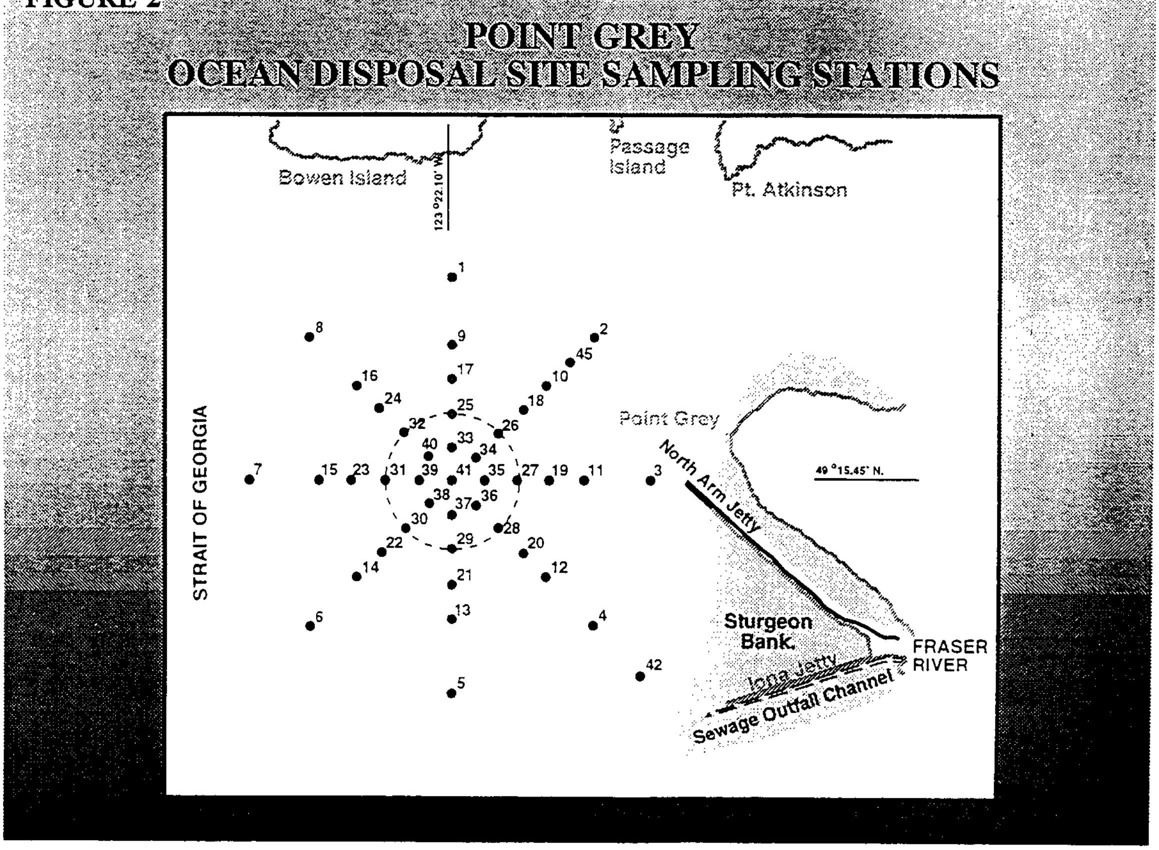



FIGURE 2



Between 1980-1993, sediments from Point Grey were collected from 0-5cm at regular intervals, and analyzed for trace metals. Cadmium, mercury and zinc were selected to illustrate any changes in the sediment chemistry at Point Grey while ocean disposal activities were occurring. Data from five other years not shown on the graphs exhibits the same pattern. Results from transects of stations across the disposal site shows no apparent increase of trace metals in the surface sediments over time and no apparent increase within the disposal site perimeters (Tables 1, 2 and 3). It would appear that the chemistry of the sediments has not been altered significantly with the current loading of dredged and excavation material at the Point Grey disposal site.

In 1993, a comprehensive monitoring survey was undertaken at the Point Grey Disposal site which included sediment chemistry, benthic community structure, bioassays (amphipod), box cores (3) and ROV video records. Preliminary results from video records indicate although ocean disposal has definite physical impacts at the disposal site, one positive consequence noted is increases in shellfish and gastropod populations because of habitat created by dumping materials (e.g. concrete) on an otherwise soft substrate. Preliminary bioassay work did not indicate any significant effects from disposal activities. Further studies at ocean disposal sites will be designed in accordance with the national monitoring guidelines that are currently being developed.

TABLE 1

CADMIUM TRENDS - LONGITUDINAL TRANSECT

| Station | 1980 | 1982 | 1983 | 1984 | 1986 | 1988 | 1989 | 1993 |
|---|---|---|---|---|---|---|---|---|
| 1 | < 0.55 | - | 1.00 | < 0.30 | 0.32 | 0.30 | - | 0.38 |
| 9 | < 0.55 | - | - | - | - | 0.30 | - | 0.06 |
| 17 | < 0.55 | < 0.30 | - | - | - | 0.22 | - | 0.07 |
| 25 | < 0.55 | 1.90 | 0.80 | < 0.30 | 0.34 | 0.55 | - | 0.28 |
| 33 | < 0.55 | - | 0.70 | < 0.30 | - | - | 0.07 | - |
| 41 | < 0.55 | < 0.30 | 0.90 | < 0.30 | 0.38 | 0.10 | 0.09 | 0.10 |
| 37 | < 0.55 | - | 0.80 | < 0.30 | - | - | 0.10 | 0.04 |
| 29 | < 0.55 | < 0.30 | 0.70 | < 0.30 | 0.28 | 0.16 | - | 0.06 |
| 21 | < 0.55 | - | - | - | - | - | - | 0.05 |
| 13 | < 0.55 | - | - | - | - | - | - | 0.05 |
| 5 | < 0.55 | - | 0.77 | < 0.30 | 0.32 | 0.28 | - | 0.13 |

TABLE 2

MERCURY TRENDS - LONGITUDINAL TRANSECT

| Station | 1975 | 1978 | 1980 | 1982 | 1983 | 1984 | 1986 | 1988 | 1989 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .38 | .27 | .16 | - | .21 | .10 | .17 | .11 | - | .11 |
| 9 | .3 | .31 | - | - | - | - | - | .10 | - | .09 |
| 17 | .26 | .36 | - | .20 | - | - | - | .08 | - | .10 |
| 25 | .48 | .39 | .21 | .14 | .15 | .11 | .15 | .07 | - | .08 |
| 33 | .33 | .39 | .16 | - | .16 | .11 | - | - | .05 | - |
| 41 | .27 | .35 | - | .13 | .16 | .14 | .22 | .04 | .09 | .06 |
| 37 | .26 | .27 | .14 | - | .18 | .17 | - | - | .06 | .10 |
| 29 | .41 | .28 | .24 | .19 | .27 | .14 | .18 | .08 | - | .09 |
| 21 | .27 | .36 | - | - | - | - | - | - | - | .10 |
| 13 | .3 | .30 | - | - | - | - | - | - | - | .10 |
| 5 | .24 | .29 | .19 | - | .18 | .19 | .19 | .08 | - | .10 |

TABLE 3

ZINC TRENDS - LONGITUDINAL TRANSECT

| Station | 1975 | 1978 | 1980 | 1982 | 1983 | 1984 | 1986 | 1988 | 1989 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 107.3 | 97.5 | 116.0 | - | 118 | 111 | 103 | 126.3 | - | 132 |
| 9 | 106.4 | 95.9 | - | - | - | - | - | 119.0 | - | 129 |
| 17 | 114.2 | 100.5 | - | 105.0 | - | - | - | 104.6 | - | 145 |
| 25 | 108.5 | 132.1 | 167.0 | 91.1 | 119 | 194 | 94 | 98.9 | - | 121 |
| 33 | 122.5 | 283.7 | 179.0 | - | 104 | 120 | - | - | 89.0 | - |
| 41 | 103.2 | 98.8 | - | 77.9 | 143 | 120 | 97 | 67.0 | 90.2 | 118 |
| 37 | 106.7 | 94.8 | 107.0 | - | 108 | 134 | - | - | 103.0 | 110 |
| 29 | 100.6 | 92.0 | 98.0 | 107.0 | 107 | 129 | 90 | 105.3 | - | 122 |
| 21 | 99.5 | 93.9 | - | - | - | - | - | - | - | 127 |
| 13 | 103.8 | 87.3 | - | - | - | - | - | - | - | 122 |
| 5 | 96.9 | 96.1 | 105.0 | - | 111 | 122 | 115 | 107.3 | - | 143 |

- concentrations expressed in ug/g dry weight

**POINT GREY DISPOSAL SITE**

**MERCURY CONCENTRATIONS 1975-1993**

| Station | 1975 | 1978 | 1980 | 1982 | 1983 | 1984 | 1986 | 1988 | 1989 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| | **.38** | .27 | .16 | - | .21 | .10 | .17 | .11 | - | .11 |
| 9 | .3 | .31 | - | - | - | - | - | .10 | - | .09 |
| 17 | .26 | .36 | - | .20 | - | - | - | .08 | - | .10 |
| 25 | .48 | .39 | .21 | .14 | .15 | .11 | .15 | .07 | - | .08 |
| 33 | .33 | .39 | .16 | - | .16 | .11 | - | - | .05 | - |
| 41 | .27 | .35 | - | .13 | .16 | .14 | .22 | .04 | .09 | .06 |
| 37 | .26 | .27 | .14 | - | .18 | .17 | - | - | .06 | .10 |
| 29 | .41 | .28 | .24 | .19 | .27 | .14 | .18 | .08 | - | .09 |
| 21 | .27 | .36 | - | - | - | - | - | - | - | .10 |
| 13 | .3 | .30 | - | - | - | - | - | - | - | .10 |
| 5 | .24 | .29 | .19 | - | .18 | .19 | .19 | .08 | - | .10 |

## POINT GREY OCEAN DISPOSAL SITE

## CADMIUM CONCENTRATIONS 1986-1993

| Station | 1986 | 1988 | 1989 | 1993 |
|---|---|---|---|---|
| 1 | 0.32 | 0.30 | - | 0.38 |
| 9 | - | 0.30 | - | 0.06 |
| 17 | - | 0.22 | - | 0.07 |
| 25 | 0.34 | 0.55 | - | 0.28 |
| 33 | - | - | 0.07 | - |
| 41 | 0.38 | 0.10 | 0.09 | 0.10 |
| 37 | - | - | 0.10 | 0.04 |
| 29 | 0.28 | 0.16 | - | 0.06 |
| 21 | - | - | - | 0.05 |
| 13 | - | - | - | 0.05 |
| 5 | 0.32 | 0.28 | - | 0.13 |

**POINT GREY DISPOSAL SITE**

**ZINC CONCENTRATIONS 1975-1993**

| Station | 1975 | 1978 | 1980 | 1982 | 1983 | 1984 | 1986 | 1988 | 1989 | 1993 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 107.3 | 97.5 | 116.0 | - | 118 | 111 | 103 | 126.3 | - | 132 |
| 9 | 106.4 | 95.9 | - | - | - | - | - | 119.0 | - | 129 |
| 17 | 114.2 | 100.5 | - | 105.0 | - | - | - | 104.6 | - | 145 |
| 25 | 108.5 | 132.1 | 167.0 | 91.1 | 119 | 194 | 94 | 98.9 | - | 121 |
| 33 | 122.5 | 283.7 | 179.0 | - | 104 | 120 | - | - | 89.0 | - |
| 41 | 103.2 | 98.8 | - | 77.9 | 143 | 120 | 97 | 67.0 | 90.2 | 118 |
| 37 | 106.7 | 94.8 | 107.0 | - | 108 | 134 | - | - | 103.0 | 110 |
| 29 | 100.6 | 92.0 | 98.0 | 107.0 | 107 | 129 | 90 | 105.3 | - | 122 |
| 21 | 99.5 | 93.9 | - | - | - | - | - | - | - | 127 |
| 13 | 103.8 | 87.3 | - | - | - | - | - | - | - | 122 |
| 5 | 96.9 | 96.1 | 105.0 | - | 111 | 122 | 115 | 107.3 | - | 143 |

## MONITORING GUIDELINES FOR OCEAN DISPOSAL

*A. Chevrier*

### Abstract

Interim Monitoring Guidelines for Ocean Disposal were published in July 1993 and are targeted at ocean disposal sites which receive dredged materials. Consideration will be given to expand to other material types in the future, particularly fish wastes. Disposal site monitoring verifies that permit conditions are met and that assumptions made during the permit review and site selection process were correct and sufficient to protect the environment.

The development of the guidelines was initiated in 1992-93 as part a five-year plan which is aimed at progressively developing, field testing and phasing in the national guidelines by 1997-98. The interim guidelines published in 1993 already cover physical and chemical monitoring. Biological monitoring guidelines will be added by the end of 1993-94 and data interpretation guidelines should be developed in 1994-95.

The interim guidelines are developed to meet the following requirements:

* disposal site monitoring is covered by the Waste Assessment Framework (WAF), and is undertaken to meet National Canadian Environmental Protection Act (CEPA) compliance and International (London Convention reporting obligations;
* the monitoring guidelines should provide for: cost-effectiveness, national consistency, comparability of results, fair and consistent information requirements from clients;
* monitoring plans are developed around the impact hypotheses derived during the permit review;
* disposal site monitoring is triggered by a set of clearly-established criteria;
* the guidelines call for a core monitoring program; and
* to optimize the use of limited resources, the guidelines identify monitoring tiers.

<u>Development of the monitoring guidelines</u>

Interim Monitoring Guidelines for Ocean Disposal were published in July 1993 and are targeted at ocean disposal sites which receive dredged materials. The guidelines are to be applied in the context of compliance monitoring at ocean disposal sites. Disposal site monitoring verifies that permit conditions are met and that assumptions made during the permit review and site selection process were correct and sufficient to protect the environment.

The development of the monitoring guidelines is undertaken over a five-year period which is aimed at progressively developing, field testing and phasing in the guidelines by 1997-98, as shown in Table 1.

**TABLE 1: Highlights of the Five-Year Development Plan**

| | Fiscal Year | Objective |
|---|---|---|
| Step 1 | 92-93 | Draft Guidelines with emphasis on Physical and Chemical Monitoring |
| Step 2 | 93-94 | Draft Biological Monitoring Guidelines |
| Step 3 | 94-95 | Draft Data Interpretation Guidelines |
| Step 4 | 95-96 | Emphasis on Field-Testing |
| Step 5 | 96-97 | Integration and final Field-Testing |

Step 1 has been completed and initial field testing occurred at three disposal sites across the country, i.e. Point Grey (Pacific and Yukon region), BlackPoint (Atlantic region) and Baie des Chaleurs (Québec region).

Step 2 will concentrate on: choosing adequate biological tools and variables; augmenting the core monitoring program and tiered monitoring scheme with biological aspects; defining required field validation. Detailed technical aspects will best be addressed as part of the development of technical guidance documents, including guidance on recommended methodology, sampling design, QA requirements, reference site selection, species selection.

Next fiscal year (Step 3), the primary objective will be to draft data interpretation guidelines to cover: decision criteria, related management decisions and actions, factors affecting data interpretation.

**Use of disposal site monitoring information**

Disposal site monitoring comes as a follow-up to the issuance of an ocean disposal permit with a view at assessing the decision rendered, i.e. collecting relevant information that will be used to verify that permit conditions are met and that the impact hypotheses derived during the application review and site selection process are correct and sufficient to protect the environment. The impact hypotheses constitute the logical foundation for any subsequent monitoring.

Another critical use of disposal site monitoring information is in the assessment of the adequacy of controls, i.e. gather information that will allow assessing whether the permit conditions, regulations and guidelines are adequate in protecting the marine environment.

Experience gained with monitoring may also point to the need for R&D projects to develop better monitoring tools. It is also expected that monitoring will uncover gaps in our understanding of impacts, particularly in the area of cause/effect relationships.

**Triggers to disposal site monitoring**

Monitoring at every ocean disposal site is not considered necessary, as current knowledge of impacts related to disposal of dredged material allow for reasonable inferences and it seems reasonable to concentrate on representative disposal sites.

In addition, it is possible to rank disposal sites in relation to the need for monitoring, taking into account: characterization of material dumped, depth of knowledge with regard to impact hypotheses, and underlying cause and effect relationships. As such, triggers to disposal site monitoring are:

1) disposal of dredged material containing contaminants above trace levels and authorized for disposal on the basis of bioassay results: to ensure that existing ocean disposal controls are providing adequate protection to the environment.

2) concerns identified at a disposal site in relation to potential impacts on nearby sensitive areas (including habitats) or potential conflicts with other nearby uses of the sea: to verify that permit terms and conditions are providing adequate time restrictions (i.e. critical times of the year when disposal at sea should not proceed) and a sufficient buffer zone between the disposal site and other valuable areas/uses to provide protection and minimize conflicts.

3) volume of dredged material dumped annually: to ensure that the major disposal sites ($\geq$ 100 000 $m^3$ per year) are visited on at least a five year cycle and that representative minor sites ($<$ 100 000 $m^3$ per year) are visited on at least a 10 year cycle.

**The first two criteria are the most important and take precedence over the third. The decision-making process is not further described at this stage and will be improved as experience is gained with monitoring.**

**Developing a monitoring plan from impact hypotheses**

Disposal site monitoring is used to verify that disposal has been carried out in compliance with permit terms and conditions and that the assumptions made during the permit review and site selection process were correct and sufficient to protect the environment, i.e. the impacts observed at the disposal site should not exceed those expected and accepted by the permit terms and conditions.

The permit application review is aimed at determining the likely environmental effects of the proposed disposal. The final stage of this assessment requires a concluding statement in support of the decision to issue a permit, including supporting rationale for permit terms and conditions. Impact hypotheses are derived from this analysis and should primarily be related to:

- conflicts with other legitimate uses of the sea;
- habitat destruction and unacceptable impacts on fish and fisheries;
- protection of sensitive areas;
- acute or chronic toxic effects in sensitive marine organisms typical of the marine ecosystem at the disposal site; and
- chemical contamination of edible fish and shellfish.

Impact hypotheses also constitute the logical foundation for any subsequent monitoring plan. Some measurements at a disposal site may be relevant to more than one impact hypothesis (eg. evidence of sediment transport may be relevant to both protection of sensitive areas and use conflicts).

Monitoring plans should be tailored to site-specific and permit-specific information (eg. permit terms and conditions, disposal site characteristics, site-specific species, local spatial and temporal scales of the variable). Furthermore, monitoring objectives should be formulated into testable hypothesis in accordance with the following format:

*"Disposal activity "X" will not cause a particular component of the ocean ecosystem to change by a specified amount at a specific location or in a specific area".*

**Parameters for the core monitoring program**

Taking into account the minimum information requirements of the permit application which provide baseline information for disposal sites, the core monitoring program outlined in table 2 must be incorporated in every monitoring plan.

**TABLE 2: PARAMETERS FOR THE CORE MONITORING PROGRAM**

| Geological surveys | Chemicals in sediments |
|---|---|
| Bathymetry<br><br>Sediment grain size<br><br>Sonar imagery or any other means of ground-truthing predictions of sediment transport modelling | Cadmium<br>Mercury<br>PCBs<br>Total PAHs<br>Low molecular weight PAHs<br>High molecular weight PAHs<br>Total organic carbon |

**Tiered monitoring**

Some monitoring results will be used in making decisions on the need for further monitoring at a given disposal site. The proposed tiers must be adapted to knowledge specific to the disposal site under study.

**The first step, which applies to all cases, is to determine the initial area of deposition and determine the disposal site boundaries as accurately as possible.** The permit application review includes a prediction of where the dumped material might end up. It amounts to predicting the area of deposition of the material, and in doing so, in predicting the disposal site boundaries (i.e. the detectable limits of the area affected by deposition). The role of monitoring is to verify whether those boundaries (impact hypothesis) have been predicted accurately. If material does fall beyond the predicted boundaries, then the disposal site has been in fact most likely enlarged in the process and the real conformation of the disposal site, as verified through monitoring, should be documented. Results will contribute to the design of any further monitoring at the disposal site.

**Study of sediment transport resulting from resuspension of deposited material from the disposal site should also be undertaken in all cases.** It will identify the need for offsite monitoring (i.e. outside of the boundaries of the disposal site established in the first step). If sediment resuspension and transport is not occurring in significant amounts in directions likely to cause concern with regard to habitat, fisheries, other uses of the sea or sensitive areas, then monitoring offsite is not required.

**The chemical parameters identified in the core monitoring program will be measured in disposal site sediments in all cases. Biological monitoring requirements**, (eg. bioaccumulation studies, evidence of diseases in key species, population and community responses in the field) will be addressed by the end of 1993/94 and incorporated into the guidelines for the 1994/95 disposal site monitoring studies.

## CONTAMINANT PATTERNS IN SEDIMENTS AND TISSUES FROM BOUNDARY BAY AND THE FRASER RIVER ESTUARY

*L. G. Swain, D.G. Walton*

B.C. Ministry of Environment, Lands and Parks perform ambient monitoring in estuaries and marine sites through two major programs. The first is the yearly program for checking the attainment of water quality objectives. This information is being presented to this forum in a paper by Mr. Ben Kangasniemi. The second is the work carried out by the Ministry through the Fraser River Harbour Commission. That information is provided in this paper.

Since 1986, the B.C. Ministry of Environment, Lands and Parks, in partnership with the Fraser River Harbour Commission, has measured contaminant concentrations in sediments, biota, and effluents at sites in the Fraser River and Boundary Bay. We will present information on patterns of contaminant levels found in sediment and tissues from Boundary Bay where we sampled in 1989 and 1993, and provide a brief summary of trends in metals in the Fraser River Estuary.

### FRASER RIVER ESTUARY RESULTS

In the Fraser River Estuary, we have sampled sediments from six sites (two in each of the Main Stem, Main Arm, and North Arm) and fish from three sites. We have previously presented information showing the significant decrease in lead concentrations in sediments from the Fraser River Estuary since 1986, due to the elimination of leaded gasoline from the Canadian market (Swain and Walton, 1993). These six sites are listed as MS-1, MS-2, NA-1, NA-2, MA-1, and MA-2 on Figure 1. The mean concentrations are usually based on at least five replicate samples.

The results showing decreasing lead concentrations in sediments are shown in Figure 2. As can be seen from the data, values have decreased to about one-third those which we measured in 1985. Correlation coefficients ($R^2$) for the declines at the six sites have been from 0.47 to 0.91. This reflects the declining use of leaded gasoline in Canada, with the total elimination as of January 1, 1990. This same pattern is apparent (Figure 3) for lead levels measured by the Greater Vancouver Regional District in suspended particulates at six sites in the Lower Mainland.

We also have measured contaminants in fish from three sites in 1988. This survey followed up on work carried out in the same general area by Singleton (1983) in 1980 and Northcote (1975) in 1971/72 The sites where fish were collected in 1988 are shown in Figure 4. We have shown that mercury concentrations in fish muscle (Figure 5) have had an apparent decrease between 1972 and 1988, for three species of fish: the largescale sucker, northern squawfish, and the peamouth chub (Swain and Walton, 1989). It is suspected that the lower mercury concentrations are due to the decreased use of mercury as a slimicide by the pulp and paper industry (Hall *et al.*, 1991).

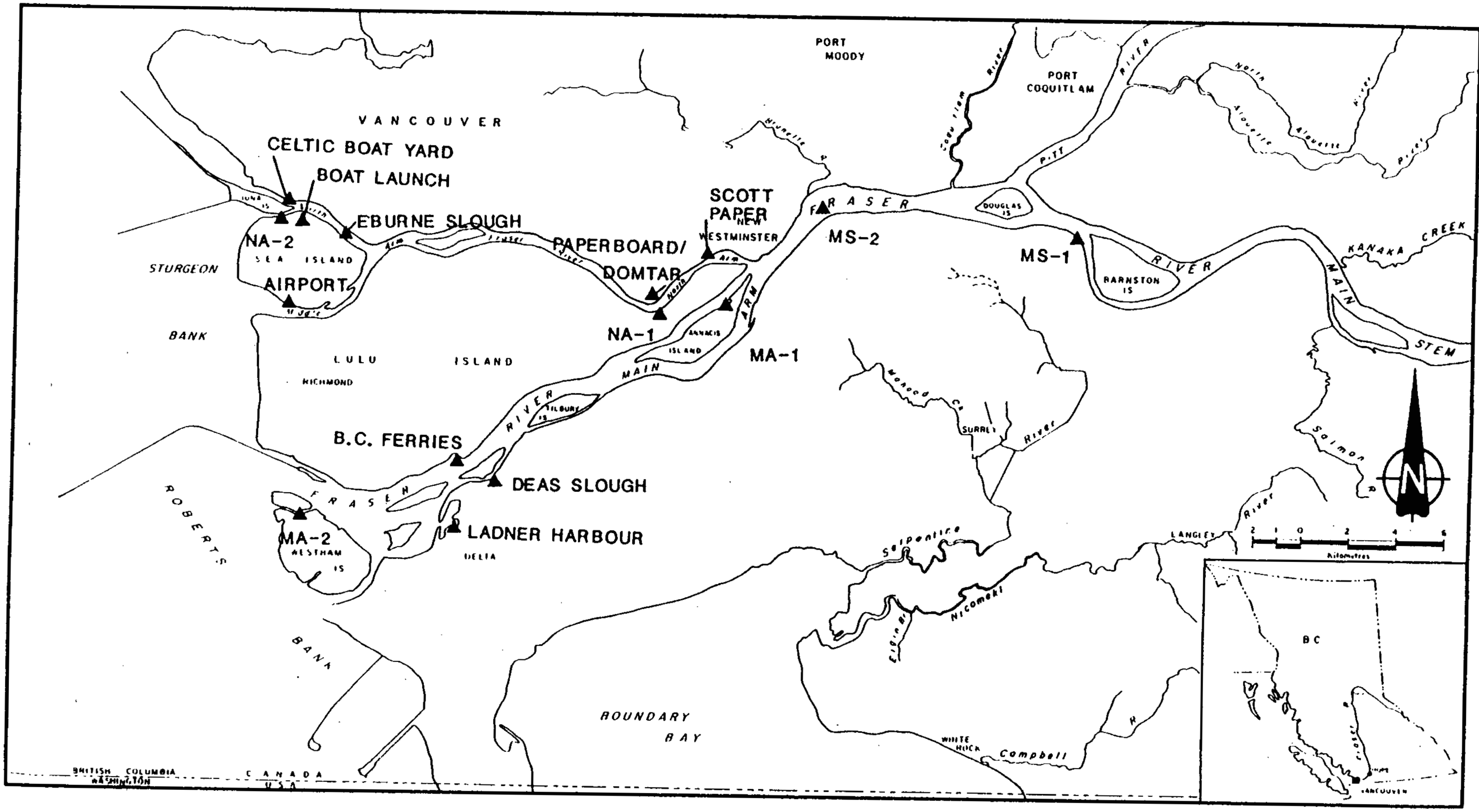


FIGURE 1 : LOCATION MAP OF SEDIMENT MONITORING SITES

FIGURE 2 : LEAD CONCENTRATIONS IN FRASER RIVER ESTUARY SEDIMENTS

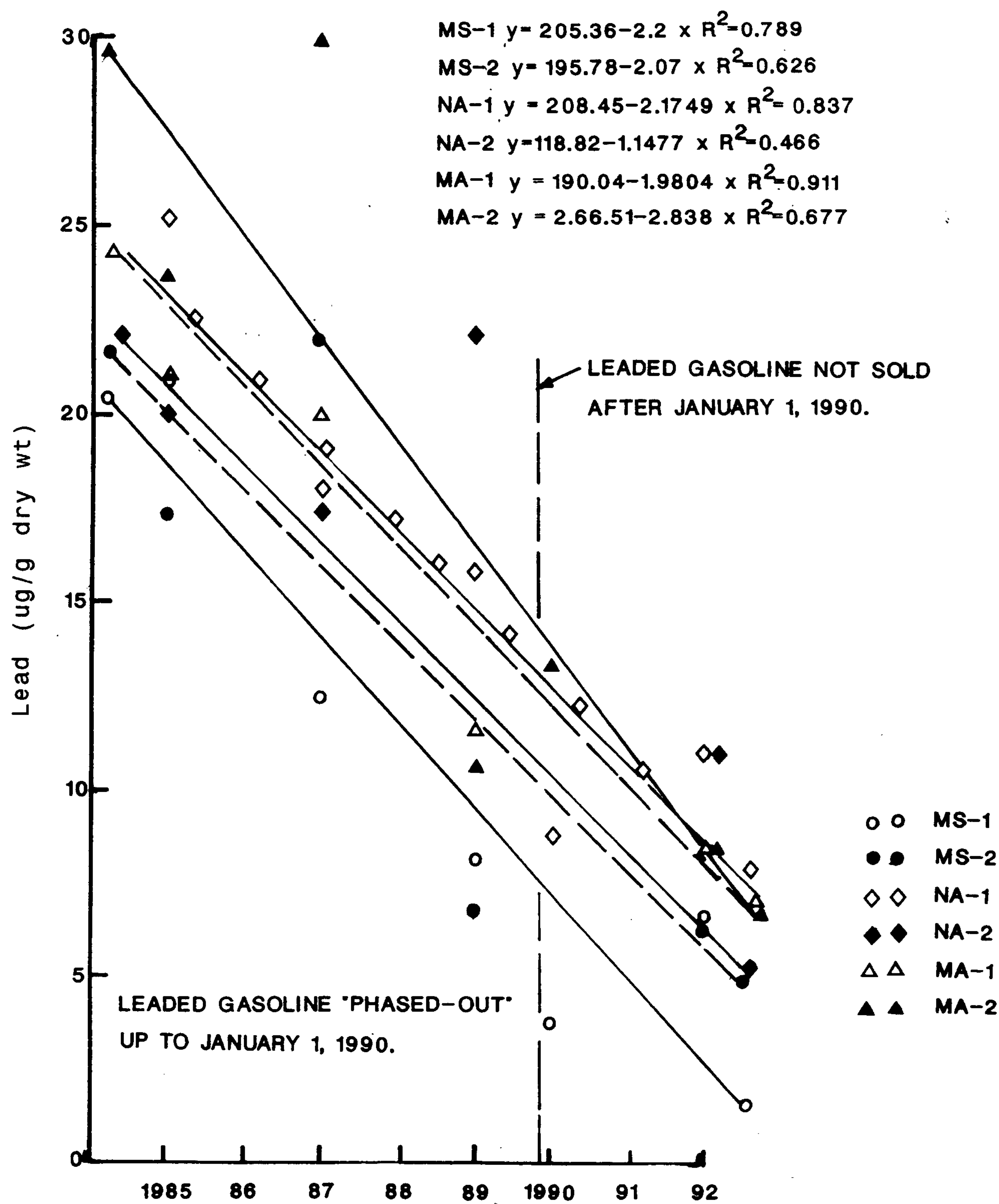
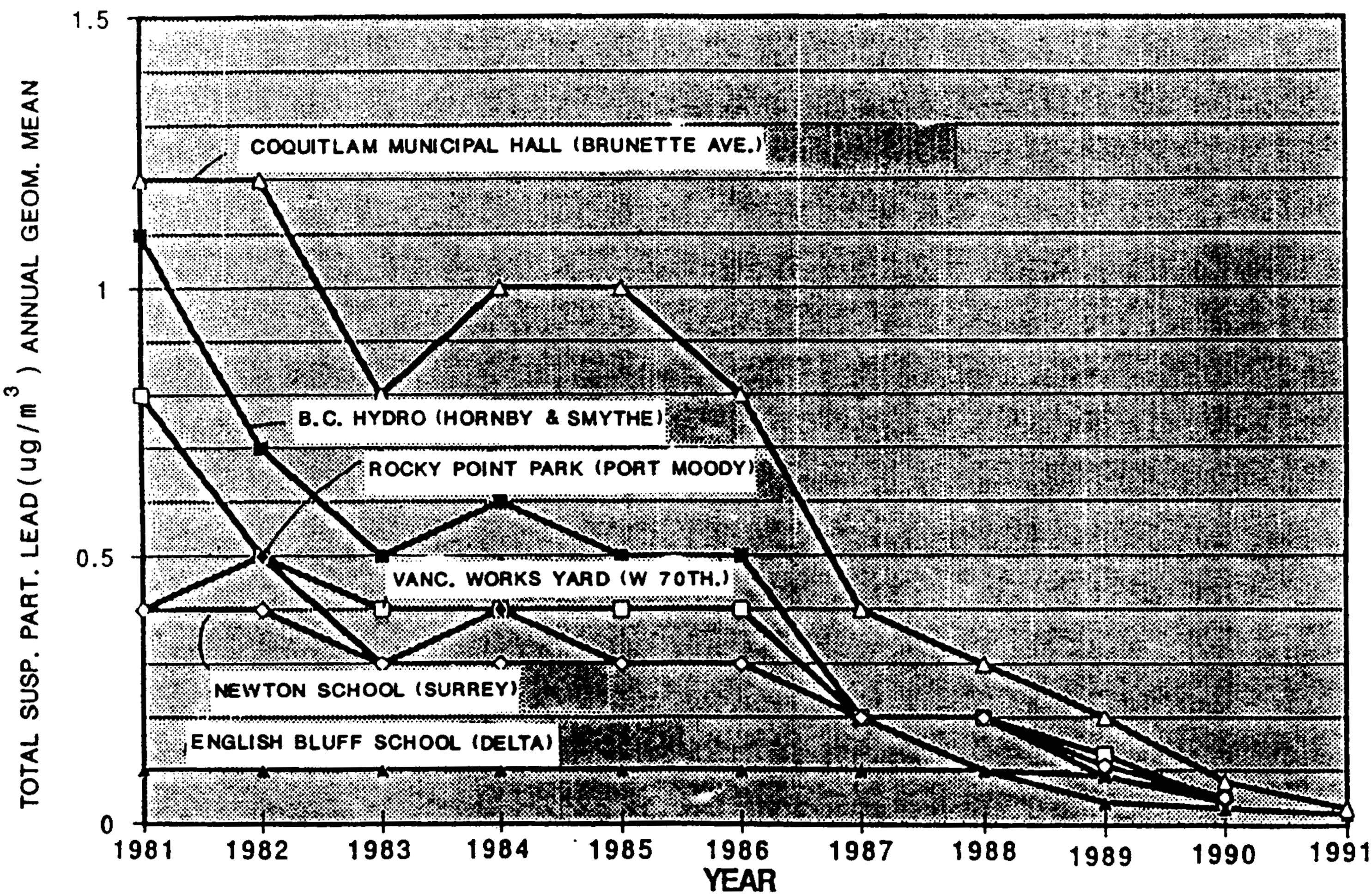


FIGURE 3 : 1981-1991 LEAD LEVELS IN SUSPENDED PARTICULATE AT SIX SITES IN THE LOWER MAINLAND



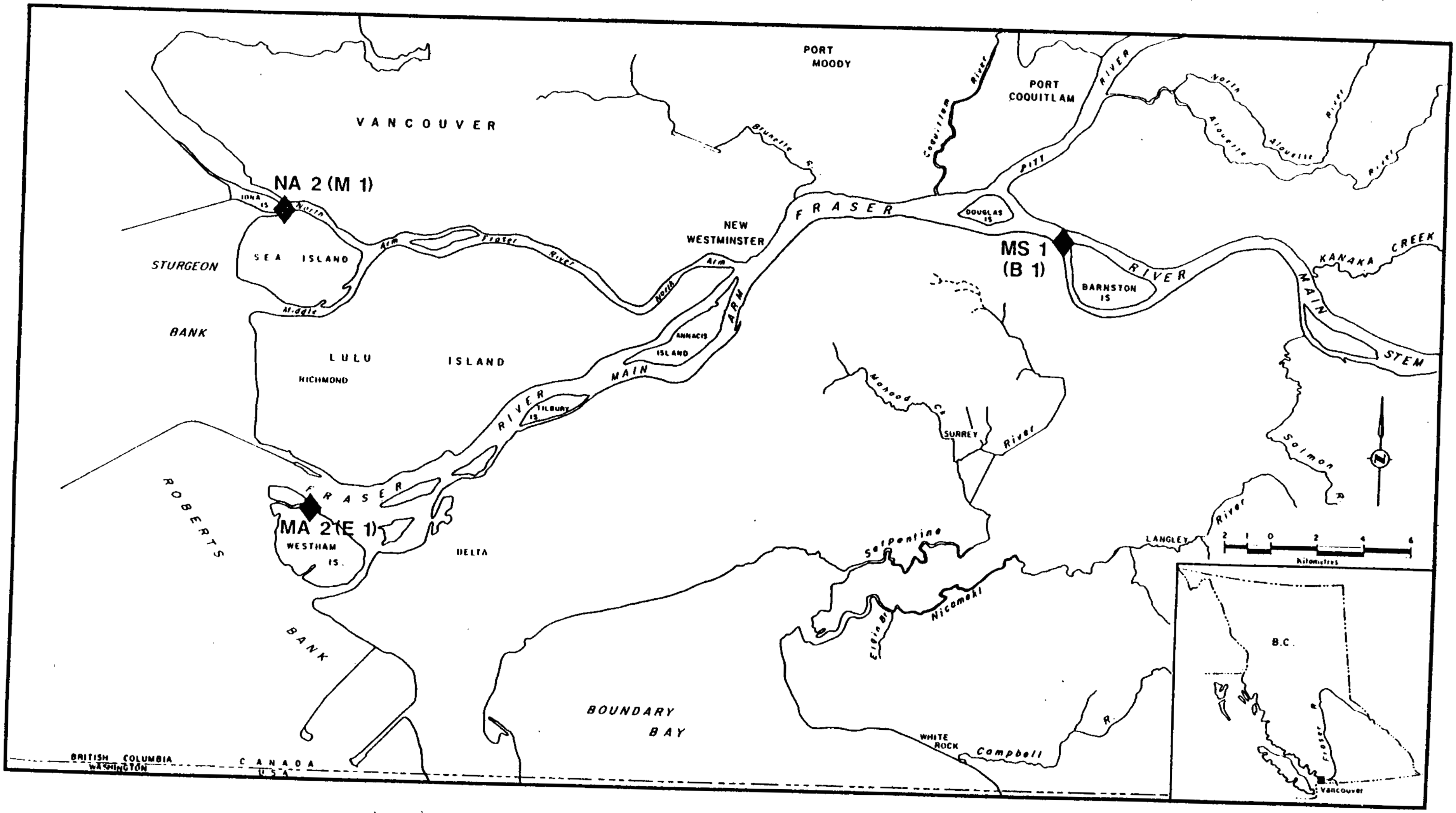



FIGURE 4 : 1988 FISH SAMPLING SITES

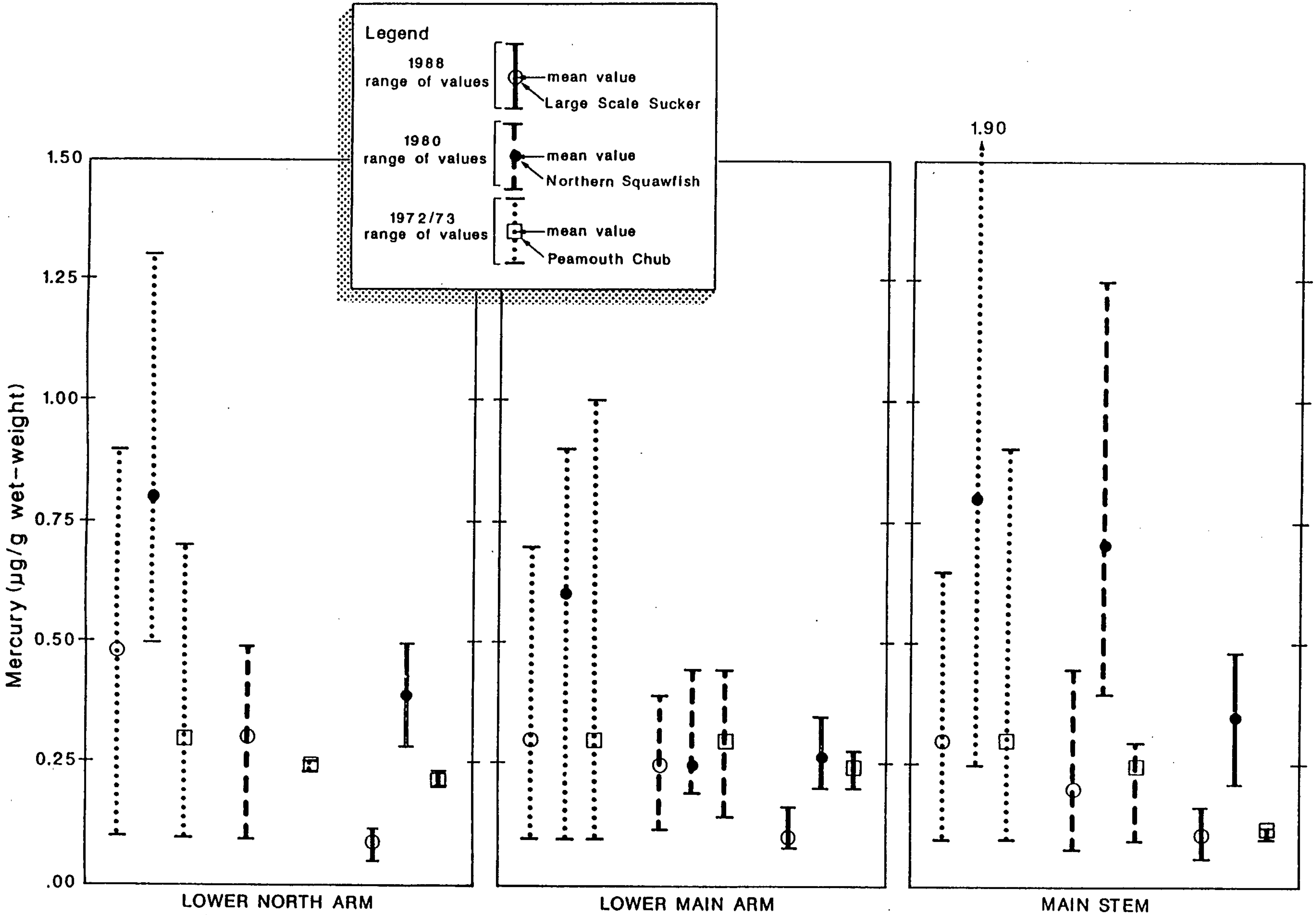



FIGURE 5 : MERCURY CONCENTRATIONS IN MUSCLE FROM SELECTED FISH SPECIES: 1972-1988

## BOUNDARY BAY RESULTS

In the Boundary Bay area, we sampled two locations in 1989 and 1993, one near the international border and about mid-point in the Bay, and a second location just north and east from White Rock. At both sites, we sampled sediments, crabs, and fish. These sites are identified in Figure 6 as the "inshore trawl" site and the "offshore trawl" site. We also sampled during 1993 at one site on Robert's Bank, as well as potential sources of contaminants to Boundary Bay (by measuring contaminant levels in sediments from the mouths of the three tributaries and in ditches leading to five land pump stations). Sediment and muscle concentrations are the mean of five individual samples.

There is generally little or no concern for organochlorine or organophosphate pesticides, chlorinated phenols or PCB's in Boundary Bay sediments since most concentrations are below analytical detection limits and water quality objectives which we have established for Burrard Inlet (Nijman and Swain, 1990) and may be appropriate for use in Boundary Bay. Organochlorine and organophosphate pesticides were not usually detectable in the sediments from the pump stations, river mouths, or ambient sites. We found that sediments from the offshore site had finer particle size, higher T.O.C. and moisture content than the sediments from the inshore site.

All PAHs at the offshore site were less than the water quality objectives for Burrard Inlet, although some individual PAHs from the inshore site exceeded slightly the long-term water quality objectives for Burrard Inlet. These slight exceedances for 1993 are shown in the following table and are not considered to be a major concern.

| PAH | Measured Concentration µg/g dry-weight | Sediment Objectives µg/g dry-weight |
|---|---|---|
| benzo (a) anthracene | 0.138 | 0.13 |
| benzo (ghi) perylene | 0.073 | 0.07 |
| fluoranthene | 0.282 | 0.17 |
| fluorene | 0.064 | 0.05 |
| indeno(1,,2,3-cd) pyrene | 0.072 | 0.06 |
| phenanthrene | 0.304 | 0.15 |

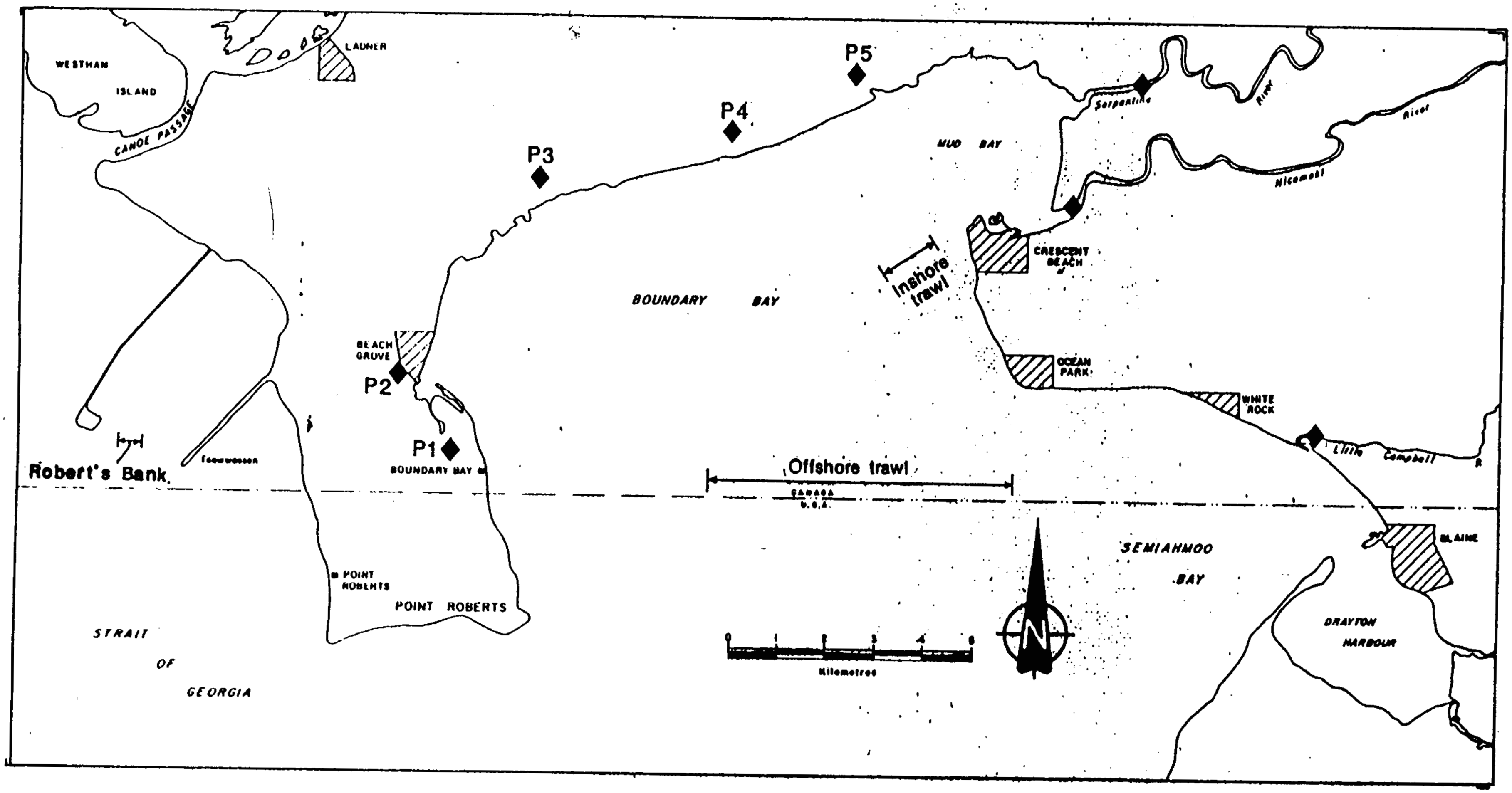



FIGURE 6 : SAMPLING SITES-1993

As was expected, metals concentrations in sediments were highest at the offshore site compared to the inshore site, likely due to the smaller particle size of sediments at that site. In comparison to the 1989 survey, we found the following:

| Site | ARSENIC | | COPPER | | LEAD | | MERCURY | | ZINC | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1989 | 1993 | 1989 | 1993 | 1989 | 1993 | 1989 | 1993 | 1989 | 1993 |
| Inshore | 1.98 | 4.6 | 4.94 | 12.2 | 2.87 | 4.42 | 0.018 | 0.052 | 21 | 60.6 |
| Offshore | 10.1 | 9.5 | 39.9 | 35.5 | 16.9 | 14.4 | 0.078 | 0.058 | 105 | 103.5 |

The data indicate that metals at the offshore site were slightly lower and at the inshore site, considerably higher, than we found in 1989. It is speculated that this is likely due to the variability in sampling location as much as it may be to actual trends.

The data reported in the following sections for tissue analyses are reported in terms of $\mu$g/g (wet-weight). All analyses are for muscle tissue, except for staghorn sculpins from the inshore site, which are for the whole fish. Liver and hepatopancreas data are reported elsewhere (Swain and Walton, 1994).

The Canadian Food and Drug Directorate level of 3.5 $\mu$g/g of arsenic in fish protein to protect humans was not met in the crabs collected at the inshore site, but was met in crabs from the offshore site, and in all the fish we collected. Arsenic concentrations in muscle from starry flounder and buttersole from the offshore site were virtually the same in 1989 and 1993, while arsenic concentrations in whole staghorn sculpins from the inshore site may have increased from 1989 to 1993. Arsenic concentrations in crab muscle are higher at the inshore site, but lower at the offshore site. This may reflect a trend since this same trend was also seen for sediments at the two sites. The actual values are listed below:

| Arsenic (ug/g ww) | | 1989 | 1993 |
|---|---|---|---|
| **Inshore** | **- Dungeness crab** | 3.24 | 4.50 |
| | **- staghorn sculpin** | 0.41 | 1.08 |
| **Offshore** | **- Dungeness crab** | 3.62 | 0.46 |
| | **- buttersole** | 0.88 | 0.81 |
| | **- starry flounder** | 1.02 | 1.08 |

In terms of cadmium, values compared as follows, with concentrations decreasing most significantly in Dungeness crabs:

| Cadmium (ug/g ww) | | 1989 | 1993 |
|---|---|---|---|
| **Inshore** | **- Dungeness crab** | 0.175 | 0.011 |
| | **- staghorn sculpin** | 0.024 | 0.024 |
| **Offshore** | **- Dungeness crab** | 0.30 | 0.013 |
| | **- buttersole** | 0.009 | <0.005 |
| | **- starry flounder** | 0.006 | <0.005 |

We found that copper concentrations in 1993 in muscle from crabs from the inshore site were slightly lower, and in muscle from crabs and buttersole from the offshore site considerably lower, than we found in 1989. Concentrations were slightly higher in muscle from starry flounder in 1993 than in 1989. Concentrations in whole staghorn sculpins were virtually the same. We do not believe at this time that there is a trend in these findings since we did not observe lower copper concentrations in sediments.

| Copper (ug/g ww) | | 1989 | 1993 |
|---|---|---|---|
| **Inshore** | **- Dungeness crab** | 9.25 | 8.8 |
| | **- staghorn sculpin** | 1.0 | 0.92 |
| **Offshore** | **- Dungeness crab** | 25.7 | 13.4 |
| | **- buttersole** | 0.65 | 0.19 |
| | **- starry flounder** | 0.37 | 0.49 |

Lead concentrations in crabs, buttersole, and starry flounder muscle were low and well below the B.C. criteria for consumption of fish and shellfish. The concentrations in whole staghorn sculpins remain virtually unchanged. The lead concentrations in these species may be marginally lower than we found in 1989; however, these possible trends are not reflected in the sediment data for these two sites.

| Lead (ug/g ww) | | 1989 | 1993 |
|---|---|---|---|
| **Inshore** | **- Dungeness crab** | 0.014 | <0.01 |
| | **- staghorn sculpin** | 0.015 | <0.01 |
| **Offshore** | **- Dungeness crab** | 0.031 | <0.01 |
| | **- buttersole** | 0.063 | <0.01 |
| | **- starry flounder** | 0.022 | <0.01 |

With respect to benthic samples, mercury concentrations in muscle from crabs and butter sole were about the same as found in 1989, and low enough to not be a concern from a consumption perspective. Mercury concentrations in the crab hepatopancreas showed that mercury (data not reported here) is not bioconcentrating in the body organ. Mercury concentrations in muscle from starry flounders captured at the offshore site were about one-half that we reported for 1989 samples from the same site. Mercury concentrations in whole staghorn sculpins were low and virtually the same as found in 1989.

| Mercury (ug/g ww) | | 1989 | 1993 |
|---|---|---|---|
| **Inshore** | **- Dungeness crab** | 0.053 | 0.054 |
| | **- staghorn sculpin** | 0.008 | 0.009 |
| **Offshore** | **- Dungeness crab** | 0.049 | 0.041 |
| | **- buttersole** | 0.023 | 0.019 |
| | **- starry flounder** | 0.054 | 0.028 |

In tissues, nickel concentrations in muscle of crabs, buttersole, and starry flounder do not appear to be higher in 1993 than in 1989; however, concentrations in whole staghorn sculpins do appear to be considerably higher in 1993 than in 1989.

| Nickel (ug/g ww) | | 1989 | 1993 |
|---|---|---|---|
| **Inshore** | **- Dungeness crab** | 0.064 | <0.20 |
| | **- staghorn sculpin** | 0.084 | 0.44 |
| **Offshore** | **- Dungeness crab** | 0.21 | <0.20 |
| | **- buttersole** | 0.013 | <0.20 |
| | **- starry flounder** | 0.06 | <0.20 |

Zinc concentrations in muscle from crabs and whole staghorn sculpins were higher in 1993 than in 1989, while levels in starry flounder and buttersole muscle were lower. There was no trend in the sediment data, so we do not believe that these changes reflect a trend.

| Zing (ug/g ww) | | 1989 | 1993 |
|---|---|---|---|
| **Inshore** | **- Dungeness crab** | 43.5 | 61.6 |
| | **- staghorn sculpin** | 13.6 | 18.0 |
| **Offshore** | **- Dungeness crab** | 34.5 | 53.4 |
| | **- buttersole** | 12.2 | 5.9 |
| | **- starry flounder** | 11.0 | 6.94 |

The largest number of detectable PAHs were in whole staghorn sculpins from the inshore site, while phenanthrene was the PAH most frequently detected in the crabs and fish. The fact that we detected PAHs in 1993 and not in 1989 was due to the use of lower analytical detection limits in 1993.

| **Species** | **St.Sc** | **CHpt** | **Fl.M** | **Fl.L** | **Bs.M** | **C.M.** | **CHpt** |
|---|---|---|---|---|---|---|---|
| **PAH/Location** | **Inshore** | **Inshore** | **Offshore** | **Offshore** | **Offshore** | **Offshore** | **Offshore** |
| Benzo(a)anthracene | 0.023 | | | | | | |
| Benzo(a)pyrene | 0.034 | | | | | | |
| Benzo(b)fluoranthene | 0.042 | | | | | | |
| Benzo(ghi)perylene | 0.028 | | | | | | |
| Chrysene | 0.03 | | | | | | |
| Fluoranthene | 0.016 | | | | | | 0.011 |
| Fluorene | | | | 0.031 | | 0.011 | |
| Indeno(1,2,3-cd)pyrene | 0.026 | | | | | | |
| Naphthalene | | 0.033 | 0.008 | 0.040 | | 0.009 | 0.041 |
| Phenanthrene | 0.007 | 0.032 | 0.006 | 0.030 | 0.018 | 0.015 | 0.040 |
| Pyrene | 0.015 | | | | | | |

St.sc = staghorn sculpin   CHpt = crab hepatopancreas   C.M. = crab muscle
Fl.M = flounder muscle   Fl.L = flounder liver   Bs.M = buttersole muscle.

There is generally little or no concern for chlorinated phenols or PCBs in Boundary Bay tissues, since most concentrations are below analytical detection limits and water quality objectives. As well, organochlorine and organophosphate pesticides were not usually detectable in fish or crabs, although there was some dieldrin measured in crab hepatopancreas from both sites, indicating that this is likely due to non-site specific contamination with this pesticide.

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## TRENDS IN CONTAMINANTS IN VANCOUVER HARBOUR[1]

*J. Boyd*

Following a review of existing environmental information (Waters 1985, 1986), Environment Canada began an environmental monitoring program to assess the impacts of selected contaminants on the benthic environment in Vancouver Harbour. In 13 surveys, conducted between May, 1985 and November, 1992, Environment Canada sampled sediment quality at about 115 stations and collected biota samples from 11 of those sites for various measures. The program focused on spatial distribution to assess the existing environmental quality but sampling was repeated at 38 of the 115 stations to provide time series data.

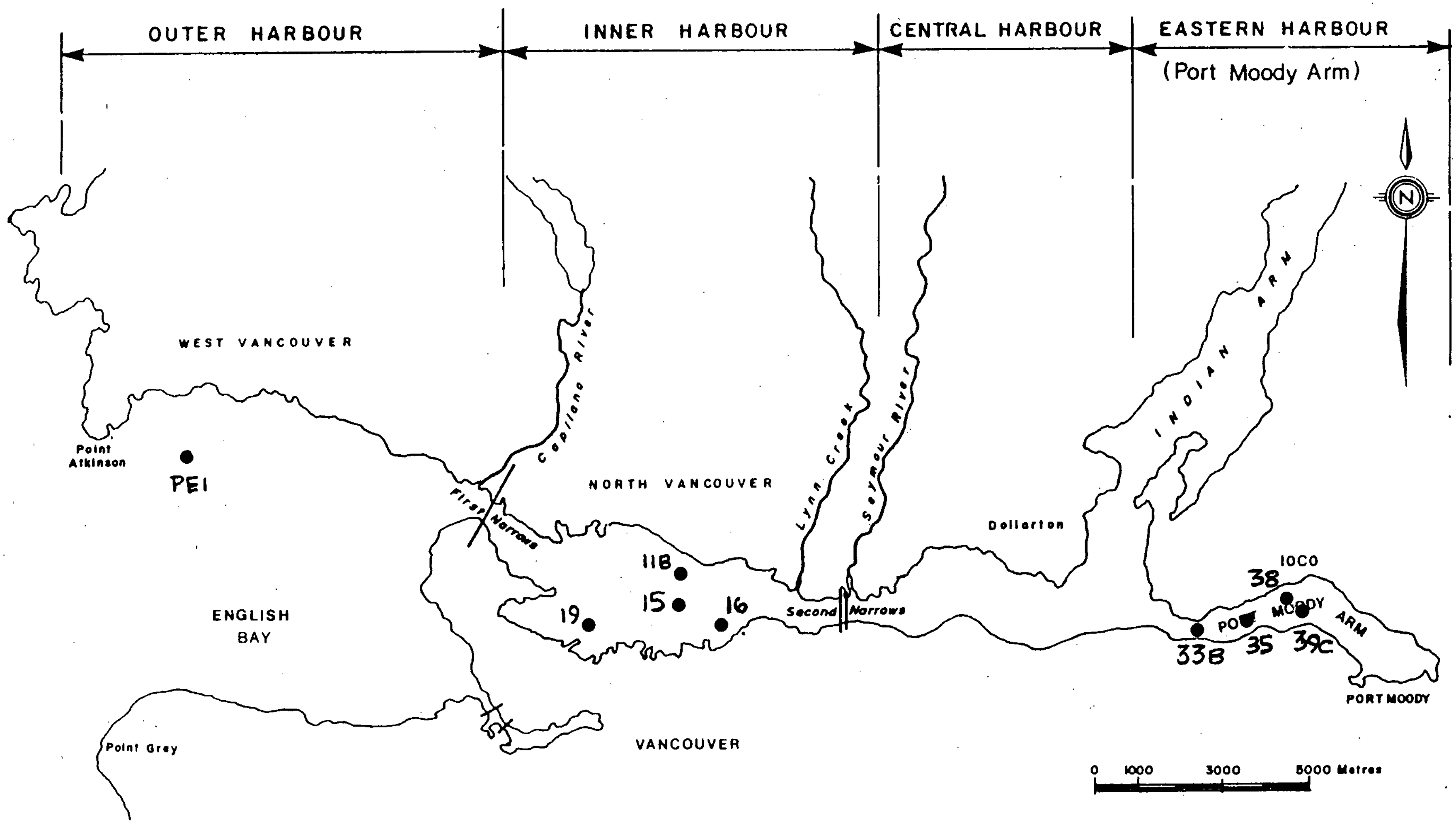
Sediment parameters measured included particle size, sediment volatile residue (SVR), trace metals, oils & grease, hydrocarbons, polychlorinated biphenyls (PCB), chlorophenols (CP), polycyclic aromatic hydrocarbons (PAH), and dioxins and furans (Goyette and Boyd 1989, Boyd and Goyette 1993, Boyd and Goyette in prep). For the biota parameters, earlier surveys focused on relative fish abundance, tissue trace metal (shrimp, crab and bottom fish) and PAH levels in English sole and Dungeness crab), and idiopathic liver lesions in English sole (Goyette and Thomas 1987, Goyette *et al.* 1988, Goyette and Boyd 1989, Brand 1990). More recent surveys expanded to include sediment toxicity tests (amphipod survival, avoidance and reburial; Neanthes growth and survival, echinoderm larvae, anaphase aberration, and clam reburial), fluorescent aromatic compounds (FAC) in fish bile, and mixed function oxygenase-ethoxyresorufin-o-deethylase (MFO-EROD) activity in English sole liver (EVS Consultants 1990, Boyd *et al.* in prep). To complement the Environment Canada program, the Institute of Ocean Sciences (DFO) assessed benthic community structure at 29 of the 115 stations (Burd and Brinkhurst 1990, Cross and Brinkhurst 1991).

To assess preliminary trends of contaminants in Vancouver Harbour, I focused on our largest time series data set, trace metals in sediment, and selected four metals of concern: cadmium, mercury, copper, and lead. My selection criterion for trend assessment included those stations sampled a minimum of four times, replicated three times each survey, and with the same median particle size within a station. Minor exceptions were permitted (e.g. single or duplicate sample once in the time series, mixed median particle size within a station if percentages were borderline between size fractions). Silts and clays predominated among the stations selected.

Given the above criterion, the metal levels presented did not represent the highest sediment metal concentrations in Vancouver Harbour. The intent here was to show relative temporal changes. Goyette and Boyd (1989) reported the ranges of these metals observed in the Harbour. Furthermore, seasonal variation was not considered in this preliminary trend assessment.

[1] The terms Vancouver Harbour and Burrard Inlet are used interchangeably throughout.

**FIGURE 1** **Vancouver Harbour Sampling Station Locations - Preliminary Contaminant Trends**



The stations selected are separated into 3 areas for comparison (Figure 1): Outer Harbour or reference area (Stn PEI), Inner Harbour (Stns 11B, 15, 16, 19), and Port Moody Arm (Stns 33B, 35, 38, 39C). The Inner Harbour experiences the most port activity. In Port Moody Arm, there is less activity but poor water circulation (Waldichuk 1965), therefore, sediments tend to accumulate in this area (McLaren 1994).

All sediment cadmium levels observed at the reference station in the Outer Harbour were below the Canadian ocean disposal criterion of 0.6 ug/g dry weight and showed a slight downward trend (Figure 2). Inner Harbour levels were relatively higher and more varied. In Port Moody Arm, they were higher again and most exceeded the ocean disposal criteria. A study in Port Moody Arm reported enriched background cadmium levels in this area (Pedersen and Waters 1989).

As for cadmium, mercury levels were generally highest in Port Moody Arm (Figure 3). Inner Harbour levels were similar or lower than the Outer harbour levels except for Stn 16. Higher mercury levels have been observed near combined sewer overflows (CSO) in Vancouver Harbour (Goyette and Boyd 1989); Stn 16 was located near a CSO.

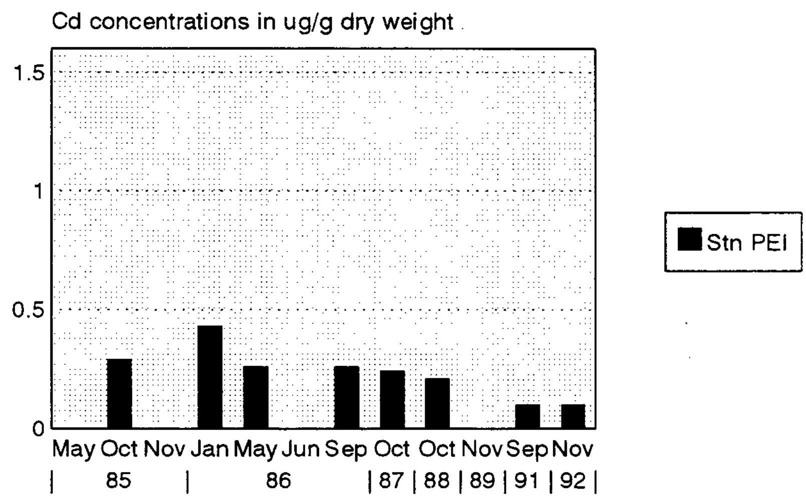
Lead displayed similar trends to cadmium, lower and relatively stable in Outer Harbour increasing on a gradient through the Inner Harbour and into Port Moody Arm (Figure 4). The slight decreases in recent years could have reflected the shift from using leaded to unleaded gasoline.

Sediment copper concentrations appeared stable at the reference station (Stn PEI) and similar to those observed in Port Moody Arm (Figure 5). Unlike the trends for the previous three metals, copper had comparatively higher concentrations in the Inner Harbour as opposed to Port Moody Arm. However, Stn 15 and Stn 19 showed a downward trend in the most recent surveys.

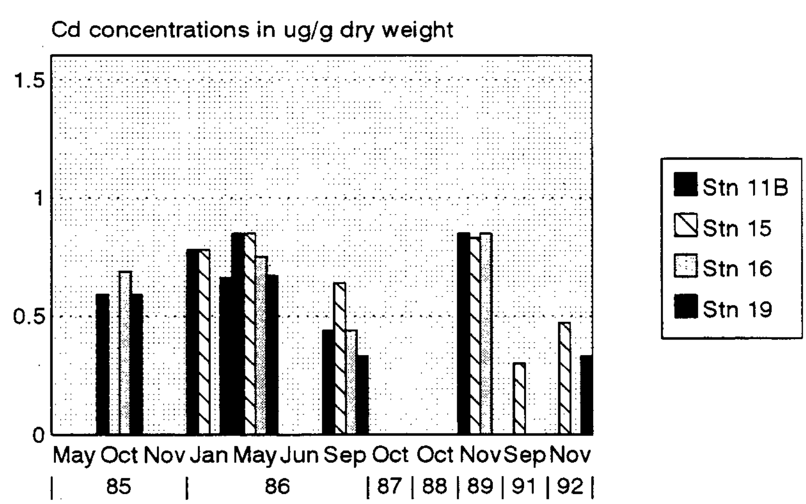
This provides an initial assessment of contaminant trends in Vancouver Harbour and is considered preliminary at this stage. Under the Burrard Inlet Environmental Action Program (BIEAP), a 5 year agreement among 5 parties (3 levels of government and a federal crown corporation), one of the primary objectives is to reduce contaminant discharges to Burrard Inlet. Each BIEAP partner (Environment Canada, Departement of Fisheries and Oceans, B.C. Ministry of Environment, Lands, and Parks, Greater Vancouver Regional District, and Vancouver Port Corporation) undertakes some environmental monitoring in the Harbour thus providing a foundation to build an integrated cost-effective program. We plan to maximize the use of existing environmental data to evaluate the effectiveness of the various parameters to measure environmental impacts, focus the list of parameters, standardize protocols, and refine the current programs to cost-effectively monitor the success of pollution abatement actions and the health of Burrard Inlet.

**FIGURE 2**

## Burrard Inlet - Outer Harbour
## Cadmium in Surface Sediment (1985-1992)




## Burrard Inlet - Inner Harbour Stations
## Cadmium in Surface Sediment (1985-1992)




## Burrard Inlet - Port Moody Arm
## Cadmium in Surface Sediment (1985-1992)

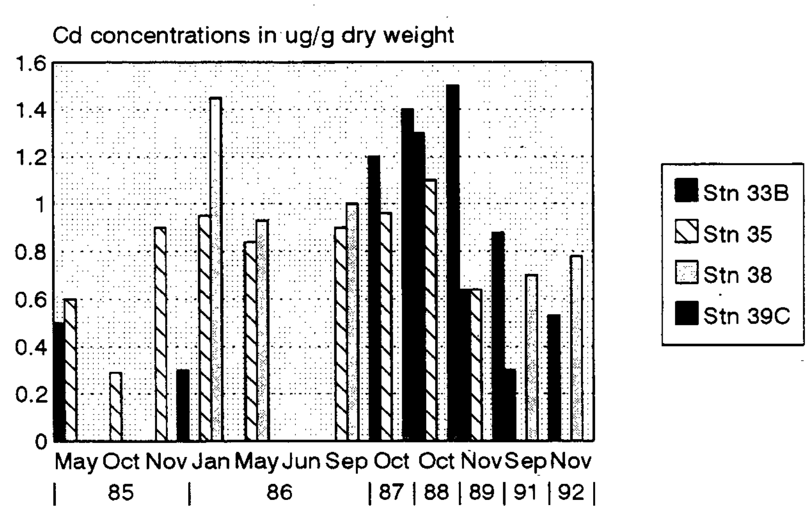
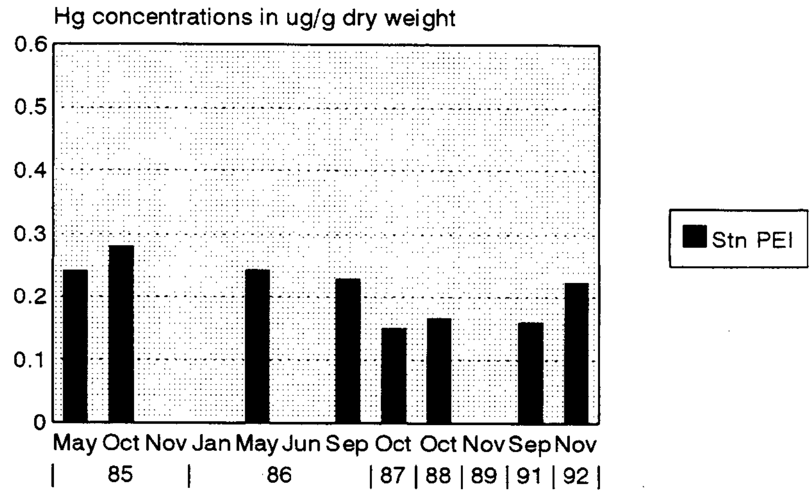
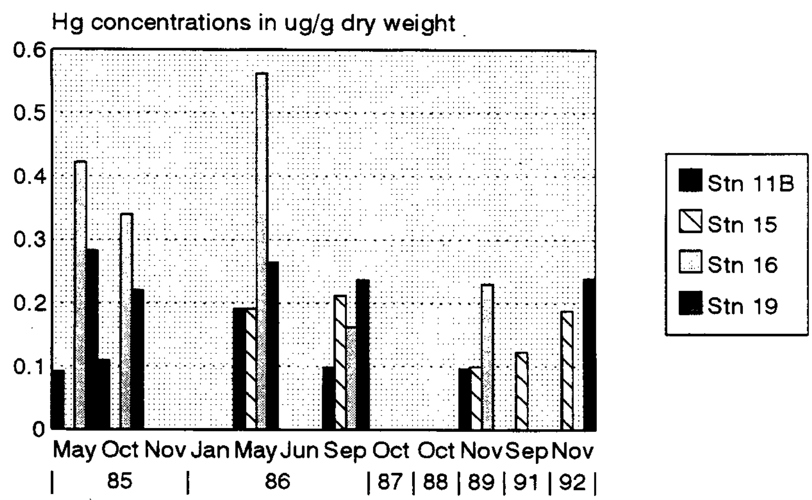


**FIGURE 3**

## Burrard Inlet - Outer Harbour
## Mercury in Surface Sediment (1985-1992)




## Burrard Inlet - Inner Harbour Stations
## Mercury in Surface Sediment (1985-1992)




## Burrard Inlet - Port Moody Arm
## Mercury in Surface Sediment (1985-1992)

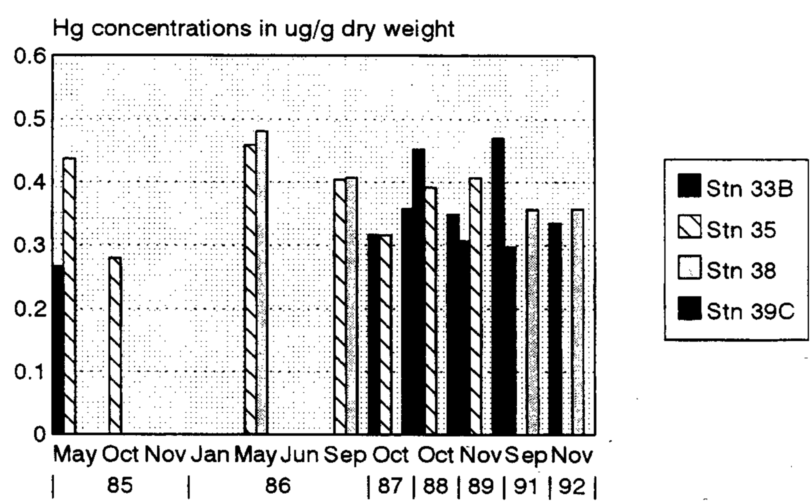
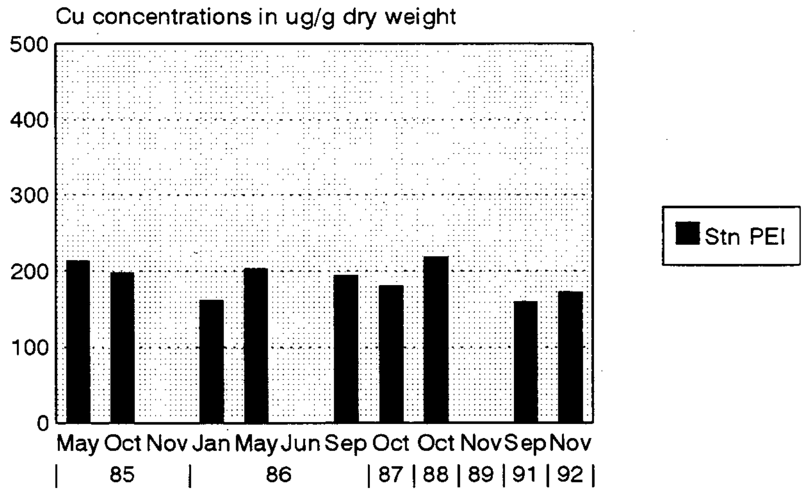
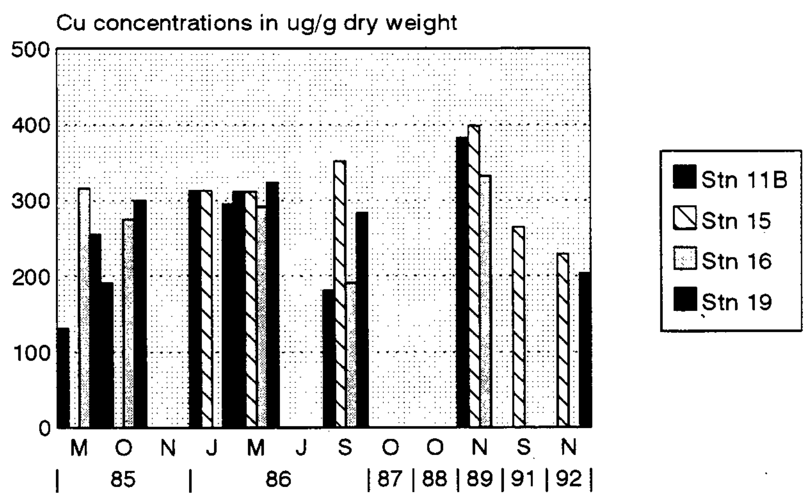


**FIGURE 4**

Burrard Inlet - Outer Harbour
Copper in Surface Sediment (1985-1992)




Burrard Inlet - Inner Harbour Stations
Copper in Surface Sediment (1985-1992)




Burrard Inlet - Port Moody Arm
Copper in Surface Sediment (1985-1992)

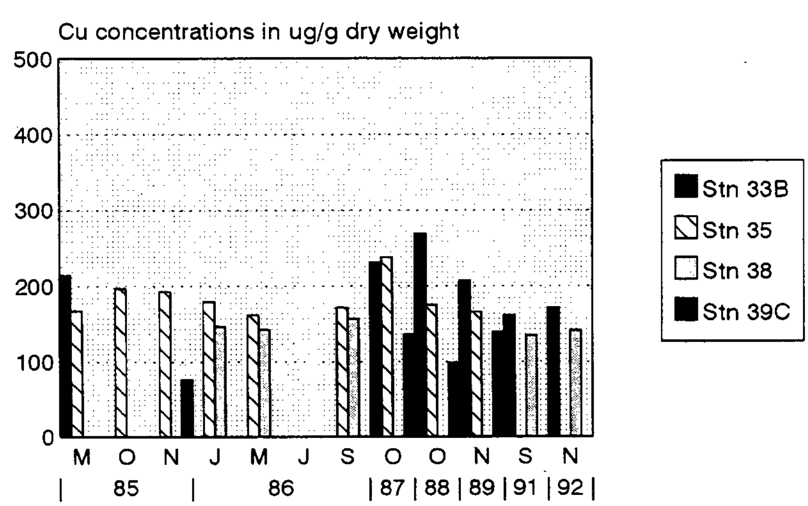
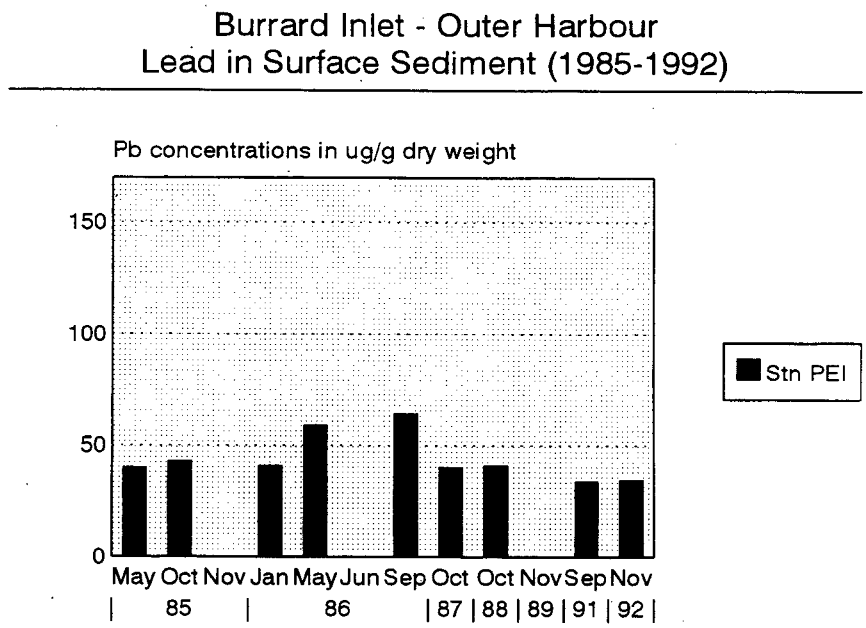
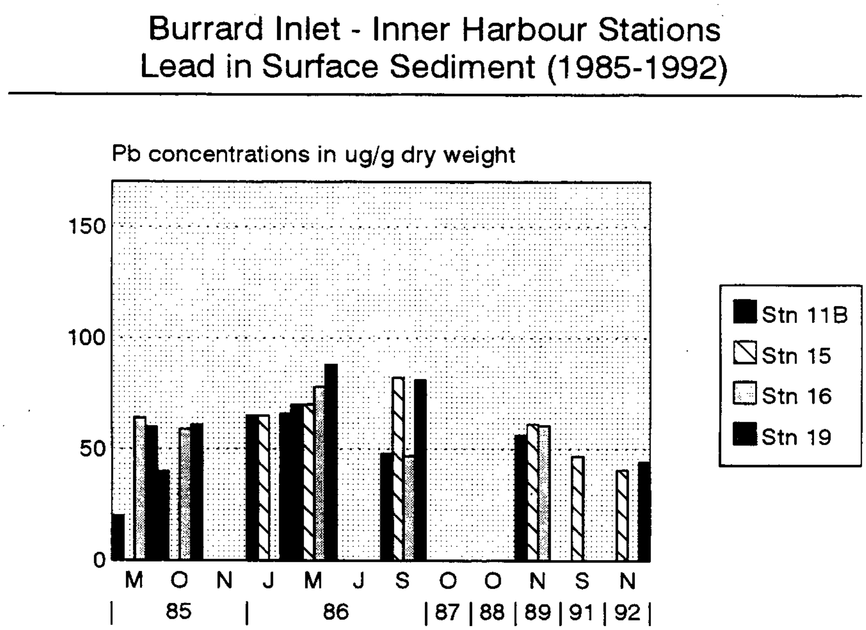
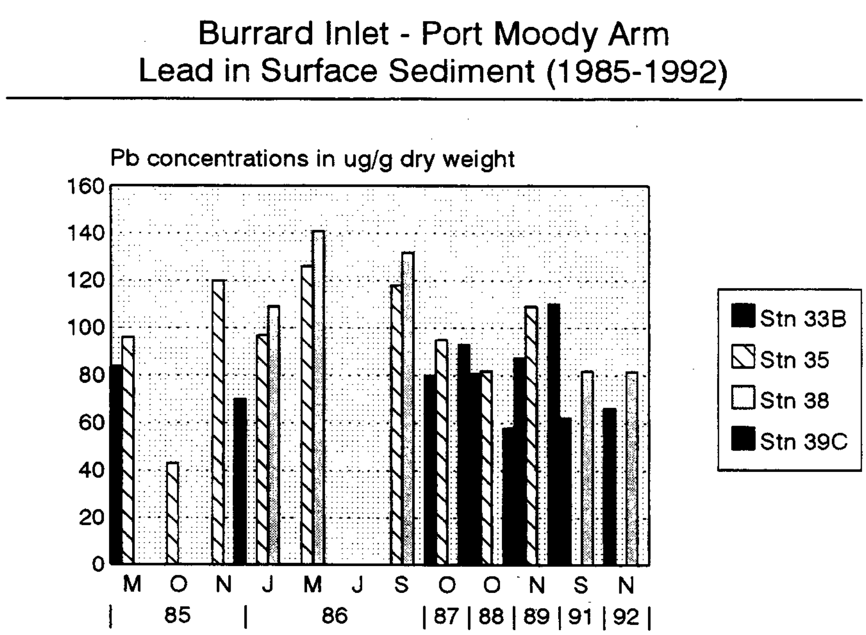


**FIGURE 5**


Burrard Inlet - Outer Harbour
Lead in Surface Sediment (1985-1992)
Pb concentrations in ug/g dry weight
150
100
50
0
May Oct Nov Jan May Jun Sep Oct Oct Nov Sep Nov
85
86
87
88
89
91
92
Stn PEI


Burrard Inlet - Inner Harbour Stations
Lead in Surface Sediment (1985-1992)
Pb concentrations in ug/g dry weight
150
100
50
0
M O N J M J S O O N S N
85
86
87
88
89
91
92
Stn 11B
Stn 15
Stn 16
Stn 19


Burrard Inlet - Port Moody Arm
Lead in Surface Sediment (1985-1992)
Pb concentrations in ug/g dry weight
160
140
120
100
80
60
40
20
0
M O N J M J S O O N S N
85
86
87
88
89
91
92
Stn 33B
Stn 35
Stn 38
Stn 39C

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# BC ENVIRONMENT OBJECTIVES MONITORING IN MARINE & ESTUARINE WATERS

*B. Kangasniemi*

## 1.0 Overview

The purpose of this presentation is to provide a summary of marine and estuarine monitoring implemented by BC Environment under the "objectives monitoring program". In addition some selected water quality trends are described.

In 1981, following a review of environmental monitoring programs, the BC Auditor General recommended that ambient monitoring results should be assessed in reference to specific environmental goals to be achieved. By 1982, a program of developing water quality objectives for fresh, marine and estuarine areas was initiated. The process involves setting objectives for specific water bodies, watersheds, basins and river reaches by considering natural background conditions, waste loadings and water uses. Objectives are set for areas which are subject to existing or potential degradation from human development and waste discharges. The objectives are expressed as numerical limits for contaminants (or indicators) to protect a water use. Water uses not only include drinking, recreation, irrigation, and industrial uses but also include the protection of all forms of aquatic life and consumers of aquatic life. Objectives for a specific contaminant are set for the most sensitive water use, thereby offering protection to all less sensitive uses. The objective is the site specific application of more general, broadly accepted criteria from other agencies such as the Canadian Water Quality Guidelines or the US EPA criteria. When applicable, criteria developed by BC Environment may be used as the basis for the objectives.

The objectives represent Ministry policy, and are used to guide decisions regarding waste management and remedial action. Following multi-agency review, the objectives are published in a series of reports, referred to as "assessment and objectives" reports. Completed reports for marine and estuarine areas are cited in Table 1.

## 2.0 Monitoring Procedures

Where objectives are in place, monitoring program design is determined by the objective. Site location, sample collection procedures, variables measured, sampling frequency, replication and other considerations are determined based on the objective. The documentation prepared to establish the objective specifies these details. In order to provide a reliable determination as to whether the objective is being attained, monitoring is generally maintained for a minimum of three years - longer in circumstances where objectives are exceeded and in high priority areas. Most sites are sampled during one period each year, the period generally being of 1 month duration and selected to represent the worst case scenario.

# Table 1. Marine and Estuarine Assessment and Objectives Reports, and Objectives Attainment Reports

## Assessment and Objectives Reports:

Arber, J.C. 1992. Water Quality Assesssment and Objectives for Sechelt Inlet (sunshine Coast Area). Executive summary 20p. Technical appendix 236 p.

Hall, R.A. 1992. Sechelt Area. Pender Harbour. Water Quality Assessment and Objectives. Executive summary 14p. Technical appendix 104 p.

Nijman, R. and L.G. Swain. 1990. Coquitlam-Pitt River Area. Burrard Inlet. Water Quality Assessment and Objectives. Executive summary 27p. Technical appendix 328 p.

Swain, L.G. and G. B. Holmes. 1985. Water Quality Assessment and Objectives. Fraser-Delta Area, Fraser River Sub-basin from Kanaka Creek to the mouth. Executive summary 16 p. Technical appendix 214 p.

Swain, L. G. and G.B. Holmes. 1991. Fraser-Delta Area. Boundary Bay and its Tributaries. Water Quality Assessment and Objectives. Executive summary 17 p. Technical appendix 168 p.

Warrington, P.D. 1993. Skeena-Nass Area. Lower Kitimat River and Kitimat Arm. Water Quality Assessment and Objectives. First update. Executive summary 25 p. Technical appendix 200p.

## Objectives Attainment Reports:

Rocchini, R.J. 1987. A check of how well water quality objectives were achieved in 1986. Resource Quality Section. 71 p.

Rocchini, R.J. 1988. The attainment of ambient water quality objectives in 1987. Water Quality Branch. 98 p.

Rocchini, R.J. 1989. The attainment of ambient water quality objectives in 1988. Water Quality Branch. 166 p.

Rocchini, R.J. 1990. The attainment of ambient water quality objectives in 1989. Water Quality Branch. 170 p.

Rocchini, R.J. 1991. The attainment of ambient water quality objectives in 1990. Water Quality Branch. 204 p.

Rocchini, R.J. 1992. The attainment of ambient water quality objectives in 1991. Water Quality Branch. 200 p.

Rocchini, R.J. 1993. Water Quality in British Columbia. Objectives Attainment in 1992. Water Quality Branch. 228 p.

In the case of water column constituents, typically 5 samples are collected during a 30 day period.

In certain circumstances, data generated by agencies other than BC Environment are incorporated into the annual objectives attainment evaluation. Other data sources are only considered if sampling protocols correspond to those specified when the objective was established.

## 3.0 Documentation of Results

Since 1986, the Water Quality Branch has produced annual summaries of objectives attainment for all areas monitored in BC (Table 1). These reports contain limited interpretation, but do report the number of times individual sites monitored met or exceeded the objectives. In addition, these reports present the monitoring results, state the objective and indicate the dates of sampling. Raw data for any site may be requested. Recently, the annual summaries have included a section on quality assurance and quality control for the constituents assessed. Sampling protocols are not presented in the annual report but are specified in the original "assessment and objectives" report specifying the objective.

Considerable opportunity for further interpretation exists using the objectives monitoring data. In situations where monitoring has been sustained for 3 or more years, trends or tendencies can be inferred. Although 5 samples collected over a 30 day period collected annually can be considered minimal, more reliable conclusions can be drawn when several years of results are viewed.

An attempt was made for this workshop to select some representative data from the summary reports for marine and estuarine areas to determine trends.

## 4.0 Study Areas and Trends

As indicated in Figure 1, six marine/estuarine areas have been subject to objectives monitoring, these include: Fraser River Estuary, Boundary Bay, Burrard Inlet, Pender Harbour, Kitimat Harbour and Arm Sechelt Inlet For the purposes of this presentation, only the first three are discussed further.

### 4.1 Fraser River Estuary

Numerous agencies monitor environmental quality in the Fraser River Estuary. These include BC Environment, Greater Vancouver Regional District, BC Ministry of Health and Environment Canada. Other agencies are involved in supporting and coordinating monitoring programs, such as the Fraser River Harbour Commission, the Fraser Basin Management Program, the Burrard Inlet Environmental Action Plan (BIEAP), and the Fraser River Estuary Monitoring Program (FREMP). FREMP has provided an opportunity for all these agencies to coordinate and share

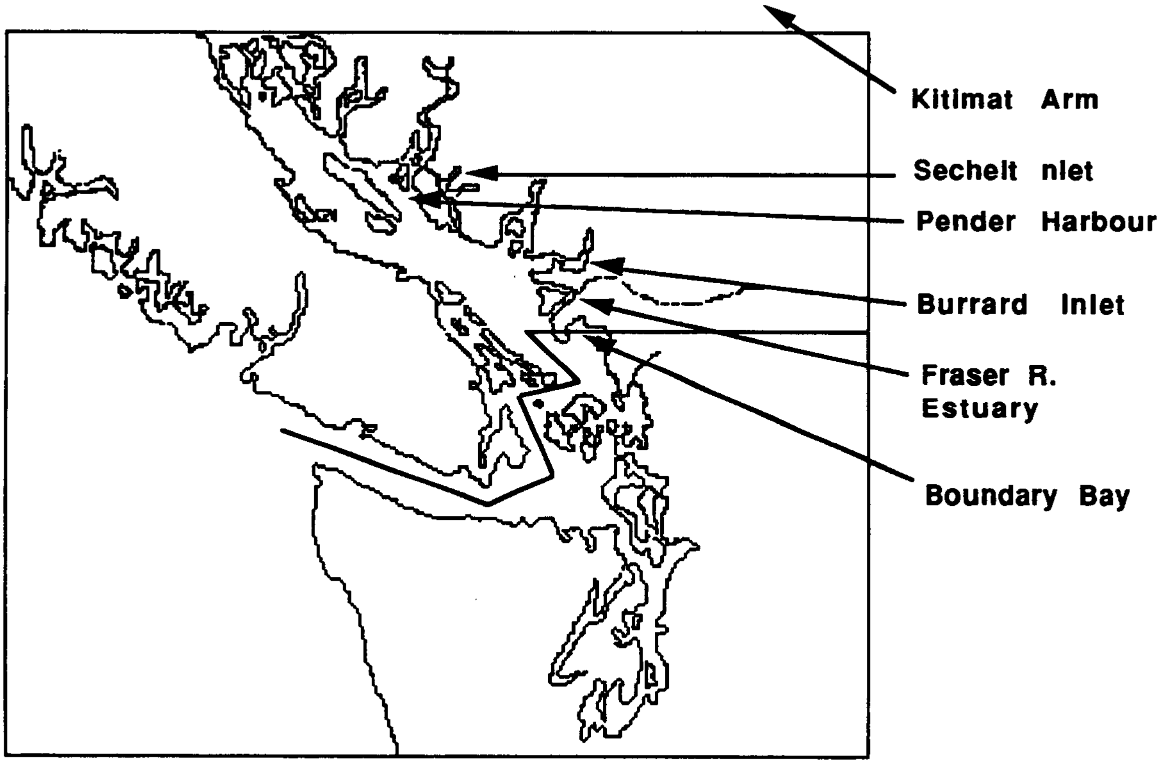



**Figure 1. Areas presently monitored for objectives attainment**

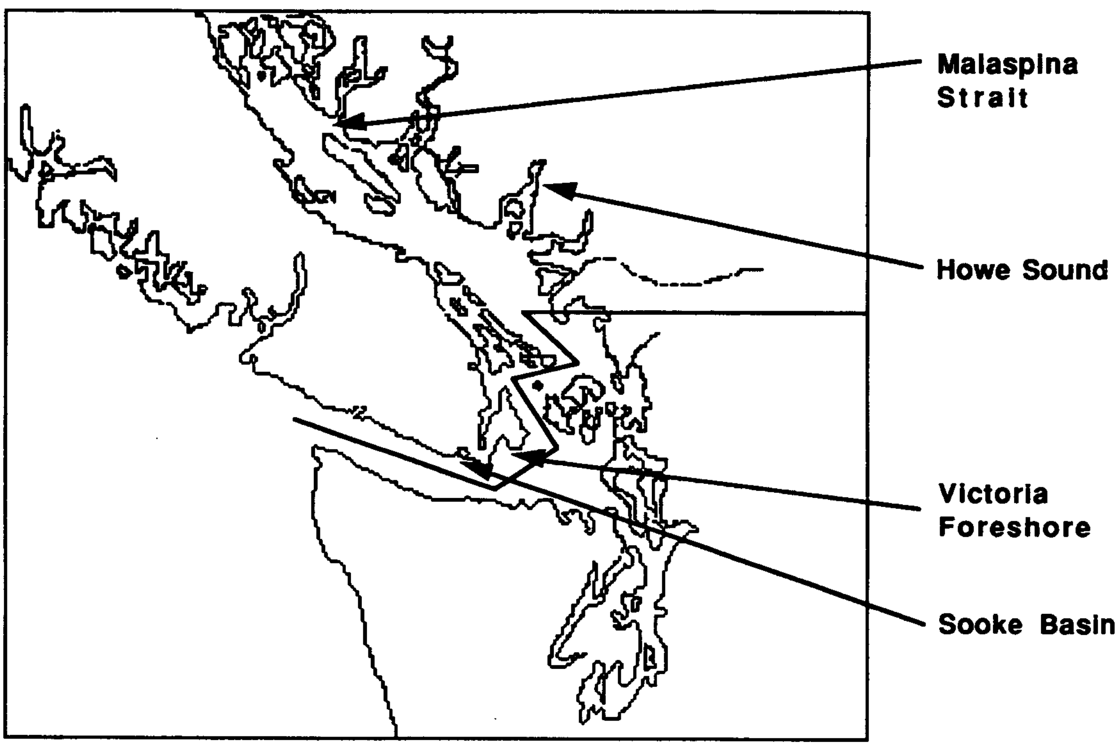



**Figure 2. Areas subject to future objectives monitoring**

the monitoring responsibilities and results. The objectives monitoring program is one of BC Environment's contributions towards monitoring in the estuary. In addition, BC Environment has also implemented monitoring of sediments and biota through an agreement with the Fraser River Harbour Commission.

Table 2 summarizes the constituents being monitored in the estuary under the objectives monitoring program at approximately 60 stations. Water, sediment and biota are monitored for 19 contaminants or indicators. Fecal coliform data from the Iona Beach sites were selected to demonstrate trends as this indicator had a relatively long data record. The 5 Iona Beach stations selected are located on the offshore side of the North Arm Jetty; all samples were collected during the summer. The objective of 200 fecal coliforms/100 mL (geometric mean) in this case is to protect primary recreational contact. Figure 3a shows this objective has not been exceeded in the six years depicted. These stations are subject to influence from 3 primary sewage treatment plants. The Annacis and Lulu plants employ chlorination, whereas the Iona plant does not. Data from the other stations located further up stream nearer the sewage treatment plants were not evaluated here.

## 4.2 Boundary Bay

Twenty-one stations in Boundary Bay are monitored regularly for 5 contaminants and indicators as indicated in Table 2. Fecal coliforms were again used, as this indicator represents the longest continuous period of record. Two beach areas in Boundary Bay were selected to depict trends, White Rock and Centennial Beach. The White Rock Stations were all clustered around the beach in Semiahmoo Bay near the International Boundary. The Centennial Beach stations are clustered near the International Boundary on the west side of Boundary Bay. Starting from 1988, five years of monitoring data collected only during the summer months are presented in Figures 2b and 2c. In this case, only the 90th percentile data are shown, however, the trends are very similar for the geometric mean results. The objective for the protection of primary contact recreation is 400 fecal coliforms/100 mL (90th percentile). For White Rock, it is apparent that the objective was exceeded by a significant margin in all years. In the case of Centennial Beach, the objective was exceeded by a significant margin in 2 of the 5 years.

There are no point source discharges in Boundary Bay, however, the chronically high coliform levels can be attributed to a number of non-point sources including contamination from agricultural activities entering from the Serpentine, Nicomekl, and Little Campbell Rivers. Land drainage pump stations located along the head of Boundary Bay have also been identified as sources.

## Table 2. Constituents Monitored

**Pender Harbour (15 stations)**

| *Water* | *Sediment* | *Tissue* |
|---|---|---|
| F. colifom | t-copper | lead-oyster |
| enterococci | t-lead | |
| turbidity | six L-PAH's | |
| ammonia | nine H-PAH's | |
| t-copper | | |
| t-iron | | |
| t-lead | | |
| t-zinc | | |
| diss zinc | | |
| TBT | | |
| D.O. | | |

**Burrard Inlet (28 stations)**

| *Water* | *Sediment* | *Tissue* |
|---|---|---|
| F. coliform | t-arsenic | lead |
| enterococci | t-chromium | mercury |
| susp. sediment | t-copper | t-chlorophenol |
| turbidity | t-lead | tt-chlorophenol |
| ammonia | t-mercury | p-chlorophenol |
| D.O. | t-nickel | PCB |
| WAD-cyanide | t-zinc | |
| pH | six-L-PAH | |
| t-arsenic | nine-H-PAH | |
| t-barium | t-chlorophenol | |
| t-cadmium | tt-chlorophenol | |
| t-iron | p-chlorophenol | |
| t-lead | | |
| t-mercury | | |
| t-nickel | | |
| t-chlorophenol | | |
| tt-chlorophenol | | |
| p-chlorphenol | | |
| TBT | | |
| ethylene dichloride | | |
| phenols | | |
| styrene | | |

## Table 2. Continued

**Fraser R. Estuary (60 stations)**

| *Water* | *Sediment* | *Tissue* |
|---|---|---|
| fecal coliform | PCB | t-chlorophenol |
| susp. sediment | t-chlorophenol | tt-chlorophenol |
| ammonia | tt-chlorophenol | p-chlorophenol |
| D.O. | p-chlorophenol | PCB |
| pH | | |
| t-copper | | |
| t-zinc | | |
| t-lead | | |
| t-chlorophenol | | |
| tt-chlorophenol | | |
| p-chlorophenol | | |

**Boundary Bay (21 stations)**

| *Water* | *Sediment* | *Tissue* |
|---|---|---|
| F. coliform | PCB | |
| susp. sediment | | |
| turbidity | | |
| D.O. | | |

**Kitimat Harbour & Arm (6 stations)**

| *Water* | *Sediment* | *Tissue* |
|---|---|---|
| F. coliform | | |
| susp sediment | | |
| turbidity | | |
| WAD cyanide | | |
| flouride | | |
| ammonia | | |
| t-aluminum | | |
| t-cadmium | | |
| t-copper | | |
| t-iron | | |
| t-lead | | |

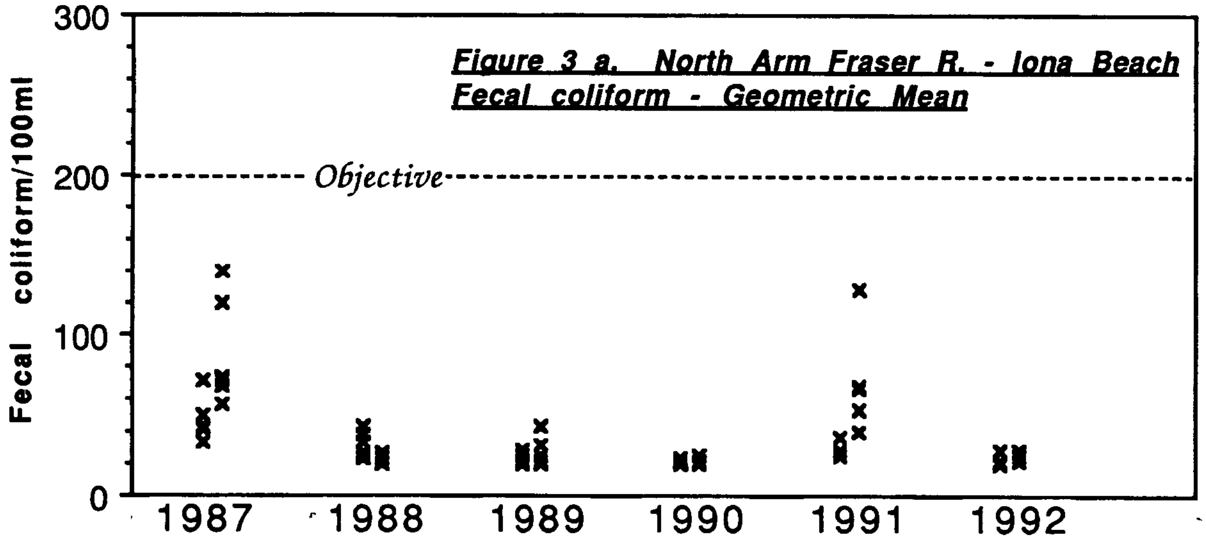


Figure 3 a. North Arm Fraser R. - Iona Beach
Fecal coliform - Geometric Mean
Objective
Fecal coliform/100ml
300
200
100
0
1987
1988
1989
1990
1991
1992

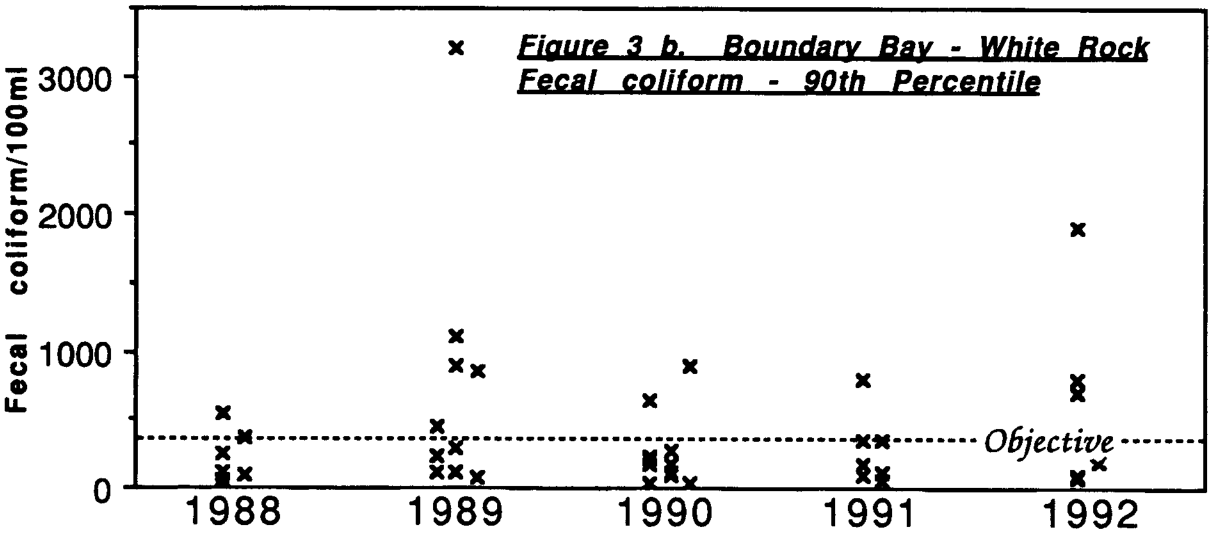


Figure 3 b. Boundary Bay - White Rock
Fecal coliform - 90th Percentile
Objective
Fecal coliform/100ml
3000
2000
1000
0
1988
1989
1990
1991
1992

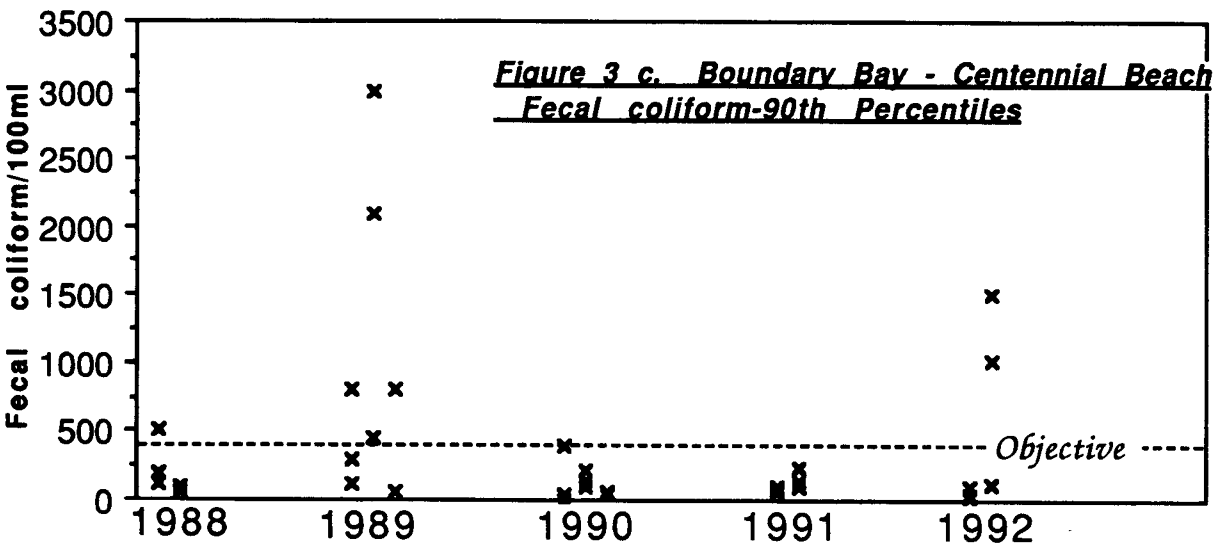


Figure 3 c. Boundary Bay - Centennial Beach
Fecal coliform-90th Percentiles
Objective
Fecal coliform/100ml
3500
3000
2500
2000
1500
1000
500
0
1988
1989
1990
1991
1992

## 4.3 Burrard Inlet

Extensive monitoring has been carried out by Environment Canada as a contribution to the BIEAP. The objectives monitoring program is one of BC Environment's contributions. As indicated in Table 2, 53 contaminants and indicators are monitored in Burrard Inlet; this monitoring occurs at 28 stations, and includes water, sediment and biota. Objectives monitoring has only been in place since 1990, therefore, trend assessment is not yet possible. Nevertheless, 2 contaminants, copper and benzo[a]pyrene(PAH), were selected to demonstrate the extent to which contamination exceeds environmental objectives in this highly industrialized water body.

For total copper in water, the objective is set at 3 $\mu g/L$ (maximum). As indicated by Figure 4a, this objective is exceeded at most stations in all of the 3 years of monitoring. The extent to which these high values may be associated with suspended particulates needs to be addressed to fully interpret the results. With respect to sediment copper, the 100 $\mu g/g$ (average) objective is exceeded for all stations for all three years. A hot spot of particular concern is the Vancouver Wharves area where the objective is exceeded by a factor of 500.

The objective for the high molecular weight PAH benzo[a]pyrene in sediment is 0.16 $\mu g/g$. Again, the objective is exceeded at most sites for both years sampled.

## 5.0 Future of Program

Objectives monitoring has recently started in Sechelt Inlet and Pender Harbour. Development of objectives are pending for Howe Sound, Malaspina Strait and Sooke Basin; work on setting objectives for the Victoria Foreshore may start soon. (Figure 2).

Given declining resources for water quality monitoring, it is becoming increasingly critical that all levels of government improve coordination of monitoring initiatives, and that programs operate through multi-agency agreements when possible. Given the environmental issues in BC and Washington State are very similar, such coordination should extend to the agencies monitoring in the Puget Sound.

It is particularly important that the maximum interpretive value be gained from monitoring programs. This can be achieved through use of consistent sampling/analytical protocols to ensure data can be shared and transferred with confidence. Experience has shown that process of setting objectives prior to the initiation of monitoring, as recommended by the Auditor General, ensures that monitoring will lead to results which are directly relevant to resource management and environmental protection issues.

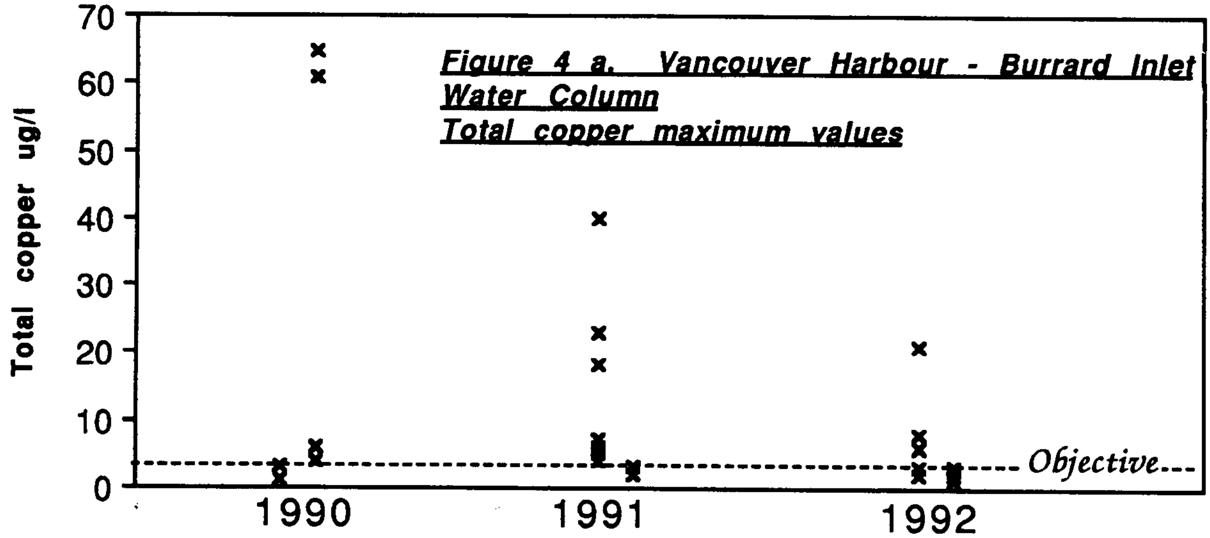


Figure 4 a. Vancouver Harbour - Burrard Inlet
Water Column
Total copper maximum values
Total copper ug/l
70
60
50
40
30
20
10
0
Objective
1990
1991
1992

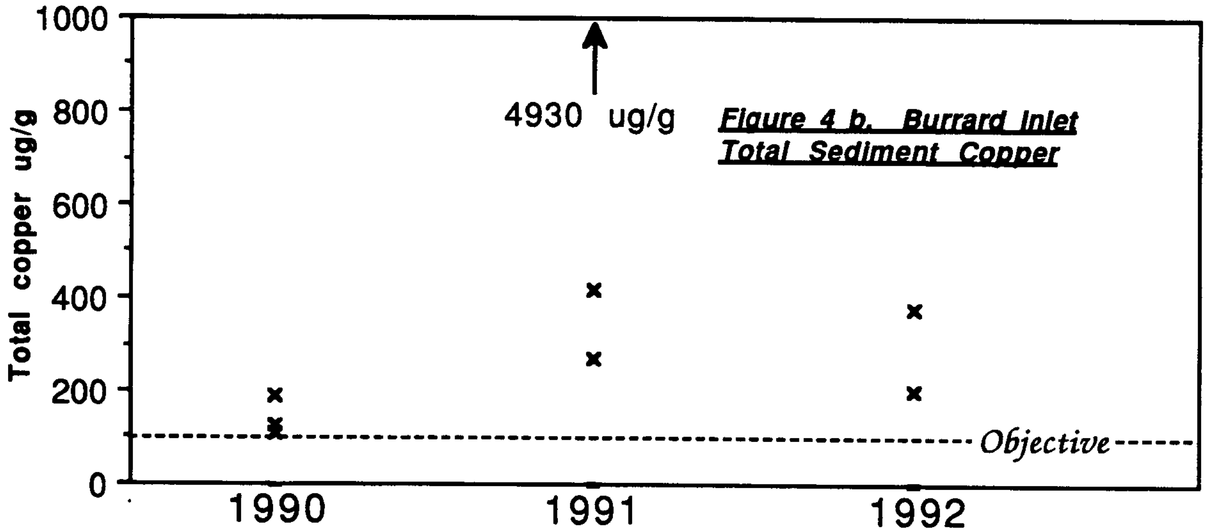


Figure 4 b. Burrard Inlet
Total Sediment Copper
Total copper ug/g
1000
800
600
400
200
0
4930 ug/g
Objective
1990
1991
1992

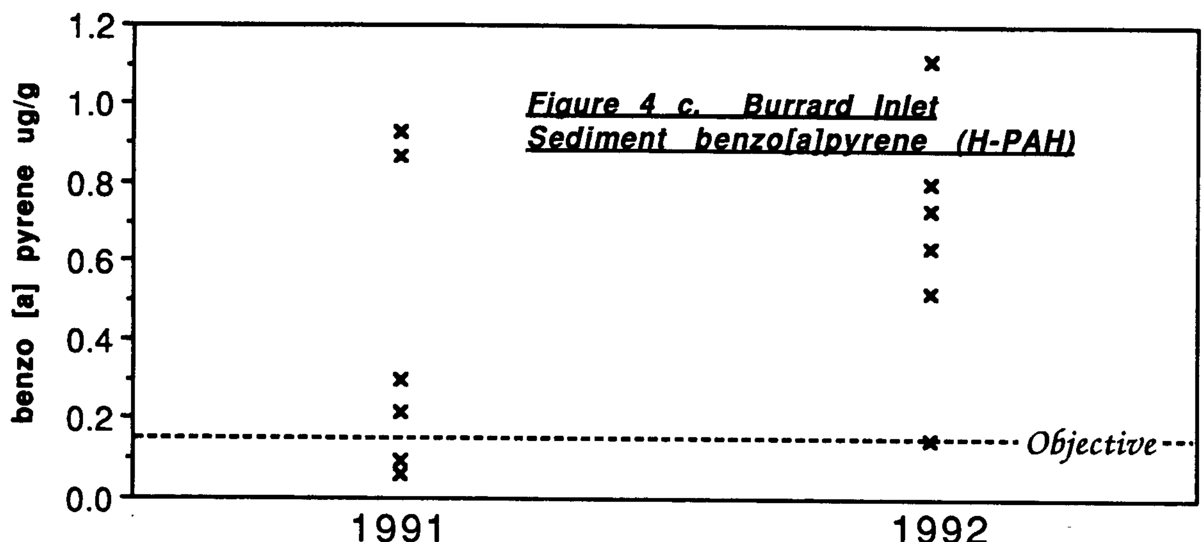


Figure 4 c. Burrard Inlet
Sediment benzo[a]pyrene (H-PAH)
benzo [a] pyrene ug/g
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Objective
1991
1992

## ANTHROPOGENIC ORGANIC COMPOUNDS IN SEDIMENTS

*W. J. Cretney and R. W. Macdonald*

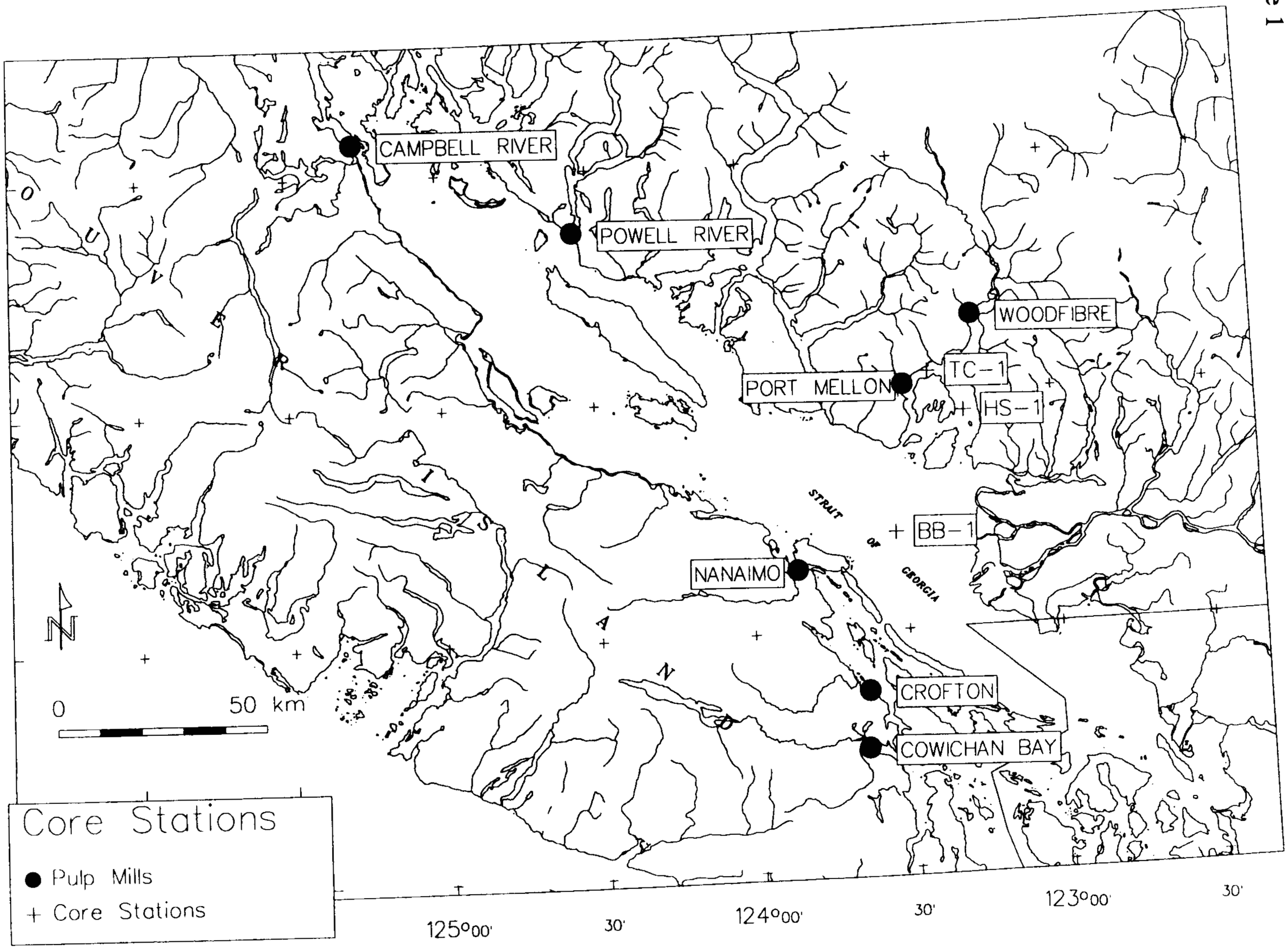
Our approach to determining time trends of anthropogenic organics in sediments has been to do what might be considered as retrospective monitoring using sediment cores. The cores are sectioned from top to bottom and the age of deposition of each sections is estimated using the half-life of natural Pb-210 or the profile of bomb Cs-137 or both. Once sections are dated, the deposition history of anthropogenic chemicals can be readily determined provided that the sedimentary deposition has been well behaved, i.e., uninterrupted by submarine slides, for example, that the chemicals of concern remain fixed once in the sediment and that the effect of bioturbation can be satisfactorily modelled. For the Strait of Georgia ecodistrict in the Pacific Marine Ecozone, we have recently published the results for two cores obtained in Howe Sound and one in Ballenas Basin (Macdonald *et al.*, 1992; Cretney *et al.*, 1992). Three anthropogenic compounds were the focus of the study: 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8,-TCDF), octachlorodibenzo-p-dioxin (OCDD), and 3,3',4,4'-tetrachlorobiphenyl (PCB 77). The fluxes of the three focal compounds were compared (Fig. 2) for two of the cores, one from Ballenas Basin in the Strait of Georgia and the other from the main channel of Howe Sound, north of Bowyer Island. Each of these cores showed little or no bioturbation.

The historical fluxes of OCDD in both cores were identical within experimental error indicating non-local sources. Estimation of source contributions indicated that automobiles were a minor source. The most probable sources identified were industrial and municipal combustion in the greater Vancouver area, which is about the same distance from both core locations, and runoff (contribution between 4 and 40 %) from lumber treated with chlorophenols (Macdonald *et al.*, 1992; Krahn *et al*, 1987).

The flux profiles for 2,3,7,8-TCDF are very similar in the two sites, except for a spike corresponding to the early 1980's. Loading estimates of the total 2,3,7,8-TCDF in effluents from the six mills around the Strait of Georgia suggest that the mills could account for the flux of the compound without considering other sources (Macdonald *et al.*, 1992). The general similarity of flux at the two sites could be a chance result of basin wide water transport and similar distances from contributing mills. The reason for the apparent spike in the Howe Sound core is unknown, but (assuming it is not an analytical artifact) it may be related to operational problems at one or the other mills in the sound in the early 1980's, although we have no knowledge of any such problems. Analysis of additional cores in the strait should shed more light on these subjects.

The flux profiles of PCB 77 in both cores are similar to the flux profiles for OCDD in showing an increase up until the late 1960's or early 1970's. The Ballenas Basin core shows a decrease from that time to 1990 in both OCDD and PCB 77 fluxes in keeping with results seen elsewhere on the continent. The profile of PCB 77 reflects the beginning of production and use of PCBs

Figure 1


CAMPBELL RIVER
POWELL RIVER
WOODFIBRE
TC-1
PORT MELLON
HS-1
BB-1
STRAIT OF GEORGIA
NANAIMO
CROFTON
COWICHAN BAY
V A N C O U V E R I S L A N D
50°00'
30'
49°00'
125°00'
30'
124°00'
30'
123°00'
30'
N
0
50 km
Core Stations
Pulp Mills
Core Stations

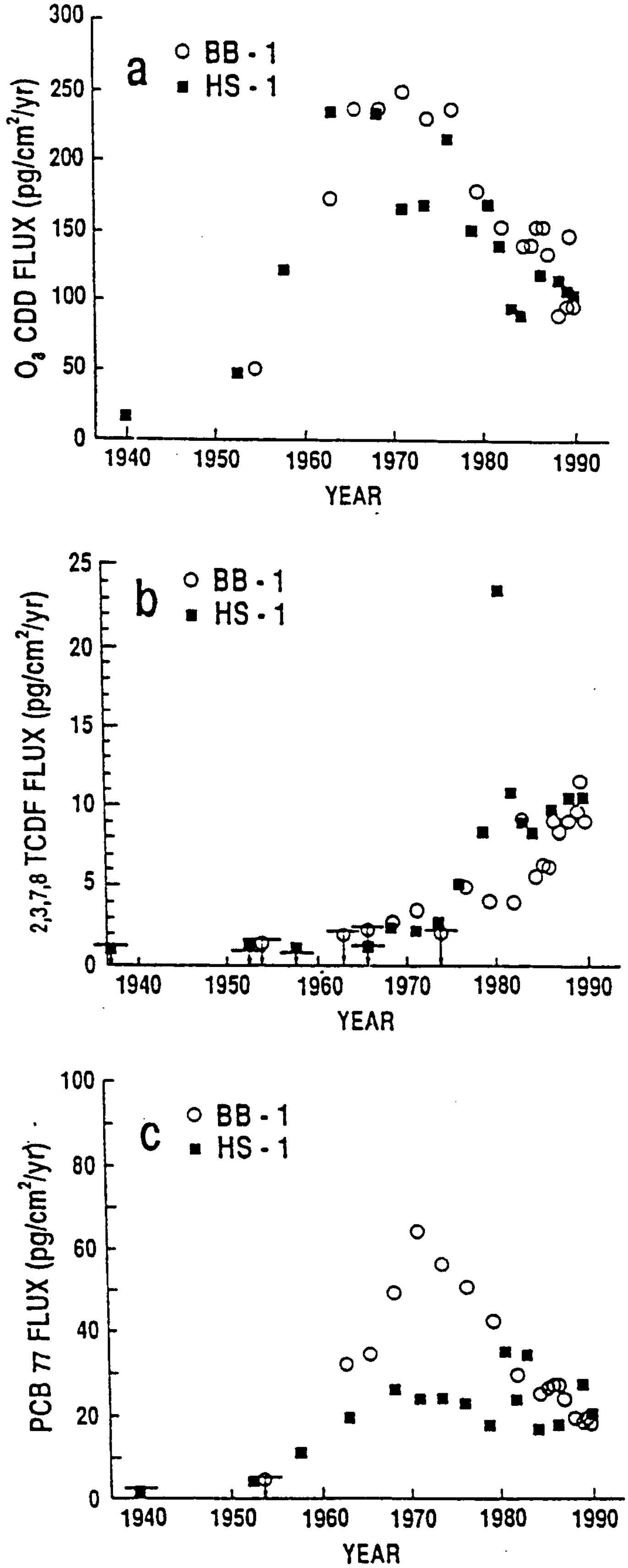



Figure 2. Comparison of fluxes in cores BB-1 and HS-1 of (a) OCDD, (b) 2,3,7,8-TCDF, and (c) PCB 77.

in the late 1930's and the curtailment of their use in the early 1970's. The OCDD profile in the Howe Sound core is in general agreement with that of the Ballenas Basin core, but with more scatter that may be related to the greater scatter in the porosity and C/N ratio with depth in this core (Macdonald *et al.*, 1992). The PCB 77 in this core shows no clear drop off with time to 1990. Again, the analysis of additional cores may elucidate the differences.

The profiles in the core from Thornbrough Channel in Howe sound are not directly comparable with those from the other sites, because the core has been biologically mixed to a depth of about 9 cm (Macdonald *et al.*, 1992). This mixing results in an intrinsic time resolution for this core of about 14 years compared to $<3$ years for the other two cores. Consequently, the mixing of sediments of different ages makes the kind of plot in Figure 2 imprecise and potentially very misleading.

Using the profiles in two unbioturbed cores to produce a source function for the Thornbrough Channel core, a numerical box model was employed to generate theoretical curves for comparison with the observed profiles affected by bioturbation (Macdonald *et al.*, 1992). As an additional test of the model, the concentration profile of mercury for the core was used. The source of the mercury was the FMC chloralkali plant at the head of the sound which began production in 1965. Contamination by mercury was discovered and corrected by 1970 so that the input is known to have been constrained to short period between the years 1965 and 1970. Thus, there is virtually no uncertainty in the source function, and how well the model predicts the actual profile tests depends on how accurately it models the actual burial and biological mixing processes.

The theoretical profile of mercury in the Thornbrough channel core is given in 5 year intervals in Figure 3a. The theoretical curve fits the data for the core obtained in 1990 gratifyingly well; so too do the curves for OCDD (Fig. 3b) and PCB 77 and Pb-210 (not shown). The theoretical profile for 1990 (Fig. 4) for 2,3,7,8-TCDF also fits the data well.

2,3,7,8-TCDF, however, presents an unusual test of the model. We know that the mill at Port Mellon changed from chlorine to chlorine dioxide/ chlorine (1:1) in the bleaching process in July of 1989, reducing by 99% the amount of chlorinated furan in the effluent. In Figure 4, the theoretical profiles at five year intervals are generated with the input of 2,3,7,8-TCDF "turned off" in 1989. The profile is also presented for 1989 as it would have been expected to appear before chlorine dioxide substitution commenced. An almost identical profile showing an increase to the surface would also have been expected for 1990 had the change in process not taken place. The model clearly fits the actual data better when the TCDF input is turned off. With some confidence, then, it is possible to run the model ahead in time to predict future profiles at this site. In Figure 4. are presented profiles from the model which has been run to the year 2005. The drop in surface concentration agrees well with the half-life of about 10 years determined for this core using a two-layer, advection-diffusion, analytical mixing model (Macdonald *et al.*, 1992).

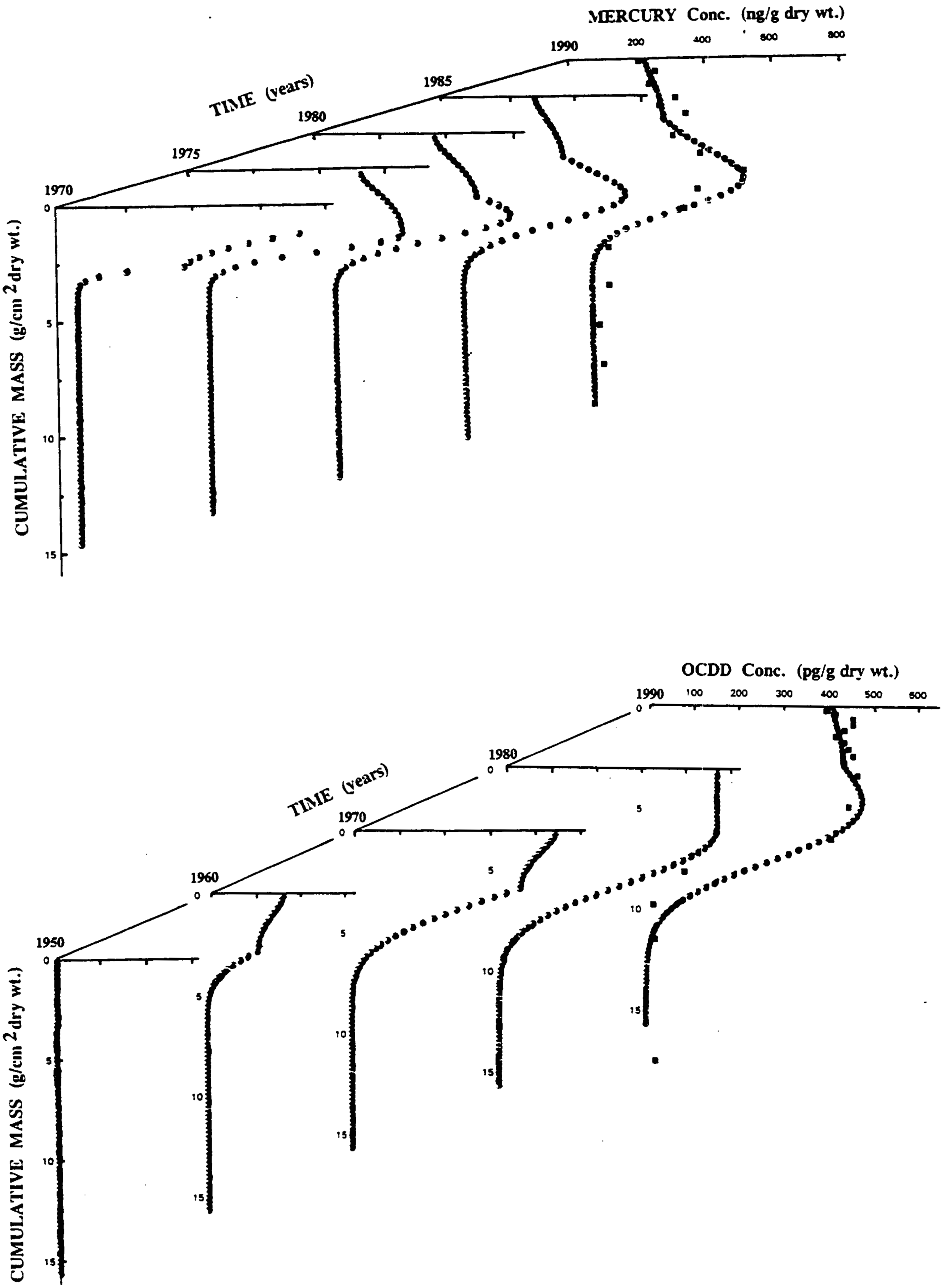



Figure 3. Theoretical concentration profiles generated at 5-year intervals for site of core TC-1 using the numerical box model and comparison with data (1990); (a) mercury profiles and (b) OCDD profiles.

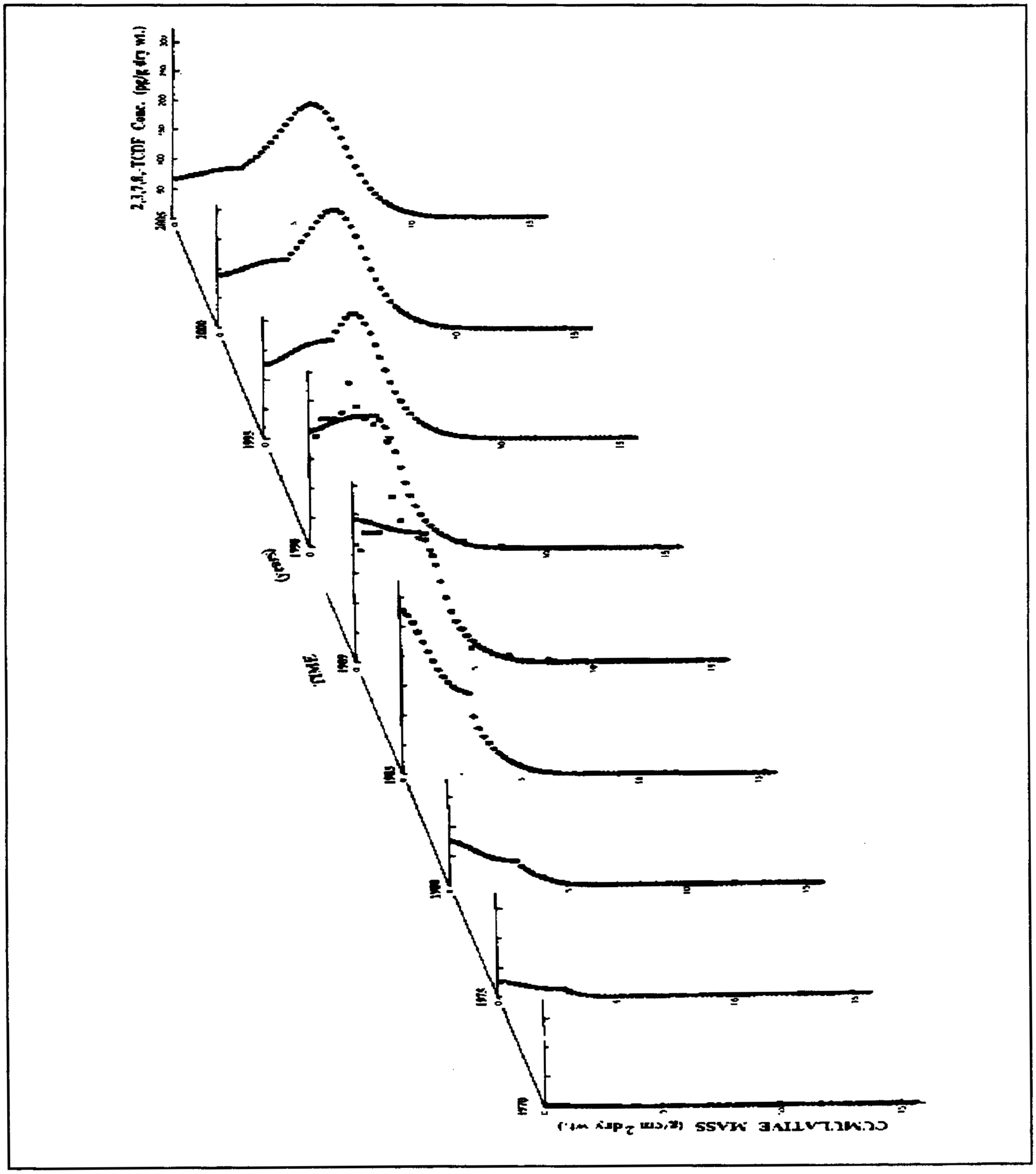


Figure 4 Theoretical concentration profiles of 2,3,7,8-TCDF for site of core TC-1 from 1970 to 2005. The data for the core, which was obtained in 1990, is also plotted on the theoretical profile for 1989 for comparison purposes.

In many respects sediment cores represent a superior way of determining time trends in sedimentary contaminants over multiyear analyses of surface sediments. Cores are not troubled absolute concentration due to bioturbation, marine slides, dumping or dredging activities can be readily identified.

Cores taken at intervals in time at the same site can establish the degree to which chemicals can be diagenetically mobilized in sediments. Chemicals that are fixed appear at the same time horizon with no vertical dispersion. Chemicals that are diagenetically mobilizable show degrees of dispersion related to their solubility in interstitial water and may move between time horizons. Further, cores collected sequentially in time can be used to test models that encompass deposition, bioturbation and diagenetic mobilization.

There is special value in knowing where in a sedimentary field the sites of bioturbation are. Particularly at these sites can strongly sediment-associated anthropogenic organic compounds be remobilized into the food web. Other sites are of less concern because they may be devoid of macroorganisms and the contaminants will become buried more quickly in the absence of bioturbation.

When the concentrations of contaminants in surface sediments are compared after the passage of a period of time, it is critical to know what marine events may have occurred to disturb the regular accumulation of sediment before meaningful comparisons can be made. Even monitoring organisms for contaminants that come directly or indirectly from sediments may be dependent for success on the orderly accumulation over time of the target contaminants in sediments.

A convincing case has been made, we hope, for carefully considering the inclusion of core sampling in receiving environment monitoring programs. Indeed, with respect to the Strait of Georgia an extensive core sampling project is planned to begin in the 1994/95 FY led by one of us (RWM) and funded through the Toxic Chemicals Green Plan to assess the historical inputs of contaminants into the strait. Also, in the Fall of 1993 cores were collected at the Point Grey dumpsite and are presently being analyzed as part of a joint study by the Ocean Chemistry Division (RWM), IOS, Department of Oceanography (Tom Pedersen) and Environmental Conservation Division (Dwayne Brothers and Dixie Sullivan), EPS. These studies should nicely complement ongoing and future ecosystem studies of the strait.

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List of Figures

# ANTHROPOGENIC AND PETROGENIC HYDROCARBONS IN SEDIMENTS

*L.R. Snowdon*

## ABSTRACT

Petroleum hydrocarbon contamination of sediments may result from catastrophic spills, from long term, low level leakage or dumping or from natural (geological) inputs. Biological hydrocarbons comprise a group of chemical compounds that are also incorporated into sediments through natural processes. The total quantity of hydrocarbons in recent sediments from the west coast and Arctic offshore of Canada typically falls into the range of a few to about 80 ppm (dry weight) and this concentration can be estimated by a number of different analytical techniques. However, in order to determine whether hydrocarbons are petrogenic or biogenic, it is necessary to carry out more detailed chemical analyses usually involving gas chromatography coupled with mass spectrometry. Using GC-MS it is possible to identify terpenoid and steroid hydrocarbons and to determine if they are modern biological materials or geological products.

The unequivocal identification of an anthropogenic contribution of naturally occurring materials is usually problematical. Maximum certainty may only be achieved when background, or baseline data are available and a presumed anthropogenic contaminant has a chemical character or fingerprint that is markedly different from that of the indigenous material. The historical record of hydrocarbon contamination (whether natural or anthropogenic) at any given location is preserved in the sedimentary record. That is, sediment core samples provide a method of determining the range of compounds preserved at a location for varying time periods. The time represented depends on sedimentation rate and the depth from which the core sample is recovered. While sediment samples may limit the time scale resolution because of low sedimentation rates, poor absolute controls or mixing of sediments, they convey the advantage of representing an integrated final outcome of deposition followed by mechanical and biological reworking.

## TRENDS IN CONTAMINANTS IN MARINE MAMMALS

*T. G. Smith*

## ABSTRACT

We have recently begun to document organochloride, dioxin and furan contaminant levels in harbour seals, *Phoca vitulina*, along the coast of British Columbia. Harbour seals tend to remain in the same area throughout their life. Since they are widely distributed along the B.C. coast but are relatively sedentary they are a good species for monitoring local contaminant levels. They are long lived, have high fat reserves in which the lipophilic contaminants accumulated and are catholic feeders. Details of their foraging behaviour and prey utilization are known and can be studied in detail.

Killer whales resident in various parts of B.C. are also available for studies on contaminants. Recently developed biopsy sampling methods permit us to obtain samples from selected animals. The long-lived killer whales, some animals are known to be 70+ years, could potentially reflect the accumulated contaminant burdens from the beginning of marine industrial contamination in B.C.. Whales are known to metabolise organochlorines more slowly than seals; they are, however, wider ranging and do not expose themselves to local sources of contaminants for as long periods of time as do the seals. Resident killer whales which feed primarily on salmon are expected to show lower contaminant levels than the transient killers which feed on seals.

Examples from a long-term arctic seal program will be used to illustrate the value of mammals in monitoring ecosystem contaminant levels.

## TRENDS IN CONTAMINANTS IN FISH

## ABSTRACT

*R. F. Addison*

A survey of the "open" and "grey" literature abstracted by Aquatic Science and Fisheries Abstracts (ASFA) and by WAVES shows that no contaminant trend data have been published for marine fish in the north-east Pacific region. Some analyses of Fraser River salmon contaminant concentrations (so far unpublished) will be presented; these show an apparent decline in some chlorinated dibenzo-dioxin and furan concentrations over an interval of about four years, in apparent response to regulations controlling pulp mill effluent composition.

To identify spatial and\or temporal trends in contaminant concentrations in marine fish, DFO has undertaken a benthic flatfish monitoring program in its marine regions. This program will use benthic flatfish as monitoring organisms; although there are no species of marine benthic flatfish which occur ubiquitously in Canada, it is hoped that the similarity of ecological niches occupied by different species will allow some inter-regional comparison. (Spatial and temporal trends within regions should be detectable, in any case.) Sampling will be undertaken to control age and size, sex, and reproductive status. Contaminants (persistent organochlorines, polynuclear aromatic hydrocarbons and metals) will be analyzed in livers pooled according to size and sex; analyses will be undertaken by the same lab. to minimize procedural differences.

The first suite of samples has already been taken (fall 1993) and submitted for analysis; results should be available in early Spring 1994.

This program is supported by the DFO "Toxic Chemicals" component of the Green Plan.

## TRENDS IN ORGANOCHLORINE CONTAMINATION IN SEABIRD EGGS

*J. E. Elliott, D.G. Noble, R.J. Norstrom and P. Whitehead*

### ABSTRACT

Eggs were collected from seven seabird species at colonies on the British Columbia coast from 1983 to 1991 and analyzed for organochlorine contaminants. Total PCB levels (wet weight) were highest in double-crested cormorants (*Phalacrocorax auritus*) from the Fraser estuary (2.91 mg $kg^{-1}$) and the Strait of Georgia (3.79 mg $kg^{-1}$). Highest DDE levels were in fork-tailed storm-petrels (*Oceanodroma furcata*) from the Queen Charlotte Islands (1.68 mg $kg^{-1}$). Organochlorine levels were generally lower in eggs from the early 1990's than in those collected in the early 1970's. Organochlorine levels in Pacific alcids and hydrobatids foraging in offshore locations were compared to those in the same or ecologically similar species from the Canadian Atlantic coast. DDT- and HCH-related compounds were higher in Pacific populations while levels of dieldrin, oxychlordane, and HCB were generally lower. With the exception of $\beta$-HCH, levels of all measured organochlorines were lower in cormorants breeding in the Fraser River estuary than in cormorants from the St. Lawrence River estuary on the Atlantic coast.

Based on statistical comparison with other marine monitoring species (fish, seals), the seabird egg is shown to be an efficient, conservative tool for monitoring organochlorine levels.

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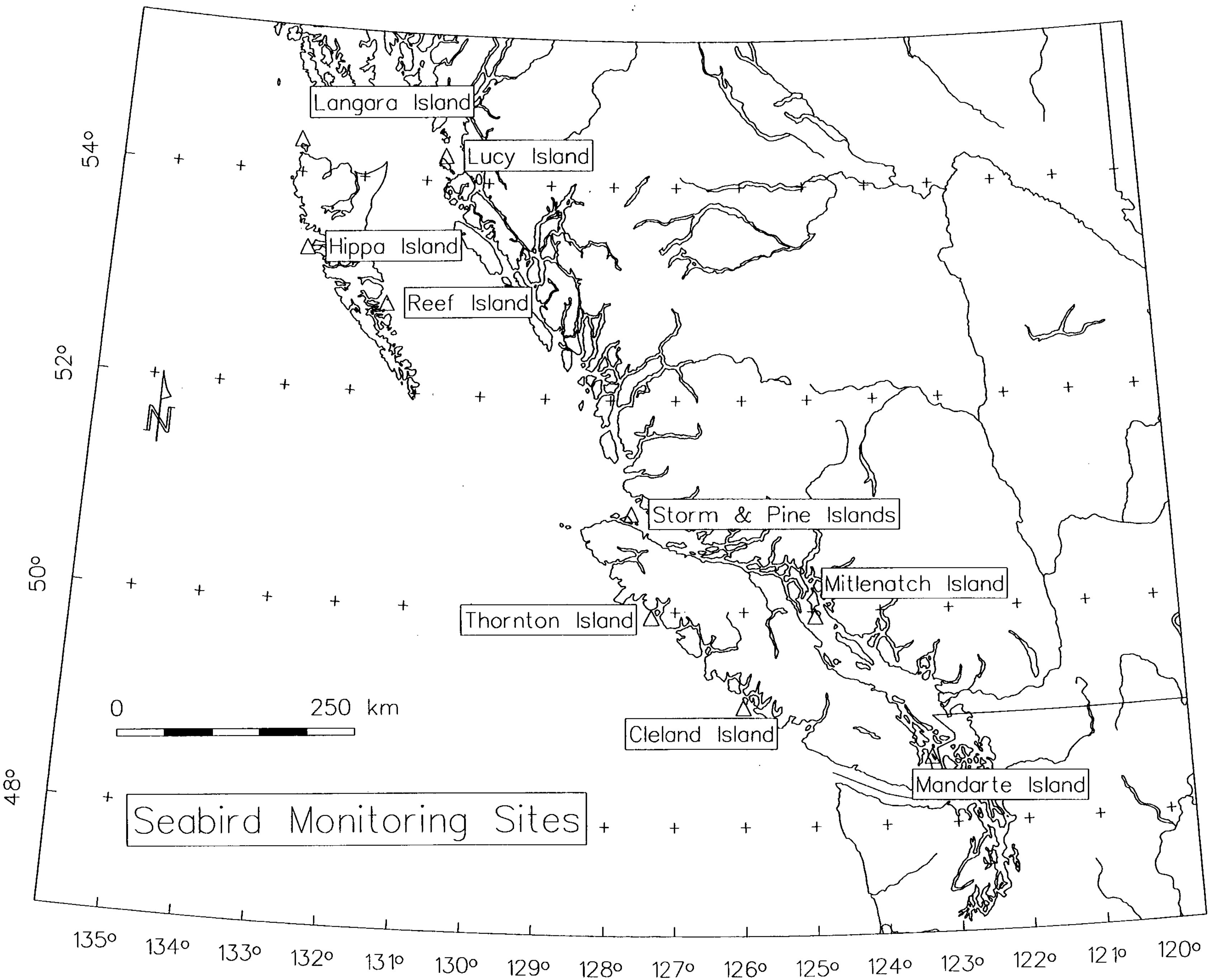
Langara Island
Lucy Island
Hippa Island
Reef Island
Storm & Pine Islands
Mitlenatch Island
Thornton Island
Cleland Island
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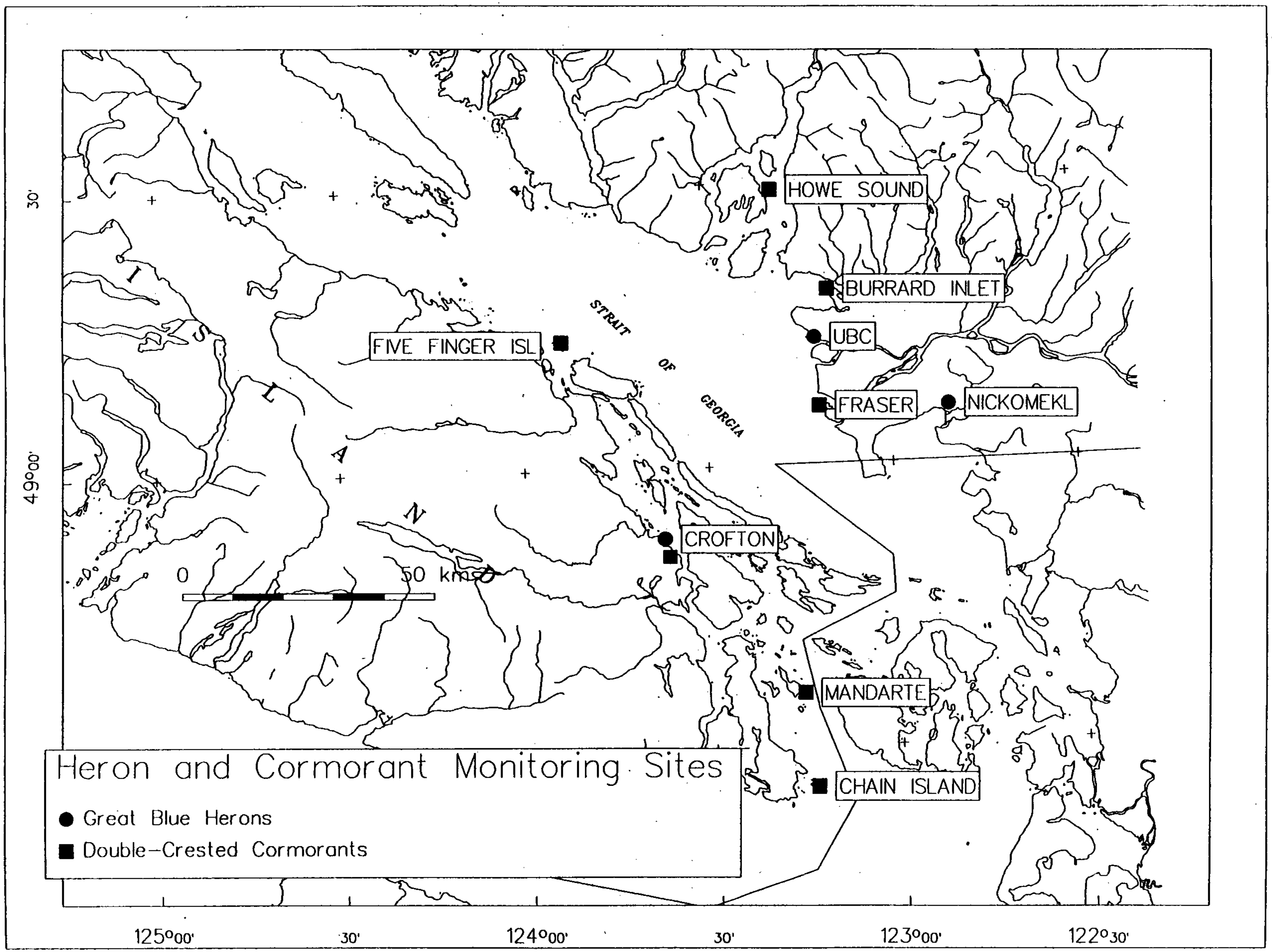
Seabird Monitoring Sites

## TRENDS IN ORGANOCHLORINE RESIDUES IN THE EGGS OF HERONS AND CORMORANTS RESIDENT IN THE STRAIT OF GEORGIA

*P. E. Whitehead, J. Elliott and R. Norstrom*

### ABSTRACT

In 1977, the Canadian Wildlife Service first surveyed organochlorine contamination in the eggs of Great Blue Herons nesting in the Strait of Georgia. While the concentrations of some organochlorine residues (PCB, DDE, dieldrin and heptachlor epoxide) were elevated, they were not considered to be toxicologically significant. In 1983 elevated levels of several 1378-substituted polychlorinated dibenzodioxins (PCDDs) and dibenzofurans (PCDFs) were discovered in eggs collected from herons foraging in the Fraser River estuary and lower reaches of the river. Concentrations of some congeners were high enough to be embryotoxic in a sensitive species. Studies were begun to determine: 1) the source(s) of the PCDDs and PCDFs; 2) the extent and severity of the contamination in fish-eating birds in the strait; and 3) whether or not the birds were being impacted. From 1983 through to 1987 elevated levels of 2378-TCDD, 12378-PnCDD and 123678-HxCDD were measured in all eggs collected from every heron colony sampled in the strait where the birds forage in the marine environment. Particularly high levels were found in a colony near the pulp mill at Crofton. In the fall of 1987 information was released that showed kraft pulp mills were a major source of those contaminants. Annual egg collections from cormorant colonies around the strait were begun in 1987 to provide information on PCDD contamination in areas where there were no heron colonies. All the eggs collected from every colony were contaminated with PCDDs. In 1988, the mechanisms for formation of PCDDs and PCDFs in the kraft process were identified, and mills around the strait began to introduce changes to reduce levels in their effluent. Soon after, PCDD concentrations began to fall in the eggs of herons and cormorants, and by 1992 were about 10% of peak levels. From 1977 to the late 1980's the levels of several organochlorine residues in heron eggs fell significantly. Since the late 1980's however, there has been little change in concentrations.



Heron and Cormorant Monitoring Sites
Great Blue Herons
Double-Crested Cormorants
HOWE SOUND
BURRARD INLET
UBC
FIVE FINGER ISL
STRAIT OF GEORGIA
FRASER
NICKOMEKL
CROFTON
MANDARTE
CHAIN ISLAND
I S L A N D
0
50 km
30'
49°00'
125°00'
30'
124°00'
30'
123°00'
122°30'


Fig. 2

## GREAT LAKES CONTAMINANTS SURVEILLANCE PROGRAM (DESIGN AND FUNCTION)

*D. M. Whittle*

In 1977 a binational program to monitor temporal and spatial trends in contaminant burdens in Great Lakes fish was initiated between Canada and the U.S.. The Department of Fisheries and Oceans and the Province of Ontario together with the U.S. Fish & Wildlife Service and EPA carry out annual surveys to assess trends in contaminant burdens measured in individual representative top predator fish species and their primary diet items as a measure of success of remedial legislation. Some of the program's additional objectives included a description of environmental quality, provision of an early warning system for assessing the significance of recently identified contaminants, determination of potential harm to fish stocks and identification of transboundary contamination. The following principles have been used in the continued implementation of this program to monitor contaminant trends in a complex and highly variable ecosystem.

Figure 1 describes the typical components of a Great Lakes foodweb used to monitor contaminant trends and dynamics. In order to adequately design an effective contaminants monitoring program the functional attributes of the system must be understood. In addition, the choice of parameters to be monitored must be consistent with the specific ecosystem to be evaluated. This list of contaminants must incorporate a knowledge of potential point sources, recognition of the magnitude and influence of remote sources and the understanding of the background concentrations. Finally a knowledge of what type and form of contaminants are bioaccumulated in biological samples must be included in the process of selecting an appropriate suite of monitoring parameters for biological matrices.

The objective of the Great Lakes contaminants monitoring program was to detect changes in environmental levels and hence all analyses were completed on whole animal samples. This type of sample provides analytical data which identify the highest possible concentration of many contaminants, particularly lipophilic organic compounds, that can be accumulated in fish. Detoxifying organs, such as liver and kidney, may also be candidates for the determination of maximum levels of accumulation for specific contaminants. Other programs, such as those designed to track human health concerns, routinely utilize data from the analyses of edible portion (muscle tissue) samples which have contaminant concentrations from 50 to 70% lower than whole animal levels. In order to track temporal trends of contaminants, data from a consistent sample must be compared over the timeframe of the study. For fish, the duration of exposure is the most important factor in controlling contaminant accumulation at any single site. Therefore, the analysis of data from a single or limited age class range is essential to produce valid temporal trend assessment of contaminant levels in fish. Due to possible changes in growth rate over time, size is not a reliable alternate to age as a variable to ensure consistent sample comparisons.

# GREAT LAKES FOOD CHAIN

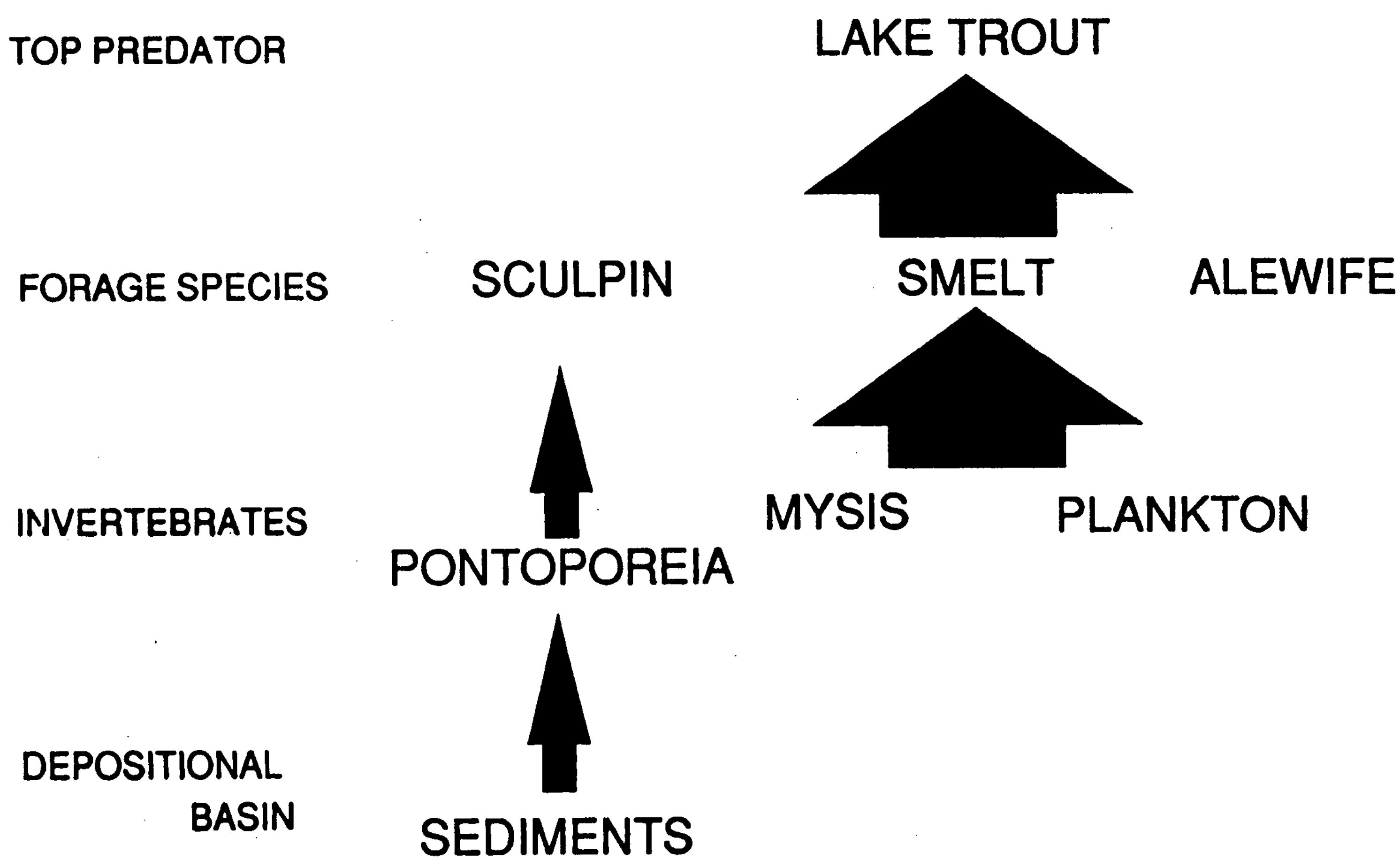



Figure 1.

Other variables that may influence contaminant accumulation and are incorporated in many monitoring programs are lipid concentrations, sex and season of collection. By ensuring that all collections are carried out prior to annual spawning activities, the importance of the remaining factors in a whole animal monitoring program are minimized. Important ancillary data to be incorporated in any sampling program should include an estimate of diet composition and average duration and extend of the species range. In any contaminants monitoring program the value of determining the biological significance of contaminant levels measured is an important element in attempting to relate the responses of fish communities to changes in contaminant concentrations. Certain contaminant related bioindicators are amenable to routine monitoring programs. These include indices of morphological anomalies, tumors, neoplasms or papillomas, functioning of enzyme systems and routine measurements of blood chemistry. All factors influencing these biological indicators must be understood and compensated for in the sampling design before they are incorporated in a routine environmental quality monitoring program encompassing contaminant measurements in fish communities.

Thus, the design of a comprehensive contaminant monitoring program to define environmental quality should start with an understanding of the dynamics of the system under study. The specific objective of the program should dictate the type and frequency of the parameters to be monitored. The objectives should also help define the type of sample to be analyzed. Appropriate ancillary data should be collected and incorporated into the analysis of both temporal and spatial trends. Finally a supportive biological effects monitoring program would be valuable in assessing the significance of any changes in community contaminant burdens.

## SESSION 2 - PATHOGENS, TOXINS AND DISEASE PREVALENCE

## SPATIAL & TEMPORAL PATTERNS IN HEPATIC LESIONS IN ADULT ENGLISH SOLE FROM VANCOUVER HARBOUR - 1986 TO 1992.

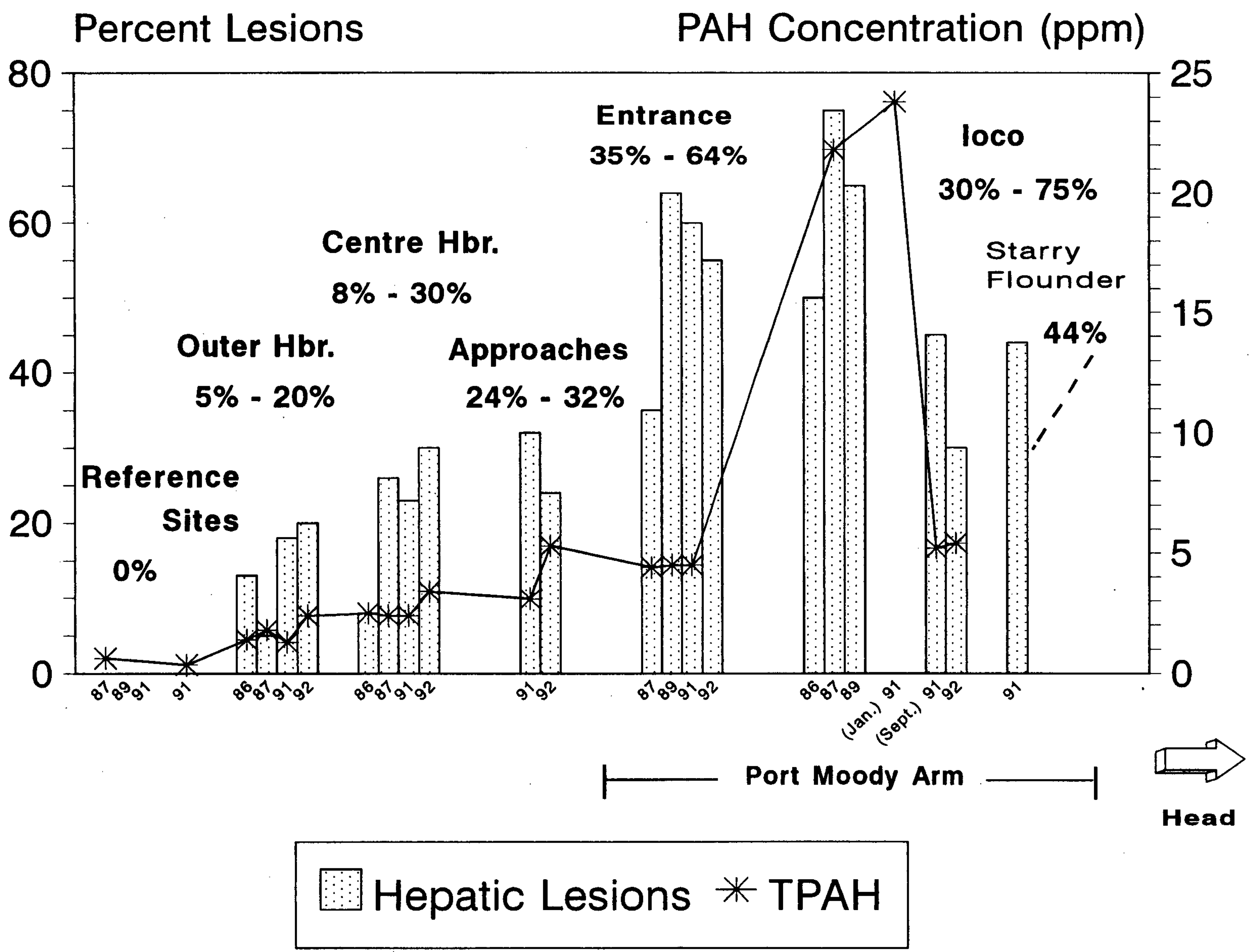
*D. Goyette*

There is mounting evidence that exposure to anthropogenic contaminants in the marine environment causes a variety of detrimental health effects in fish (Johnson, *et al.*, in prep.). Of special interest are the elevated levels of hepatic metabolizing enzymes, presence of liver DNA adducts, and prevalences of idiopathic liver lesions in flatfish, particularly English sole (*Pleuronecter vetulus*), associated with exposure to such chemicals as chlorinated and aromatic hydrocarbons. These biochemical and pathological conditions have been commonly found in fish from heavily polluted areas of Puget Sound, but also observed in fish from moderately polluted sites with total aromatic hydrocarbon levels in sediment as low as 1 ppm.

Between 1986 and 1992, Environment Canada conducted a series of surveys to determine the sediment contaminant distribution patterns in Vancouver Harbour (Goyette, *et al.*, 1988; Goyette and Boyd, 1989). During these investigations liver samples were taken from adult English sole (i.e. greater than 25 cm. fork length) and examined histologically for idiopathic lesions, similar to those found in fish from contaminated urban/industrial waterways in Puget Sound (Myers *et al.*, 1987; Myers *et al.*, 1990). This paper summarizes the prevalences of liver neoplasms (liver cell adenoma & hepatocellular carcinoma) and preneoplastic lesions (specifically, basophilic, eosinophilic and clear cell foci) in various regions of Vancouver Harbour, their temporal patterns and relationship to sediment polycyclic aromatic hydrocarbon (PAH) concentrations (Figure 1.).

Sampling sites were located along the north shore of the outer harbour or approaches to Vancouver Harbour; the central portion of the inner or main harbour and; three areas at the eastern end of the harbour, the approach to Port Moody Arm, entrance, and immediately adjacent to the Ioco refinery located towards the head of Port Moody Arm. In general, between 1986 and 1992, prevalences of neoplastic or preneoplastic lesions in English sole ranged from 5% to 75%, depending upon the area of capture (Figure 1.). Prevalences the outer harbour and central portion of the inner harbour ranged between 5% and 30%. The highest percentages were found in Port Moody Arm, one of the more heavily polluted areas of the harbour. In this region, liver lesions were found in 24% to 75% of the English sole sampled. Until 1991, the highest percentages occurred in along the north shore of the arm adjacent to the Ioco oil refinery where between 50% and 75% of the fish were affected by either neoplasms or preneoplasms, or both. Near the entrance and approaches to Port Moody Arm percentages were between 24% and 64%. Many of the liver samples from fish captured at the Ioco sampling site also showed signs of other hepatocellular disorders (e.g. nonspecific necrosis, cholangiofibrosis and increased vacuolation). In most instances, liver disorders needed to be determined by histological examination, but occasionally, numerous white tumors on the surface of liver samples could be seen visually. The histologist also noted a difference in the consistency of the liver samples from

Figure 1. Percentage of Hepatic Lesions in Adult English Sole vs. Total Sediment PAH
Vancouver Harbour - 1986 to 1992



Port Moody Arm, making sectioning more difficult (Brand, pers. com.). In 1991 and 1992, the frequency of lesions at the Ioco sampling site had dropped to 45% and 30%, respectively.

In contrast to results from Vancouver Harbour, histological studies on both English and flathead sole from several B.C. coastal reference inlets: Loughborough Inlet, located north of Campbell River; Alice Arm, north of Prince Rupert and Barclay Sound, on the west coast of Vancouver Island (Brand, pers. com.), showed no evidence of liver lesions or other hepatocellular disorders.

Field and laboratory studies on flatfish from Puget Sound have shown a strong positive correlation between a number of biochemical and pathological responses, including increased prevalences of liver lesions, and exposure to sediment PAHs. These responses have been attributed to PAH concentrations as low as 1-3 μg/g, dry wt. (Johnson, *et al.*, 1993). This was also evident in the results from Vancouver Harbour. From 1986 to 1992, sediment PAH concentrations at the outer and inner harbour sampling stations consistently remained between 1.3 μg/g and 3.4 μg/g, total PAH with a mean of 1.7 μg/g and 2.7 μg/g, respectively (Figure 1.) (Goyette and Boyd, 1989; unpubl. data). Lesion prevalences at these two sampling sites, as indicated earlier, were between 5% and 30%.

Total sediment PAH concentrations at the entrance and approaches to Port Moody Arm were slightly higher, ranging from 3.0 to 5.0 μg/g. Lesion prevalences in this area were 24% to 64%. The highest prevalences occurred off the Ioco refinery where, until January 1991, nearshore sediment PAH levels were about 22 μg/g to 24 μg/g. In September 1991 and in 1992, concentrations in the same general area had dropped to around 5.0 μg/g. This was accompanied by a decrease in lesion prevalence to 45% and 30%, down from the previous 50% to 75%.

The Ioco refinery was established in 1917 and until March 1989 discharged both treated stormwater and process effluent directly into Port Moody Arm. In 1989, the process effluent was re-directed to the Greater Vancouver Regional District's sewer system. Although there is very little information on the movements of flatfish in Port Moody Arm and one might expect a reasonable amount of time before seeing a response in lesion frequency, the reduction in lesion prevalence in 1991 and 1992 suggest that response to changes in treatment and process effluent discharge at the Ioco refinery can occur quickly. Additional sampling over the next 3-5 years, however, will be required to determine if this trend is real or simply within the normal range of variability.

Monitoring the prevalence of hepatic lesions in flatfish can provide an important tool to assess the impact of urban/industrial sources. Observations following changes at the Ioco refinery in Port Moody Arm suggests that changes in lesion frequency can be relatively rapid and may provide an important and sensitive measure of pollution abatement effectiveness. The sharp contrast in lesion prevalence between English sole from Port Moody Arm and those from other areas of the harbour, along with a strong homing instinct which has been shown by others, suggests that sole from Port Moody Arm represent a distinct local population. However, specific information on their behaviour and movements will be necessary to completely understand any trends in pathology and their relationships to changes in contaminant sources in Port Moody Arm.

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# FECAL COLIFORM CONTAMINATION IN GEORGIA STRAIT

*H. Nelson*

## INTRODUCTION

Molluscan bivalve shellfish and the waters in which they grow are routinely monitored for the presence of sewage contamination. Since these shellfish feed by filtering suspended particles from their aquatic environment they can indiscriminately extract and concentrate bacteria and viruses which are either natural to the environment or a result of contamination. In shellfish growing areas which have become contaminated by sewage there may be bacteria and viruses which have the capability of causing disease in humans. These pathogenic agents can result in illness ranging from mild gastroenteritis (stomach ache) to typhoid fever and infectious hepatitis. Although cooking will generally destroy the pathogenic organisms, shellfish are often eaten raw or undercooked, exposing the consumer to potential disease. Testing growing waters or tissue for specific pathogens is very expensive and difficult due to low numbers which can easily go undetected and problems with culturing the organisms. As a result regulatory agencies test for indicator organisms rather than actual pathogens.

The indicator organisms currently used by Canadian agencies to determine the sanitary quality of water and molluscan shellfish belong to the coliform group of bacteria. This group is considered a good indicator of sewage pollution as it contains bacteria found primarily in the intestinal tract of warm-blooded animals. Fecal coliforms and the principal member of this group, *E. coli*, are directly associated with the feces of warm blooded animals and meet the requirements of a good indicator organism i.e., easy to test for, consistently present in large numbers in sewage (6 million/100 mls), not normally present in seawater but able to survive as well as the pathogens and they are unable to multiply in seawater.The sanitary water quality of shellfish growing areas in Georgia Strait is assessed under the Canadian Shellfish Sanitation Program (CSSP) using national fecal coliform standards for water and tissue and an assessment of other existing and potential pollution sources.

## CANADIAN SHELLFISH SANITATION PROGRAM

The CSSP is jointly administered by the Department of Environment (DOE) and the Department of Fisheries and Oceans (DFO). It is based on the Canada/U.S. Shellfish Agreement signed in 1948 to control and improve the sanitary practices found in molluscan bivalve shellfish industries of the two countries. Compliance to protocols and practices outlined in a Manual of Operations under the bilateral Agreement is a pre-requisite to transboundary shipment of shellfish products. DFO is responsible for inspection, patrol and enforcement activities, the marine biotoxin control programs and is the designated contact with the U.S. Food and Drug Administration concerning the bilateral Agreement. DOE is responsible for monitoring the water quality of growing areas and the classification of these areas with respect to shellfish harvesting based on survey results.

This mandate is accomplished under Environment Canada's Shellfish Water Quality Protection Program.

## SHELLFISH WATER QUALITY PROTECTION PROGRAM

Environment Canada has been assessing the sanitary quality of shellfish growing waters in Georgia Strait on a regular basis since the early 1970's. Monitoring activities increased dramatically in 1988 as a result of the allocation of new resources to the program. Surveys are conducted according to protocols outlined in the CSSP and water quality is assessed in part against the following water quality standard:

- the median or geometric fecal coliform Most Probable Number (MPN) does not exceed 14/100 ml and not more than 10% of the samples exceed 43/100 ml in the multiple tube fermentation (MTF) test.

In addition to the bacteriological monitoring surveys, growing areas may be assessed using hydrographic and dye release studies, shoreline investigations of point and non-point pollution sources, outfall modelling and sewage treatment plant evaluations. Previously unsurveyed areas must have a comprehensive survey completed prior to any commercial harvesting. If the water quality standard is met (based on 15 data points per station) and no point or non-point pollution sources are identified, the area is classified Approved for harvesting. Following initial classification each area undergoes an annual sanitary review and a complete re-evaluation every three years. Georgia Strait and almost all of the rest of the southern British Columbia (B.C.) coast has now been classified, however, large areas of the north coast and Queen Charlotte Islands have only been surveyed for the harvesting of sub-tidal clams (geoducks).

B.C. has a coastline of 26,000 km. On the south coast about 3000 km or 310,000 hectares (ha) has been surveyed for shellfish harvesting and at present about 237,000 ha or 74% is classified Approved. Of the 73,000 ha classified Closed to harvesting about 55,000 ha are in Georgia Strait. This includes Burrard Inlet, the Fraser River estuary and Boundary Bay which are closed due to a variety of potential pollution sources in addition to bacteriological contamination. For monitoring purposes DOE has divided the south coast into 32 growing areas which are further sub-divided into 153 sectors. Georgia Strait includes at least a portion of 29 of the growing areas and is the most productive shellfish area on the south coast. There are 1300 ha of Georgia Strait under provincial shellfish tenure out of a total of 1800 ha for the whole B.C. coast.

Shellfish growing water quality in Georgia Strait is assessed using a network of approximately 1500 marine and 800 freshwater sampling stations from which 6000 samples are collected annually for fecal coliform analyses. Salinity measurements are also taken on the marine samples for comparison with precipitation data obtained from the Atmospheric Environment Service. The survey results are used to assess the adequacy of shellfish closure boundaries, to evaluate water quality at new aquaculture and wild harvest sites and to quantify pollution levels at point and non-point sources.

## TRENDS IN SHELLFISH CLOSURES

DOE survey results are presented to the Pacific Shellfish Classification Committee (PSCC) which meets bi-annually to review the data and make recommendations with regard to priority issues, survey needs and sanitary closure action. The Committee is chaired by DOE with members from DFO and the provincial ministries of Environment Lands and Parks, Agriculture, Fisheries and Food and Health. When necessary, closure action is taken by issuing Closure Orders under the Management of Contaminated Fisheries Regulations of the federal Fisheries Act.

There are presently approximately 180 Closure Orders under the Fisheries Act. Multiple pollution sources account for the largest area closures, followed by sewage outfalls, agriculture/hinterland drainage, boat sewage discharges, urban run-offincluding septic seepage and pulp millpollution (see Table 1 and Figure 1). The number of Closure Orders required to put in new closures or extensions to existing closures has been increasing in recent years. For example, in 1991/92 there were 12 actions taken, in 1992/93, 15 and to date in 1993/94, 20 closure actions have been taken. Of the 20 closure actions this year, 15 were in growing areas of Georgia Strait. During the same three year period there have been three closures revoked and three reduced.

During 1993/94 there have been re-evaluation surveys completed in the following growing areas of Georgia Strait:

- Gabriola Island (April 19-30)
- Ladysmith Harbour (April 19-30)
- Nanaimo (April 19-30)
- Thetis/Kuper Islands (April 19-30)
- Jervis Inlet (September 13-24)
- Malaspina Strait (September 13-24)
- Okeover Inlet (October 11-22)
- Powell River (October 11-22)

In addition, seasonal key station marine water stations were sampled from Desolation Sound to Saanich Inlet in August, November and December 1993 and January 1994. Another seasonal key survey is planned for March 1994.

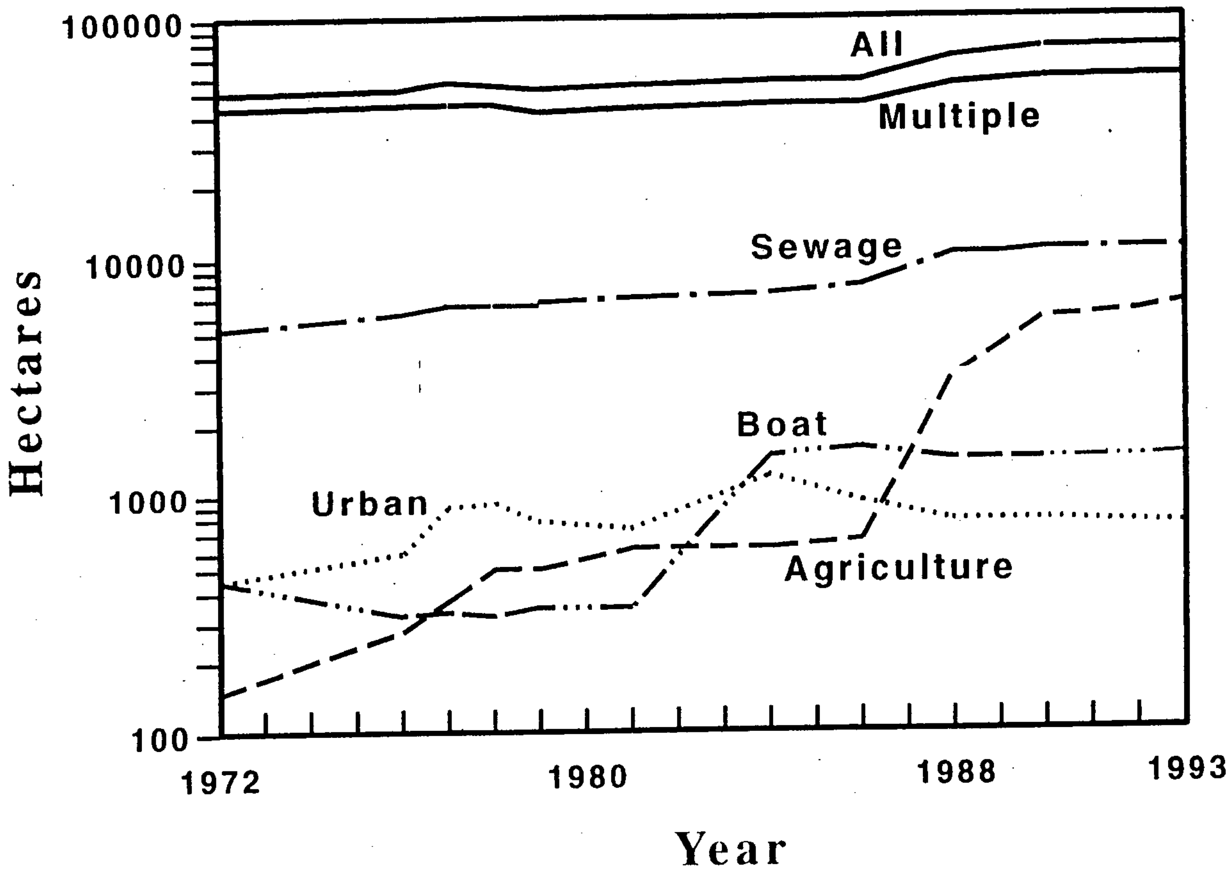
In April 1993 DOE and DFO conducted a joint study in Fisheries Management Area 17 from Nanaimo to Crofton including the adjacent Gulf Islands. The study was initiated by the PSCC to examine the dilemma of contaminated shellstock (based on the national tissue standard of 230 FC/100 grams) from areas approved for harvesting based on DOE water

TABLE 1

| TRENDS IN BRITISH COLUMBIA SHELLFISH CLOSURES | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pollution Sources | Total Closure Area (Hectares) | | | | | | | | | | | | | |
| | 1972 | 1976 | 1977 | 1978 | 1979 | 1981 | 1984 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 |
| Multiple Sources | 45 407.2 | 46 232.7 | 46 212.6 | 45 654.2 | 43 540.2 | 44 017.9 | 44 457 | 48 497.0 | 57 209.5 | 55 115.9 | 55 115.9 | 55 135.3 | 55 173.2 | 55 552.4 |
| Marine Sewage Outfalls | 5 211.2 | 5 981.3 | 6 439.1 | 6 466.3 | 6 466.3 | 6 881.2 | 7 090 | 5902.4 | 10 290.6 | 9 313 | 10 214.4 | 11 151.6 | 10 782.2 | 10 784.1 |
| Septic Seepage, Urban Runoff | 438.8 | 638.7 | 969.2 | 1 097.1 | 840.3 | 789.2 | 1 184 | 605.7 | 739.4 | 693.6 | 686.1 | 855.5 | 792.4 | 710.6 |
| Agricultural, Hinterland Drainage | 145.8 | 272.0 | 369.2 | 503 | 503 | 630.4 | 609 | 292.6 | 3 195.8 | 4 536.9 | 4 537.5 | 4 027.4 | 3 934.9 | 4 307.2 |
| Vessel Discharges | 452 | 301.3 | 315.4 | 301.4 | 344.1 | 344.1 | 1 387 | 1 470.7 | 1 313.5 | 1 349.2 | 1 376 | 1 379.5 | 1 371.4 | 1 461.3 |
| TOTAL (Hectares) | 51 655.0 | 53 426.0 | 54 305.5 | 54 022.0 | 51 693.9 | 52 462.8 | 54 727 | 56 768.4 | 72 748.8 | 71 008.6 | 71 929.9 | 72 549.3 | 72 054.1 | 72 815.6 |

FIGURE I

# TRENDS IN B.C. SHELLFISH CLOSURES 1972-1993



surveys. DFO had recorded a rejection rate of 26% for commercial lots from this area. Thestudy included marine water, shellstock and sediment sampling, however, no conclusive relationship between these variables was identified. This area will remain open to harvesting pending further study. The PSCC had considered a recommendation to close the whole area which would have removed about 500,000 pounds of clams from the commercial wild clam harvest as well as a significant recreational harvest and aboriginal food fishery.

At its May 1993 meeting the PSCC also contemplated a total harvesting closure in Saanich Inlet. There were already a number of closures in Saanich Inlet and it was expected that water quality would continue to deteriorate with the rapid population growth in the area. In addition, DFO had recently determined that few remaining beaches were suitable for clam harvesting. Nevertheless, the Committee felt that the impact of an overall closure on recreational and native fisheries warranted further evaluation prior to total closure. Two closure areas were extended to maintain an adequate level of public health protection and the area will be re-evaluated following further surveys.

Population growth, even on a seasonal basis in relatively remote areas of Georgia Strait can result in harvesting closures. The September 1993 sanitary shoreline survey in Jervis Inlet in conjunction with previous observations resulted in a closure of 8 kilometres of shoreline on Blind Bay, Nelson Island. In a 1990 sanitary survey 20 of the 36 mostly seasonal homes then in existence were found to have either a direct marine sewage discharge (straight pipe) or an outfall as part of a septic system. Some of the homeowners had put in a septic tank and tile field system, however, due to the geographic features (steep, rocky, very little topsoil) very few if any would be considered legal. Due to the remote nature of the area there is no official community plan and no zoning bi-laws enforced which would require an effluent discharge permit in conjunction with a building permit. An increase in uncontrolled building in recent years prompted the PSCC to recommend a seasonal closure at the December 1993 meeting.

## PREVENTION/REMEDIATION EFFORTS

With existing program resources we are not able to become actively involved in many pollution prevention/remediation studies beyond those required of our 'core' program. Delivery of the core monitoring requirements ensures compliance with the CSSP and the Canada/U.S. Shellfish Agreement with regard to public health protection and transboundary marketing. Where possible DOE has adopted a pro-active approach to prevention and restoration by providing information to other regulatory agencies as follows:

- through Regional District referral systems, DOE assists municipal and regional planning departments by providing information on local shoreline sanitary conditions, shellfish resources and on concerns about sewage disposal, storm water control and farm waste management practices.

- through referral systems for the federal Ministry of Transport, Navigable Waters Protection Act and the provincial Waste Management and Crown Lands Acts, DOE comments on siting and effluent handling concerns with respect to shoreline installations and floating operations such as aquaculture facilities, logging and fishing camps.

- through the PSCC recommendations are made to the provincial Ministry of Environment Lands and Parks for the designation of water bodies under the new Pleasure and Non-pleasure Craft Sewage Pollution Prevention Regulations.

- DOE reviews and comments on draft provincial Environmental Guidelines for Agriculture.

## CONCLUSIONS

The degradation of water quality in Georgia Strait is continuing and it is pervasive. The main contributing factor to the deterioration in sanitary marine water quality is untreated domestic sewage. This condition is aggravated by decades of neglect of sewage and water treatment infrastructure. Although there have been few reported cases of illness related to consumption of contaminated shellfish on the B.C. coast, the potential for disease outbreaks is increasing. The management and enforcement of harvesting bans in closed areas is a formidable and growing task. It is believed that illegal harvesting has increased substantially in recent years as more and more growing areas are eliminated due to contamination. The sale of illegally harvested product is a direct threat to public health.

The solution to the problem is regulation and education. More stringent regulations are necessary for sewage and wastewater treatment at the local and regional level. Outdated and inadequate community sewage treatment systems should be upgraded and controls on the installation and maintenance of standard septic tank and tile field absorption systems should be tightened. For example, the use of the percolation test as a single standard for assessing the sustainability of soils for sub-surface disposal in foreshore areas is totally inadequate. Finally, the message must get to the public that good planning and maintenance of their single family sewage system is necessary to protect the amenities afforded by living on the shores of Georgia Strait.

## PROPOSED NATIONAL MUSSEL WATCH PROGRAM

*E. McKnight*

## BACKGROUND:

The classification of shellfish growing areas depends on shoreline surveys, identifying pollution sources, bacteriological sampling of overlay waters and an evaluation of chemical contamination. It was with the goal of strengthening this last aspect of the program that a review document (Sojo et al 1990) of Mussel Watch Programs in North America and elsewhere in the world was prepared for the Shellfish Water Quality Protection Program of Environment Canada. The document provided some evaluation of the benefits and problems associated with Mussel Watch programs, and a basis for further discussions within Environment Canada and other federal agencies as to the potential for beginning a Mussel Watch program in Canada.

A draft of this document was used as background material for a panel discussion held in conjunction with the Aquatic Toxicity Workshop, November, 1990. The objective presented to the panel of experts was to develop a program to measure contamination concentration in bivalves in approved shellfish growing areas as part of the requirements of the Canadian Shellfish Sanitation Program (CSSP). The intent was to develop a baseline range of reference levels, establish a national data bank, identify potential "hot spots" and establish trends in contaminant data. Recommended objectives include the following:

- to strengthen compliance with CSSP program requirements by providing DOE with data on the concentration of contaminants in bivalves to meet obligations in the classification of shellfish growing areas

- within shellfish growing areas
    - to establish a "baseline" or range of reference levels for contaminant concentration
    - to establish a national data bank to contribute to SOE reporting
    - to identify "hot spots" (if any)
    - to identify trends (if any)

Expansion of the monitoring network to include other areas as part of a more complete status and trends program would be considered if the pilot growing area program was successful. It was generally agreed that the program would serve both a human health protection monitoring strategy and an environmental (status and trends) monitoring strategy, but that primarily it would provide environmental data which health officials and environmental managers could use.

The panel concluded that there was sufficient merit in proceeding with a program to measure contaminant levels in bivalve mollusca and sediments from shellfish growing areas and other reference sites.

Coincidentally the Gulf of Maine Council on the Marine Environment initiated a pilot scale monitoring program involving five jurisdictions: Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia. Monitoring of the blue mussel Mytilus edulis was chosen as one of the environmental indicators to be used and the focus of the pilot monitoring effort. It was believed that participation by Environment Canada, Atlantic Region, in the "Gulfwatch" program provided an opportunity to develop and field test a mussel monitoring protocol which would be compatible with existing U.S. programs (e.g. NOAA Status and Trends and Gulfwatch) and Canadian program requirements.

**CONCEPT:**

A large body of information exists on the biology of blue mussel and use of indicators of contamination. Mussels have been referred to as "ecological canaries" providing reliable advance warning of problems where rapid managerial responses are required. Mussels are relatively abundant in both east and west coasts of Canada and are easily accessed with minimal equipment requirements. Mussels are sedentary, responding to their immediate environment thereby eliminating complications of interpreting results introduced by mobile species. Since mussels are filter feeders it is presumed that they reflect present day water column conditions but uptake is complex and depends upon many factors including bioavailability, exposure time and route of uptake. Routes of uptake include direct into the blood across the gill and mantle epithelium or by normal feeding mechanisms. They are able to concentrate low levels of contaminants reducing problems of detection.

However, recent research indicates that mussels as indicators of environmental health may be less than ideal. That is, they do not integrate all contaminants of concern equally and bioaccumulation is not always proportional to ambient water chemistry (Phillips and Segar 1986), and measured concentrations may depend more on food quantity and quality, (Chou and Uthe 1991). Mussels may not necessarily be considered the best or only means of measuring marine environmental health. However, the pilot mussel watch will be an important step in delivering the requirements of the Canadian Shellfish Sanitation Program (CSSP). And in a comprehensive and fully integrated monitoring program the mussel watch can play a significant contributing role.

In order to correctly classify a shellfish growing area for the safe harvesting of shellfish, the CSSP not only requires bacteriological sampling of the overlay waters but also recommends sampling of the shellstock for chemical contaminants in areas where chemical contamination may exist.

## KEY COMPONENTS OF THE PROPOSED MUSSEL WATCH

### Hypotheses

- tissue concentrations of selected contaminants in mussels from reference areas equal those of mussels from test areas;
- tissue concentrations of selected contaminants in mussels from reference and test areas are the same from sample period to sample period;
- tissue concentrations of selected contaminants are less or equal to regulated limits;

### Sites

- key continuing reference stations are be identified for comparison with test sites (spacial control);
- test sites will be in important shellfish growing areas that have active sources of contamination or contaminated sediments;
- test sites will be sub-tidal;

### Mussels

- the focus will be on indigenous, undepurated shellstock (generally Mytilus edulis);
- mussels will be standardized on size, (50 -60mm) and species;
- width:height ratio and condition index will be measured;
- the use of caged mussels will be limited to areas near major pollution sources where there may be a pollution gradient;

### Sampling

- sampling will occur prior to spawning or at least the time of sampling will be consistent from site to site and year to year;
- there will be a minimum of four composite samples from each site (for a coefficient of variation of 0.3 this will allow detectable differences between means of 90%)

**Parameters**

- parameters to be measured will include metals, PAHs, PCBs, dioxins and furans, DDT and other selected pesticides;

**Metals (Major and Trace Elements)**

Arsenic
Cadmium
Chromium
Copper
Iron
Mercury
Lead
Zinc
Nickel
Manganese
Aluminum
Antimony
Selenium
Silver
Tin

**Aromatic Hydrocarbons**

Naphthalene
2 - Methylnaphthalene
1 - Methylnaphthalene
Biphenyl
2,6 - Dimethylnaphthalene
Acenaphthylene
Acenaphthene
2,3,5 - trimethylnaphthalene
Fluorene
Phenanthrene
Anthracene
1 - Methylphenanthrene
Fluoranthene
Pyrene
Benzo(a)anthracene
Chrysene
Benzo(b)fluoranthene
Benzo(k)fluoranthene

**Aromatic Hydrocarbons**, cont...

Benzo(e)pyrene
Benzo(a)pyrene
Perylene
Indeno(123cd)pyrene
Dibenzo(ah)anthracene
Benzo(ghi)perylene

**Polychlorinated Biphenyls**

| **IUPAC** | **Congener** |
|---|---|
| 8 | 2,4'-dichloro |
| 18 | 2,2',5-trichloro |
| 28 | 2,4,4'-trichloro |
| 29 | 2,4,5-trichloro |
| 44 | 2,2',3,5-tetrachloro |
| 50 | 2,2',4,6-tetrachloro |
| 52 | 2,2',5,5'-tetrachloro |
| 66 | 2,3',4,4'-tetrachloro |
| 77 | 3,3',4,4'-tetrachloro |
| 87 | 2,2',3,4,5-pentachloro |
| 101 | 2,2',4,5,5'-pentachloro |
| 104 | 2,2',4,6,6'-pentachloro |
| 105 | 2,3,3',4,4'-pentachloro |
| 118 | 2,3',4,4',5-pentachloro |
| 126 | 3,3',4,4',5-pentachloro |
| 128 | 2,2',3,3'4,4'-hexachloro |
| 138 | 2,2',3,4,4',5'-hexachloro |
| 153 | 2,2',4,4',5,5'-hexachloro |
| 154 | 2,2',4,4',5,6'-hexachloro |
| 170 | 2,2',3,3',4,4',5-heptachloro |
| 180 | 2,2',3,4,4',5,5'-heptachloro |
| 187 | 2,2',3,4',5,5',6-heptachloro |
| 188 | 2,2',3,4',5,6,6'-heptachloro |
| 195 | 2,2',3,3',4,4',5,6-octchloro |
| 200 | 2,2',3,3',4,5',6,6'-octachloro |
| 206 | 2,2',3,3',4,4',5,5',6-nonachloro |
| 209 | decachloro |

**Pesticides**

Hexachlorobenzene
Heptachlor
Aldrin
4,4'-DDE
Mirex
Lindane
Heptachlor Epoxide
cis-Chlordane
trans-Nonachlor
Dieldrin
2,4'-DDE
2,4'-DDD
4,4'-DDD
2,4'-DDT
4,4'-DDT
alpha-Endosulfan
beta-Endosulfan

**Dioxins and Furans**

Dioxins

2,3,7,8 - tetrachlorodibenzodioxin
1,2,3,7,8 - pentachlorodibenzodioxin
1,2,3,4,7,8 - hexachlorodibenzodioxin
1,2,3,6,7,8 - hexachlorodibenzodioxin
1,2,3,7,8,9 - hexachlorodibenzodioxin
1,2,3,4,6,7,8 - heptachlorodibenzodioxin
octachlorodibenzodioxin

Furans

2,3,7,8 - tetrachlorodibenzofuran
1,2,3,7,8 - pentachlorodibenzofuran
2,3,4,7,8 - pentachlorodibenzofuran
1,2,3,4,7,8 - hexachlorodibenzofuran
1,2,3,6,7,8 - hexachlorodibenzofuran
2,3,4,6,7,8,- hexachlorodibenzofuran
1,2,3,7,8,9 - hexachlorodibenzofuran
1,2,3,4,6,7,8 - heptachlorodibenzofuran
1,2,3,4,7,8,9 - heptachlorodibenzofuran
octachlorodibenzofuran

**Canadian action limits/tolerances**

| | |
|---|---|
| TOTAL DDT | >5 PPM |
| PCB | >2 PPM |
| DIOXIN | >20 PPT |
| MERCURY | >0.5 PPM |
| MIREX | >0.1 PPM |
| ALL OTHER AGR. CHEMICALS | >0.1 PPM |

**Data Storage**

- data will be stored in a database compatible with ENVIRODAT.

**QA/QC**

- objectives for QA/QC include:
  - development and use of standardized field sampling procedures, and
  - performance standards for analytical protocols;
  - interlaboratory comparisons of analytical methods;
  - periodic quality assurance workshops;
  - use of Standard Reference Materials (SRMs) and Reference Materials (RMs).

**CURRENT STATUS**

In August of 1991, four monitoring sites were established in Nova Scotia and New Brunswick as part of the Gulf of Maine monitoring initiative. Monitoring was also initiated at two additional locations in Nova Scotia and one in Eastern New Brunswick as part of the EP Atlantic growing area pilot effort. In 1992, additional sites were chosen in PEI and in Newfoundland in 1993.

Costs for the project have been shared through Atlantic Coastal Action Plan (ACAP) funding, Green Plan Toxics, as well as Shellfish Program funding. Metal analyses of all Gulf of Maine locations were carried out by the State of Maine laboratories. All organic analyses of the Gulf of Maine locations were carried out by Environment Canada (EC), Atlantic Region. Samples from sites not part of the Gulf of Maine were analyzed by the EC Laboratory, Atlantic Region. All dioxin and furan analyses were contracted to Axys Analytical Services Ltd., Sidney, B.C.

Gulf of Maine protocols used were modified from NOAA protocols. From these, a draft protocol for a Canadian Mussel Watch is being developed through John Machell, EC, Atlantic Region as lead. Statistical help in the design of the sampling strategy is being provided by Glenn Atkinson EC. Paul Lobel, Memorial University, has provided guidance with respect to speciation of *Mytilus*. Jack Uthe and Ken Freeman of the Department of Fisheries and Oceans and Gunnar Lauenstein, US NOAA, have also provided guidance. In addition, Chris Roberts, EC, Atlantic Region in cooperation with the Gulf of Maine participants, is designing a PC-database structure to handle the data generated by the project.

Several workshops have been part of the Gulf of Maine initiative. Through these workshops, EC/EP Atlantic Region has been involved in the planning, implementation and interpretation of the Gulfwatch. Peter Hennigar, EC, Atlantic Region has also participated in a NOAA interlaboratory check sample program and QA/QC workshop and is coordinating the QA/QC aspects of the Canadian Mussel Watch.

## FUTURE GOALS

The draft protocols have been circulated to the Shellfish Program Managers and Steering Committee members and will be circulated again for wider review once further revisions are made. By the end of 1993-94, pilot studies will have been carried out in all three shellfish growing area regions (Atlantic, Quebec and Pacific and Yukon). The extent of the pilot project will depend on the funding available and what integration with other programs such as status and trends is possible. Protocols will be reviewed after the draft protocols have been tested in all three regions. Expansion to include sediments will also be evaluated.

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# SHELLFISH BIOTOXIN LEVELS AS AN INDEX OF TOXIC ALGAL BLOOMS

*R. Chiang and R. Loy*

## ABSTRACT

Reviewed Shellfish Biotoxin Monitoring Program in British Columbia. Historic toxicity data collected from 1985 to 1993 suggest major blooms are most likely to occur in September and October.

## INTRODUCTION

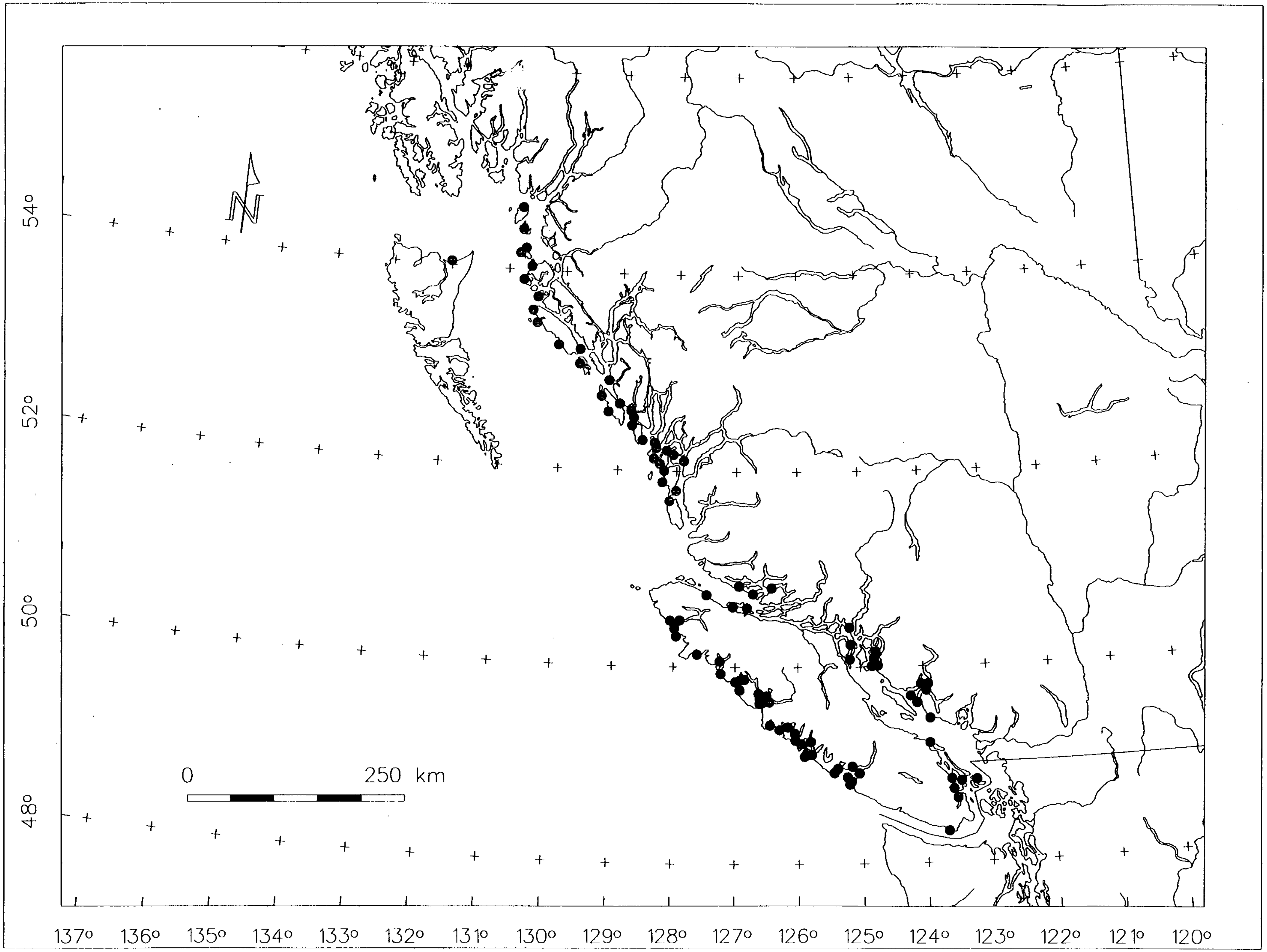
The federal Department of Fisheries and Oceans (DFO) has compiled paralytic shellfish (PS) toxicity records in British Columbia since 1942 (Quayle et al, 1966). In 1982, weekly sampling of mussels at 9 selected sites from May to October provided a constant base line for PS toxicity assessment. The number of sites increased substantially in 1988 with funding from the Enhanced Shellfish Program. By 1992, there were 63 sites south of Cape Caution plus 22 sites in the Central Coast and 1 site at North Beach on the Queen Charlotte Islands. Data from these sites could provide an indication on the activities of toxic algal blooms in the represented areas.

## BIOTOXIN MONITORING

The major component of the monitoring program consists of a series of sampling sites where mussels are collected on a weekly or biweekly basis. Local residents are paid a fee for sample collection. To expedite the sampling, a supply of sea mussels (*Mytilus californianus*) are placed in vinyl meshed socks and submerged in sheltered water. Weekly samples can thus be collected independently of tide conditions. The samples are shipped to Inspection Laboratories for extraction and toxicity determination. The turn-around-time is generally within 5 workings days of sampling, where shipping takes 2 days and analyses are completed within 3 days.

## MONITORING SITES SOUTH OF CAPE CAUTION

Since 1990, 62 sites have been established along the Straits (Johnstone and Georgia) and the West Coast of Vancouver Island. With few exception, most of these sites remain unchanged. Indeed, seven of these sites have been sampled since 1982. The sampling sites for 1992 are illustrated in Figure 1.


54°
52°
50°
48°
0
250 km
137°
136°
135°
134°
133°
132°
131°
130°
129°
128°
127°
126°
125°
124°
123°
122°
121°
120°

## MONITORING SITES IN THE CENTRAL COAST

In 1992, 22 monitoring sites from the Central Coast were added to the program. Seven of these sites included both mussels and geoduck clams (*Panope abrupta*). The sampling cost was borne by two user groups, the Heiltsuk Band Council of Waglisla (Bella Bella) with funding from DFO, and the Underwater Harvesters' Association (UHA). The monitoring provided harvest opportunities for Manila and native littleneck clams as well as geoducks in the area. The number of sites was reduced to 13 in 1993.

## MONITORING SITES IN THE NORTH COAST

The geoduck fishery north of Cape Caution is based on a 3 year rotational opening among the Central Coast (Aristazabal Island to Calvert Island), North Coast (Alaska border to Aristazabal Island), and Queen Charlotte Islands.

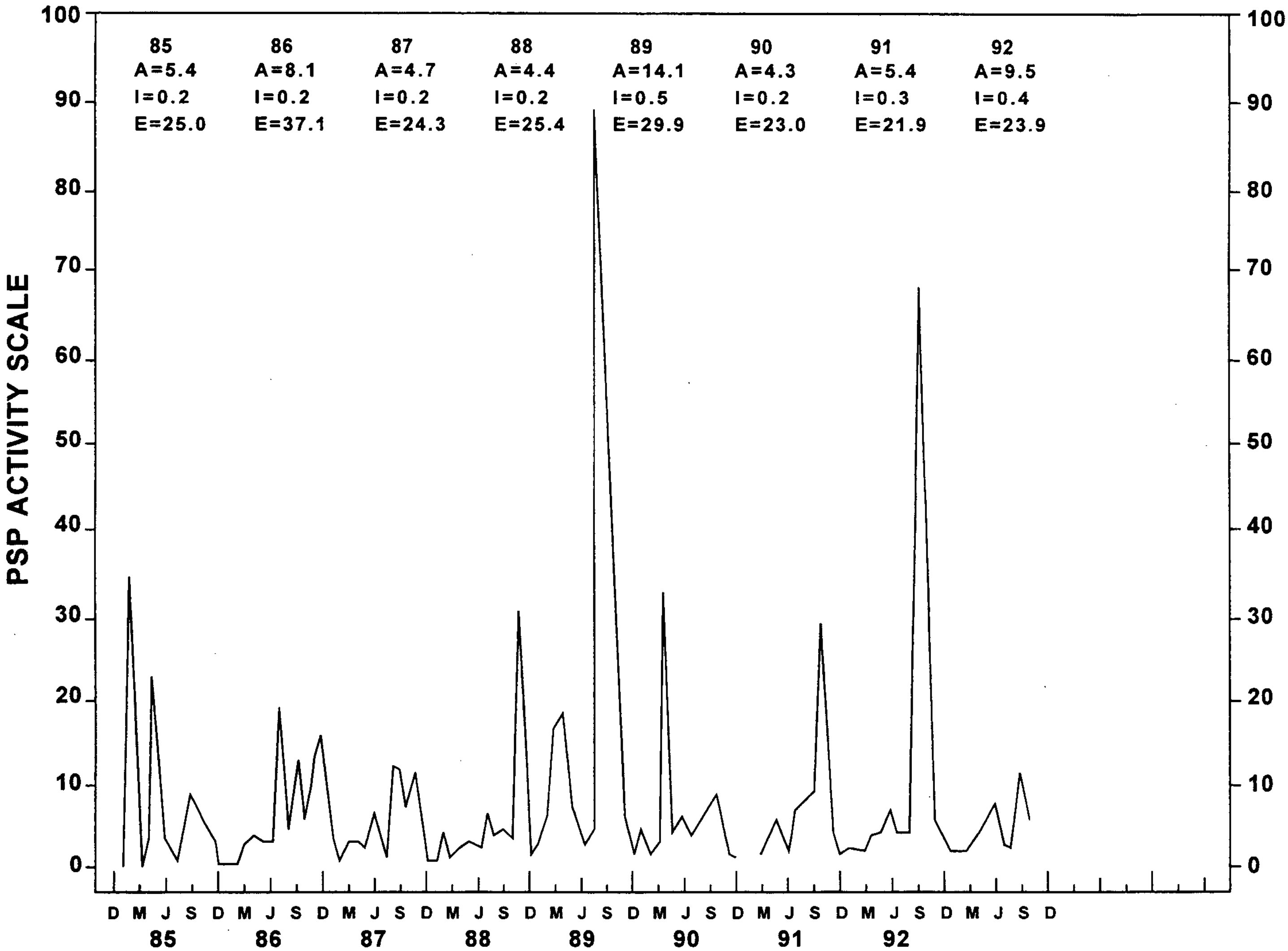
In 1993, 16 monitoring sites from Dundas Island to Aristazabal Island were added.

## TOXICITY FINDINGS AND DISCUSSIONS

A macroscopic approach to describe toxicity levels in terms of the intensity (how high) and the extensity (how wide) of toxic blooms was proposed (Chiang, 1985). Historic data from 1963 onwards were evaluated under this model, where an index, terms PS Activity Scale (A), is obtained by multiplying the intensity and extensity indices (Quayle, 1969. The PS Activity Scale for the British Columbia Coast since 1963 is illustrated in Figure 2. It should be noted that the huge fluctuations in the 60's and 70's were influenced by the volume of data derived from the canning of butter clams during the winter in the North Coast. Long retention time of toxicity in butter clams, coupled with frequent sampling of raw products prior to canning in the winter, could bias the data and lead historians to conclude that toxic blooms were more rampant in the winter months in the North Coast. With the cessation of butter clam canning in the late 70's, this bias was mitigated. The data gathered from the year round monitoring of 62 mussel sampling sites since 1990 will provide a solid base for the indexing of toxic algal blooms in the waters along the West Coast of Vancouver Island and the inside water of Johnstone Strait, the Strait of Georgia and Juan De Fuca Strait.

Analysis of the monthly PS Activity index indicates that during the nine year period between 1985 to 1993, PS activities were detected in all of the months. From December to March, the probability of having a toxic outbreak is 0.5 or less, whereas the probability of having an outbreak along the B.C. Coast approaches 1.0 from April to November. Interesting enough, September and October are the two months where major outbreaks are most likely to occur.

## Fig.2: PSP ACTIVITY BY MONTH



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## TOXIC ALGAE AND FISH FARMS

*E. A. Black*

### Introduction

I will start with a basic model of bloom occurrence, and define some often confusing terminology. I will then outline our present knowledge of blooms in the B.C. coast and the value and limitations of fish farming in monitoring them.

### The Basic Model

### N.E.B.E.

HyperNutrification - a measurable increase in the levels of algal nutrients.

Eutrophication - a measurable increase in primary productivity often incorrectly associated with an increase in the standing stock of algae. Usually such an increase in standing stock usually involves a broad spectrum of species. Discoloration of the water may or may not be associated with this increase in primary productivity.

Bloom - a measurable increase over historical levels in the standing stock of algae usually associated with dominance of a single algae species and often the production of bioactive substances by the dominant species. Discoloration of the water may or may not be associated with this increase in algal standing stock. I recognise the usage of the term bloom can also be applied in the seasonal sense of a spring or fall bloom of algae but for this talk I am primarily concerned with increases in standing stocks which exceed these which are normally experience at any one time of year.

Effects - This may be any discernible anomaly from water discoloration, through kills of wild or cultured marine organisms, to sets of human symptomology such as P.S.P.(Paralytic Shellfish Poisoning), D.S.P.(Diarrhetic Shellfish Poisoning) and A.S.P. (Amnesic Shellfish Poisoning).

### Another Confusing Term

Red tide - This refers to any unusual algal mediated discoloration of the ocean. It may be any colour including green, brown, whitish, or red. It is a localised increase in algal standing stock. It does not have to result from N-->E-->B-->E progression. It can result solely from concentration of otherwise normal levels of algae by current patterns and it may or may not be associated with allopathic effects.

## Fish Farm Effects

On this coast two types of algae are associated with fish farm mortalities.

One is a bean-shaped biflagellated chloromonad approximately 20 $\mu$ in size called *Heterosigma akashiwo*. This is referred to as *Heterosigma* by most of the fish farming community. Fish kill caused by this algae occur at elevated cell concentrations often associated with a reddish-brown discoloration of the water however, the fish mortalities often start before there is any perceptible discoloration.

The other problem algae for fish farmers involves the algae *Chaetoceros convolutus* or *Chaetoceros concavicori*. It is not altogether clear whether these algae represent two species or two forms of the same species. Fish farms refer to these algae as *Chaetoceros*. Fish kills associated with these algae often involve cell concentrations that do not discolour the water.

## Fish Farms Monitoring Algal Blooms

Fish farms are useful as a bioassay for algal effects in that they are a continuous long term bioassay for years at a time. However, a disadvantage is that the industry may shift around. For example,initially fish farming in the mid-1980s was centred in the area around Jervis and Sechelt inlets. In the late 1980's the centre started to shift north to the upper end of the Strait of Georgia (off Campbell River) with a few farms located on the outer coast of Vancouver Island. Since then most of the farms have moved out of the Jervis and Sechelt Inlet areas due to algal blooms and are now located off Campbell River, in the Southern Queen Charlotte Strait and along the west coast of Vancouver Island.

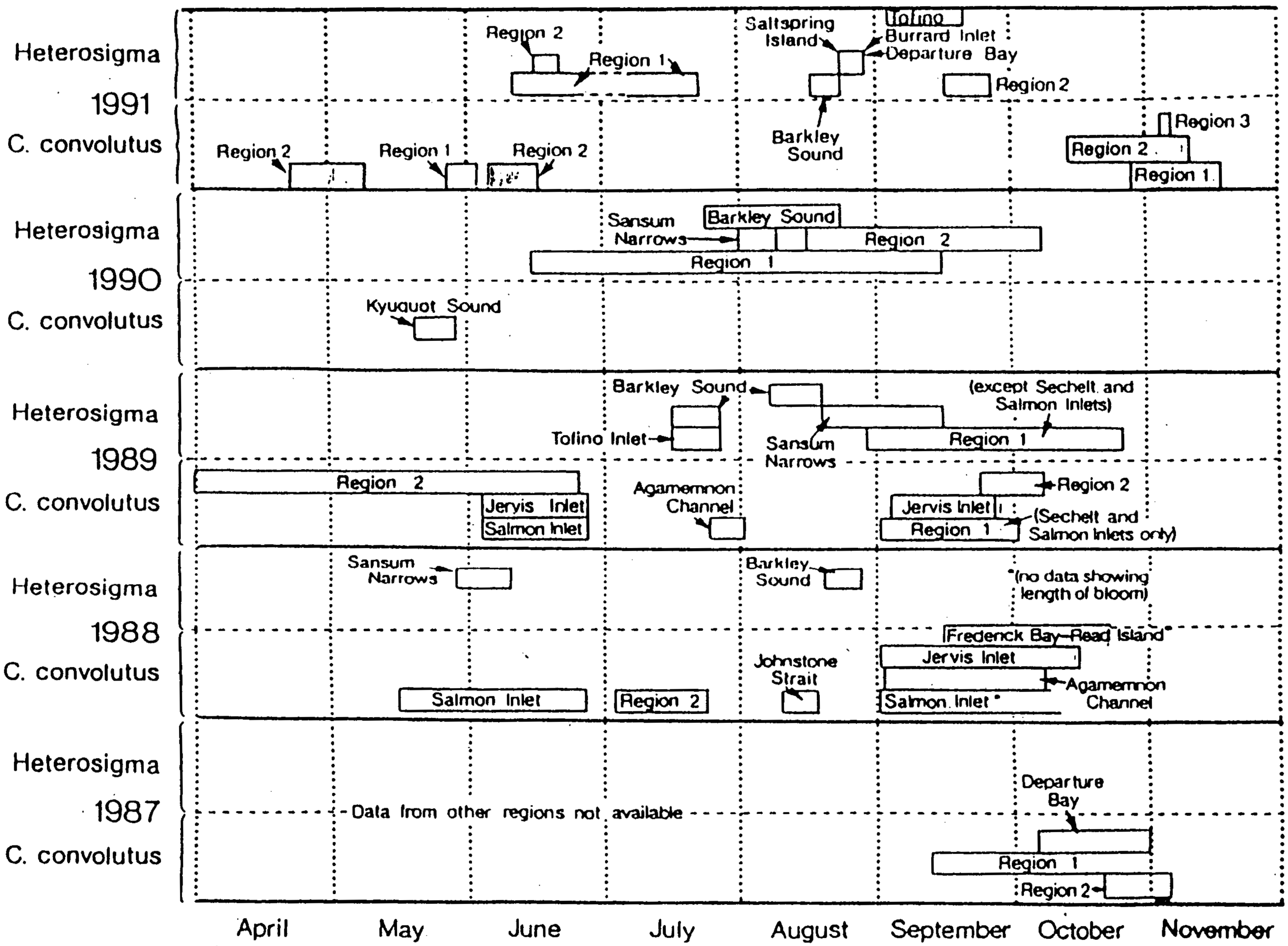
Another negative feature is that they do not cover the entire coast. For example there is a dearth of fish farms on B.C.'s central and northern coasts.

They also do not monitor the algae associated with human illnesses such as P.S.P., D.S.P. and A.S.P.

Since the development of fish farming in the mid 1980's the B.C. Ministry of Agriculture Fisheries and Food (MAFF) helped train fish farmers how to identify and enumerate problem algae. MAFF was responsible for the creation of the first English language key of problem algae for aquaculture and for the only video film to help farmers with phytoplankton identification. These were an attempt to introduce some aspect of quality control into the algal identifications done by the industry.

In conjunction with that training, between 1987 and 1991, MAFF instituted a quality assurance component to algae identifications it then used in compilation to help elucidate the pattern of algal occurrence around fish farms. The farm identifications proved to be accurate for the species of concern to the fish farmer and the results of those identifications are shown in Figure 1.

Figure 1 Major Blooms Harmful to Pen-reared Salmon: 1987-1991



The general pattern is as might be expected. Problems associated with the diatoms are primarily a spring/fall phenomenon and the flagellate problems occur mostly in the summer. Further, those years when *Heterosigma* is commonly wide spread do not have a lot of *Chaetoceros* associated. 1990 was anomalous.

**Bloom Development**

Knowing the most probable location of blooms development is of considerable importance in monitoring for algal based events. Over the development of the fish farming industry in B.C., we have seen a pattern of bloom development.

From information the farmers have supplied it appears that fish killing blooms of *Chaetoceros* have developed either in Sechelt inlet and been transported to farms in the vicinity or have developed in the Northern part of the Strait of Georgia and been washed onshore where the farms are situated. Fish killing blooms of these algae are not common on the outer coast or in the Queen Charlotte Straits areas.

Fish mortalities from *Heterosigma* blooms are more frequent than those of *Chaetoceros* and are more wide spread. This type of bloom occurs in the Strait of Georgia, off Vancouver Island North-west Coast, and off Barkely Sound on the central part of Vancouver Islands west coast.

We have less information on the origin of blooms off Vancouver Islands west coast. However, one of the *Heterosigma* blooms of the North-west Coast of Vancouver Island was associated with the development of water discoloration in a large gyre 70 km. west of the northern tip of Vancouver Island. Similar fish killing bloom in Barkely sound appeared to be associated with the development of what from satellite imagery may have been a frontal zone caused by the intrusion of warm water offshore of the southern Coast of British Columbia.

As a result of the work of R. Haigh and F.J.R. Taylor in the Strait of Georgia and my own work in the Jervis Inlet area we have a good description of the development of blooms in the Strait. Haigh and Taylor's work shows that concentrations of *Heterosigma* initially develop off the beaches around Vancouver and gradually spread North along the Eastern side of The Strait of Georgia eventually moving to the west side of the Strait and then southward. This pattern was shown to occur in each of the three consecutive years the study was underway. In one of those years 1989 a major fish killing bloom was experienced by fish farms in and around Jervis Inlet. During that bloom I was able to document the movement of the bloom into the Jervis Inlet Area from the Strait and maintenance of the bloom discoloured water in Jervis Inlet long after it had disappeared from the Strait.

In all three locations it would appear that fish farms were experiencing blooms which developed in other areas and secondarily arrived at the farm site.

**Variation in bloom types and effects**

Concentrations of algae can have very different effects at different times.

A good example of this is demonstrated in data taken at the Pacific Biological Station fish farm over a number of years. Between 1973 and 1985 records of *C. convolutos* concentrations and associated fish mortalities were kept. In 1977 cell concentrations of 8,000 per litre killed 43, 37, 18, and 15 percent of their Coho, Chinook, Pink and Chum stocks respectively. In 1978 with cell concentrations of 28,800 per litre none of these stocks lost more than .05 percent.

This variation can also be seen in data of the effect of *Heterosigma* related fish kills in the Inland Sea of Japan. As can be seen in Figure 2 *Heterosigma* was a fairly consistent portion of the blooms which occurred. Yet as shown in Figure 3 some years this species was more responsible for fisheries losses than in other years.

This figure also shows how over time the species responsible for fish loss can change without altering the relative species compositions associated with blooms. In the early 1970's *Noctiluca* sp., *Heterosigma*, *Prorocentum* sp. and other species were responsible for the largest portion of fisheries losses. During that time losses to *Chattonella* were insignificant. By 1987 those species contributed little to the fisheries losses. *Chattonella* however, had by then become the dominant cause of fisheries losses.

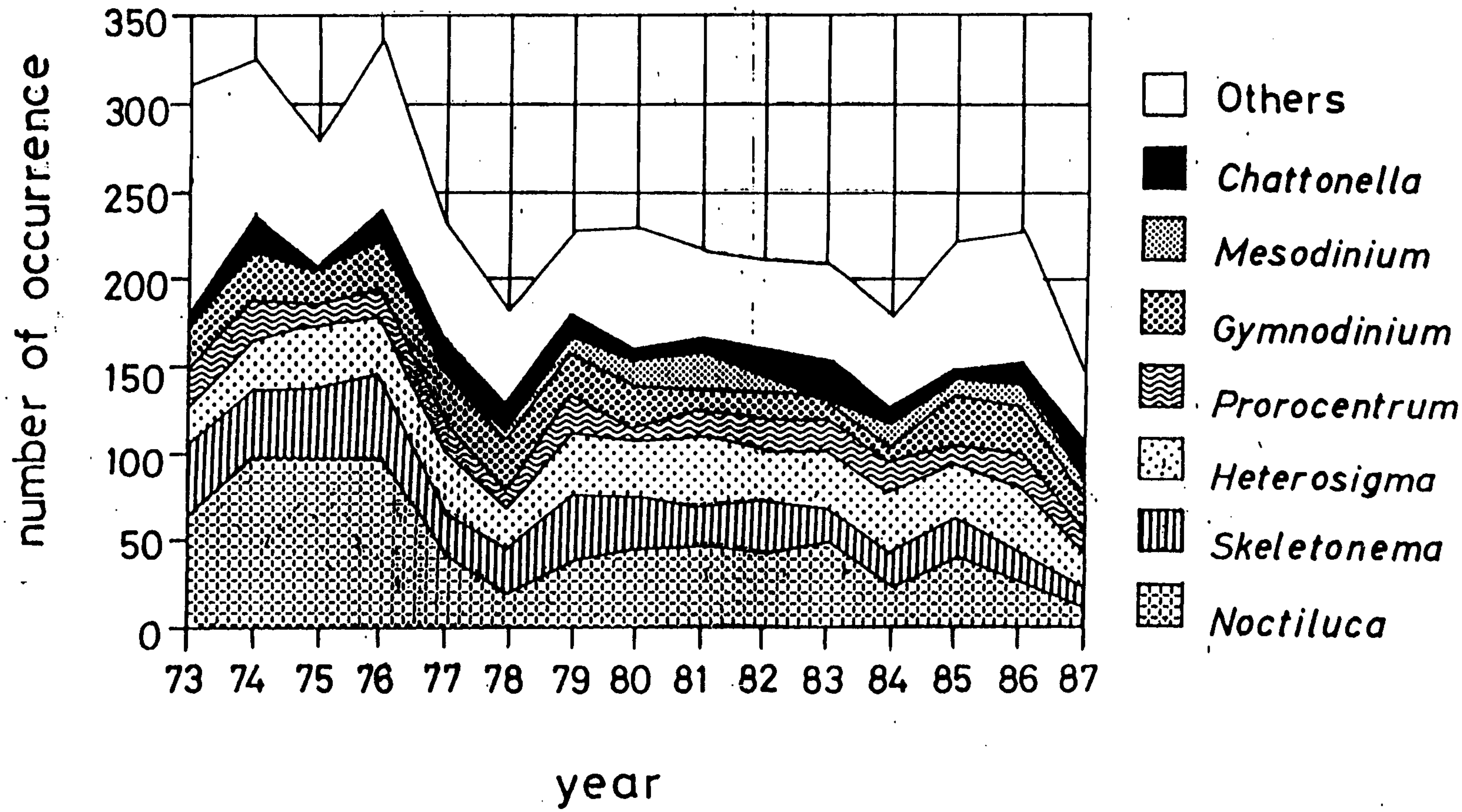
I believe this may have been the result of increasing water temperatures. In the context of monitoring algal blooms and increasing sea water temperatures on our coast this example should demonstrate to us the need to monitor not only for species which have been problematic in the past but also for new hitherto undetected problem species. On that point I would add that though *Chattonella* is not generally recognised on this coast and has not been associated with local fish mortalities, one phytoplankton taxonomist has claimed to have detected this species in samples of B.C. phytoplankton. In some ways this is not unexpected only previously unreported. Most of the problem phytoplankton are found throughout the world within certain latitudes.

**Conclusions:**

Fish farms, though they have limitations as monitors of fish killing algal blooms, can contribute significantly to our understanding of problematic algal species on this coast.

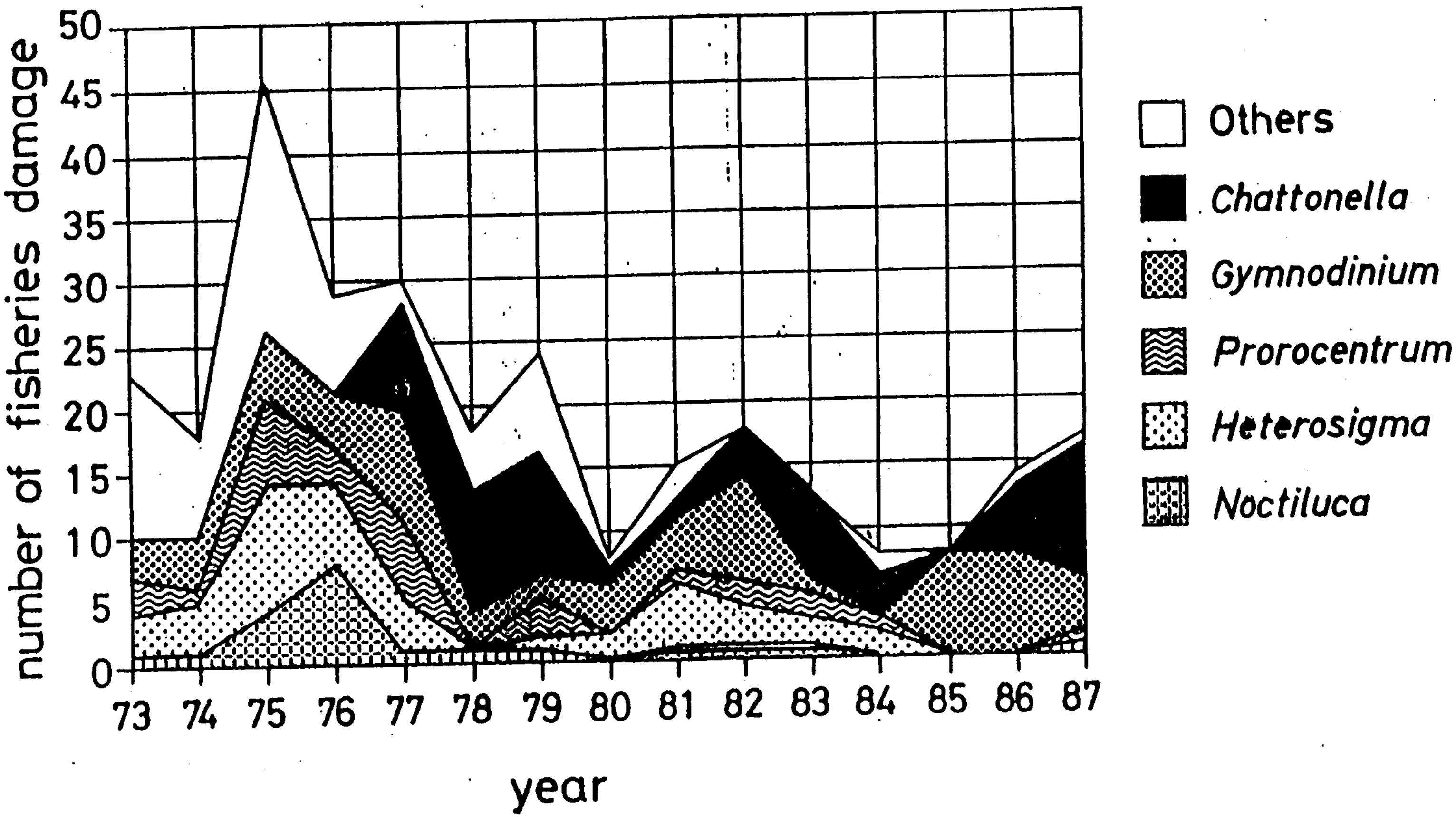
The presence of fish farms has already led to the identification of some algal "hot spots" (areas in which algal blooms appear to be a more common occurrence). This historical record makes possible identification of future changes in algal species causing effects on fishes. Unfortunately, because the industry can and does change its distribution, there will be weaknesses in any analysis of fish farm data for changes in the distribution or overall frequencies of these blooms. In spite of this weakness it can be a very powerful tool when combined with some other techniques such as the satellite remote sensing you will hear about later in a presentation by Dr. Gower.

Figure 2



number of occurrence
350
300
250
200
150
100
50
0
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
year
Others
Chattonella
Mesodinium
Gymnodinium
Prorocentrum
Heterosigma
Skeletonema
Noctiluca

Figure 3



number of fisheries damage
50
45
40
35
30
25
20
15
10
5
0
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
year
Others
Chattonella
Gymnodinium
Prorocentrum
Heterosigma
Noctiluca

## IMPOSEX IN MARINE GASTROPODS

*J. Thompson*

The use of tributyltin (TBT)-containing antifoulants has had varying degrees of impact on shellfish populations around the world in the last 20-30 years (Thompson, et al., 1985 and references cited therein). In oysters, the effects were manifested in reduced growth rates and populations and shell thickening. Controlled experiments with oyster larvae resulted in high mortalities at water concentrations of less than 50 ng.L-1. TBT was identified as the most likely cause of imposex in female neogastropods.

The term imposex applies to the induction of male sex characteristics in female whelks. Its occurrence was first observed in *Nassarius obsoletus* along the southern coast of England (Smith, 1971); but it was not linked to organotin compounds until the mid-1980s (Bryan, *et al.*, 1986, 1987; Gibbs, *et al.*, 1987) when the whelk, Nucella lapillus was found to be severely affected. Quantification of the degree of the effect was made by measurement of penis length in the female. In extreme cases, penile growth blocked the oviduct, thus rendering the animal effectively sterile. In English coastal waters, populations of N. lapillus, have been severely reduced, even at TBT concentrations (water) in the low ng.L-1 range (Gibbs and Bryan, 1986). Thus, imposex induction can be seen as a highly sensitive indicator of TBT contamination and may indeed be useful as a tool in the long-term monitoring of ecosystem trends.

In British Columbia coastal waters imposex has been observed in several neogastropod species. However only *Nucella lamellosa, N. canaliculata*, and *N. emarginata* have shown promise as TBT bioindicators; and only the response of N. emarginata could be related to TBT bioaccumulation using a limited number of samples (Bright and Ellis, 1990). Saavedra Alvarez and Ellis (1990) surveyed species distribution and the incidence of imposex at 38 sites on Vancouver Island and in Washington State and found that six species were affected. All female whelks collected within one km of marinas and harbors showed imposex, with lower incidence under lighter boat traffic conditions. Even at remote sites occurrence of imposex was noted, with only populations at two sites showing no incidence of the condition. The authors concluded that if TBT contamination were the sole cause of imposex in neogastropods, then the entire inside waters of the Straits of Georgia and Juan de Fuca, and Puget Sound must be affected by TBT.

Federal government activities relating to the organotin issue on the Pacific coast were limited (until recently) to a monitoring program managed by DOE begun in the mid-1980s. Analysis for TBT and its degradation products was performed primarily on commercial and recreational fishery species around marinas, harbors and salmon aquaculture facilities. As the use of TBT-based antifouling paints on vessels less than 25 m in length was banned in 1989, the *a priori* assumption might be that concentrations of TBT and its degradation products would begin to subside. Although information from the DOE program is still forthcoming, it appears that concentrations of the butyltin compounds in finfish and invertebrates are decreasing, albeit not as rapidly as some published studies may have predicted. Imposex surveys and related tin analyses were not included in this work.

At the Institute of Ocean Sciences, recent work on sediments and biota also suggests that TBT degradation rates in sediments are slower than half-life determinations would predict. In addition, concentrations of TBT and its ratio to dibutyltin (DBT) also show that: 1. TBT concentrations in shellfish are decreasing slowly and, 2. TBT/DBT ratios in the tissues (including samples of *N. canaliculata*) indicate that significant intake of TBT is continuing (Stewart and Thompson, 1994). Reasons for this may be a combination of the slower degradation rates in sediments and fresh input from ocean-going ships and local sources.
As mentioned above, imposex may serve as a useful and sensitive tool for monitoring environmental TBT changes. Given that the primary source of TBT has been removed it can be expected that its presence in water, sediment and biota will lessen. Because of the sensitivity of species of Nucella to very low concentrations of TBT it may be possible to assess the "cleansing" process by monitoring:

1. re-establishment of populations in areas such as Victoria Harbor where large reductions were observed;
2. using relative penis size (between normal males and affected, immature females) as a measure of the degree of perturbation (Gibbs *et al.*, 1987); and,
3. determining organotin concentrations in pooled samples.

Aside from the studies of Ellis and co-workers (Bright and Ellis, 1990; Saavedra Alvarez and Ellis, 1990) no longer-term monitoring program has been attempted by either government agencies or university researchers. This has been due to a lack of funding at the university level and to a lack of interest in and/or education on the subject by governments. Data from our work and recent reports from the US would suggest that TBT will continue to be a subject of some interest for the foreseeable future. The monitoring of the incidence and degree of imposex in neogastropods is, in our opinion, a viable means of following the fate of TBT in the marine ecosystem.

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# SESSION 3 - SPECIES DIVERSITY AND SIZE SPECTRUM

## TRENDS IN ABUNDANCE AND AVAILABILITY OF ZOOPLANKTON OFF THE B.C. COAST

*D. L. Mackas*

### Rationale for zooplankton monitoring

Zooplankton are the small animals (about 0.1-2.0 cm in body size) that live suspended and swimming in the water column. They occupy a key intermediate position in the pelagic food web. Zooplankton are the main consumers of phytoplankton cells larger than a few $\mu$m in diameter and of the microzooplankton that graze smaller phytoplankton. They are also the principal food source for many pelagic (and some demersal) fish, seabirds, and marine mammals. Although the full local zooplankton community is species rich (100s of species), most of this total food energy transfer passes through relatively few taxa (about 20 species within 6 phyla).

Our rationale for monitoring zooplankton time series is to track the present state of the ocean food web, and compare this against our estimate of past or "average" state. Zooplankton biomass and composition data have several advantages as monitoring variables:

- They provide a direct index of the amount and quality of food available to planktivorous predators (including many harvested finfish, seabirds, and marine mammals).
- Because they are abundant and relatively easy to sample, they provide a good model for direct physical effects (transport, dispersal) on early life stages of other, rarer species.
- Compared to fishery time series, "environment" and "harvest" impacts are more easily distinguished.
- Life cycle duration (usually $\leq$ 1 yr) allows good resolution of important time scales of ecosystem fluctuation: seasonal, year-to-year, and (provided the time series is maintained) decade-to-decade.

### Present activities

DFO has three zooplankton time-series sampling efforts in Canada's west coast Exclusive Economic Zone (EEZ). These are:

- The La Perouse Project (1985-date) off southern Vancouver Island. The bulk of this report will discuss design criteria, results to date, and implications of these results for ecosystem indicators such as "biodiversity", "size spectrum change", and "long-term trends".

- The Cooperative Plankton Research Program (COPRA, 1990-date, led by Shaw) Monitoring goals are similar to the La Perouse Project, but spatial coverage is more broad-brush (see W. Shaw abstract, this volume).

- Jervis Inlet/Strait of Georgia sampling of euphausiid biomass, spatial distribution and size composition (1990-date, led by D. Mackas). The primary goal of these surveys is to provide stock-assessment information for a localized commercial fishery. However, we are also accumulating information about the causes and variability of local spatial aggregation ("patchiness"). Plankton aggregation has a major effect on "availability" to higher trophic levels.

**Design criteria for the La Perouse zooplankton time series**

The La Perouse Project is an interdisciplinary effort involving both "process study" and "monitoring" activities, and scientists at both IOS and PBS. The need to develop a sustained and consistent continental shelf time series was made obvious by the 1982-83 El Niño. By Murphy's Law, this major oceanographic "event" coincided exactly with a lull in scheduled outer coast "process" field work (Brown, this volume?). Both scientists and science managers became very conscious of the need to track interannual variability of physical oceanographic and biotic conditions off the B.C. outer coast. The La Perouse Project was therefore initiated in 1985 to measure changing patterns of currents; water properties; spatially-averaged plankton biomass and species composition; and fish diet, distribution and abundance. Within DFO, a major long-term goal is to learn what components of ecosystem variability are most strongly transmitted up the food chain to commercially exploited stocks.

The zooplankton sampling to date has consisted of net tows at 10-15 standard sites (fig. 1), visited during 5-6 research cruises/year, over a span of 9 years (1985-present). Sampling methods (vertical hauls with Bongo nets) were intentionally kept basic to allow sample collection by non-specialist staff. Sampling locations were chosen to provide stratified "replicates" within statistical regions distinguished by major features of bathymetry and average circulation pattern (Fig. 1). Data analysis procedures were designed to quantify and/or filter out other important components of zooplankton variability, such as small-scaleness and the annual seasonal cycle (Table 1).

Figure 1

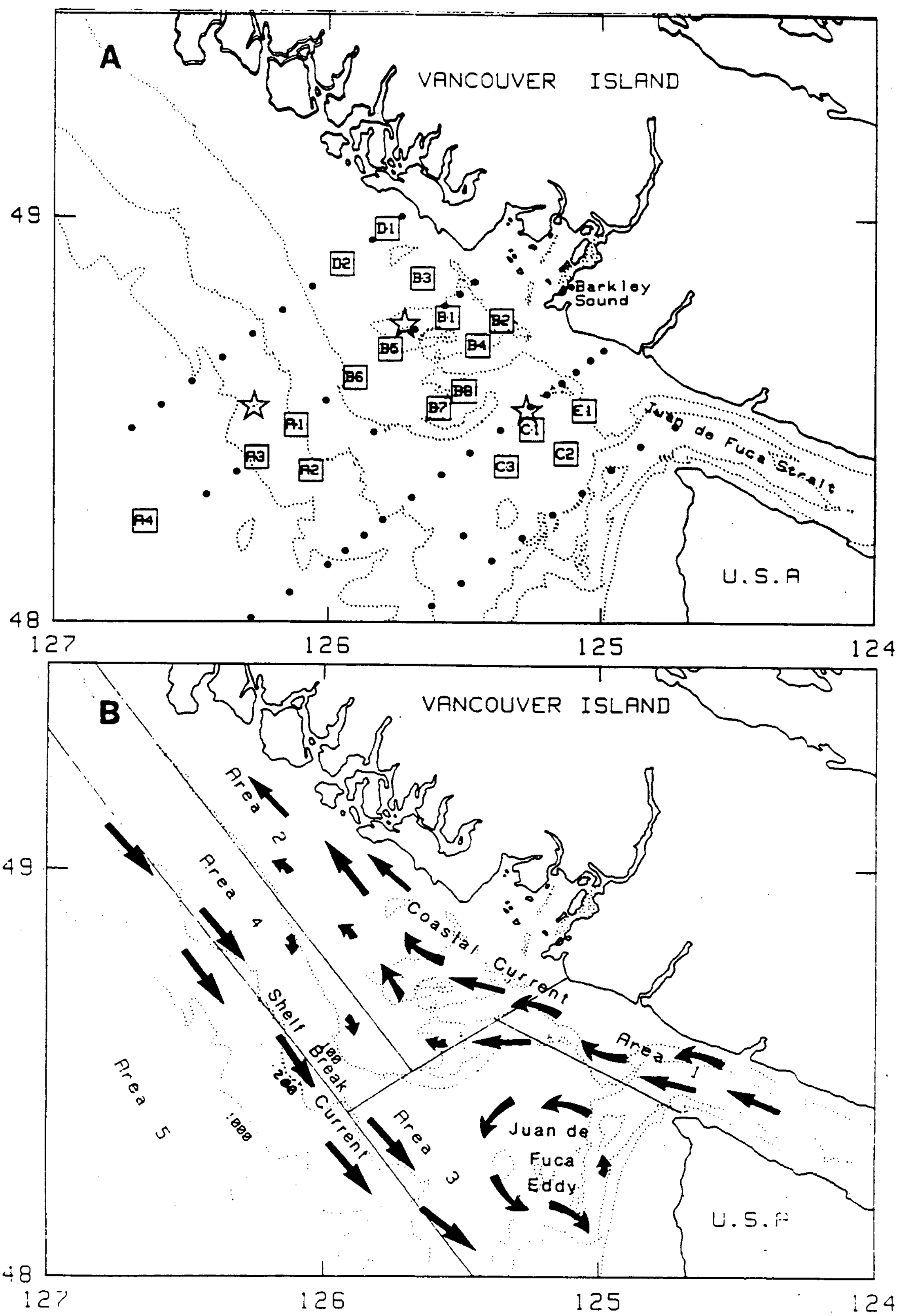

A
VANCOUVER ISLAND
Barkley Sound
Juan de Fuca Strait
U.S.A
D1
D2
B3
B1
B2
B4
B5
B6
B8
B7
E1
C1
C2
C3
A1
A3
A2
A4
49
48
127
126
125
124
B
VANCOUVER ISLAND
Area 2
Area 4
Coastal Current
Area 1
Shelf Break Current
Area 5
Area 3
Juan de Fuca Eddy
U.S.A
49
48
127
126
125
124

Table 1: Components of zooplankton variability and their treatment within the La Perouse Project time series.

| Source/scale of zooplankton variability: | | How dealt with: |
|---|---|---|
| 1. | Small scale and transient patchiness | In time series, minimized by averaging of "replicates" at all levels. (Also treated as "signal" in local process studies) |
| 2. | Persistent mesoscale spatial structure | Stratification of samples into spatial averaging units |
| 3. | Annual seasonal cycle | Averaging within seasons and regions across years |
| 4. | Interannual variability | Averaging within years and regions across seasons of "anomalies" = deviations of "cruise" mean from seasonal mean |

**La Perouse Project results**

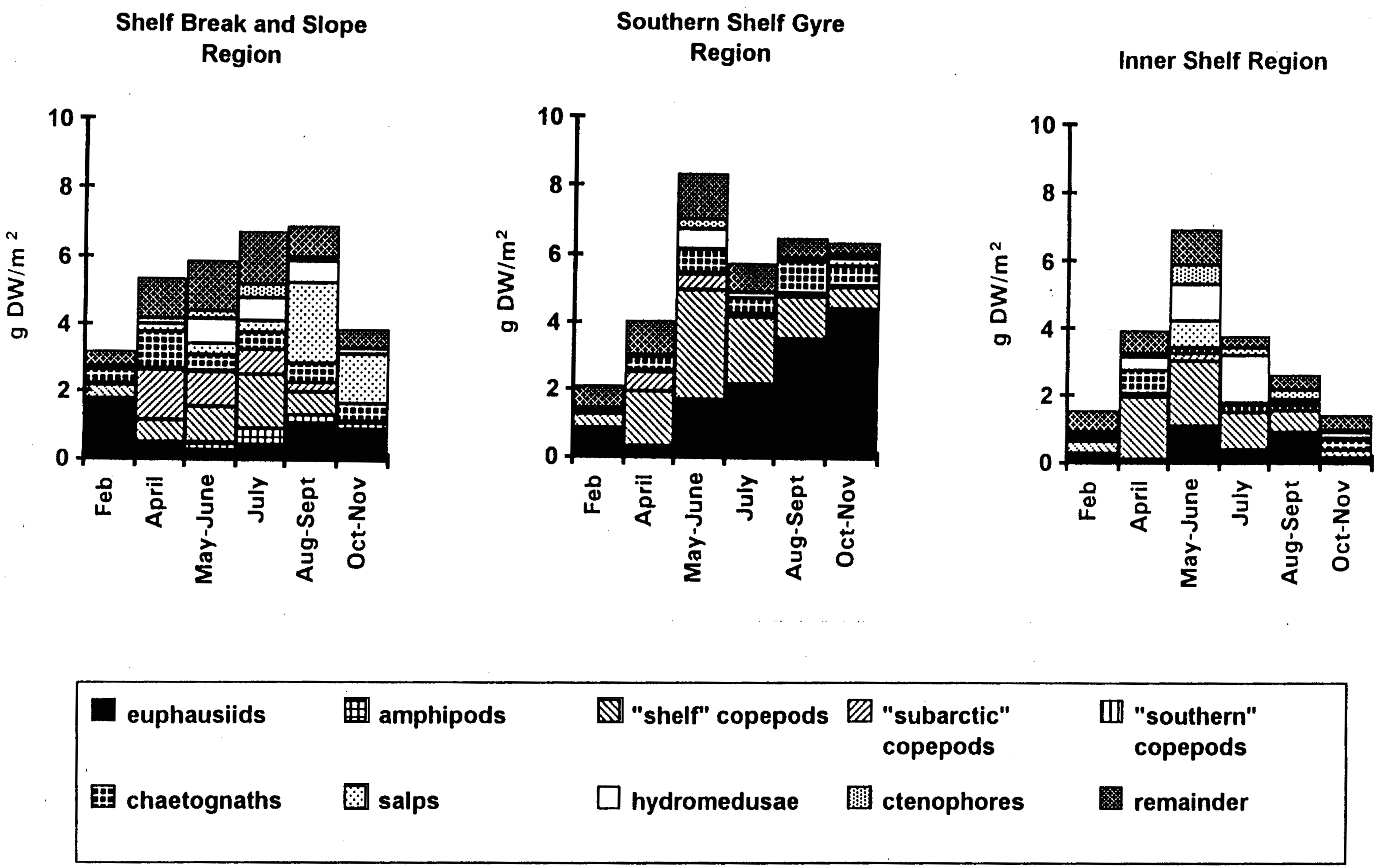
Average zooplankton seasonal cycles within the three statistical areas are shown in Fig. 2 (from Mackas 1992). What is the most important mode of variability? The list of species "present" is essentially the same throughout. But each region clearly has a strong seasonal cycle in both total biomass and component species composition, and the cycles clearly differ among regions. Both the seasonal and among-region differences are comparable in magnitude to what we would consider significant long term change. To avoid aliasing, it is necessary to evaluate long term change relative to a sufficiently resolved "baseline" pattern: in this case the "average" biomass and composition within the appropriate and particular spatial region and season.

Some of the observed year-to-year zooplankton changes are shown in Fig. 3 (from Mackas, 1994 in press). Note that anomalies in biomass-within-species are expressed on a logarithmic scale. An anomaly of +0.3 represents an approximate doubling relative to the long term geometric mean, an anomaly of -0.3 represents about half the long term average. To save space and show shared patterns, anomaly time series of taxonomically and ecologically similar species have been "stacked" in these graphs. What can be learned (so far) from these anomaly time series?

- Most of the dominant taxa show interannual deviations from the multiyear average seasonal cycle that are both statistically and ecologically significant.
- The anomalies last rather a long time (0.3-5 years depending on taxonomic group)
- Within-taxa, the anomalies tend to be larger along and seaward of the continental shelf break than on the continental shelf.

Figure 2

## Average (1979-1991) Zooplankton Seasonal Cycles



Gyre Region

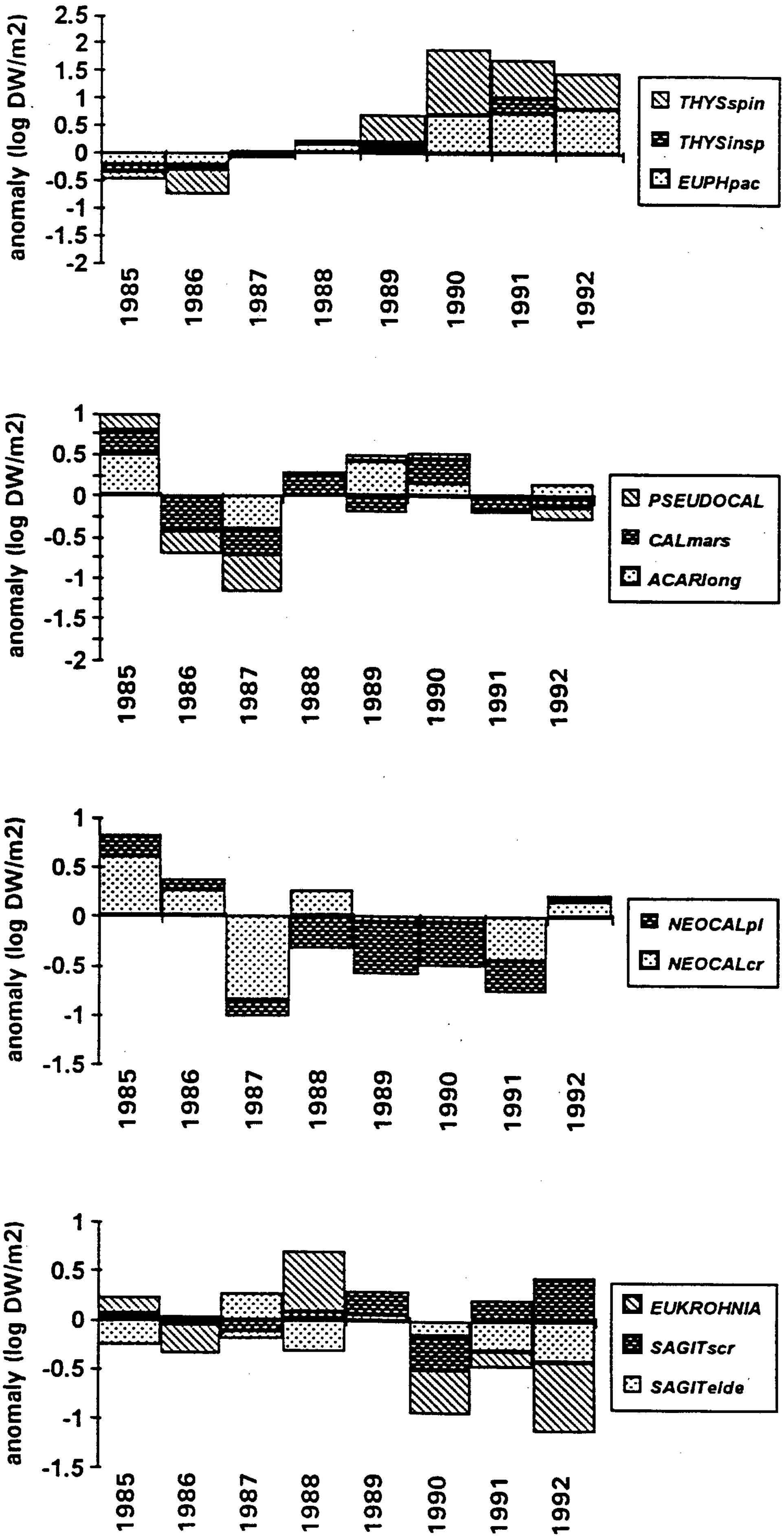



Figure 3

- Significant zooplankton anomalies occur throughout the time series; they are not confined to El Niño years. Both time scale and phasing of anomalies suggest coupling to longer term variations in North Pacific atmosphere-ocean conditions.

**Implications for "State of the Environment" monitoring:**

**1. "Biodiversity"**

The diversity of biological communities has two components:

- "richness" = the total number of different kinds of taxa present, regardless of their relative abundance, and

- "evenness" = a measure of relative abundance ranking, specifically the degree to which many vs. few species are needed to account for "most" of the total biomass.

The term "biodiversity", as used in both UNCED and the popular press, matches neither of these exactly. It usually reflects a concern with the "lost and gone forever" aspect of ecosystem change: species that are in danger of becoming either extinct or extirpated within a significant chunk of their previous habitat.

Although the La Perouse zooplankton data show major changes in species dominance, there is little or no evidence for species loss. Part of the lack of evidence may be due to capability of detection. It is difficult to quantify from non-selective and very large composite zooplankton samples the abundance trends of the rarest species. But there are also sound reasons (high dispersal rate and range, low fixed habitat structure, large total habitat extent) to expect that biodiversity in the marine planktonic ecosystem is less at risk than in more "island-like" terrestrial and shoreline habitats.

As yet, there is also relatively little evidence for outbreaks of introduced exotic species. The major area of concern with the plankton is for potential introduction of toxic phytoplankton species (Chiang, this volume). Although zooplankton specimens (especially if rare or unfamiliar) have fairly frequently been assigned "non-local" species names, the cause seems as likely to be shifting taxonomic definitions as discontinuous long-range (i.e. between hemisphere or between ocean) shifts in distribution. But very clearly, there isn't (yet) a local marine zooplankton equivalent of zebra mussels.

**2. "Size spectrum change"**

This is happening at both seasonal and interannual time scales, as a result of fairly major changes in species dominance hierarchy among the zooplankton.

## 3. "Trends"

I observe significant zooplankton community change over interannual and longer time scales, and have for the most part interpreted this change as driven by large-scale variability of the physical environment (rather than local environmental "poisoning"). For both scientific and management purposes, there are important issues of definition. First, is change over a 5-10 year time scale a "trend" or is it a segment within an interdecadal fluctuation? Extrapolation/prediction of future system behaviour is critically dependent on which of these models we choose. Second, is observed change driven by "natural" or "anthropogenic" forcing? Climate and hydrology are key "natural" forcing variables for the B.C. coast. But they are also influenced by human activity. If we intend to use monitoring output to manage and limit adverse anthropogenic impacts, we need to develop clear and complete lists of what human activities have "leverage" on the natural system.

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## Figure Legends:

Fig. 1. Maps of the La Perouse Project study area off the southwest coast of Vancouver Island, British Columbia. Upper panel shows standards sites for conductivity-temperature-depth (CTD) profiles (filled dots); zooplankton net tows (open squares); and grouping of net tows into three statistical averaging regions: "offshore" sites over the continental shelf break and slope ("A"); "gyre" sites near the Juan de Fuca submarine canyon ("C"); and "inner shelf" sites ("B") in areas strongly affected by the Vancouver Island Coastal Current. Lower panel shows bathymetry and typical summer surface current pattern. (from Mackas, 1992).

Fig. 2. Thirteen-year average (1979-1991) seasonal cycle of zooplankton biomass and community composition in each of the three La Perouse zooplankton statistical regions. Most of the total zooplankton biomass is accounted for by about 20 species in the 9 higher order taxonomic groups shown. There is a strong seasonal cycle in all three regions, but the regions differ in species mix and in the timing and duration of the biomass peak. (from Mackas 1994, in press).

Fig. 3. Time-series of annual anomalies for major zooplankton taxa in the southern shelf "gyre" region. Euphausiid anomalies show a strong trend of increasing biomass: negative anomalies 1985-1986 and positive anomalies 1989-1990. The "shelf" copepods *Calamus marshallae* and *Pseudocalanus* have large negative anomalies in 1986-1987. *Neocalanus* spp. have negative anomalies from 1987-1991. Chaetognath anomalies are mostly small for the dominant species *Sagitta elegans* but are frequently significant for the "oceanic" species *Eukrohnia hamata* and *S. scrippsae.*

# PATTERNS IN INTERTIDAL COMMUNITIES ON VANCOUVER ISLAND AND THE FRASER RIVER ESTUARY, BRITISH COLUMBIA

*R. W. Elner and G. S. Jamieson*

## ABSTRACT

A cooperative experimental monitoring program is investigating long-term trends in abundance and composition of invertebrate communities in intertidal habitats on Vancouver Island and the Fraser River estuary. Two soft-bottom and three hard-bottom monitoring sites around Vancouver Island were established by the Department of Fisheries and Oceans in 1990-1991 as part of an initiative to detect changes in bivalve populations due to global warming. Subsequently, the sites have been jointly maintained with the Canadian Wildlife Service, Environment Canada and combined into a network investigating the ecology of shorebirds and their infaunal invertebrate prey. These remaining sites comprise four 2 kilometre transects located on the extensive sandy\mud intertidal area of the Fraser River estuary, between Westham Island and Boundary Bay, since 1992. Long-term temperatures recorders have been positioned at each of the nine monitoring sites. Sampling frequency has been dependent on biological and tidal considerations, tempered by logistical constraints of such a sustained program. Separate sampling protocols have been developed for Vancouver Island soft-bottom sites, Vancouver Island hard-bottom sites and Fraser River Estuary sites.

Difficulties in invertebrate identification have been overcome with the assistance of taxonomists and the establishment of a reference collection. The database accumulated to-date have allowed the identification of broad seasonal and spatial patterns in invertebrate distribution and diversity plus some appreciation of changes in relative abundance. However, causative physical and\or biological mechanisms for observed patterns and shifts in abundance can only be elucidated by future experimental studies. Also, the patchy distribution of the invertebrates in time and space has brought into question the statistical power of the monitoring procedures; more rigorous statistical designs are necessary. Experience and data show that what was originally perceived to be a relatively simple monitoring project is in fact a complex and expensive, albeit valuable, undertaking.

## CHANGES IN MARINE MAMMAL ABUNDANCE

*T. G. Smith*

## ABSTRACT

Populations of harbour seals have been increasing in B.C. waters since the end of hunting in the late sixties. Rates of increase of 12% \annum were documented for over a decade. There is some indication from recent surveys that this is beginning to level off.

California sea lions, *Zalophus Californianus*, have also increased in numbers in the Strait of Georgia in recent years. Almost all of the sea lions are males which return to southern areas during the summer months.

Stellar sea lions, *Eumetopias jubatus*, appear to be increasing in B.C. at a rate of approxiamtely 2-4%\annum. This contrasts with the drastic decline of the same species in Alaskan waters over the last four years.

Killer whale populations are healthy and well documented in B.C.. A newly discovered offshore group in the northern Queen Charlotte area has added 50+ identified individuals to the already existing catalogue of approximately 300 northern and southern residents. The less well documented transient whales whcih feed on other marine mammals number approximately ------ identified individuals.

Other species of large whales include the relatively numerous gray whales and humpback whales. These populations have all been protected from commercial hunting since 1972 and are increasing in numbers. Little work is usually being done on these species.

Pelagic dolphins and porpoises such as the Pacific white sided dolphin (*Lagenorhynchus obliquidens*), Dahl's porpoise (*Phocoenoides dalli*) and the harbour porpoise (*Phocenaaa cpocena)*, are less well known, locally or regionally abundant, and in need of study.

# A PROGRAM TO MONITOR THE STATUS OF SMALL CETACEANS IN BRITISH COLUMBIA

*R. W. Baird*

## INTRODUCTION

Since 1987 the Marine Mammal Research Group has coordinated a program to monitor sightings, strandings and incidental mortality of cetaceans in the province (see e.g., Baird and Guenther in press; Baird and Stacey 1991, 1993; Baird *et al.* in press; Guenther *et al.* 1993). The purpose of this report is to summarize information on the program, emphasizing the type of information collected and its use in evaluating and monitoring the status of small cetaceans, particularly Dall's porpoise (*Phocoenoides dalli*) and harbour porpoise (*Phocoena phocoena*), in the province.

## METHODS

The program utilizes a toll-free telephone number to collect information from the public (1-800-665-5939). This number is advertised province-wide in coastal communities. A log-book program is also used to collect information from whale watching vessels, researchers, lighthouse keepers, fishery patrol vessels, and some commercial fishermen. When stranded cetaceans are reported (the majority of which are animals found dead on a beach or floating), specimens are collected for examination of natural and anthropogenic causes of mortality, feeding habits, levels of contaminants, and for genetic and life history studies.

## RESULTS

Since the inception of the program almost 300 stranding records and approximately 6,000 sighting records of 20 different species of whales, porpoises and dolphins have been collected. Several biases exist in the distribution of records. The majority of records are concentrated in highly populated areas in southern British Columbia (see e.g., Figure 1), and a seasonal bias also occurs, with few records obtained in winter months.

The number of both sighting and stranding records has increased each year since the inception of the program. The trend in stranding records shown in Figure 2 likely represents an increase in effort, rather than an increase in the number of animals stranding in the province each year. The most common stranded cetaceans each year are Dall's porpoise and harbour porpoise, and in fact the programs' value is greatest in monitoring the distribution, relative abundance, causes of mortality and natural history of these two species.

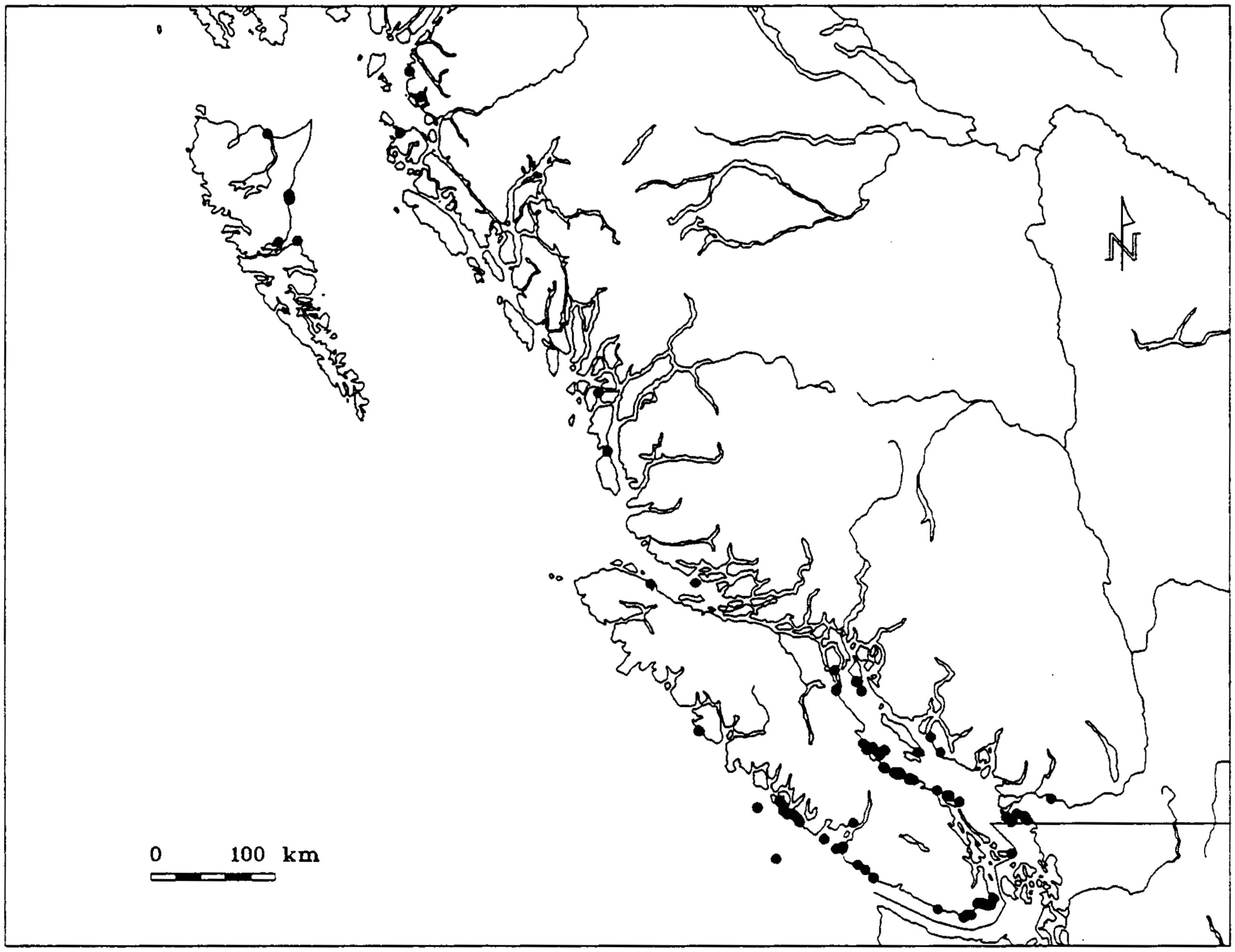


Figure 1. Distribution of stranding and incidental catch records for harbour porpoises (1934-1993), reflecting a geographic bias in reporting effort to populated areas.

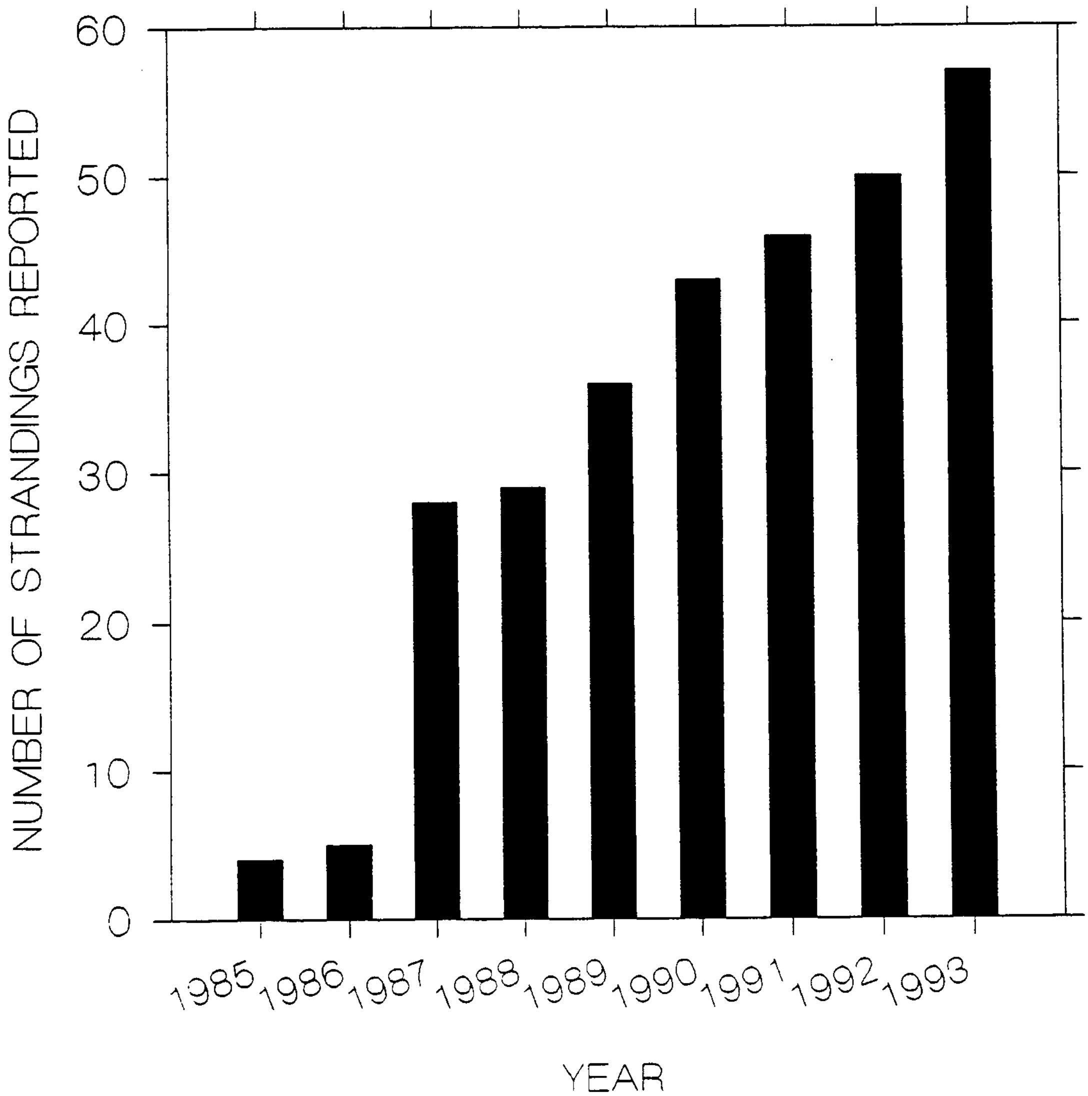


Figure 2. Trend in the number of stranding and incidental catch records reported in British Columbia since 1985. The sudden increase in records in 1987 represents the establishment of the Stranded Whale and Dolphin Program of B.C., while the steady increase in records since then represents a gradual increase in reporting effort.

Information on relative abundance of these two species can be used to identify areas of concentration, even in the absence of other measures of observational effort. For example, utilizing sightings collected in the Victoria area from 1987-1991, there are clear differences in habitat use between Dall's and harbour porpoise (Figure's 3 and 4). Harbour porpoise appear to be generally restricted to depths between 10 and 100 m, while Dall's porpoise are found in virtually all areas deeper than 50 m (Baird and Guenther 1991).

## TRENDS

No information is available on trends in abundance of Dall's porpoise. For harbour porpoise however, anecdotal evidence implies a general decline in abundance since the 1940's. More recently, a comparison of harbour porpoise records around southern Vancouver Island collected between 1987-1993 (Baird and Guenther 1991; Baird unpublished) with records collected through surveys undertaken in the late 1970's (Everitt *et al.* 1980; Flaherty and Stark 1982) indicates a large decline in the population in Haro Strait and Boundary Pass.

## SOURCES OF MORTALITY

Anthropogenic sources of mortality identified include accidental drowning in commercial salmon drift gillnet fisheries, salmon seine fisheries, trawl fisheries, and federal government test and research fisheries. Two harbour porpoises also washed up in Boundary Bay which were killed in U.S. native set gillnet fisheries in the Semiahmoo Bay area of Washington State, apparently the first evidence of cetacean mortality in that fishery (Baird and Guenther in press). Unfortunately no information is available to estimate absolute levels of mortality.

When comparing the size distribution of stranded harbour porpoise in British Columbia with stranding records from elsewhere in North America, there appears to be an unusually high level of neonatal mortality (Baird and Guenther in press). The cause(s) of this high level of neonatal mortality remains unknown however. A combination of sighting and stranding information also allows for the determination of unusual population events, while the occurrence of such events may be missed by periodic population censuses. For example, a small-scale "die-off" of porpoises was recorded around southern Vancouver Island in the spring of 1993. Twenty-four porpoises (both harbour and Dall's) were found dead around Victoria over a two month period, about a ten-fold increase over the average number occurring in that period in previous years (Baird *et al.* 1993). Sighting information collected during this period indicated that the large number of dead porpoises recorded was not due to an increase in the number of porpoises in the area.

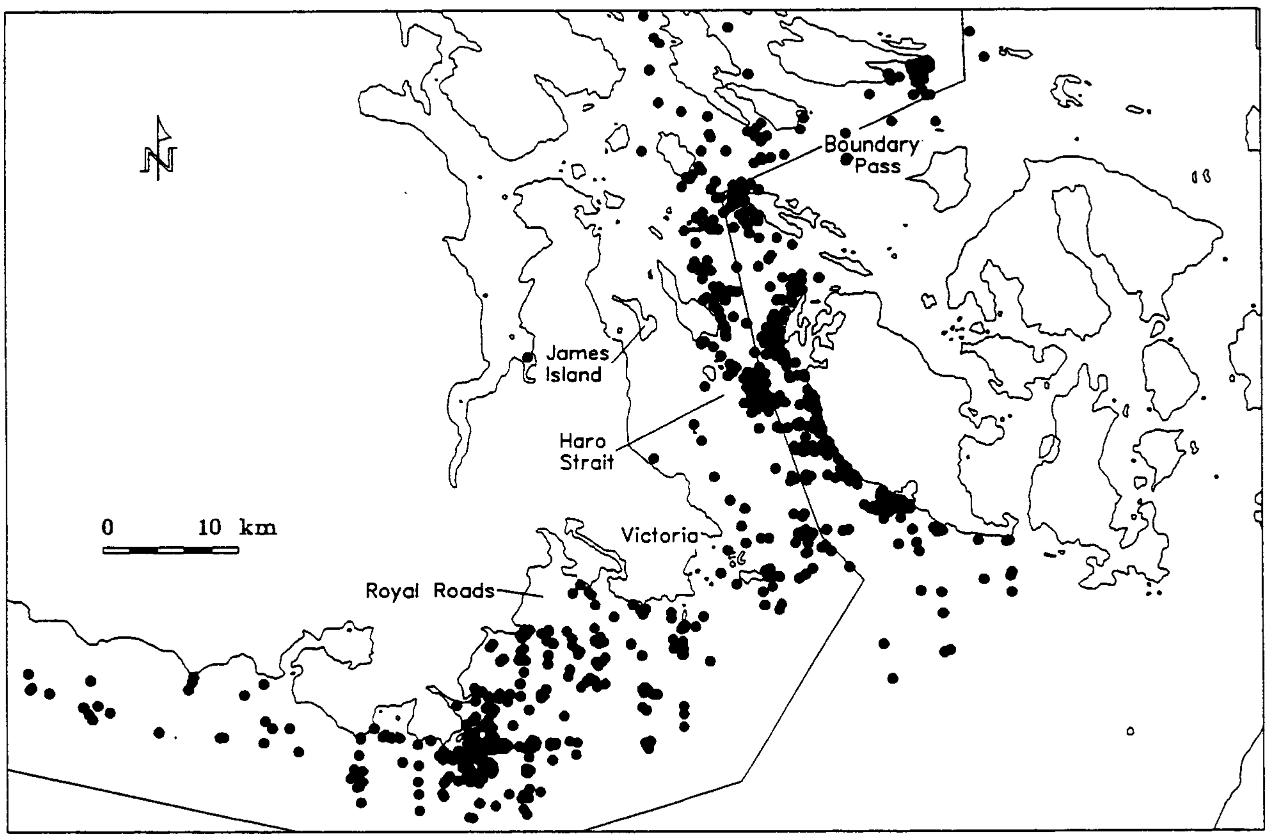


Figure 3. Distribution of sightings of Dall's porpoise in the Victoria area (1987-1991). Note the concentration of records in eastern Haro Strait and in Boundary Pass and the lack of records around James Island and in the Royal Roads area.

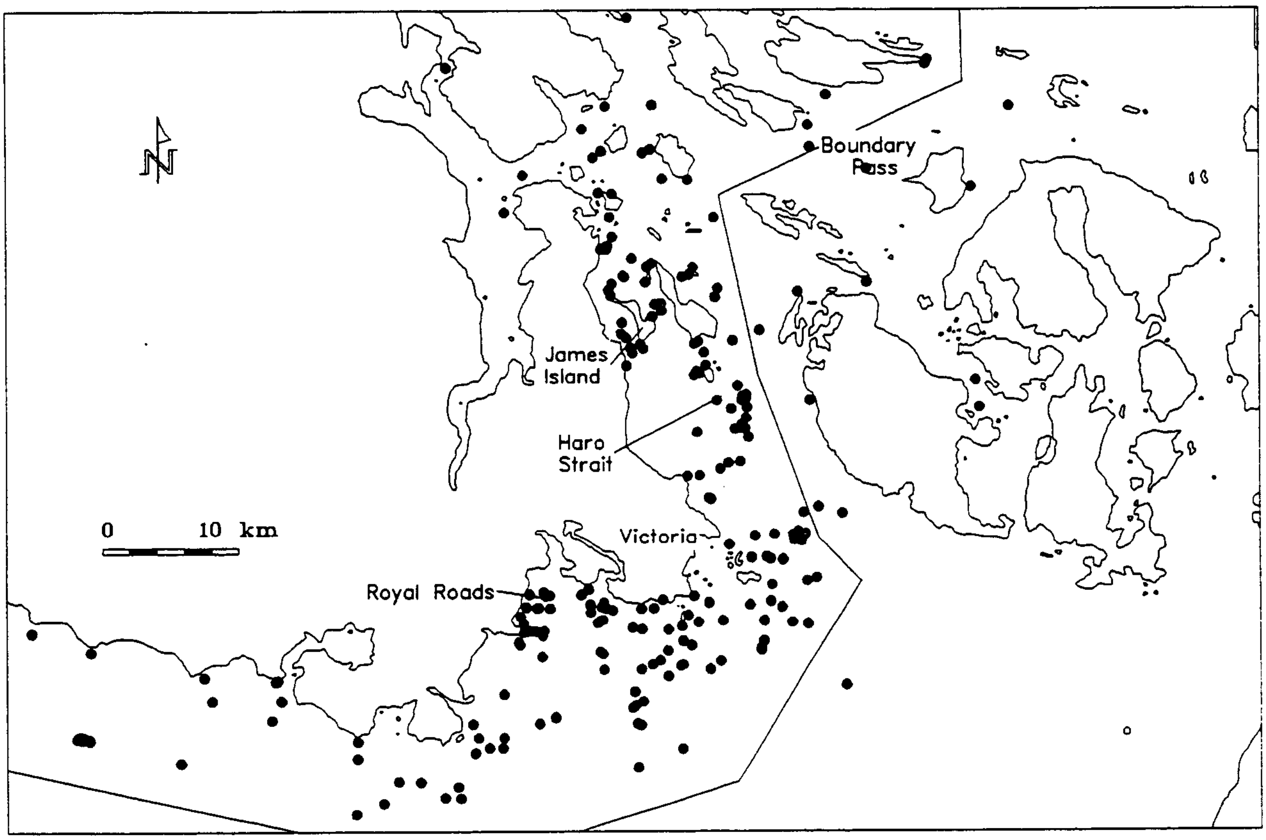


Figure 4. Distribution of sightings of harbour porpoise in the Victoria area (1987-1992), recorded from the same sources as records shown in Figure 3. Virtually no harbour porpoises were recorded in eastern Haro Strait and Boundary Pass, while sightings are regularly recorded around James Island and in the Royal Roads area. Comparisons in distribution of records between species can be used to identify areas of concentration for harbour and Dall's porpoise.

## CONTAMINANT ANALYSIS

Samples of liver, kidney and blubber from approximately 35 porpoises have been analyzed for heavy metals and organochlorines. In addition, samples from over 20 additional individuals of other species of cetaceans have been analyzed. These include killer whale (*Orcinus orca*), false killer whale (*Pseudorca crassidens*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), gray whale (*Eschrichtius robustus*) and minke whale (*Balaenoptera acutorostrata*). Information on some of these contaminant analyses have been previously presented (see e.g., Baird *et al.* 1993).

## RESEARCH NEEDS/FUTURE PLANS

For a variety of reasons (outlined below) harbour porpoise are the most valuable and important candidate for monitoring programs, of the three species of small cetaceans which are regularly found in the province. Harbour porpoises are the most common stranded species of cetacean in the province, therefore the largest sample sizes for toxicology and pathology would be available for this species. As noted, there is circumstantial evidence of a population decline in southern B.C. since the late 1940's, and between the late 1970's and the last five years, but the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was unable to designate the B.C. population due to insufficient information (while the east coast population listed as Threatened). Pollutant ratio information and their year-round presence implies that harbour porpoise have fairly limited movements (Calambokidis and Barlow 1991); thus animals found in areas like the Strait of Georgia likely reside there year-round. As they are generally restricted in habitat to shallow (< 100 m) water, this species is the most likely species of cetacean to spend extended periods of time in prolonged exposure to anthropogenic influences. Their propensity for entanglement in fishing gear also puts harbour porpoise populations at risk in the province. Lastly, utilizing samples collected through this program, it was determined that harbour porpoises have the highest levels of dioxins and furans for cetaceans in the Strait of Georgia, as well as high levels of organochlorines and heavy metals (Muir *et al.* 1991).

A variety of factors are necessary to evaluate and monitor the status of harbour porpoise in the province. These include:

1. Mapping the extent of habitat available for harbour porpoise to identify areas where surveys should be undertaken.

2. Increasing effort for sightings/strandings in northerly and remote areas of the province, as well as effort during winter months.

3. Evaluating levels of incidental mortality in fisheries. This could be done through the use of a questionnaire survey of fishermen. As evidenced by a survey undertaken by Stacey *et al.* (1990), individual fishermen in British Columbia do not appear to perceive incidental mortality of small cetaceans as a serious management problem, possibly because the number of animals caught by any individual fishermen each year is fairly small. Thus a questionnaire survey has the potential to greatly increase our knowledge of the levels, species, and areas where incidental mortality occurs in the province.

4. Initiation of baseline boat- or air-based censuses in areas where potential habitat has been identified.

5. Monitoring of trends in these populations through repeated censuses between years.

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## POPULATION TRENDS OF NESTING MARINE BIRDS IN THE STRAIT OF GEORGIA AND ON THE WEST COAST OF VANCOUVER ISLAND

*K. Vermeer*

Seven species of seabirds nest in the Strait of Georgia, but only four commonly: Glaucous-winged Gull, Pelagic and Double-crested cormorants, and Pigeon Guillemot. The numbers of Rhinoceros Auklet, Tufted Puffin and Brandt's Cormorant that breed are too small to provide trends.

About half of the B.C. population of Glaucous-winged Gulls occurs in the Strait of Georgia. The Glaucous-winged Gull is the most numerous species, making up 71.2% of all seabirds in the strait. The population is rapidly increasing (Table 1), partially due to the availability of garbage, which it uses extensively as food. As colonies of this species increase in size, their reproductive success tends to improve. Smaller colonies appear to be more vulnerable to predation by river otters, Bald Eagles and Northwestern Crows, and have lower productivity (Vermeer and Devito, 1989). An increase in Bald Eagle numbers in the last decade has resulted in increased predation on Glaucous-winged Gulls, but not to an extent to cause their numbers to decline (Vermeer, Morgan, Butler and Smith, 1989).

Nesting populations of Double-crested Cormorants have increased since 1960 (Table 1). Although there is archaeological evidence that Double-crested Cormorants have used the area for the past 5,000 years (Hobson and Driver, 1989), the species has only resumed breeding in B.C. since the late 1920's (Vermeer, Morgan and Smith, 1989). Both species of cormorants show a deceleration of population growth rates since 1983. Little is known of cormorant survival rates and reproductive success, and this impairs our ability to determine causes of population fluctuations. Banding studies are needed to confirm whether there is broad-scale movement among colonies.

Table 1. Colonial seabird populations, Strait of Georgia, B.C., 1960-86 (number of nests or pairs).

| | 1960 | 1975 | Avg. Ann. increase | 1983 | Avg. Ann. increase | 1986-87 | Avg. Ann. increase |
|---|---|---|---|---|---|---|---|
| Glaucous-winged Gull[a] | 6150 | 9791 | 3.1% | ---- | ---- | 13002 | 2.6% |
| Double-crested Cormorant[b] | 203 | 671 | 8.3% | 1606 | 11.5% | 1981 | 5.4% |
| Pelagic Cormorant[b] | 953 | 2149 | 5.6% | 2448 | 1.6% | 2356 | 1.9% |
| Pigeon Guillemot[c] | 658 | 685 | ---- | ---- | ---- | 931[d] | ---- |

[a] from Vermeer and Devito 1989
[b] from Vermeer, Morgan and Smith 1989
[c] from Emms and Morgan 1989
[d] number of individuals not pairs

Trends in numbers of Pigeon Guillemots are difficult to interpret because surveys in different years did not use standardized methodology. Part of the problem in determining Pigeon Guillemot numbers is the difficulty in locating nests, which are well-hidden in crevices or under boulders and logs. To assess the status of this species, it will be necessary to use a standardized census methodology (Vermeer, Morgan and Smith, 1993).

Feeding and nesting conditions within the Strait of Georgia are quite different than on the west coast of Vancouver Island. Many nesting species which are important outside of the strait (e.g. Fork-tailed and Leach's storm-petrels, Cassin's Auklets, Common Murres, Rhinoceros Auklets and Tufted Puffins), but are either not present or scarce within it, likely restricted by lack of appropriate nesting sites, especially for burrow nesting species (Vermeer 1983). Different food composition on the outer west coast, including greater availability of zooplankton (especially copepods), also undoubtly influences the distribution of seabirds, such as Cassin's Auklets, Fork-tailed and Leach's storm-petrels.

The trends of nesting seabird populations on the west coast of Vancouver Island are much less well documented than in the Strait of Georgia. Comparison for nesting populations of Pelagic Cormorants and Glaucous-winged Gulls on the west coast between 1974-75 and 1989, showed that cormorant numbers had declined by 70% and those of gulls by 13% (Vermeer, Morgan and Ewins, 1992). The difference in gull numbers between those periods may be the result of a difference in census methodology. The cause of the drastic decline of cormorants in 1989 is unknown, and may have been a one year phenomenon only, as cormorants are known to skip breeding in "poor" food years (Boekelheide and Ainley 1989).

Population censuses have also been conducted on different alcid species nesting on Triangle Island, at the north western tip of Vancouver Island in the late 1970's and throughout the 1980's (Vermeer 1979; Vermeer, Vermeer, Summers and Billings 1979; Rodway 1990; Rodway, Lemon and Summers 1992). In 1989, population increases of Common Murres, Cassin's Auklets, Rhinoceros Auklets and Tufted Puffins were observed over previous years. Increases resulted from a combination of low reproductive success in earlier years (Common Murres), higher burrow occupancy rate in 1989 (Cassin's Auklets, Rhinoceros Auklets and Tufted Puffins), and because of more thorough censuses held in later years (all species). The only species which expanded both its population and nesting habitat was that of Rhinoceros Auklet. The reason for its expansion is unknown, but may be related to the availability and abundance of its prey, which consists of small fishes.

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## TRENDS IN SELECTED FINFISH SPECIES

*J. Rice*

Unlike many other groups of organisms, often there are significant amounts of data available for finfish species of commercial interest. This makes them potentially useful for identifying trends over time. However, not all data are of equal quality. One cannot interpret patterns in catch data as if they represented patterns in populations. Fig. 1 displays the contribution of major species to the commercial catches in the Strait of Georgia in 1967 and 1990. It is incorrect to infer the herring stock has decreased in size by over a third and hake has increased greatly. Rather, Canada has adopted a more conservative exploitation rate of herring stocks, so catches are a lower percentage of the stock. Also, a market has been found for Pacific hake, stimulating a new fishery. Only when catch data have been analyzed in a full assessment, commonly with some form of sequential population analysis (SPA), can population trends be seen.

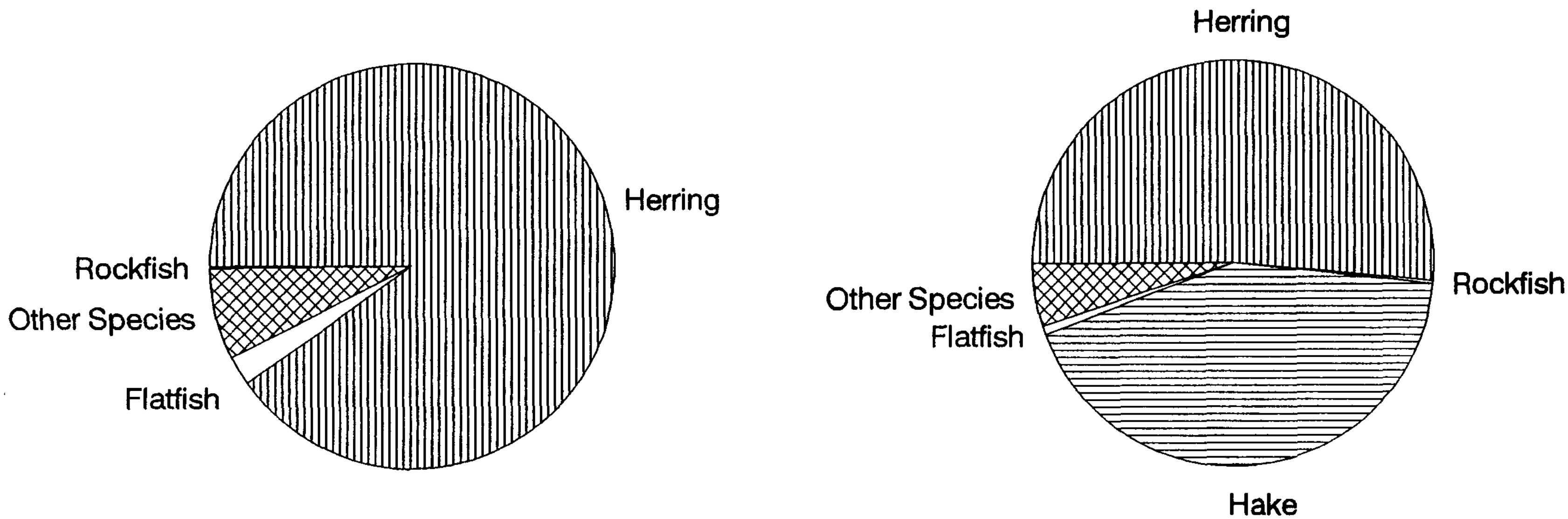
Even the presence of substantial catch (and aging) data does not guarantee the ability to track population trends. There can be changes in fishing vessel efficiency, as well as changes in management policies and market conditions. Pacific Ocean Perch was fished heavily by foreign fleets in the 1960's and the stocks were depressed significantly (Fig. 2). Depending on how much more efficient vessels are today than in 1963, the Perch stock may not have recovered at all (lowest line, 1 unit of effort in 1992 = 5 units of effort in 1963), or may have rebuilt almost completely (uppermost line, 1 unit of effort in 1992 = 2 units of effort in 1963).

Flatfish stocks in Hecate Strait are suitable for identifying population trends. We believe we understand effort in the fishery, we trust the catch, several ages are present in the fishery and the population at any time, and the fishery has been pursued for several decades. From the SPA we have seen both English Sole and Rock Sole have varied two or three fold over 40 years, but presently are at a high level (Fig. 3).

The Hecate Strait Pacific cod fishery has many of the properties of the Hecate Strait flatfish fishery. The stock differs, though, because the natural mortality is higher and recruitment is more variable from year to year. We see much greater variation in the population over the past three decades (Fig. 4), and at present the population is declining. The decline is from a record high level in the late 1980's however, and the stock is still well within the range of observed historic variation.

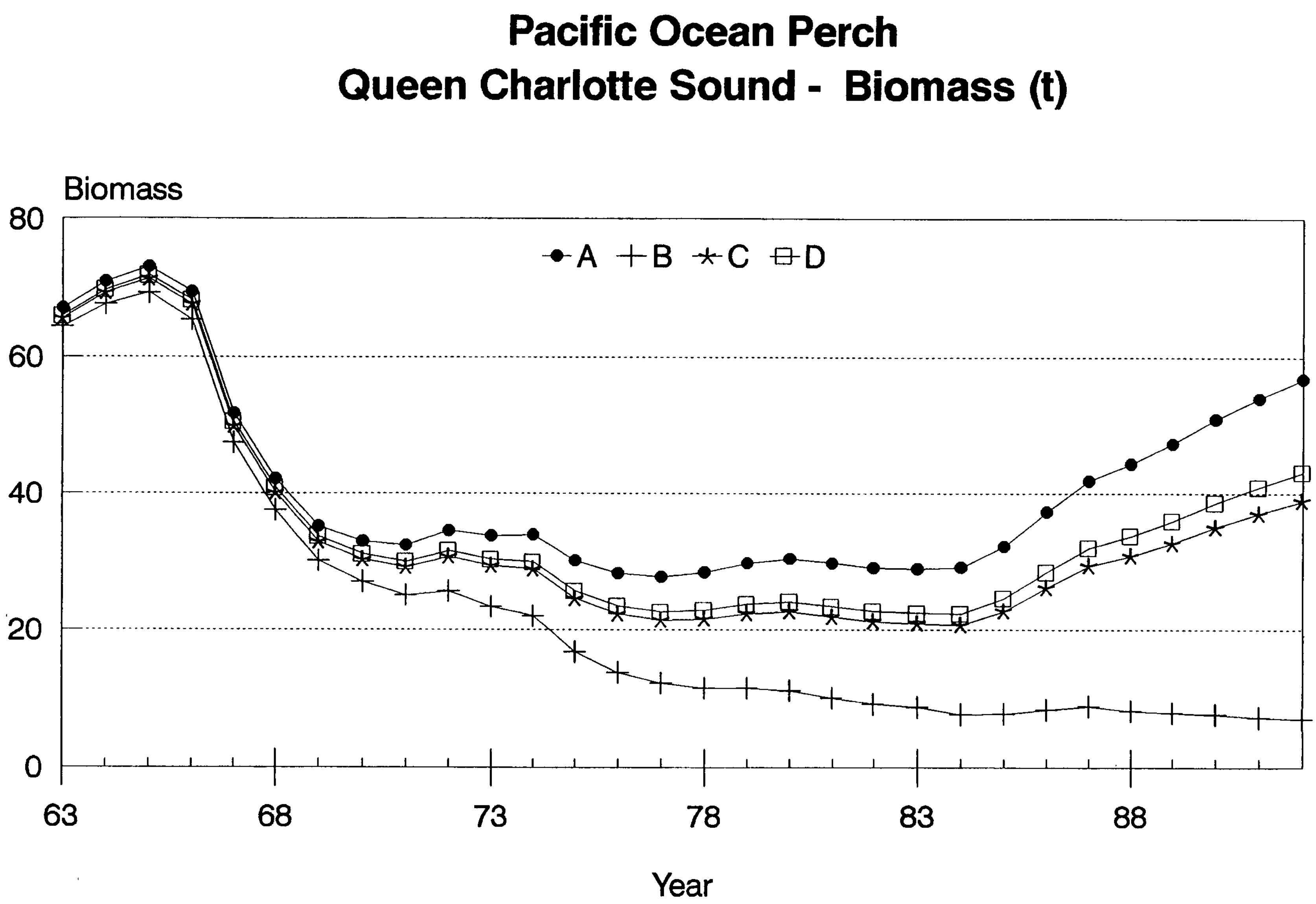
Within the Strait of Georgia, herring are the largest fishery. Although the catch is substantially lower now than prior to the late 1970's, the spawning biomass is a record high level (Fig. 5). We see clearly the change in exploitation rate adopted by Canadian managers of this stock. Spawning biomass is still highly variable over periods of a decade or more, due to environmentally induced variation in recruitment. However, the variability is around

# Strait of Georgia Trawl Landings (t)
## 1967 and 1990



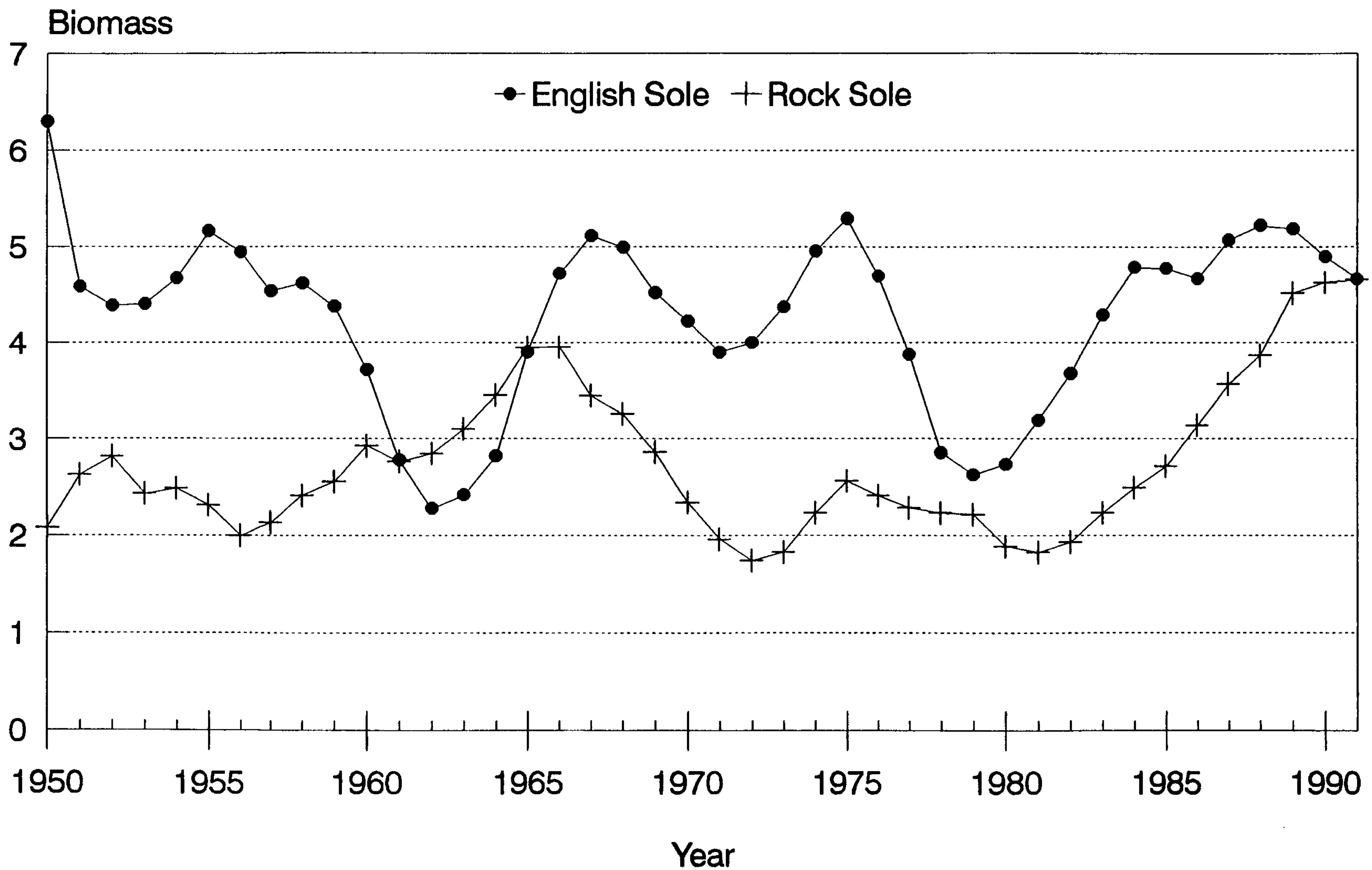

**1967** **1990**

**Note: Herring Landings by all gear types**

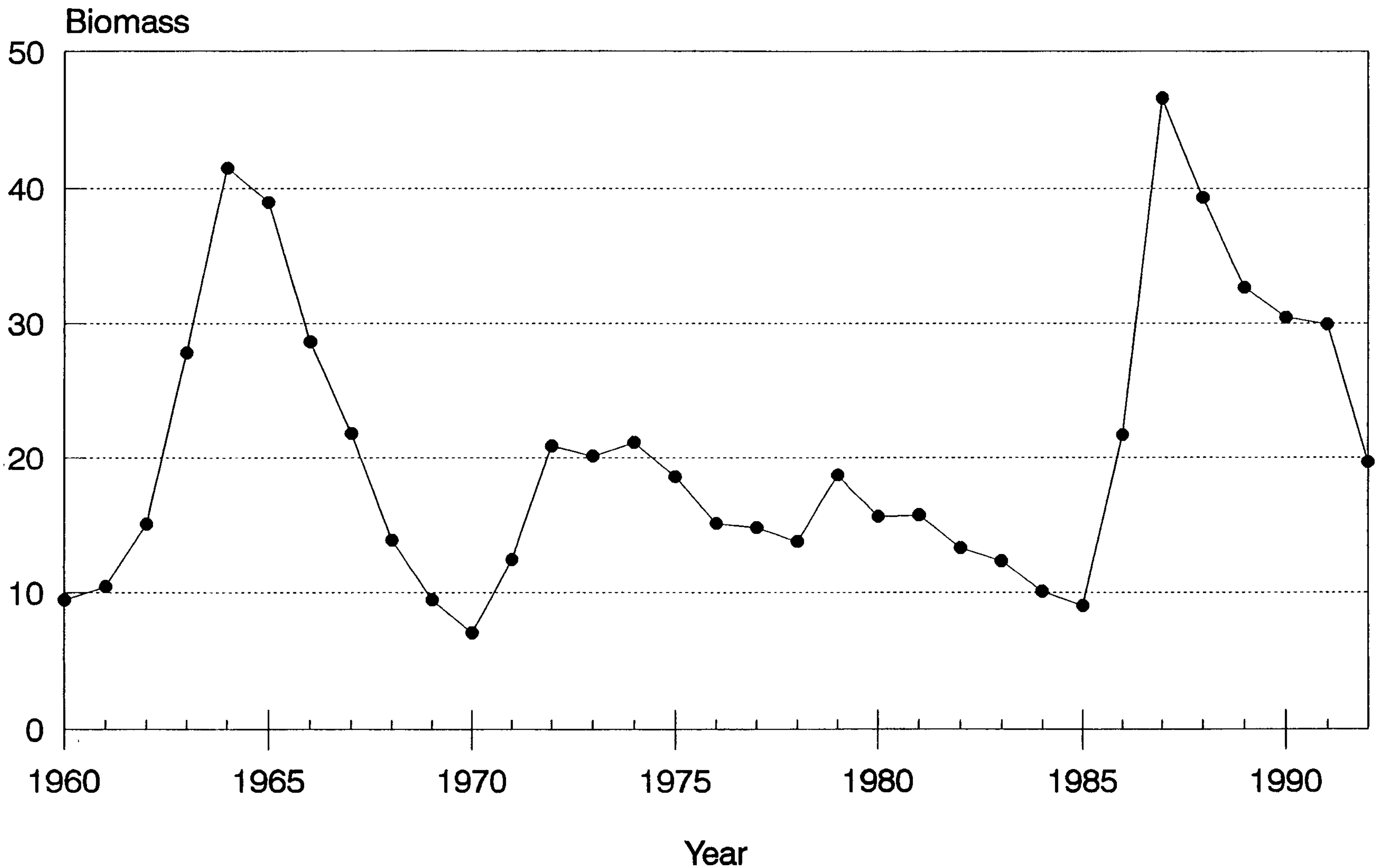



**Various biomass trajectories derived using different assumptions about the relationship between CPUE and Biomass**

## Biomass - English Sole and Rock Sole
## Hecate Strait

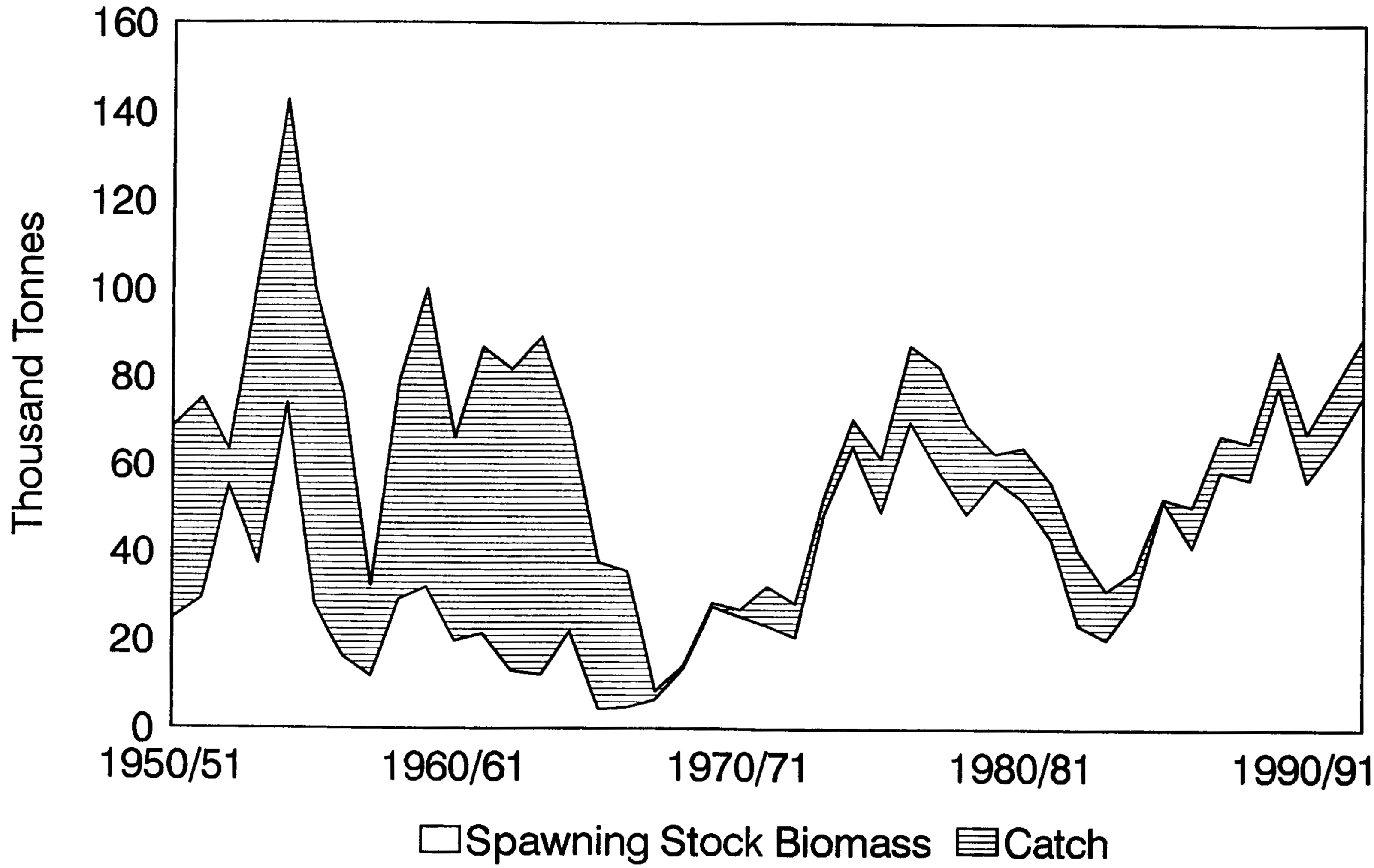


## Pacific Cod Biomass (tonnes)
## Hecate Strait



# Herring Catch & Spawning Stock

St. of Georgia

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a much higher mean level than previously, and recruitment variation is buffered somewhat byrepresentation of several age groups in the spawning biomass.

The other major finfish stock in the Strait of Georgia is Pacific Hake. We have not conducted a full analytical assessment on this stock each year, because of the sporadic nature of the fishery. However, in 1981 three hydroacoustic surveys were conducted. The three surveys estimated similar amounts of total biomass of hake in the Strait, but showed significant changes from January to April in how that biomass was distributed (Table 1). In 1993 the area was resurveyed. Total biomass was substantially larger than in 1981, but population did not change in consistent ways in all areas of the Strait.

Offshore Pacific Hake have been assessed annually for both fishery and survey data. Again, recruitment is highly variable from year to year. Moreover, the stock overwinters off the Southern US, and only part of the stock migrates into Canadian waters. The portion of the stock which enters Canadian territory is larger in warm summers than in cool ones. At present the Canadian portion of the stock is declining, but again from atypically high levels (Fig. 6). The population is still above the long term average biomass.

The distribution of offshore Pacific Hake also illustrates the degree of change in distribution from year to year. The Canadian biomass in 1990 and 1991 were quite similar. However, in 1990 the bulk of the biomass was in the south and east portions of the West Coast of Vancouver Island (Fig. 7); very little hake was found north of 48°39'. In 1991 there was substantial biomass up to 49°00' and beyond the 100 m contour.

In summary, most stocks of commercially fished flatfish are in good shape. Those in decline generally are declining from atypically high levels relative to long term average stock sizes. There are some finfish stocks which are in poor shape, notably lingcod and several species of inshore rockfish in the Strait of Georgia. Those stocks are in good condition outside the Strait.

These examples represent only a few of the many species of finfish the Canadian Pacific. They illustrate trends in which we have confidence. I make no attempt to illustrate patterns in the biomass of all finfish together, however, or of species which are not fished, such as sand lance and eulachon. In some of these species we have some data, but the data are of poor or inconsistent quality. Coverage of the coast is incomplete, and there is no reason to assume the areas covered represent population (or higher grouping) trends. Combining the good data we have on some stocks with poor data on other stocks degrades the value of the good data without enhancing the value of the poor data. It might be interesting to compare the coverage and quality of the data on non-commercial species (which we can show through comparative analyses with our data from commercial species is likely to be unreliable) with data on non-finfish species and communities.

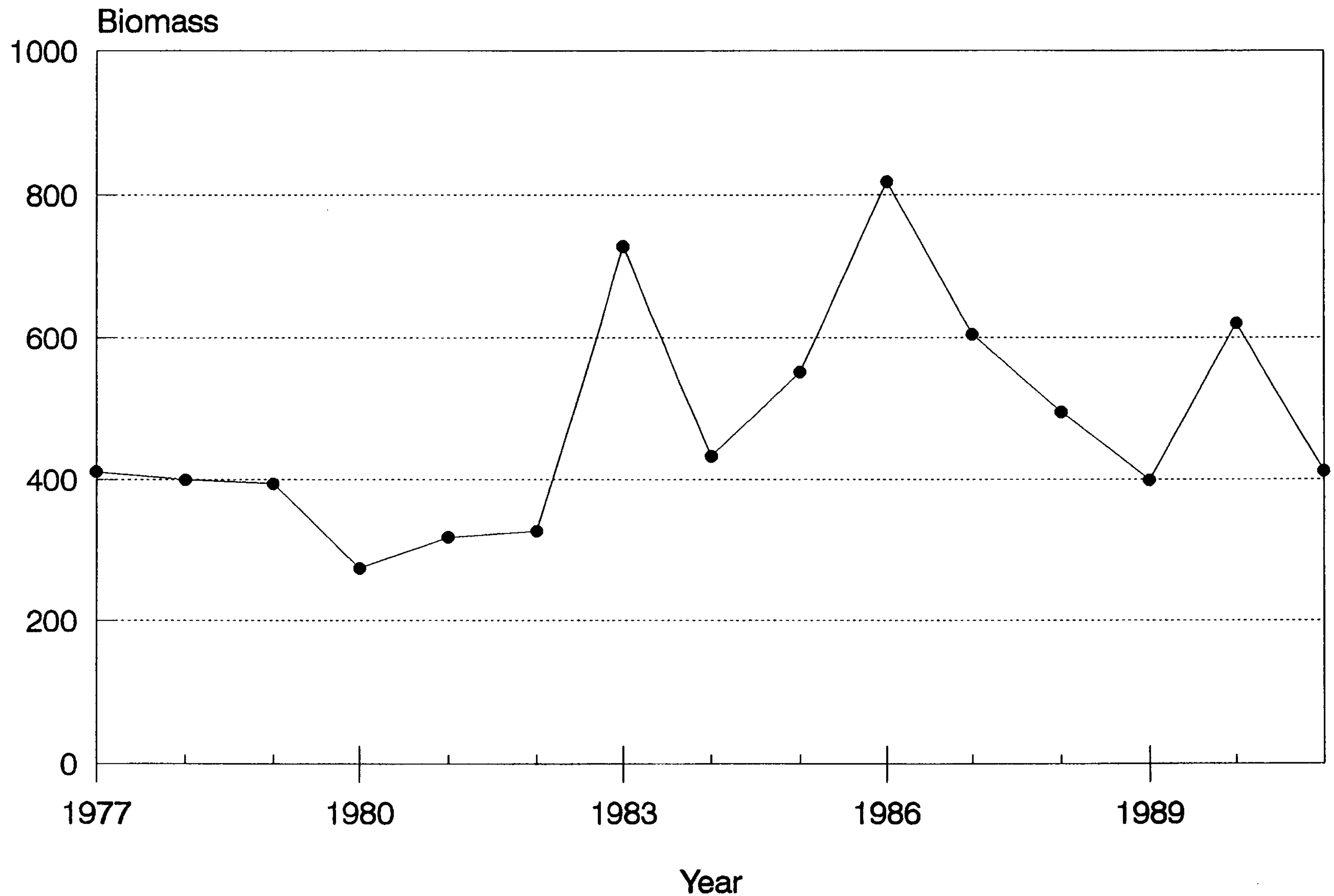
Table 1.

# Hydroacoustic Biomass Estimates of Pacific Hake Georgia Strait - by survey and area

| | Hydroacoustic Survey | | | | |
|---|---|---|---|---|---|
| | 1981 | 1981 | 1981 | 1988 | 1993 |
| Area | JAN | FEB | APR | MAR | MAR |
| South | 43,200 | 78,400 | 100,800 | 128,462 | 134,416 |
| North | 28,000 | 36,800 | 12,760 | - | 87,118 |
| Malaspina | 19,960 | 22,600 | - | - | 14,832 |
| NE | 5,380 | 5,140 | - | - | - |
| Sabine | 2,000 | 7,380 | - | - | 8,099 |
| Total | 98,540 | 150,320 | 113,560 | 128,462 | 244,465 |
| Area ($km^2$) | 4,618 | 4,492 | 4,491 | 1,184 | 4,902 |

| | Sept-volume Survey | |
|---|---|---|
| | 1981 | 1988 |
| Area | MAR | MAR |
| South | 125,600 | 112,545 |

## Offshore Pacific Hake



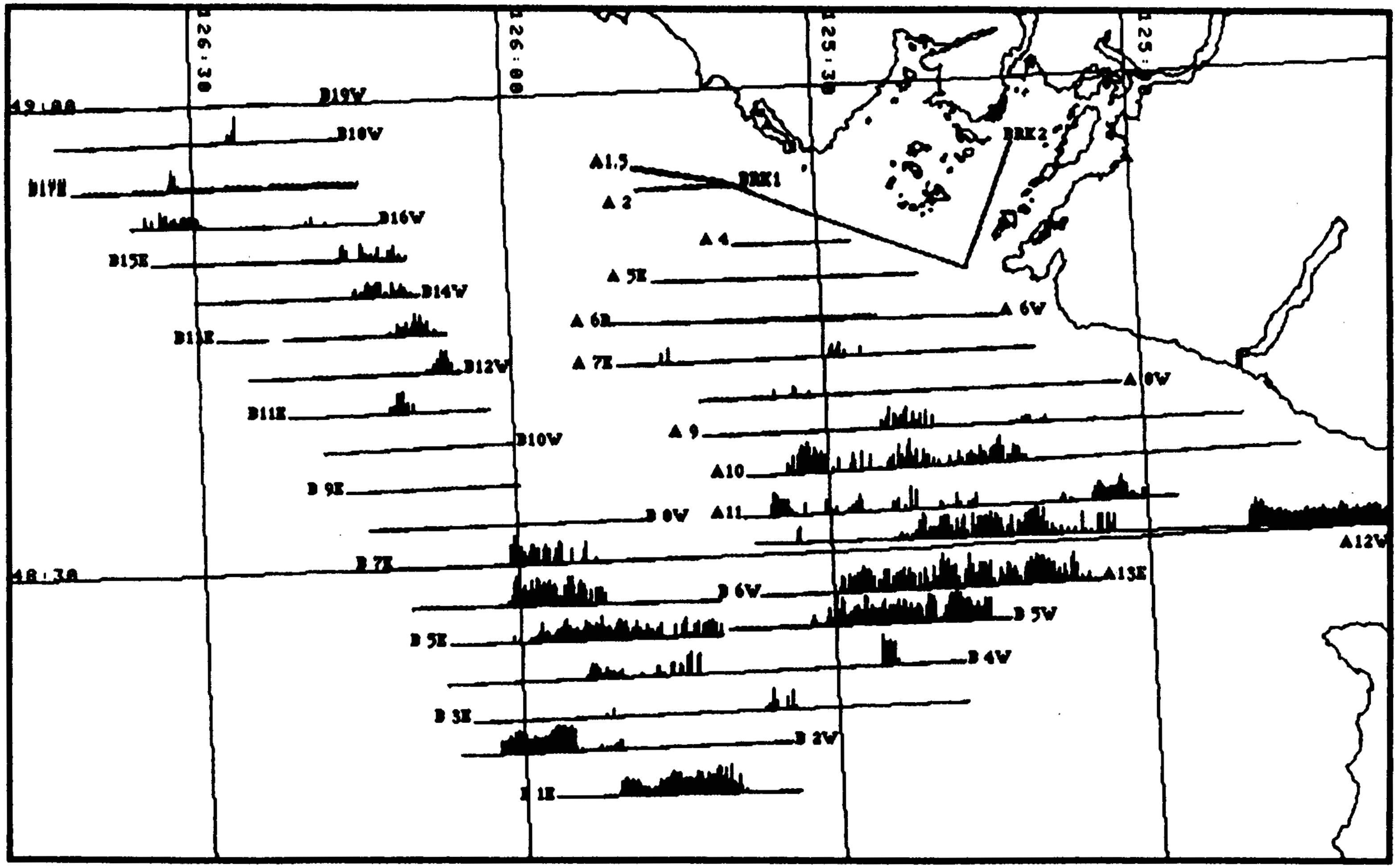


Figure 7. The surface density for hake only, 'A' and 'B' transects. Surface densities are represented by vertical bars on a long scale ranging from 0.01 to 1.0 kg/m$^2$.

# SESSION 4 - PRIMARY PRODUCTIVITY AND NUTRIENTS

## REMOTE SENSING OF ALGAL BLOOMS

*J.F.R. Gower*

Overview

1 Satellite observations of blooms

Ocean Colour Observation by Satellite
NOAA AVHRR for "bright water" events
"Red tide" or suspended sediment?
Queen Charlotte image series
Access to data: local receiver, Seawifs

2 Use of satellites in bloom prediction

GF-9 numerical model and input data
NOAA AVHRR surface temperature
NOAA AVHRR "bright water" plumes
Data communication
Status

3 Conclusions

### Satellite Ocean Colour Measurements

Satellite images can show the near-surface concentration of marine phytoplankton by optical measurement of water colour.

CZCS: In 1978 NASA launched an experimental Coastal Zone Colour Scanner, CZCS, which lasted under 1986.

Seawifs: In 1994, after an 8 year data gap, Orbital Sciences Corp. will launch the follow-on "Seawifs", under a contract to NASA>

Other: Specialized instruments will seen be launched by Japan, France and Europe.

MERIS: ESA's "MERIS" instrument will also exploit the chlorophyll fluorescence investigated by Canada's FLI and CASI instruments.

General purpose eg NOAA AVHRR satellite optical imagers will also sense plakton blooms when these are sufficiently intense. Two spectral bands of the AVHRR can be used to form "Bright water" satellite images.

Band 1 - band 2 difference images are formed with signal scaling adjusted for optimal cloud and sun glint suppression. A variable offset allows for signal changes across the swath.

Pseudocolours represent increasing band 1 (- band 2) radiance, from dark to light blue to green, yellow, red and finally white, corresponding to about 5% reflectance. Clouds and land are masked to black.

All images are partly obscured by clouds, some dates show full cloud cover. In 1992, the image sequence is also interrupted by weekends when staff were not available to steer the antenna. An automated system has been in operation since October 1992.

Band 3, 4 and 5 images show associated water temperature pattersn. They show no clear correlation between temperature and brightness. They are also more sensitive to thin cloud than the difference images shown here.

**NOAA AVHRR data availabiltiy**

NOAA AVHRR images can now be collected with low-cost satellite receivers, costing about $US 15,000. Such a system has been installed on the roof of the Institute of Ocean Sciences in Sidney, B.C.

The systems use a dish only 1.2 m in diameter, which requires no special installation.

Systems are PC compatible. Data files from a full swath, with the 10 bits stored in 16 bit words occupy about 100 Mbytes.

Image data can be stored on DAT ane Exabyte tapes which hold 10 to 30 files at a cost of about $1 each.

Data is avaialble from NOAA 9, 10, 11, 12, but only 11 has the "afternoon" equator crossing that gives better illumination. NOAA 13 was in an even better "noon" orbit, but was lost during launch.

**IOS receives and stores the data from two passes of NOAA satellites each day. Images are photographed and can be viewed at IOS to assess coverage and cloud cover. Digital images can then be retried from tape and provided to users in a variety of formats. Each band of an image of a small sub-area of 512 by 512 pixels, covering about 560 km square, occupies 250 Kbytes, so that about four such images can be stored on a floppy dis.**

Seawifs should be compatible with these AVHRR receiving stations, making them good investments for "ocean" institutes. They are being installed at IML, NAFC, BIO, CCIW. Queen Charlotte Image Sequence.

A series of "Bright water" satellite images from the first year of operation of the IOS reciever shows what appear to be intense plankton blooms in Hecate Strait and Queen Charlotte Sound from July 28 to August 24, 1992. Figure 1 shows a map of the area. Images are geometrically corrected, with a coastline superimposed. Each scence is 560 km across, centered on Cape St. James. Orientation is governed by the mean azimuth of NOAA 11 at this altitude. Images are scaled to allow for different mean sun elevations over the target area on different days.

The water colour changes should have been clearly visible from a boat or aircraft, but the only other records of this event were an aircraft sighting near Milbanke Sound and a water sample showing a bloom of *Noctiluca scintillans* off Moresby island.

Up to July 24, images show fait patterns near the north end of Vancouver Island, but no features in Hecate Strait. On July 28 and 29, patches of brightened water appeared along the shoreline of Milbanke Sound and off the east coast of Moresby Island and spread and brighten on July 30 and 31 (Figure 2). On the 4th and 6th of August the event covered an area about 60 km across, and appeared to have reached its peak (Figure 3). On the 7th clear sky gives a view of jets being pulled from both patches by surface currents, eastwards from Moresby Island and south-westwards from Milbanke Sound (Figure 4). By the 12th, aptterns had started to face and the whole of Hecate Strait was covered with complex patterns characteristic of an eddying current field (Figure 5). The patterns finally disappeared by August 26.

No similar event was observed in 1993.

**Bottom Sediment Re-suspenion?**

In some areas, for example shallow seas with high tidal currents, presence of variable amounts of suspended sediments will confuse the detection of plankton blooms using only "brightness" in satellite images.

On the west coast of Canada this appears to be a problem only in fjords and near river mouths.

Sediment resuspension by waves is possible in some shallow areas of Hecate Strait. However, buoy measurements of winds, waves and temperatures are available at several locations in the area including buoys 46183 and 46185 whose locations are shown in Figure 1.

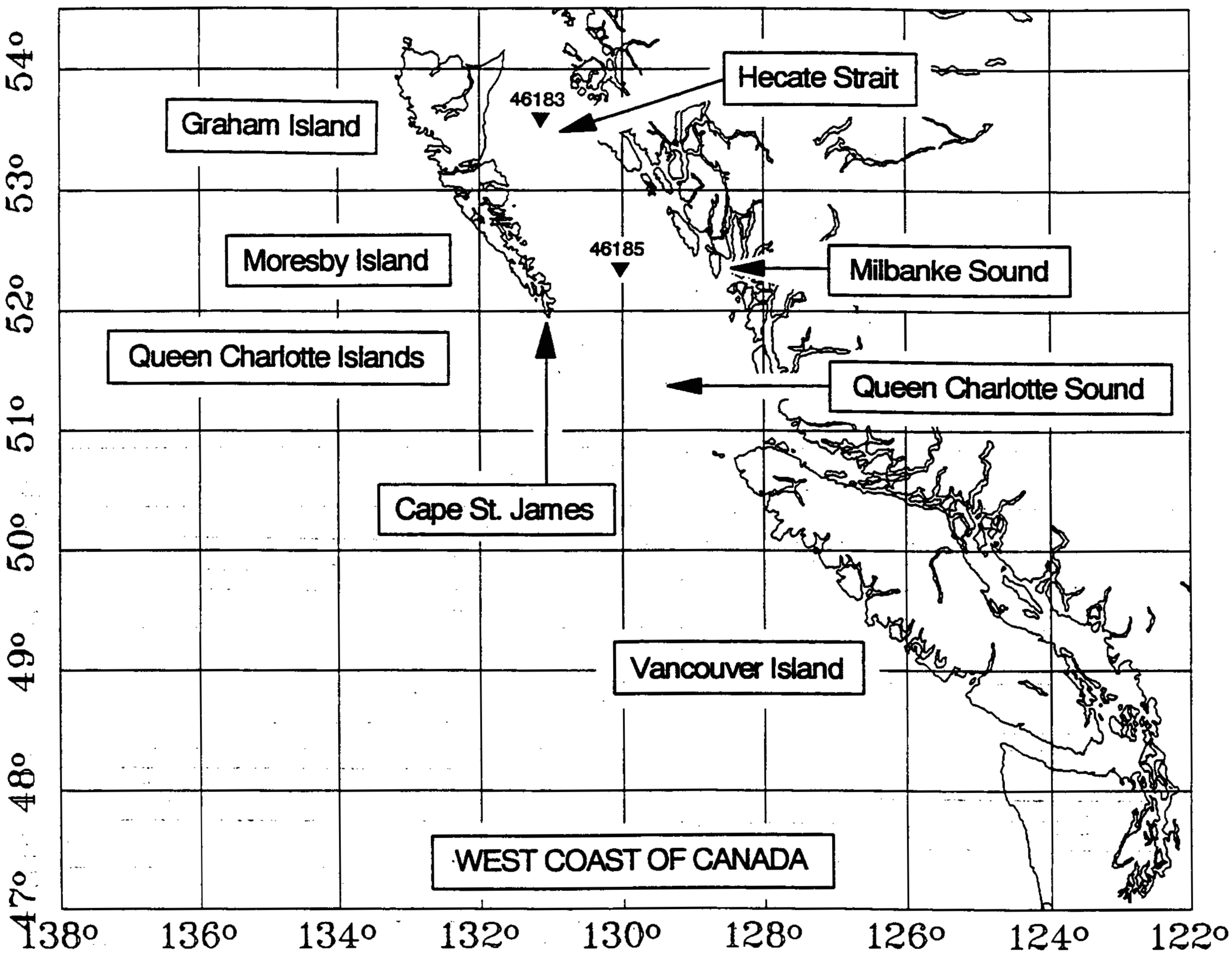



Figure 1. Map of the study area showing locations referred to in the text.

11N19845 AVHRR 31 July 1992

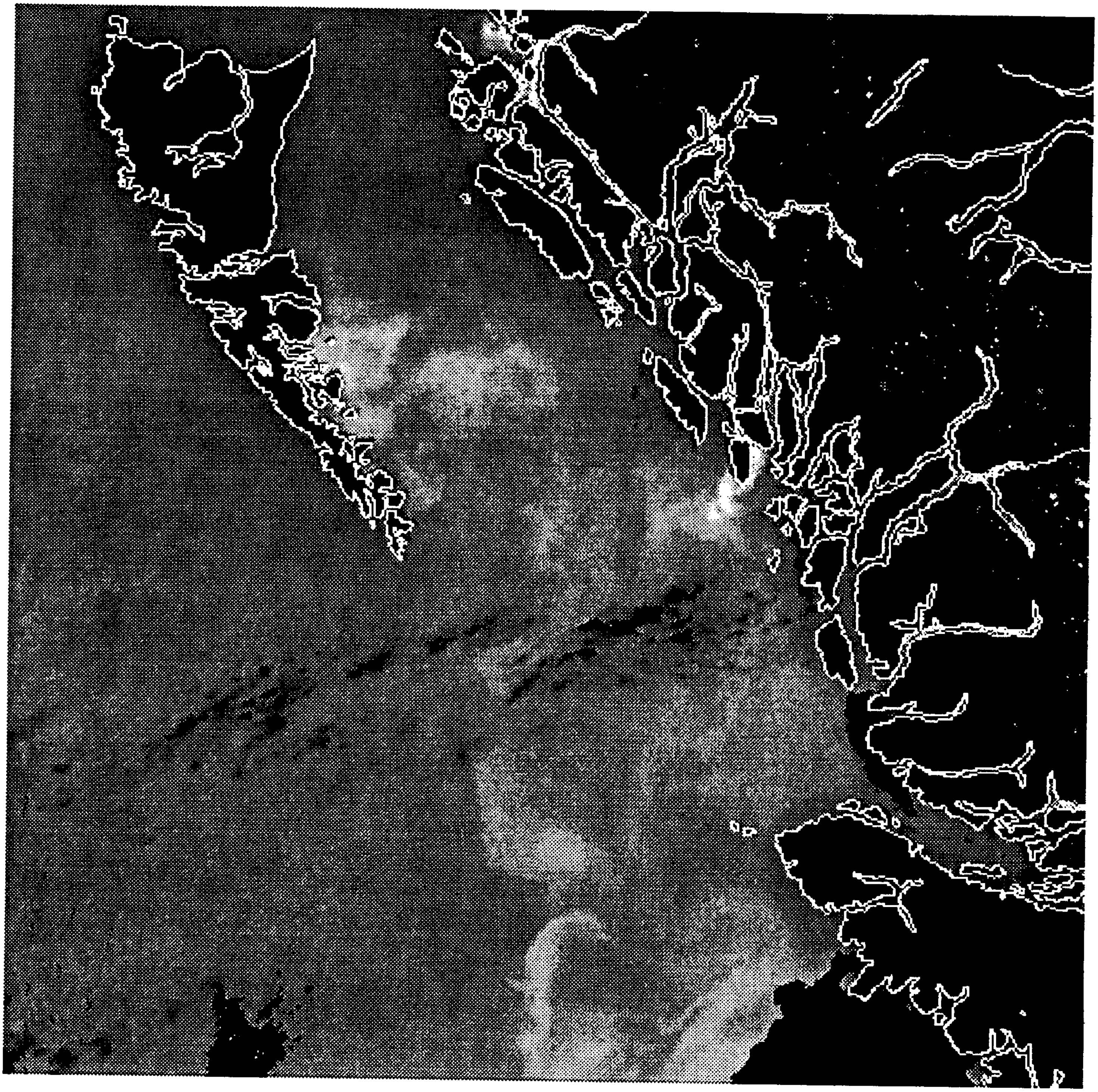


Figure 2. Image derived from NOAA AVHRR satellite data (bands 1 and 2) showing areas of brightened water in Hecate Strait and Queen Charlotte Sound due to a plankton bloom on July 31 1992.

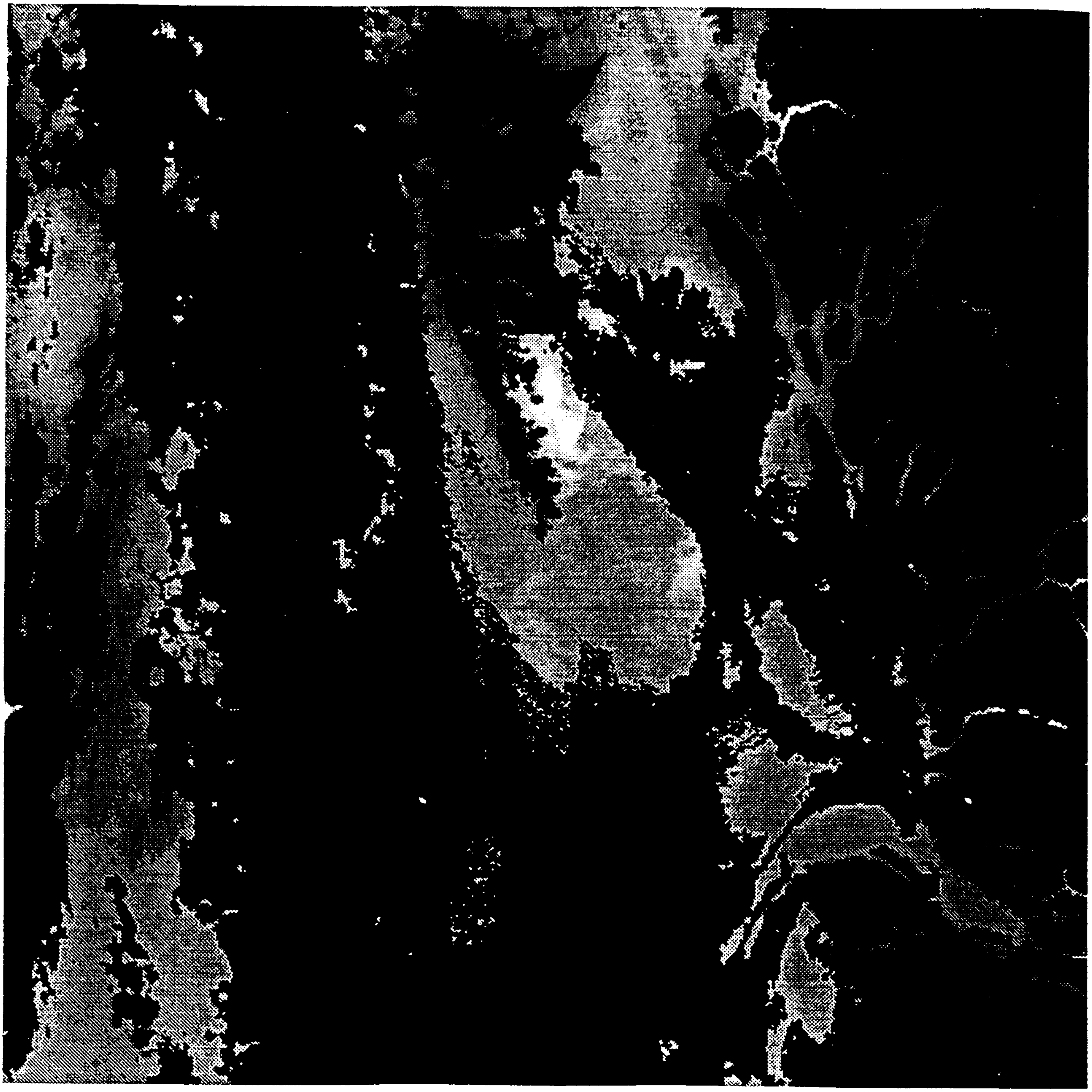


Figure 3. As for Figure 2, but for August 4, 1992.

11N19944 AVHRR 7 August 1992

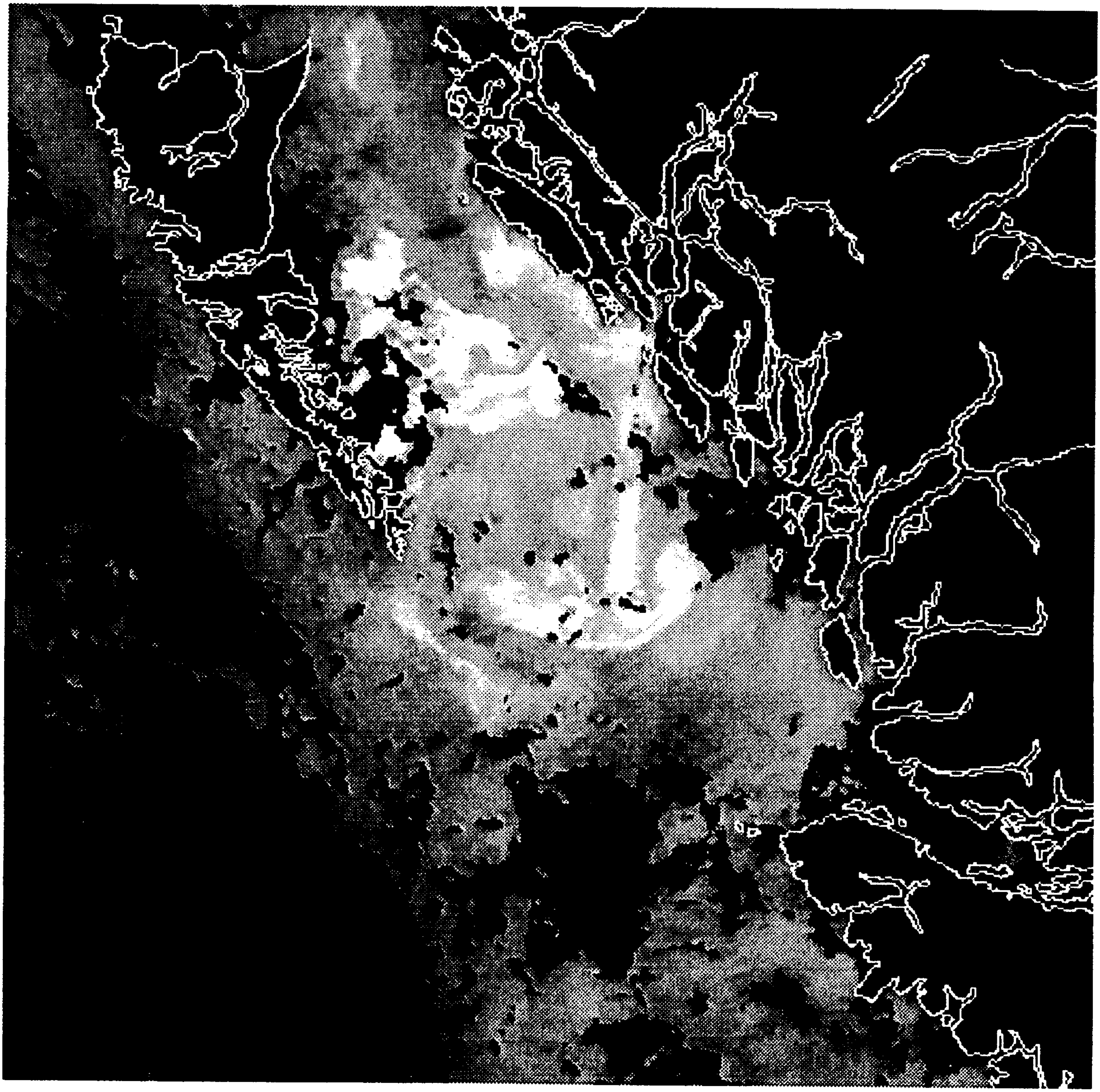


Figure 4. Image derived from NOAA AVHRR satellite data (bands 1 and 2) showing areas of brightened water in Hecate Strait and Queen Charlotte Sound due to a plankton bloom on August 7 1992.

11N20015 AVHRR 12 August 1992

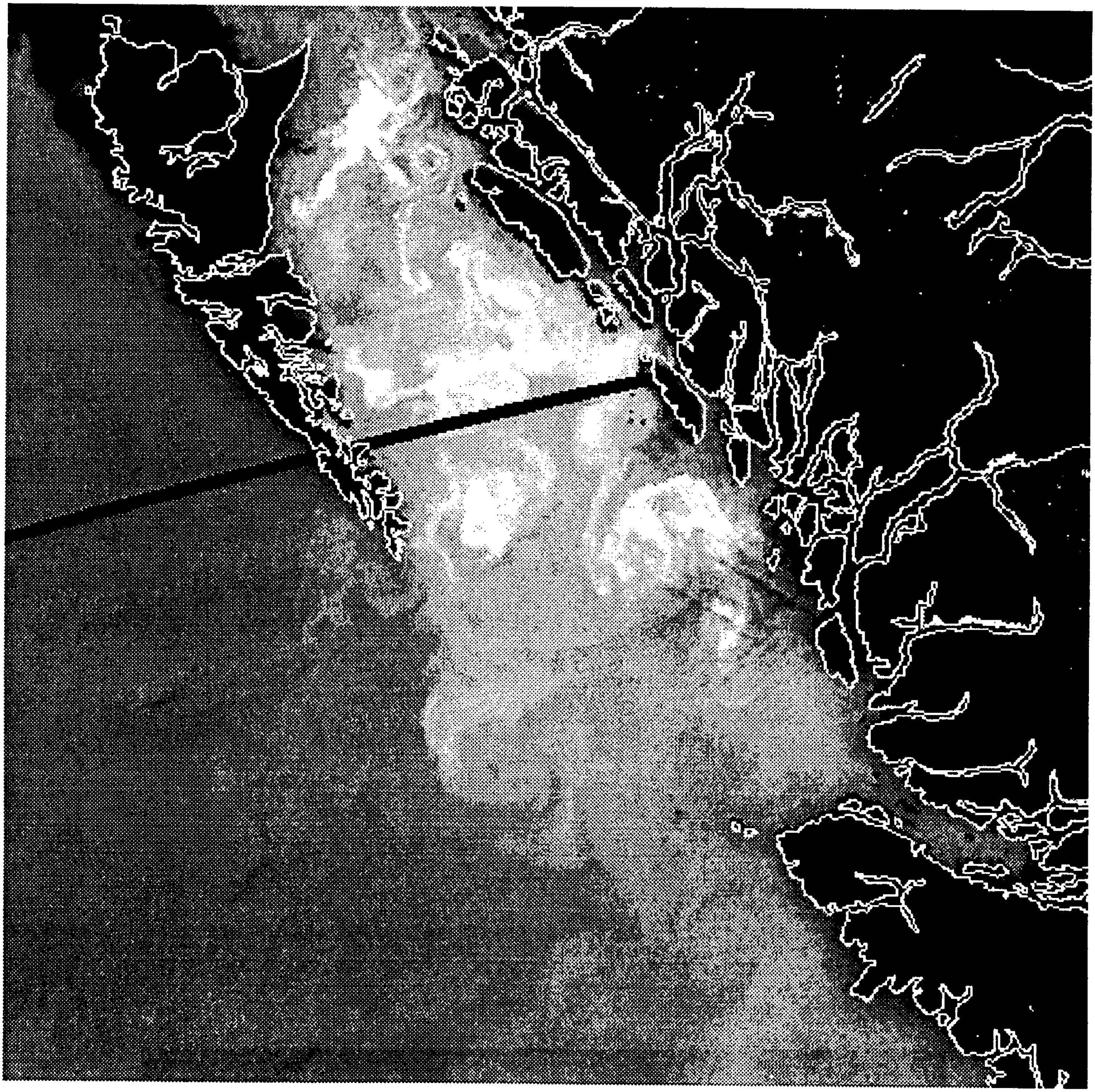


Figure 5. Image derived from NOAA AVHRR satellite data (bands 1 and 2) showing areas of brightened water in Hecate Strait and Queen Charlotte Sound due to a plankton bloom on August 12 1992.

For July/August 1992:

Winds rarely exceeded 6 m/s.
Signficant wave heights rarely exceeded 2 metres (Figure 6).
On three occasions strong swell propagated into the area.
The August 4 and August 6 images showed no appreciable effect of the (5 m) August 5 event.
Water temperature was at annual maximum (13 to 15 C), suitable for red tide occurrence.

**Use of satellites in bloom prediction**

GF-9 numerical model modified for temperature prediction.

A series of three-dimensional hydrodynamic numerical models (GF-1 to GF-9) have been developed at IOS to describe the response of the Georgia/Juan de Fuca Straits to forcing by tides, wind, fresh water inputs and the waters of the Pacific Ocean. Modification for temperature prediction required adding effects of radiation flux, and sensible and latent heat.

Model validation agianst NOAA AVHRR surface temperature.

Comparison of predicted patterns against satellite observations show good agreement in many cases but highlight problem areas, such as frequently occurring cool area near Halibut Bank, not reproduced in the model, and a flow of warm water out of Howe Sound not observed in the satellite images (Figures 7a and b).

NOAA AVHRR "bright water" patterns.

The same bright water images as discussed for blooms above show the plume of the Fraser River very clearly, and map it to the resolution capability (1 to 2 km) of the satellite sensor (Figure 8). The result can be compared to the output of the GF-9 model.

Data communication.

Use of the model for prediction will only be possible to the extent that wind and insolation data are available in real time. IOS has acquired an Anikcom 100 satellite link to give on-line access to observations from buoys and lighthouses.

Status

Accuracy of the model appears to be limited by the accuracy of wind fields over the water. Comparison of field interpolated from lighthouses with data from the few buoy sites shows the problem. Various soluations are being tried.

AVHRR Thermal Image  23 June 1992

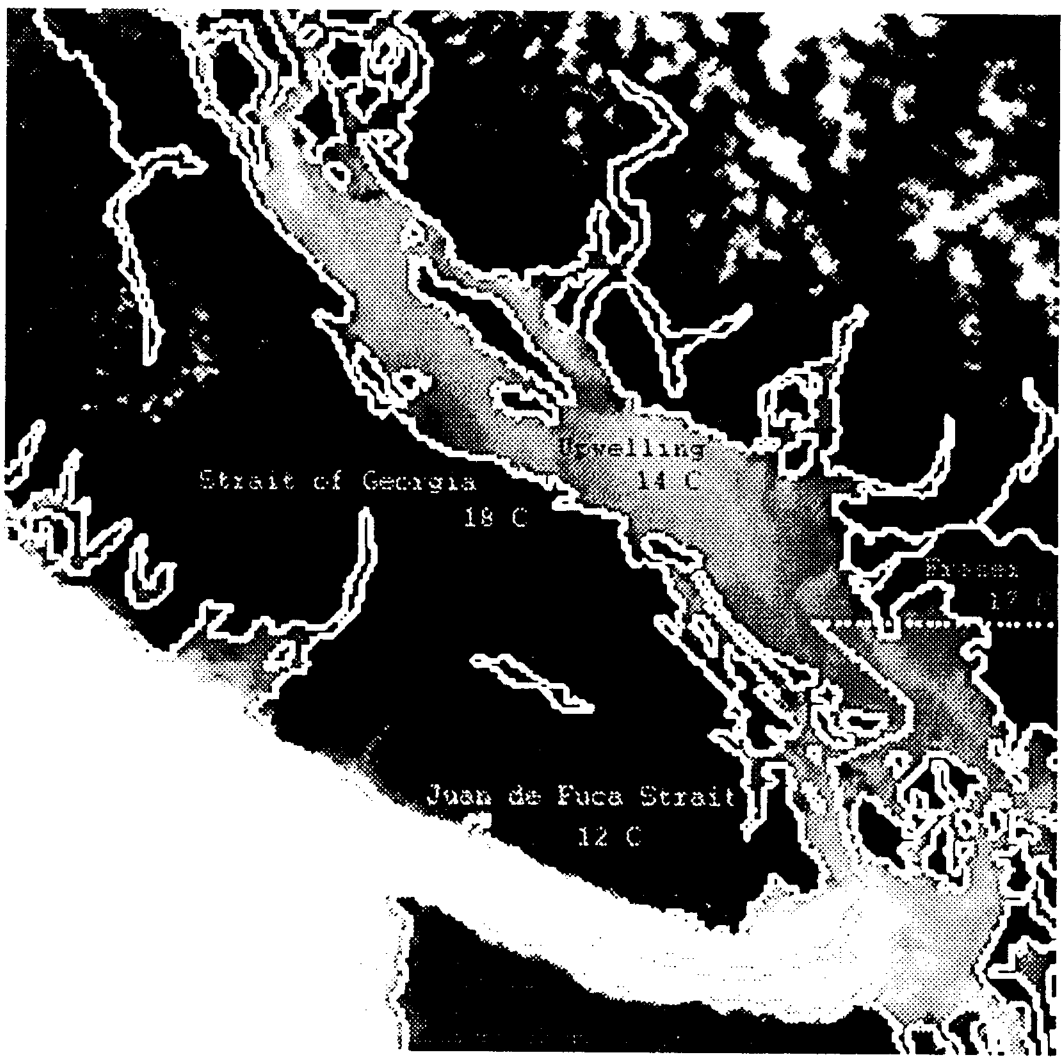



Figure 7a Satellite image showing temperature patterns in Georgia Strait and Juan de Fuca Strait on June 23 1992. Colder water is darker.

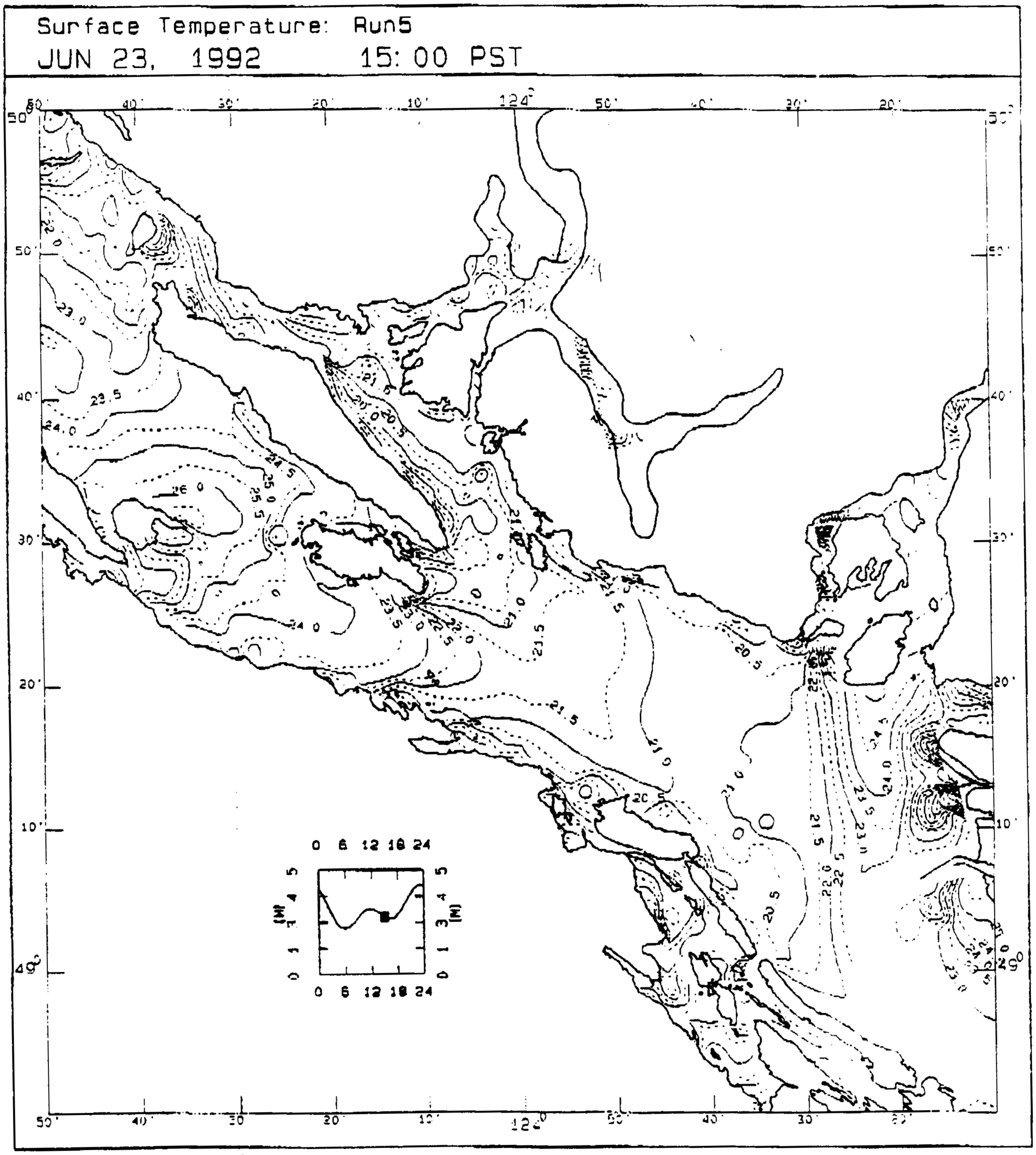



Figure 7b. Model output of surface temperatures for the same time as Figure 7a. The model has failed to duplicate the patch of colder water in the middle of Georgia Strait and shows a tongue of warmer water extending south from Howe Sound which is not seen in Figure 7a.

23 jun 1992, band 1 - band 2, 25,86

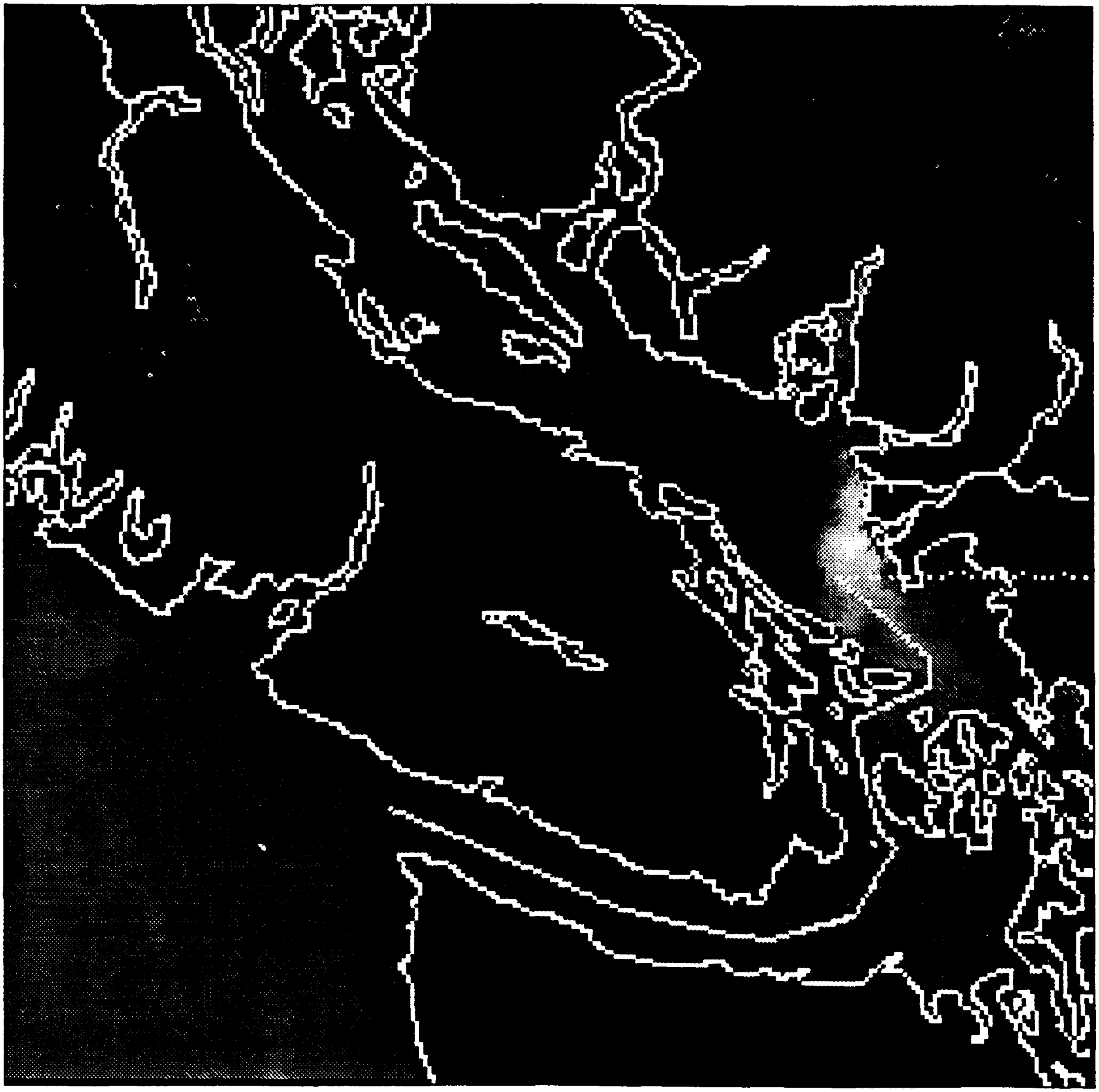


Figure 8. Satellite image produced using the same algorithm as for Figures 2 to 5 showing the distribution of the turbid water in the Fraser plume at 15:00 PST on June 23 1992.

## Conclusions

Satellites can certainly see some blooms.

Better access to satellite data shows many more events.

Better satellite sensors are coming (Seawifs this year).

Even NOAA satellites show major (unreported) events.

Existing numerical models can be used to make predictions.

Better input data availability is needed.

# PRIMARY AND SECONDARY PRODUCTION TRENDS IN THE LA PEROUSE BANK UPWELLING ECOSYSTEM

*C. Robinson and D. Ware*

## ABSTRACT

A numerical, trophodynamics simulation model of the La Perouse Bank upwelling ecosystem has been developed. The model simulates the daily biomass flux between eight dynamic pools: diatoms, copepods, euphausiids, herring, hake, salmon, dogfish and man (commercial fishery). Primary production is driven by observed weekly changes in sunlight, nutrients (upwelling), and water temperatures, the physical and chemical valuables that support the base of the marine food pyramid; and copepod and euphausiid grazing pressure from higher trophic levels. The complexity of the model (57 variables) matches current understanding of this ecosystem, in the sense that the model is neither trivially simple, nor unjustifiably complex. State variables were estimated from empirical data, from literature values, and, in a few cases, by matching the simulated biomass and feeding patterns to empirical data. The model is able to reproduce quite accurately what is known about the seasonal biomass changes in diatoms, copepods, euphausiids, herring and hake.

Sufficient environmental and fisheries data were available from 1972-1990 (19 yrs) to simulate daily biomass flux and annual production. During this period, diatom production averaged 345 $gC/m^2/yr$, copepod production, 16.4 $gC/m^2/yr$, and euphausiid production, 13.9 $gC/m^2/yr$. Due to a combination of "bottom-up" and "top-down" forcing, copepod production exhibited the largest interannual variability (CV=69%), followed by euphausiids (CV=31%). The diatom pool was controlled almost completely by "bottom-up" forcing (from sunlight, nutrients, and temperature) and therefore was less variable (CV=18%).

Over the span of the 19-yr simulated time series, the model suggests that due to the observed pattern of environmental forcing there was a general increase in primary production, particularly after 1975. Copepod production decreased sharply from 1972-75, then tended to increase for the rest of the time series. Euphausiid production has increased slightly. Herring production has declined to a low level, while hake production has increased. The efficiency of the La Perouse upwelling ecosystem in turning diatom production into fish production has ranged from a low of 0.5% to a high of 1.2%; it was lowest in the mid-1980s and has recently been rising.

The model has been sufficiently tested and validated to warrant using it to generate an annual, proxy index of primary and secondary production, exactly like the sea level pressure data are used by the National Marine Fisheries Service, Monterey, to generate an upwelling index. The simulated production record can be used to: 1) describe the general effect of climate change on the productivity of the west coast of Vancouver Island ecosystem, and 2) by fisheries scientists to determine if the simulated changes in the productivity of this ecosystem can "explain" observed variability in the growth and survival of specific fish stocks.

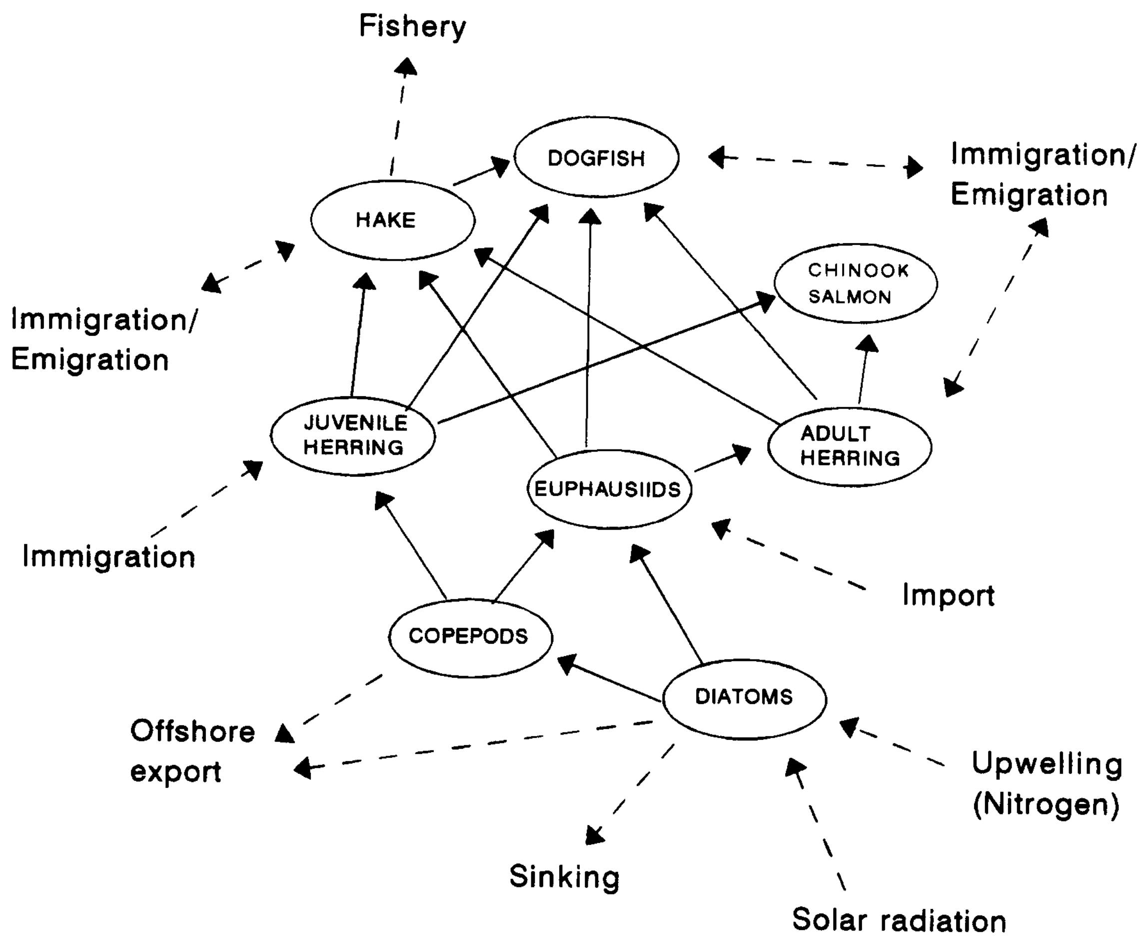



Figure 1. Overview of the feeding interactions (solid lines and arrows) and other processes included in the Juan de Fuca tropho-dynamics model. Water temperature affects diatom growth, all feeding interactions, and hake biomass.

## LONGTERM BIOLOGICAL AND PHYSICAL OCEANOGRAPHIC MONITORING PROGRAM

## COOPERATIVE PLANKTON RESEARCH PROGRAM - COPRA

*W. Shaw*

## INTRODUCTION

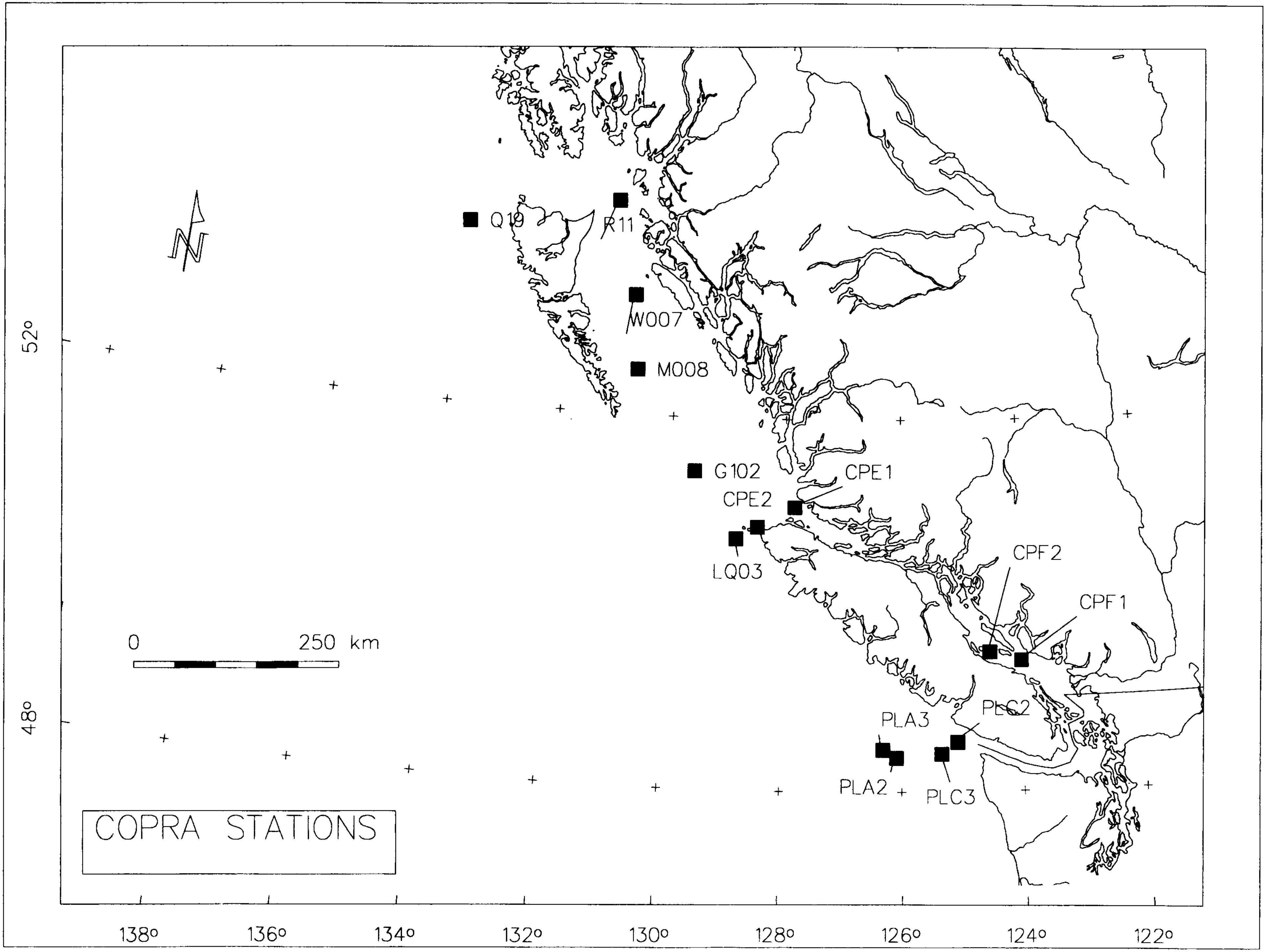
In 1990 the "Cooperative Plankton Research Program" (COPRA), was initiated at the Pacific Biological Station in response for a need of a time series data base that outlines information of the plankton communities, and temperature/salinity regimes for the west coast of British Columbia (Shaw 1994).

A total of 14 stations are located in 5 different regions along the coast (Figure 1). The total network of stations includes 3 outer shelf stations, 9 inner shelf stations, and 2 shelf-break stations:

1. Strait of Georgia (Stns. CPF1, CPF2) is really an inland "sea" which has some special oceanographic properties due to its restricted circulation and large fresh-water inflow. Station CPF1 is located off Ballenas Island and CPF2 is near Sisters Island. Both stations are outside the range of the Fraser River plume. The intention was to have monitoring stations not affected by anomalous variability in the plankton community as a result of the plume.

2. La Perouse Bank (Stns. PLC2, PLC3, PLA2, PLA3) is in the Coastal Upwelling Domain off the southwest coast of Vancouver Island. Stations PLC2 and PLC3 are situated in the "Tully Eddy" which is an important feeding area in the summer for migratory stocks of Pacific hake and resident stocks of commercially important fish species. Stations PLA2 and PLA3 are located at the shelf-break and will provide information on the composition of the off-shore plankton. These stations have been sampled by the La Perouse Project since 1985. Consequently, these stations form part of the longest existing time series of biological and physical oceanographic data in the region. Monitoring these stations will help to quantify local variability across the La Perouse Bank.

3. Queen Charlotte Sound/North Vancouver Island (Stns. CPE1, CPE2, LQ03, GI02) is in a transitional area. This area is characterized by intermittent topogriahically-enhanced, wind induced upwelling off the Scout Islands and Brooks Peninsula, with subsequent longshore transport within the equatorward flowing shelf-break current (Ware and Thomson 1991).


COPRA STATIONS
Q19
R11
W007
M008
G102
CPE1
CPE2
LQ03
CPF2
CPF1
PLC2
PLA3
PLA2
PLC3
0
250 km
52°
48°
138°
136°
134°
132°
130°
128°
126°
124°
122°

4. Hecate Strait (Stns. M006, W007, R11) is also in the Transitional area characterized by shelf areas. This experiences weak upwelling in the eastern side along the deep Moresby Gully, and strong tidal action along the shallow shelf on the western side. Sampling stations M008, W007 and R11 are located in the middle of Hecate Strait along Moresby Gully. The plankton stations are close to Two Peaks fishing bank, and near Bonilla Island lighthouse monitoring station.

5. Dixon Entrance (Stn. Q19) is in a Transitional area between Coastal Upwelling and Downwelling Domains. One sampling station, Q19, is located near Langara Island.

Since 1990 sampling activities for both bongo tows and CTD Guildline and STD-12 Plus casts usually occurred from February to December (Figure 2). In almost all cases both bongo and CTD casts were done concurrently.

The stations most frequently occupied were CPF1 and CPF2 in the Strait of Georgia (Figure 3). This is due to other ongoing sampling programs by PBS, and by DND participation at CPF1. The La Perouse Bank stations appear similar in the frequency of sampling between years. Stations located around Queen Charlotte Islands receive less attention since fewer surveys take place in this area.

Analysis of the zooplankton and ichtheyoplankton communities is currently in progress.

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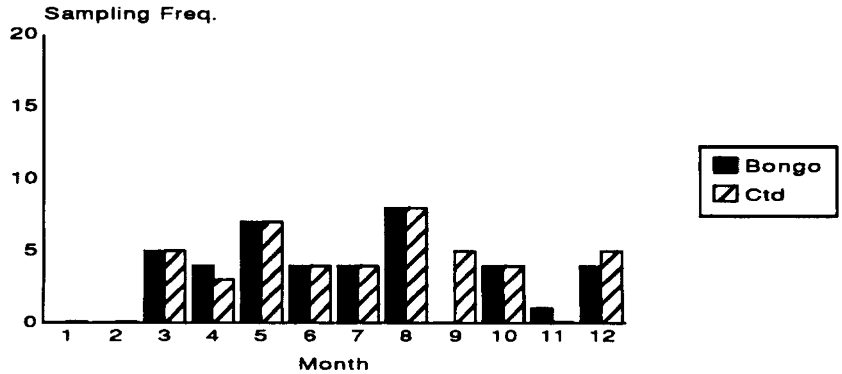
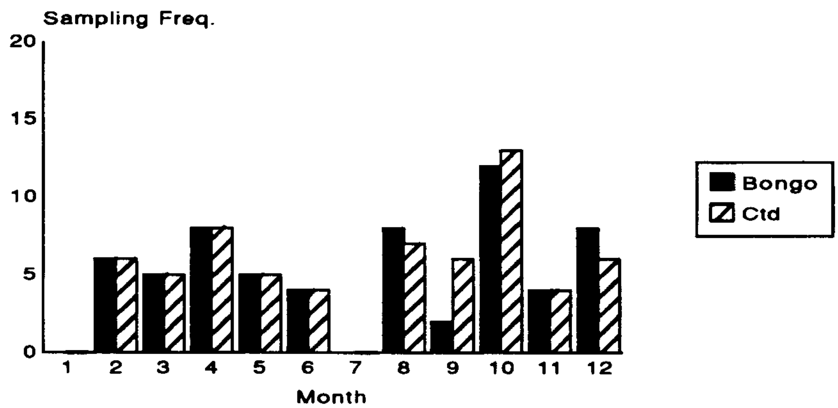
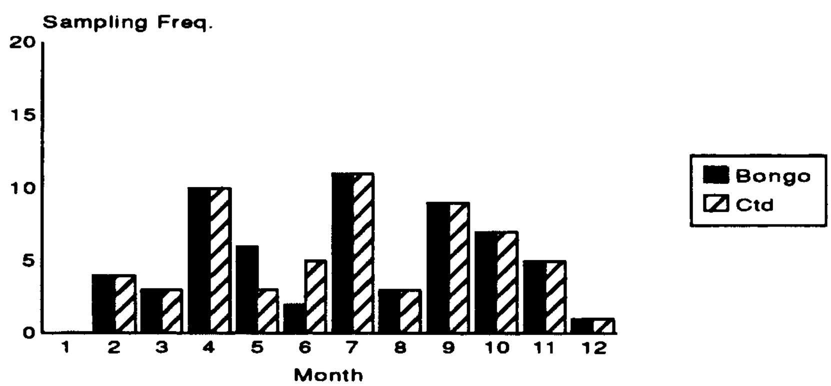
1990



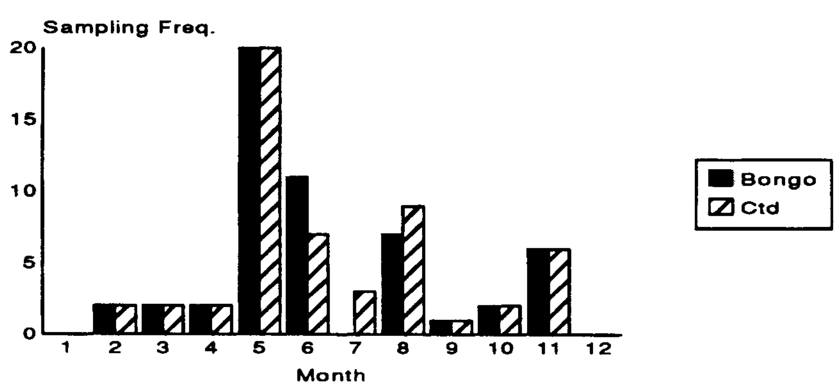

1991



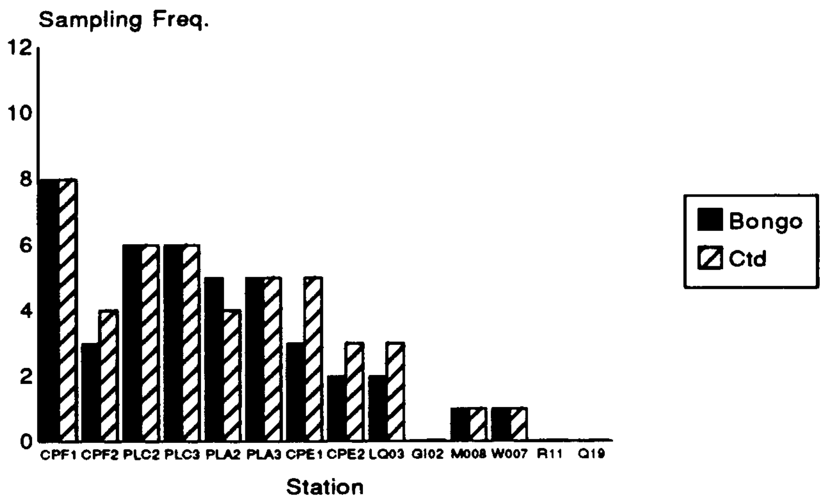

1992



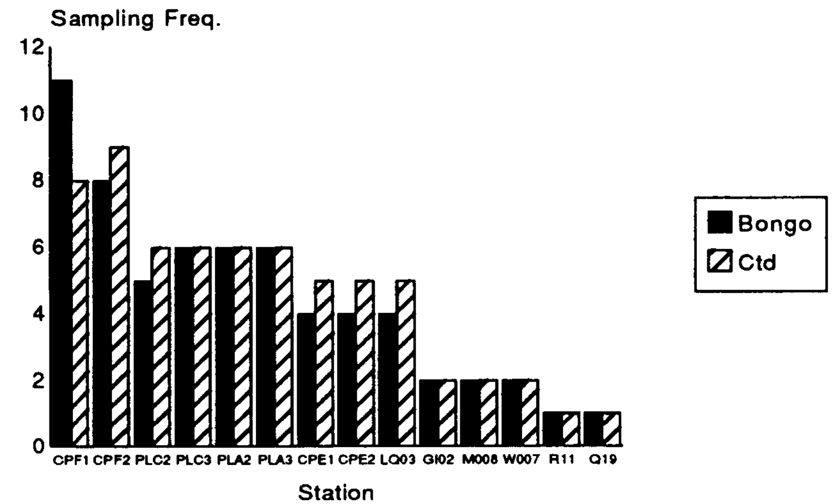

1993



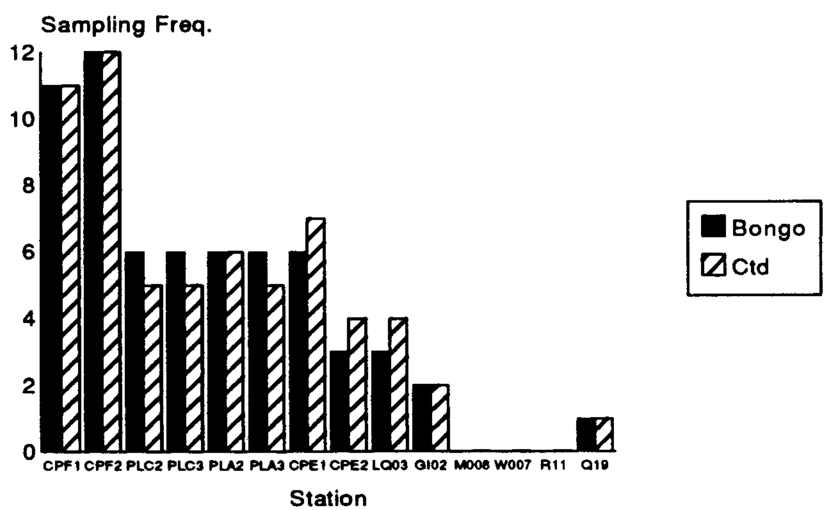
1990



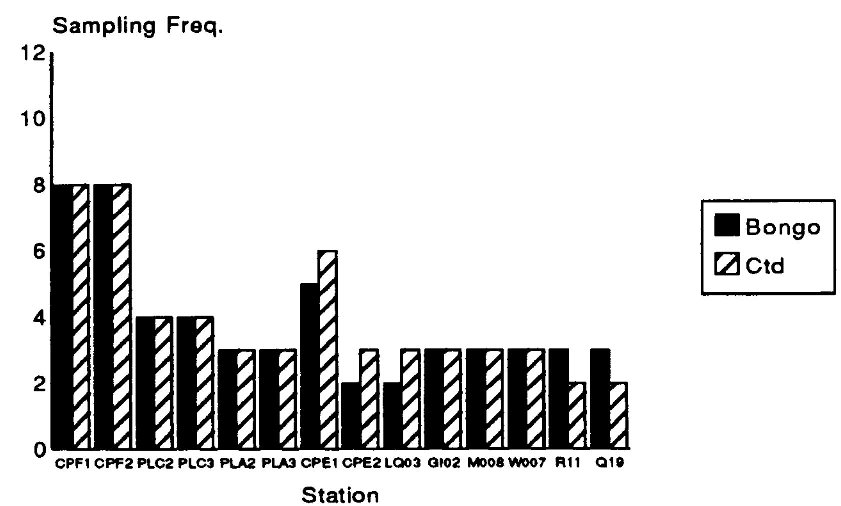

1991




1992




1993



# NUTRIENTS, CHLOROPHYLL AND PRIMARY PRODUCTIVITY IN THE FRASER RIVER ESTUARY

*P. J. Harrison*

## ABSTRACT

Nutrients ($NO_3$, $NO_2$, $NH_4$, urea, DON, $SiO_4$, $PO_4$) were measured in the vicinity of the Fraser River estuary from 1987 to 1992, mainly in May/June, but with some seasonal coverage in April, August and October. Temporal variability was assessed on time scales of days (flood/ebb tides), fortnightly (spring/neap tides) and seasonally. Spatial coverage included stations in the Fraser River, the riverine plume (49°05.1' N 123°22.4' W) the plume boundary and beyond the plume (49°21.4' N 124°11.0' W).

From our five year data set and previous sporadic data sets there appears to be no apparent long term trend in nutrients, chlorophyll and primary productivity. Since the area around the plume is highly dynamic and rapidly flushed, monitoring in more quiescent inlets and bays (e.g. Boundary Bay, inner Burrard Inlet, Sechelt Inlet, etc.) would most likely be the sites where early warning signs of eutrophication effects would occur. Key monitoring parameters should include chl, deep water $O_2$ and nutrients ($NO_3$ and $NH_4$).

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# SESSION 5 - INSTABILITY

## ASSEMBLING CTD DATASETS FOR ANALYSIS OF LONG TERM TRENDS

*R. Brown and J. Linguanti*

### 1. Introduction

As part of an overall objective to improve the utility of historical Conductivity - Temperature - Depth (CTD) data , we have begun assembling an on-line archive of CTD data for the continental shelf of the west coast of Vancouver Island. The steps in creating and maintaining this archive are outlined, as well as the lessons learned about the difficulties in generating a useful archive of large data sets. In addition, some summary information on the contents of the IOS CTD data archive for the La Perouse Study area are presented.

### 2. Steps in creating a useful archive of CTD data

#### 2.1 Find out what data you are supposed to have.

At IOS, most CTD, current meter and hydrographic bottle sample data are stored off-line (nine track magnetic tape). New datasets are brought on-line for data processing analysis and display, then archived to magnetic tape. Following archival, the files are deleted from disk to free up disk space.

In order to rebuild the archive, we must first locate the datasets and determine where they reside in the tape library. This information has not been rigorously maintained in a single location in past, so we used a combination of notebooks, a magnetic tape contents database and personal interviews to uncover this information.

#### 2.1 Retrieve the data from off-line storage

Once the location of datasets in the magnetic tape archive were determined, the files were restored to disk. In this process, problems with tape/hardware compatibility and format were encountered, as data were discovered that had not migrated to newer storage formats. In general, we had little difficulty reading old tapes of known formats, but tapes written on obsolete hardware using non-standard recording formats caused problems.

#### 2.2 Verify file and data formats and units

This task was very time-consuming for the older data. Many different data file formats have been used over the years. Older file formats tended to be very compact, and much supporting information was omitted from the files. Some important items such as depth and salinity units and time zone used in recording are omitted entirely from the files and written notes - in many cases, these were inferred from our knowledge of the standard practices of the time, but some ambiguity remains.The raw data were not recovered - the processed (1 metre depth bins usually) are retrieved and put into the archive. Raw data files remain as an off-line (magnetic tape) archive. For older data raw data files (prior to 1985) we probably have insufficient information to reprocess the data.

2.3 Recover the missing metadata from files, logbooks etc.

We have developed a minimum standard for the metadata (information about the data) that should accompany the data files. This information is attached to the data files in the archive. Much of this information is missing from the data files recovered from off-line storage. We returned to logbooks, processing notes and other sources to assemble the missing information. Where possible, we attempted to include references to published data reports for each dataset.

2.4 Reformat the data and add the missing metadata to the files

A set of conversion utilities was written to both convert to a common data format and to merge missing metadata into the new archive files. Each different source data format required special conversion utilities.

2.5 Verify the data - (times, dates, locations as well as measurements)

We have attempted a 'first-order' verification of the assembled CTD data archive. The staff at the Marine Environmental Data Service were of great assistance here. MEDS has a fairly sophisticated quality control process (QC) for CTD profiles. This process was particularly good for detecting errors in station positions and times/dates. In addition, the MEDS QC process is good at identifying duplicate casts, which we also encountered. The MEDS QC software is NOT able to ensure that the actual profile data meets our internal standards for reliable CTD profiles. It will be necessary to review much of the older data profile by profile to ensure that unacceptable or questionable profiles are marked as such.

2.6 Build up a searchable database

The CTD data archive covers data from all IOS projects and includes many areas. Our storage hierarchy is based on the dataset (typically all the CTD profiles for a single cruise). One dataset may contain profiles for multiple projects and sampling areas. In order to allow the users to find the files they are interested in, we have developed a relational database containing ONLY the metadata. The user then runs 'queries' that incorporate the appropriate selection criteria (areas, parameters, start and end time etc.) against this database to produce summary reports or lists of files in the archive that match these criteria. External programs can then use such a list as a definition for the of the archive to be used.

Sample reports are shown in Table 1 (summary of information about datasets) and Table 2 (a listing of profiles/data files that meet selection critera)

2.7 Maintain the archive and the searchable database

In order to maintain the utility of the archive, minor maintenance activities are required. These include ensuring proper backups of the on-line archive, corrections to erroneous profiles and metadata and updating the searchable database. These processes are not fully automated and require a modest ongoing effort.

**Lessons learned:**

3.1 Avoid proprietary data recording formats and systems

Proprietary (hardware and/or operating system-specific) data recording formats can cause big problems where recovering historical data. We have encountered datasets that were very difficult and time-consuming to recover to this problem. Binary data files, in particular, cause problems for use in a diverse computing environment - for example, binary files written for one UNIX platform (e.g. SUN) are not directly readable on DEC Alpha platforms that also run UNIX.

3.2 Trap as much information as possible automatically

Much of the effort in building the on-line archive went into collecting and correcting data about the profiles. In some cases, we have a perfectly good CTD profile for which we are unable to determine the location or sampling time, making the observation completely useless. Most people operate at low efficiency when conditions in the field are poor, so human errors in data entry are frequent. In some cases, we were unable to find this information at all.

At IOS, we have made an attempt to trap as much information (metadata) as possible automatically (e.g. interfacing CTD data acquisition systems to GPS ) to avoid error in manual data entry. This information is be propagated through the data processing and archival system - for example, any comments entered in the field at the beginning of data acquisition remain embedded in the data file throughout the data processing stream.

3.3 Provide logbooks/logsheets to trap information as a backup

Despite our efforts in automatically trapping metadata, there are still some problems with errors or uncertainties in station names, positions and sampling times. Where suitable logsheets, cruise notes and bridge logs are available, we can usually resolve these problems, but lack of suitable logsheets/logbooks makes this difficult or impossible.

3.4 Data files should be self-documenting

Older data recording formats were often forced to be very compact and the amount of metadata that could be embedded in the file was severely restricted. The rapid decline in costs for disk storage has removed this concern. Our experience is that each file (the smallest unit of our data archive) should contain enough information to be self-supporting and readable directly by users, as well as computers. We have developed a FORTRAN package to read and write extensible, flexible headers for oceanographic data files. An example of such a header is shown in Table 3. In addition, our data processing systems have been modified to 'stamp' each file with the necessary information to allow the user to determine what processing and/or corrections have been applied to the data.

3.5 The primary archive should be on-line and accessible

The maintenance of an off-line (magnetic tape) archive is a large chore. When errors are discovered in a dataset, the appropriate files must be restored from tape, corrected and then archived once more to tape. A system of pointers must be established to point to the current 'correct' version of the dataset or file. This strategy requires more effort and diligence than we have been able to apply. When the system breaks down, it becomes difficult to establish which version of a file or dataset is 'correct' and efforts are duplicated.

Our strategy is to create a single on-line archive of working data. In general, this will be processed data that have been examined and corrected for instrument calibrations and spikes. Programs are then developed to produce user-specified subsets of these data ( for example, values at standard depths). If problems are discovered in the down stream data products, corrections are made to the main archive and the user-specified data subset generated again. This process ensures a single version of the source data files.

We have used extended computer system security tools to help in this. Users who require access to the CTD data archive are assigned to a 'read-only' class of users, while a few data processing and managing staff have abilities to alter or update the data. The relatively wide 'read-only' abilities discourage users from setting up their own 'sub-archive", which in turn helps preserve the integrity and validity of the main archive.

Both local area networks and wide area networks aid in allowing users to share the data without having duplicate copies whose contents may diverge over time.

3.6 A search tool is needed

One difficulty in a single CTD data archive is that users find it difficult to find the subset of data they are interested in within this large archive. We have developed a database (the Data Archive Data Base or DADB) that allows users to generate both summary information (at the cruise or dataset level) or detailed lists of stations/files that meet complex search criteria. This database does not contain the data - the actual data files are simple ASCII files.

4. Results

The on-line archive of CTD data currently contains 255 datasets and totals about 14,000 stations for the years 1972 to 1992. There will be additional data added for this time period, but we estimate that > 90% of all IOS data is now included. The CTD archive current occupies about 300,000 megabytes of disk space on the IOS computer system.

Rick Thomson has defined a broad La Perouse study area for assembling CTD data for analysis on trends and anomalies (see Figure 1) . The study area contains 182 datasets (1972-1992) and about 7200 individual profiles, as shown in Figure 2). The distribution of these data through time is shown in Figure 3.
The main feature of the distribution of CTD profile data through time is the very low coverage during the 1982 and 1983 El Nino, which fall between the intensive CODE ( Coastal Ocean Dynamics Experiment) and the La Perouse experiment. The effect of decreased ship time and effort due to the loss of the C.S.S. Parizeau to the east coast and declining O&M budgets is also shown.

## Table 1: A sample dataset summary report

Run: February 7, 1994 | DFO_IOS Scientific Computing Services | Page: 1
By: OPS$DATAMAN | *** LIST OF DATASETS *** | LAP_DSLIST.SQL VER 1.0
All DATASETS of type: CTD | WHERE LATITUDE between 47.5 and 51.0 AND LONGITUDE between 124.5 and 131.0 | RESULTS printed to file: ds.LIS

| YEAR | DSID | DATASET | NSTN | AGY | VESSEL | CRUISE_DESCRIPTION | STARTDATE | END_DATE | SCIENTIST | GEOGRAPHIC_AREA |
|---|---|---|---|---|---|---|---|---|---|---|
| 1989 | 109 | CTD 89-01 | 12 | 101 | JP TULLY | CTD & HYDRO SURVEY; SAIL | 13-FEB-89 | 26-FEB-89 | TABATA S | LINE P |
| | 117 | CTD 89-80 | 15 | 101 | | CTD-12 PROFILES, LING COD SURVEY | 18-MAR-89 | 21-MAR-89 | RICHARDS L | WCVI |
| | 237 | CTD 89-81 | 36 | 310 | unknown | PBS cruise - AML CTD-12 - DATA FROM BILL SHAW | 07-APR-89 | 17-APR-89 | SHAW W | WCVI |
| | 112 | CTD 89-10 | 57 | 101 | PARIZEAU | CTD/TRANSM. & HYDRO CASTS, CM MOORINGS, AMBIENT NOISE DRIFTERS | 18-APR-89 | 26-APR-89 | THOMSON RE | WCVI, GEORGIA, JUAN DE FUCA |
| | 110 | CTD 89-02 | 15 | 101 | PARIZEAU | CTD/TRANSM. & HYDRO CASTS, RDI DOPPLER CM, SEDIMENT TRAPS | 01-MAY-89 | 12-MAY-89 | TABATA S | LINE P |
| | 116 | CTD 89-50 | 69 | 101 | PARIZEAU | CTD/TRANSM. PROFILES, DRIFTERS, PLANKTON HAULS | 23-MAY-89 | 26-MAY-89 | FREELAND HJ | WCVI |
| | 113 | CTD 89-11 | 43 | 101 | PARIZEAU | CTD/TRANSM. & HYDRO CASTS, CM MOORINGS | 27-MAY-89 | 09-JUN-89 | THOMSON RE | WCVI, JUAN DE FUCA |
| | 236 | CTD 89-30 | 53 | 301 | PARIZEAU | Ocean Ecology Cruise 89-06 (CTD/Rosette, net tows, BIONESS etc) | 08-AUG-89 | 14-AUG-89 | DENMAN KL | LaPerouse, WCVI |
| | 114 | CTD 89-12 | 87 | 101 | PARIZEAU | CTD/TRANSM. & HYDRO CASTS, RDI DOPPLER CM, CM MOORINGS | 15-AUG-89 | 25-AUG-89 | THOMSON RE | WCVI |
| | 111 | CTD 89-03 | 22 | 101 | PARIZEAU | CTD/TRANSM. & HYDRO CASTS, SEDIMENT TRAP MOORINGS, RDI DOPPLER CM, CM MOORINGS, DRIFTERS, XBT'S | 03-OCT-89 | 22-OCT-89 | TABATA S | LINE P |
| | 115 | CTD 89-13 | 31 | 101 | PARIZEAU | CTD/TRANSM. PROFILES, RDI DOPPLER CM, CM MOORINGS | 22-OCT-89 | 27-OCT-89 | THOMSON RE | WCVI, JUAN DE FUCA |
| 1990 | 120 | CTD 90-10 | 25 | 101 | J P TULLY | CTD SURVEY, PLANKTON HAUL | 29-JAN-90 | 09-FEB-90 | THOMSON RE | WCVI |
| | 129 | CTD 90-81 | 28 | 101 | W E RICKER | CTD SURVEY, NET HAULS | 21-MAR-90 | 15-DEC-90 | SHAW B | WCVI |
| | 121 | CTD 90-11 | 104 | 101 | PARIZEAU | CM RECOVERY/DEPLOYMENT, CTD SURVEY | 17-APR-90 | 24-APR-90 | THOMSON RE | WCVI |
| | 238 | CTD 90-31 | 24 | 301 | PARIZEAU | Ocean Ecology 90-03 CTD/Rosette, JGOFS sediment traps/RCM , BIONESS, net tows | 25-APR-90 | 02-MAY-90 | DENMAN KL | WCVI, LaPerouse, Brooks Peninsula |
| | 118 | CTD 90-01 | 35 | 101 | PARIZEAU | CTD SURVEY, CM & SEDIMENT TRAP MOORINGS RECOVERY/DEPLOYMENT | 10-MAY-90 | 29-MAY-90 | TABATA S | LINE P |
| | 122 | CTD 90-12 | 97 | 101 | PARIZEAU | CTD & RDI-ADCP SURVEY, DRIFT NETS, CM MOORING | 11-JUN-90 | 21-JUN-90 | THOMSON RE | WCVI |
| 1990 | 123 | CTD 90-13 | 17 | 101 | PARIZEAU | CTD CURVEY | 28-JUN-90 | 13-JUL-90 | CRAWFORD WR | HECATE STRAIT, DIXON ENTRANCE |
| | 125 | CTD 90-30 | 2 | 101 | WESTERLY WIND | CTD SURVEYS IN SUPPORT OF SURFACE CURRENT MEASUREMENTS BY LORAN-C DRIFTERS | 05-JUL-90 | 28-AUG-90 | CRAWFORD WR | DIXON ENTRANCE, HECATE STRAIT |
| | 239 | CTD 90-32 | 73 | 301 | JP TULLY | Ocean Ecology 90-04 JGOFS sediment traps, BIONESS, net tows etc. | 18-JUL-90 | 25-JUL-90 | DENMAN KL | WCVI |
| | 128 | CTD 90-80 | 46 | 101 | W E RICKER | CTD SURVEY, NET HAULS | 26-JUL-90 | 06-AUG-90 | HARGREAVES B | WCVI |

## Table 2: A sample station/file report

Run: February 7, 1994 DFO_IOS Scientific Computing Services Page: 98
By: OPS$DATAMAN *** LIST OF STATIONS *** LAP_EVENT.SQL VER 1.0
ALL Stations for the LAPEROUSE project

| DS_NAME | SCIENTIST | EVENT | DDATE | LATIT | LONGIT | STN | FILE_NAME |
|---|---|---|---|---|---|---|---|
| CTD 92-82 | SAUNDERS M | 004 | 31-JUL-92 | 48.622 | 125.093 | LB03 | 92820004.CTD |
| CTD 92-82 | SAUNDERS M | 005 | 31-JUL-92 | 48.594 | 125.146 | LB04 | 92820005.CTD |
| CTD 92-82 | SAUNDERS M | 008 | 31-JUL-92 | 48.567 | 125.203 | LB05 | 92820008.CTD |
| CTD 92-82 | SAUNDERS M | 009 | 31-JUL-92 | 48.538 | 125.257 | LB06 | 92820009.CTD |
| CTD 92-82 | SAUNDERS M | 011 | 31-JUL-92 | 48.478 | 125.367 | LB07 | 92820011.CTD |
| CTD 92-82 | SAUNDERS M | 012 | 31-JUL-92 | 48.423 | 125.476 | LB08 | 92820012.CTD |
| CTD 92-82 | SAUNDERS M | 013 | 31-JUL-92 | 48.389 | 125.341 | BA3 | 92820013.CTD |
| CTD 92-82 | SAUNDERS M | 015 | 31-JUL-92 | 48.423 | 125.129 | BA2 | 92820015.CTD |
| CTD 92-82 | SAUNDERS M | 016 | 31-JUL-92 | 48.528 | 125.063 | LBA1 | 92820016.CTD |
| CTD 92-82 | SAUNDERS M | 017 | 31-JUL-92 | 48.485 | 125.254 | C1 | 92820017.CTD |
| CTD 92-82 | SAUNDERS M | 018 | 01-AUG-92 | 48.368 | 125.578 | LB09 | 92820018.CTD |
| CTD 92-82 | SAUNDERS M | 019 | 01-AUG-92 | 48.258 | 125.688 | LB10 | 92820019.CTD |
| CTD 92-82 | SAUNDERS M | 020 | 01-AUG-92 | 48.257 | 125.792 | LB11 | 92820020.CTD |
| CTD 92-82 | SAUNDERS M | 021 | 01-AUG-92 | 48.218 | 125.860 | LB12 | 92820021.CTD |
| CTD 92-82 | SAUNDERS M | 022 | 01-AUG-92 | 48.177 | 125.933 | LB13 | 92820022.CTD |
| CTD 92-82 | SAUNDERS M | 023 | 01-AUG-92 | 48.141 | 125.999 | LB14 | 92820023.CTD |
| CTD 92-82 | SAUNDERS M | 026 | 02-AUG-92 | 48.432 | 126.229 | LC09 | 92820026.CTD |
| CTD 92-82 | SAUNDERS M | 027 | 02-AUG-92 | 48.377 | 126.062 | CB6 | 92820027.CTD |
| CTD 92-82 | SAUNDERS M | 028 | 02-AUG-92 | 48.374 | 126.339 | LC10 | 92820028.CTD |
| CTD 92-82 | SAUNDERS M | 031 | 03-AUG-92 | 48.830 | 126.061 | LD05 | 92820031.CTD |
| CTD 92-82 | SAUNDERS M | 032 | 03-AUG-92 | 48.770 | 126.167 | LD06 | 92820032.CTD |
| CTD 92-82 | SAUNDERS M | 033 | 03-AUG-92 | 48.710 | 126.281 | LD07 | 92820033.CTD |
| CTD 92-82 | SAUNDERS M | 035 | 03-AUG-92 | 48.595 | 126.498 | LD09 | 92820035.CTD |
| CTD 92-82 | SAUNDERS M | 036 | 04-AUG-92 | 48.886 | 125.952 | LD04 | 92820036.CTD |
| CTD 92-82 | SAUNDERS M | 037 | 04-AUG-92 | 48.943 | 125.840 | LD03 | 92820037.CTD |
| CTD 92-82 | SAUNDERS M | 038 | 04-AUG-92 | 48.973 | 125.783 | LD02 | 92820038.CTD |
| CTD 92-82 | SAUNDERS M | 039 | 06-AUG-92 | 48.455 | 125.822 | LCB5 | 92820039.CTD |
| CTD 92-82 | SAUNDERS M | 040 | 06-AUG-92 | 48.540 | 125.588 | LCB4 | 92820040.CTD |
| CTD 92-82 | SAUNDERS M | 041 | 06-AUG-92 | 48.575 | 125.503 | LCB3 | 92820041.CTD |
| CTD 92-82 | SAUNDERS M | 042 | 06-AUG-92 | 48.691 | 125.448 | LCB2 | 92820042.CTD |
| CTD 92-82 | SAUNDERS M | 043 | 06-AUG-92 | 48.747 | 125.374 | LCB1 | 92820043.CTD |
| CTD 92-82 | SAUNDERS M | 044 | 10-AUG-92 | 48.840 | 125.464 | LC01 | 92820044.CTD |
| CTD 92-82 | SAUNDERS M | 045 | 10-AUG-92 | 48.811 | 125.518 | LC02 | 92820045.CTD |
| CTD 92-82 | SAUNDERS M | 046 | 10-AUG-92 | 48.783 | 125.574 | LC03 | 92820046.CTD |
| CTD 92-82 | SAUNDERS M | 047 | 10-AUG-92 | 48.724 | 125.691 | LC04 | 92820047.CTD |
| CTD 92-82 | SAUNDERS M | 048 | 13-AUG-92 | 48.666 | 125.792 | LC05 | 92820048.CTD |
| CTD 92-82 | SAUNDERS M | 049 | 13-AUG-92 | 48.608 | 125.899 | LC06 | 92820049.CTD |
| CTD 92-82 | SAUNDERS M | 050 | 13-AUG-92 | 48.547 | 126.007 | LC07 | 92820050.CTD |
| CTD 92-82 | SAUNDERS M | 051 | 15-AUG-92 | 48.340 | 126.184 | NSTN | 92820051.CTD |
| CTD 92-82 | SAUNDERS M | 052 | 18-AUG-92 | 48.623 | 125.989 | B101 | 92820052.CTD |
| CTD 92-82 | SAUNDERS M | 053 | 18-AUG-92 | 48.624 | 126.073 | B102 | 92820053.CTD |
| CTD 92-82 | SAUNDERS M | 054 | 18-AUG-92 | 48.624 | 126.209 | B103 | 92820054.CTD |
| CTD 92-82 | SAUNDERS M | 055 | 18-AUG-92 | 48.625 | 126.409 | B104 | 92820055.CTD |
| CTD 92-82 | SAUNDERS M | 056 | 18-AUG-92 | 48.624 | 126.539 | B105 | 92820056.CTD |
| CTD 92-82 | SAUNDERS M | 057 | 18-AUG-92 | 48.623 | 126.715 | B106 | 92820057.CTD |
| CTD 92-82 | SAUNDERS M | 058 | 19-AUG-92 | 48.832 | 126.846 | LF08 | 92820058.CTD |
| CTD 92-82 | SAUNDERS M | 059 | 19-AUG-92 | 48.898 | 126.745 | LF07 | 92820059.CTD |
| CTD 92-82 | SAUNDERS M | 060 | 19-AUG-92 | 48.968 | 126.648 | LF06 | 92820060.CTD |
| CTD 92-82 | SAUNDERS M | 061 | 20-AUG-92 | 49.032 | 126.551 | LF05 | 92820061.CTD |
| CTD 92-82 | SAUNDERS M | 062 | 20-AUG-92 | 49.098 | 126.457 | LF04 | 92820062.CTD |
| CTD 92-82 | SAUNDERS M | 063 | 21-AUG-92 | 49.414 | 126.978 | LH04 | 92820063.CTD |
| CTD 92-82 | SAUNDERS M | 064 | 21-AUG-92 | 49.355 | 127.076 | LH05 | 92820064.CTD |
| CTD 92-82 | SAUNDERS M | 065 | 21-AUG-92 | 49.293 | 127.178 | LH06 | 92820065.CTD |
| CTD 92-82 | SAUNDERS M | 066 | 21-AUG-92 | 49.228 | 127.273 | LH07 | 92820066.CTD |
| CTD 92-82 | SAUNDERS M | 067 | 24-AUG-92 | 49.668 | 127.975 | NSTN | 92820067.CTD |
| CTD 92-82 | SAUNDERS M | 068 | 26-AUG-92 | 49.806 | 128.047 | LL05 | 92820068.CTD |
| CTD 92-82 | SAUNDERS M | 069 | 26-AUG-92 | 49.868 | 127.942 | LL04 | 92820069.CTD |
| CTD 92-82 | SAUNDERS M | 070 | 26-AUG-92 | 49.928 | 127.838 | LL03 | 92820070.CTD |
| CTD 92-82 | SAUNDERS M | 071 | 26-AUG-92 | 49.989 | 127.734 | LL02 | 92820071.CTD |
| CTD 92-82 | SAUNDERS M | 072 | 27-AUG-92 | 50.155 | 128.061 | LM02 | 92820072.CTD |
| CTD 92-82 | SAUNDERS M | 073 | 27-AUG-92 | 50.088 | 128.174 | LM03 | 92820073.CTD |
| CTD 92-82 | SAUNDERS M | 074 | 27-AUG-92 | 50.027 | 128.285 | LM04 | 92820074.CTD |
| CTD 92-82 | SAUNDERS M | 075 | 27-AUG-92 | 49.964 | 128.391 | LM05 | 92820075.CTD |

**Table 3: A sample self-documenting header for  CTD data files**

```
*1993/08/25 18:40:42.24
*IOS HEADER VERSION 0.4  1992/11/17

*FILE
    START TIME          : UTC 1993/03/25 13:07:55.000
    NUMBER OF RECORDS   :          290
    FILE TYPE           : ASCII
    FORMAT              : (f11.3,f9.5 ,f9.5 ,f8.4 ,f5.0 )
    DATA TYPE           : REAL*4
    RECORD LENGTH       :           35
    NUMBER OF CHANNELS  :            5

    $TABLE: CHANNELS
    ! No Name                      Units           Minimum        Maximum
    ! -- ------------------------ --------------- -------------- --------------
       1 PRESSURE                  DBAR            10.6           299.6
       2 TEMPERATURE               'DEG C (ITS68)' 7.75871        9.61264
       3 CONDUCTIVITY_RATIO        n/a             0.7324         0.79052
       4 SALINITY                  PSS-78          29.7422        30.9806
       5 Number_of_bin_records     n/a             ' '            ' '
    $END

*ADMINISTRATION
    PROJECT             : SAUNDERS
    CRUISE              : 93-04

*LOCATION
    STATION             : NSTN
    EVENT NUMBER        :            3
    LATITUDE            :  49  26.65000 N
    LONGITUDE           : 124  24.96000 W

*INSTRUMENT
    TYPE                : Guildline CTP
    MODEL               : 8709
    SERIAL NUMBER       : 53,997

    $TABLE: SENSORS
    !   Name                 Rel Depth       Serial No
    !   -------------------- --------------  ----------
        Pressure             n/a             ?
        Temperature          n/a             ?
        Conductivity_Ratio   n/a             ?
    $END

*HISTORY

    $TABLE: PROGRAMS
    !   Name     Vers    Date       Time     Recs In  Recs Out
    !   -------- ------ ---------- -------- -------  -------
        RAW_CNVT  3.0    1993/06/02 16:39:07 ' '      ' '
        CALIB     5.0    1993/07/09 11:52:48    1678     1678
        DELETE    4.0    1993/07/09 11:54:15    1678     1361
        METERAVE  2.0    1993/08/25 18:40:42    1361      290
    $END
    $REMARKS
        -The following CALIB parameters were used:
         Calibration type = R
         Pressure offset =       -2.0
         Calibration file =
        -The following DELETE parameters were used:
         Swells deleted
        -The following METERAVE parameters were used:
         Averaging interval =     1.0 .  Bin type = press
         Bin press  was used
         Interpolated values were NOT used for empty bins
    $END
```

**Table 3 (cont'd): A sample self-documenting header for CTD data files**

```
*RAW
    START TIME          : UTC 1993/03/25 13:07:55.000
    END TIME            : UTC 1993/03/25 13:11:58.000
    TIME INCREMENT      : 0 0 0 0.4E-01 0 ! = 0.462962952614934 36E-06 days
    NUMBER OF RECORDS   :        1809

    $TABLE: CHANNELS
    !   Name                    Raw Units
    !   --------------------    ----------
        Pressure                Percent_FS
        Temperature             'DEG C'
        Conductivity_Ratio      n/a
    $END

*CALIBRATION
    START TIME          : UTC 1993/03/25 13:07:55.000
    TIME INCREMENT      : 0 0 0 0.4E-01 0 ! = 0.462962952614934 36E-06 days

    $TABLE: RAW CHANNELS
    !   Name                  Units Fmla  Pad     Coefficients
    !   --------------------  ----- ----  ------  ------------
        PRESSURE              n/a     10  ' '     (-2 1)
        TEMPERATURE           n/a     10  ' '     (0.1321E-01 0.99942)
        CONDUCTIVITY_RATIO    n/a     10  ' '     (0.77E-03 0.99867)
    $END

    $TABLE: CALCULATED CHANNELS
    !   Name       Units    Fmla  Pad     Coefficients
    !   ---------- -------- ----  ------  ------------
        SALINITY   PSS-78     30  ' '     (PRESSURE TEMPERATURE
                                           CONDUCTIVITY_RATIO)
                                          ()
    $END

*COMMENTS
    set 24 930325
*END OF HEADER
```

**Figure 1: La Perouse CTD study area**

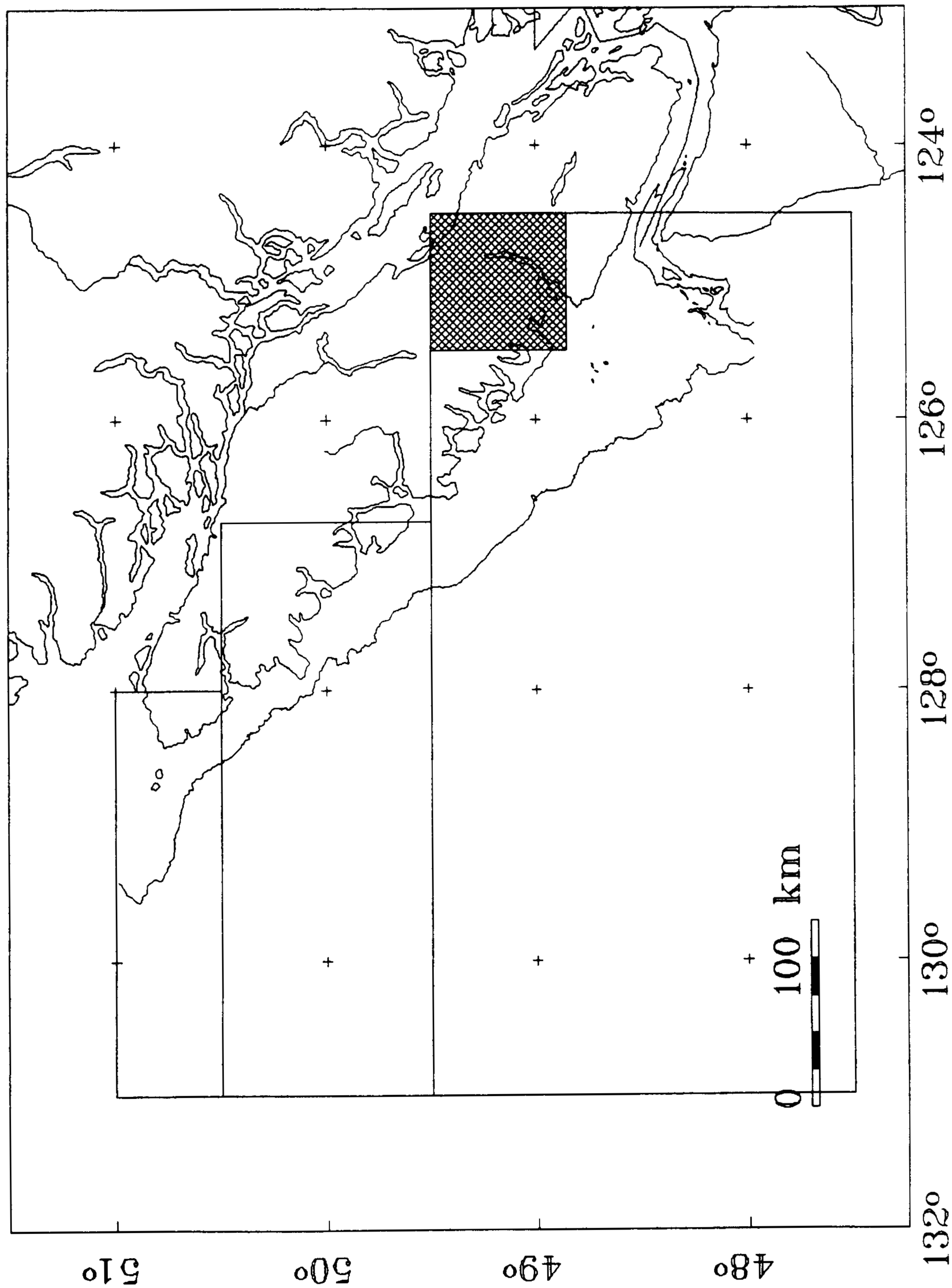


**Figure 2: Locations of CTD profiles - 1972 - 1992**

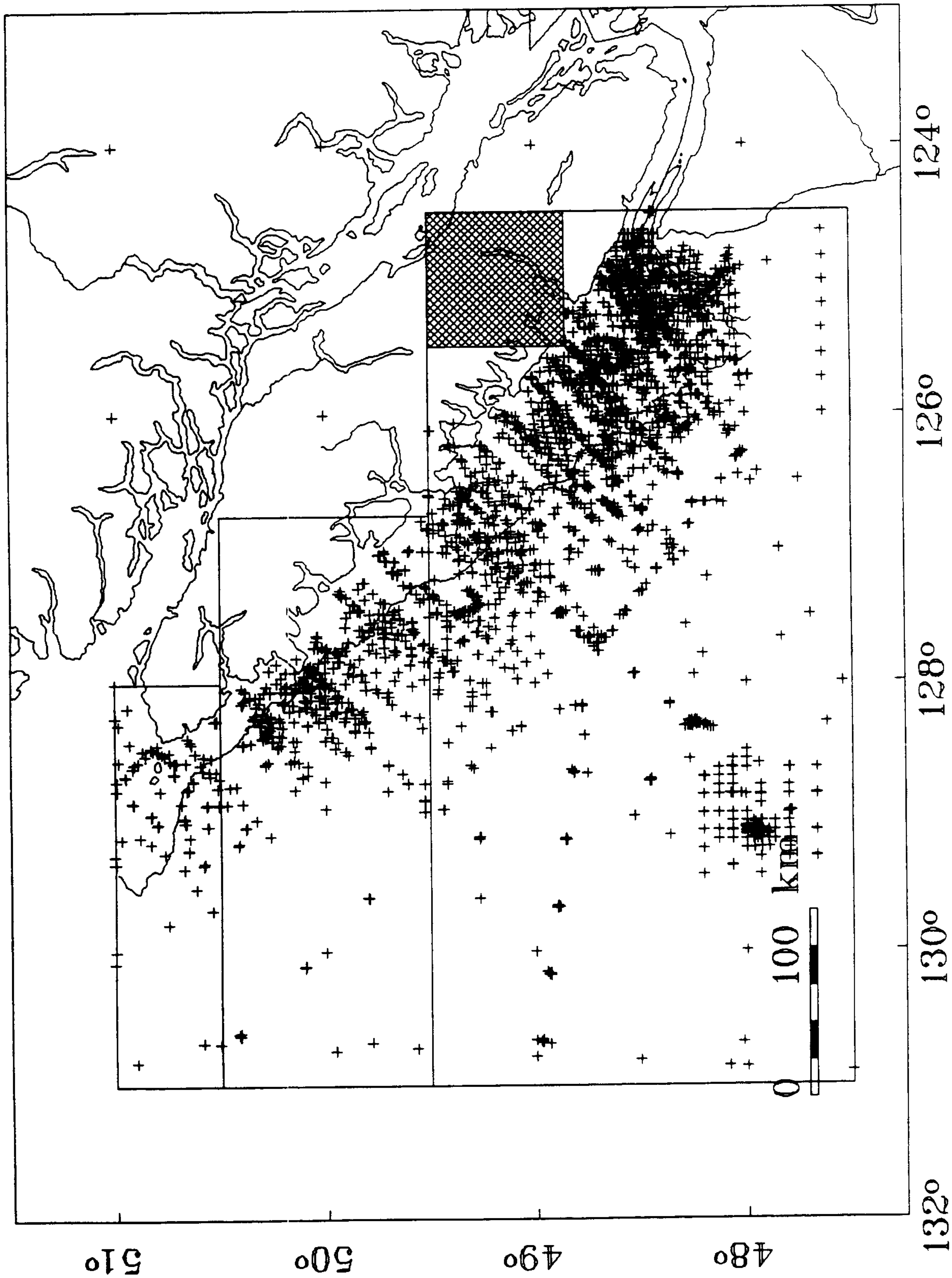
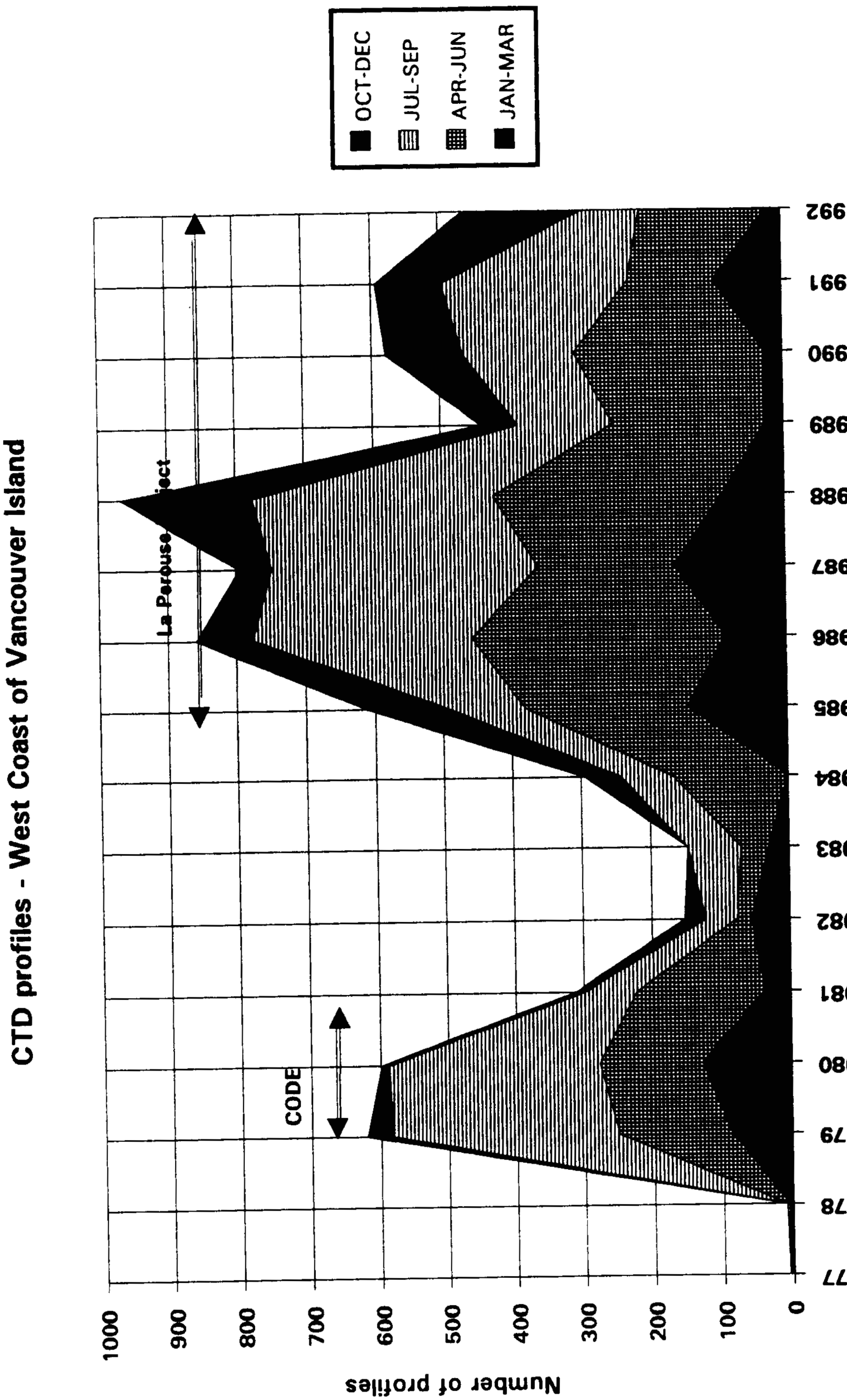


**Figure 3: Distribution of CTD profiles (by year; by quarter)**



## SHORT-TERM AND LONG-TERM CHANGES IN THE CARRYING CAPACITY IN THE STRAIT OF GEORGIA

*R. J. Beamish*

Measuring ecosystem health is only possible if natural changes can be separated from anthropogenic changes. Because fish are important sources of revenue to maritime economies, the health of fish stocks is frequently associated with ecosystem health. Changes in the abundance of fishes can occur for natural reasons, from overfishing, and as a result of pollution or physical damage to habitat. Pacific salmon abundance trends are affected by all of these factors, and the health of their stocks should be an excellent indicator of the health of the environment.

In the past, studies of salmon stock dynamics have concentrated on fishing effects and freshwater habitat effects such as logging impacts. In this report, I will examine the impact of the marine environment on the abundance trends of chinook and coho salmon in the Strait of Georgia. The marine phase of the life history of salmon is known to result in high levels of natural mortality (85% to 98%), and consequently, small changes in survival in the ocean can have profound effects on the numbers of salmon that are caught in the fishery or escape the fishery to spawn.

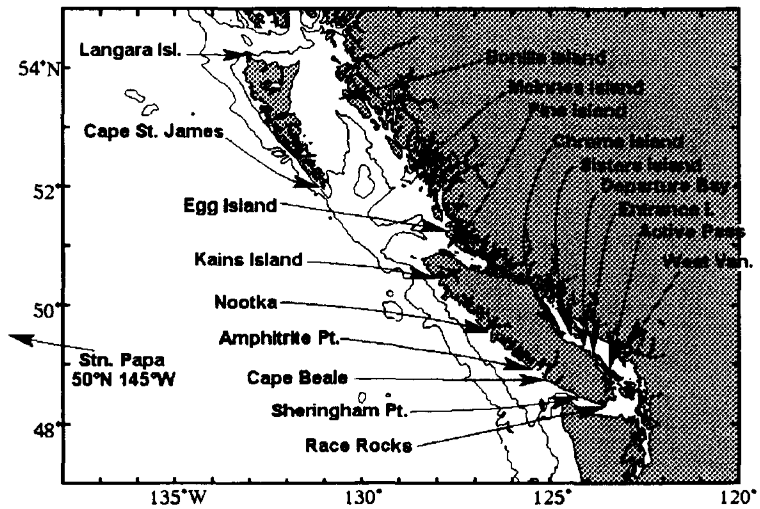
In the Strait of Georgia, the major effects of the environment on stock dynamics may be predictable or at least understandable in terms of abundance changes. We may be able to detect carrying capacity changes and estimate their impacts, but at present we do not understand the changes that occur within a carrying capacity for a particular species.

We now know that there are two types of carrying capacity changes in the Strait of Georgia. The short-term or interannual effects are associated with the annual fluctuations in the amount of Fraser River discharge, and the long-term shifts are related to the chemistry of the bottom water that enters the Strait of Georgia from offshore. Both of these short-term and long-term changes appear to be closely related to the survival trends of chinook and coho salmon in the Strait.

The existence of short-term and long-term environmental changes indicates that while monitoring the changes of abundance of fish and the physical and chemical properties in the Strait is important, an assessment of ecosystem health will only be possible with the appropriate research that will permit meaningful analysis of the data collected.

## TRENDS IN SEA-SURFACE PROPERTIES

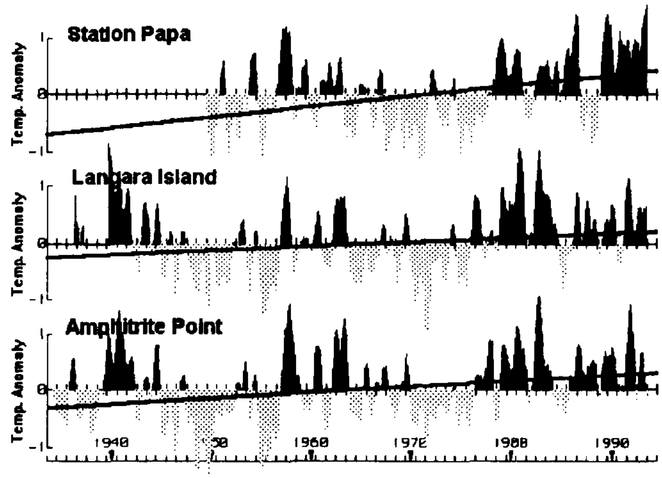
*H. Freeland*




Sea water properties have been sampled at about 14 locations around the coast of B.C. since 1914 at Departure Bay, 1921 at Race Rocks and since 1936 at most other locations. Figure 1 opposite shows the distribution of sampling locations. At most locations sea surface temperature and salinity are observed and recorded daily. The resulting data set is remarkable firstly because of the length of (almost) unbroken time series, and secondly because the sampling regimes and protocols have remained virtually unchanged throughout the history of the program. Most of the sampling sites are lighthouses, run by the Canadian Coast Guard. The keepers perform a minor sampling program for us under contract. At a few other locations different departments are involved. For example, the sampling at Departure Bay is done at the Pacific Biological Station by a D.F.O. employee. The sampling at Cape St. James is completed courtesy of Environment Canada. Despite the longevity of many of these time series, they are fragile and can be lost very easily. For example, both Amphitrite Point and Sheringham Point are locations that were automated by the CCGS. In the case of Sheringham Point a variety of circumstances prompted us to abandon that sampling location at that time. However, to maintain the time series at Amphitrite Point we now contract the sampling to a local resident. Cape St. James was automated by A.E.S., and the manual sampling was replaced by a nearby buoy. However, the buoy is outside the upwelling area close in to Cape St. James and the temperature regime shows a definite offset from the 60 year time series. That time series should now be regarded as having been lost.

Being in possession of such long time series it is natural to ask what trends are exhibited in the physical variables. Figure 2 opposite shows a plot of sea-surface temperature anomaly at two lighthouse locations and at Station Papa (50°N, 145°W). The anomalies are calculated by estimating the mean annual cycle and subtracting that from the monthly averaged sea-surface temperatures (SSTs). The areas shaded solid black are periods that have positive SST anomalies, the light shaded areas have negative anomalies. Regression lines are shown by the bold straight lines. The regressions in almost every case indicate a warming trend.

However, it should be clear from figure 2 that though the data indicate a warming trend, there is a very large amount of background variability that makes the standard error estimate large. It is interesting that the variability evident in figure 2 has a very large spatial scale. The variations seen at Amphitrite Point, Langara island, and at Station Papa have a great degree of similarity.




The sense that a large amount of variability exists that might confound trend estimates is verified when we estimate the trends and their confidence levels, illustrated in the table below.

| Station | trend °C/cent | dof | C95 | C90 |
|---|---|---|---|---|
| Langara | +0.74 | 127 | ±0.88 | ±0.74 |
| Cape St. James | +1.17 | 120 | ±0.87 | ±0.73 |
| Pine Island | +1.01 | 102 | ±0.72 | ±0.60 |
| Kains Island | +0.36 | 124 | ±0.82 | ±0.69 |
| Amphitrite Pt. | +1.02 | 149 | ±0.75 | ±0.63 |
| Station Papa | +1.82 | 115 | ±1.18 | ±0.99 |
| Race Rocks | +0.37 | 156 | ±0.40 | ±0.33 |
| Departure Bay | +0.70 | 211 | ±0.49 | ±0.41 |
| Entrance Island | +0.75 | 177 | ±0.70 | ±0.59 |
| N. Hemisphere | +0.45 | 553 | ±0.09 | ±0.07 |

Clearly, large trends appear in the first group of entries, representing SST trends at exposed coastal locations. In most cases these trends show marginal significance. In all cases the number of degrees of freedom is estimated according to the method described by Bayley and Hammersley (1946). A very large trend is seen at Station Papa, and this does appear to be significant. The trends observed at protected (inside) locations, Race Rocks, Departure Bay and Entrance Island, are all small and insignificant. The final location presented is the trend for the Northern Hemisphere land based air temperatures as computed by Jones et al. (1986). This well known time series has a large and highly significant trend.

Figure 3 opposite shows the well known northern hemisphere time series as computed by Jones et al. The large and obvious trend is frequently ascribed to the Greenhouse Effect, but careful examination shows that this explanation has problems. For example, how do we account for the long period between 1935 and 1970 when despite rising concentrations of greenhouse gasses global air temperatures declined? Of more important significance is the fact that our lighthouse time series largely began in the mid 1930's. If we cover the part of figure 3 extending from 1880 to 1935 and restrict ourselves to an analysis of what remains, we have a time series with a weak trend and lots of variability. Indeed it would be hard to convince anyone based on that remaining data set that any trend existed.

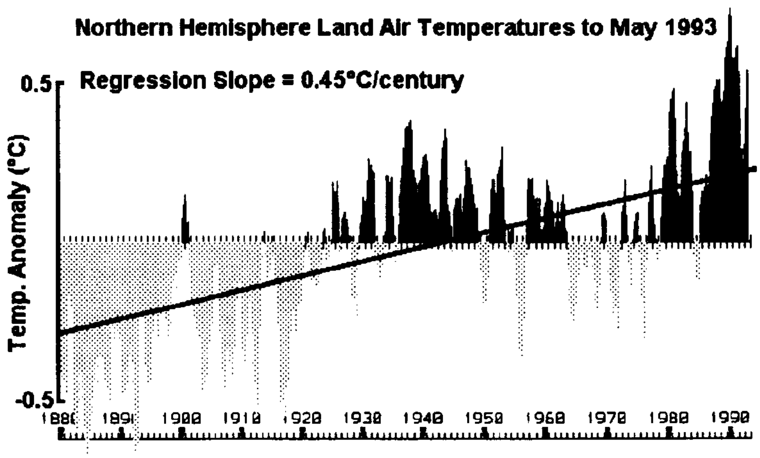
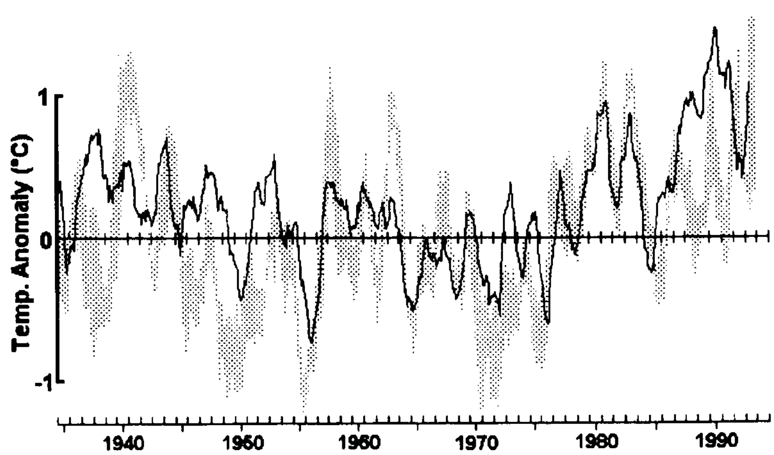
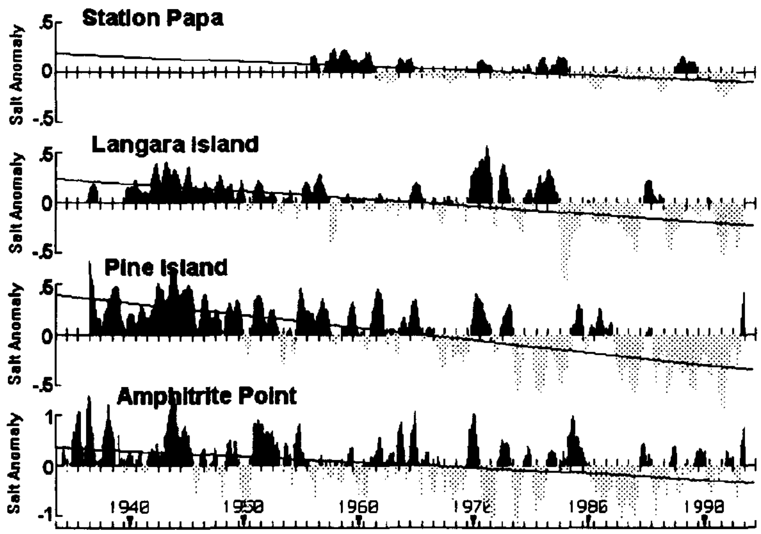



Figure 4, opposite, shows a complicated plot of the Jones et al time series and the lighthouse data. The light shaded area shows the range of anomalies seen off the west coast of B.C. between 1935 and the present time. Specifically, I look at the anomalies at Amphitrite Point, Nootka, Pine Island, Cape St James and Langara Island for each month of observations, find the largest and smallest anomaly for each month and shaded that range. The solid line is the Jones et al time series superposed for comparison, and rescaled to have the same variance as the coastal observations. These time series have no data in common at all. Despite that it is clear that coastal temperatures show very high coherence with the Jones et al time series. If we assume that this high coherence is not a chance happening of the last two thirds of the 20th century, then we are forced to the conclusion that large trends in sea surface temperature must have existed over the last 120 years or so.



Recently a new time series has become available near Seward in Alaska. This is an open ocean site, similar in concept to Station Papa, that is maintained by the University of Alaska. The site shows massive variability in SST and no significant trend. It is noticeable that the fluctuations observed (over a period of about 20 years so far) show no coherence with any of the BC shore stations or with ocean station Papa.

It was mentioned earlier that both temperature and salinity are monitored at the BC coastal stations, and also at Station Papa, of course. Figure 5, opposite, shows a plot of the sea surface salinity (SSS) anomalies computed in the same way that SST anomalies were computed. A glance at the diagram makes it clear that there are large trends in SSS, and relatively small local variability.




Once again, over the scale of the coast of BC and out as far as Ocean Station Papa very substantial coherence is evident. The Alaska series also contains salinity data, this, as in the case with the SSTs, shows no significant trend and shows no resemblance to the BC time series.

Once again the evidence of our senses is borne out with a detailed examination of the statistics, as shown in the table below.

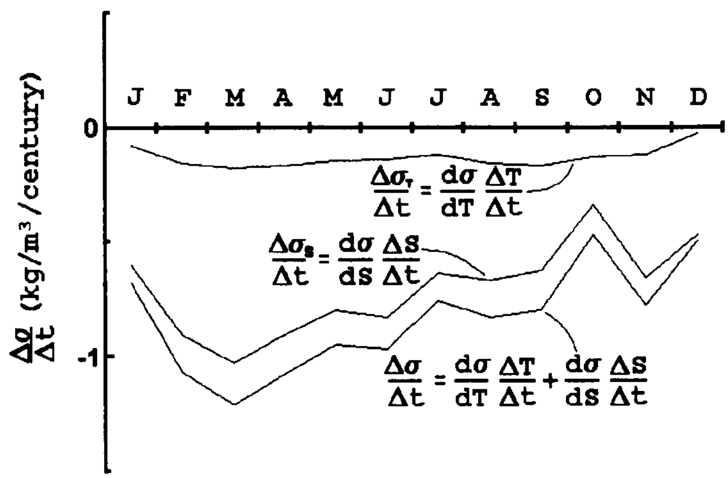
Sea Surface Salinity Trends

| Station | trend ppt/cen | dof | C95 | C90 |
|---|---|---|---|---|
| Langara | -0.73 | 136 | ±0.28 | ±0.23 |
| Cape St. James | - | - | - | - |
| Pine Island | -1.22 | 154 | ±0.28 | ±0.24 |
| Kains Island | -0.79 | 199 | ±0.66 | ±0.55 |
| Amphitrite Pt. | -1.13 | 321 | ±0.55 | ±0.46 |
| Station Papa | -0.47 | 41 | ±0.31 | ±0.26 |
| Race Rocks | +0.11 | 105 | ±0.44 | ±0.37 |
| Departure Bay | +0.49 | 277 | ±0.94 | ±0.79 |
| Entrance Island | +0.84 | 173 | ±1.04 | ±0.87 |

This table confirms that the sea-surface salinities are large and are at a high level of significance in the outside waters, along the coast and at Station papa. The observed trends at sheltered locations are not significant.

The salinity trend is negative, tending towards decreasing density, and the temperature trend is positive, warmer water, tending also towards decreasing density. It is clear that the salinity trend is more significant, is that because the signal is larger? Or is it because there is less innate variability in sea-surface salinity? Figure 6 attempts to answer that question.

Figure 6, opposite, shows a plot of the temperature and salinity trends broken down by month. Furthermore, the actual temperature and salinity trends are converted to sigma-t trends where sigma-t = 1000(density - 1.0) by multiplying by the appropriate expansion coefficients. One should note that these coefficients, particularly the thermal expansion coefficient, are extremely non-linear and need to be evaluated at the actual in situ monthly averaged temperatures and salinities. This accounts for the break-down by season. In this plot the temperature and salinity trends are expressed in the same units and it is evident that the downward salinity trend is considerably more important than is the temperature trend. The total rate of decrease of surface density of 1 sigma-t unit per century is really very large and should be a matter of concern. A decrease of surface density by 1 sigma-t unit will increase the density contrast between the deep and shallow water masses, increase the work required to mix the surface layers of the water column and so reduce the rate at which nutrients can be mixed into the near surface layers. It would be worth while estimating what effect this long term trend might have on primary productivity.



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Jones P.D., S.C.B. Raper, R.S. Bradley, H.F. Diaz, P.M. Kelley and T.M.L. Wigley. 1986. Northern Hemisphere surface air temperature variations: 1851-1984. J. Climate Appl. Meteor. **25**, 161-179.

# CONCLUSIONS

## SESSION SUMMARIES

*Diana Valiela*

## SESSION 1 - CONTAMINANTS

### Panel Question: Are Contaminants Biomagnifying in Marine Food Webs?

There is no doubt that certain persistent contaminants are biomagnifying in marine food webs in the Pacific Ecozone. Although there are no instances of detailed documentation of biomagnification from trophic level to trophic level in a specific food web, there are many instances of very high concentrations of persistent contaminants in animals occupying high trophic levels. In some cases, these compounds have been shown to biomagnify in the world literature.

Examples of compounds found and thought to be biomagnifying reported in the panel presentations include:

* dioxins and furans in fish, shellfish, harbour seals, harbour porpoises, and birds that feed on fish and shellfish.

* PCB's and chlorinated pesticides, as well as mercury and lead, in fish, shellfish, fish-eating birds, and harbour porpoises.

* Other contaminants, such as arsenic and PAH's, were found in sediments, fish and shellfish. Because these compounds are not thought to biomagnify, their presence in these compartments are thought to be due to accumulation and bioconcentration. It was noted that the bioavailability of metals is a major factor determining bioaccumulation, but that we do not yet have appropriate measures for monitoring bioavailable forms of metals.

In the last few years, there has been a decrease in the concentrations previously found in some ecosystem compartments in response to specific regulation of releases of certain contaminants in the Pacific coast. Examples include:

* lead in sediments
* mercury in fish tissues (apparent, yet statistically untested, decrease)
* chlorinated organics and dioxins and furans in some species of birds.

Panel Question: What are the Best Indicators of Biomagnification?

* The best indicators of biomagnification depend on the substances and the ecosystems affected, but are generally concentrations of contaminants in animals occupying high trophic levels.

* There was a suggestion that the variability in data from eggs of fish-eating birds was less than that from seal blubber, and that in turn less than that from fish tissues. However, this hypothesis requires much greater analysis. In addition, the variablity in seals and fish can be greatly reduced by standardization procedures, such as comparisons of animals matched for age and reproductive condition, calculation of tissue concentrations on a dry weight basis, and normalizing for percent lipids in fish and shellfish tissues.

* Other useful indicators of contamination being used include uptake of "standard" exposed organisms, such as the Mussel Watch program, morphological abnormalities, biochemical responses, and sediment core studies.

## SESSION 2 - PATHOGENS, TOXINS, AND DISEASE PREVALENCE

Panel Question: Is Disease Prevalence Changing? Is it Caused by Anthropogenic Changes? Is it Pervasive or Confined to "Hot Spots"?

A high incidence of certain specific biological effects of pathogens, toxins, and disease has been documented in Pacific coast marine organisms.

* The most widespread problem is contamination of shellfish growing waters with fecal coliforms, resulting primarily from human sewage. Fecal coliforms commonly enter marine waters from land-based untreated or insufficiently treated sewage and boat sewage discharges. The extent of contamination seems to be increasing, and new areas are closed to shellfish harvesting annually.

* Shellfish closures also result from contamination with biogenic compounds causing P.S.P. (Paralytic Shellfish Poisoning). P.S.P. problems are quite widespread geographically and, although occurring mostly in summer, are not confined to that season. The P.S.P. index seemed to be declining or steady on the West coast of Vancouver Island and the Strait of Georgia, but it is not clear whether this apparent change is a long-term trend or only a short-term random fluctuation. Further, the species and sites monitored for commercial products have changed over time, making the data unsuitable for long-period trend analysis.

* The presence of domoic acid in shellfish has also resulted in shellfish harvesting closures. Distribution and trends in contamination with domoic acid are not well known; for the moment, contamination seems confined to "hot spots." Monitoring procedures began immediately after the 1987 outbreak in the East Coast, but analytical methods have changed. Domoic acid in Pacific coast commercial products was first detected in the Fall of 1992.

* Toxic algal blooms are widespread and may be related in part to nutrient inputs, but it is not known whether these are anthropogenic or natural. Fish mortalities due to toxic algal blooms are well characterized in cultured fish farms, but these data have some limitations in monitoring the overall distribution and trends of toxic algal blooms because the industry changes its area of operations over time.

* Imposex in marine gastropods is also widespread and known to be caused by use of TBT (Tributyl Tin) and closely associated compounds in boat paints and salmon pen anti-fouling. Although the incidence of imposex is expected to decrease as TBT use is discontinued for most purposes, it seems to be stabilizing at only a reduced level.

* Liver lesions in flatfish have been found in a number of urban/industrial areas in B.C. and Puget Sound, Washington. These pathological conditions are known to be caused by exposure to anthropogenic chemicals, particularly chlorinated and aromatic hydrocarbons and specifically, polycyclic aromatic hydrocarbons (PAHs). Histopathological studies in Burrard Inlet and several B.C. pulp mill sites have shown the presence of neoplastic and preneoplastic liver lasions in English sole and other flatfish species. In some regions of Burrard Inlet, lesions were found in up to 75% of the sole sampled. A decline in the incidence of liver lesions in one location of Burrard Inlet suggests that they may respond rapidly to implementation of abatement programs. Further sampling to establish a trend is required.

## SESSION 3 - SPECIES DIVERSITY AND SIZE SPECTRUM

Panel Question: How do We Measure Biodiversity?

Species diversity is only one component of biodiversity. Biodiversity includes concepts of diversity in genetic make-up within species, of species within communities, and of ecosystems within a geographical area ("landscape" or "seascape" diversity). Both species richness and evenness are included in useful measures of community diversity, since two communities with identical total numbers of species may differ dramatically in how common or rare one species is versus other species. The lay concept of biodiversity relates to rare or endangered single species.

Genetic, species, and ecosystem diversity are all being altered by anthropogenic influences. We know this is happening because of examples such as the Salmon Enhancement Program, as well as targeted salmon fisheries, which are surely changing the genetic diversity of salmon species on the Pacific coast. Salmon genetic stocks are estimated to have been reduced by one-third since the turn of the century. With respect to changes in species composition, obvious examples are the intentional introduction of exotic species, such as the Japanese oyster, which is now common and widespread throughout the B.C. coast, as well as of other species of oysters, scallops, clams, and Atlantic salmon. Ecosystem diversity is altered by anthropogenic factors such as dredging, log storage and handling, sedimentation from construction and other activities.

Panel Question: What are the Trends? How Useful is Biodiversity as an Indicator? Are the Ecological Size Spectra Deformed?

In most cases, none of the types of diversity has been measured, and it is not known to what extent the changes due to anthropogenic factors can be separated from changes that might occur absent human influences. In most cases, we only have information reflecting changes in the relative abundance of certain species. In most cases available data are neither of the quality or quantity to allow defensible calculation of species diversity. Because calculation of species diversity of communities over time requires aggregation of huge numbers of data, it would necessarily involve mixing a few good quality data sets, for example for some commercially important fish species, with other data sets of variable quality and quantity. For most other types of communities, the quality and period of record of data would be even worse.

* Studies of zooplankton biomass and species composition show that zooplankton fluctuates dramatically, both seasonally and interannually, in species dominance patterns and in size spectra. No statements can be made at present about long-term trends. No species loss or outbreaks of exotic species are seen in zooplankton, but it is possible that such changes are taking place and are undetected. Important processes that may be reflected in the zooplankton include physical changes in the water column, effects of harvesting fish, and an indication of the food sources available for fish.

* Measures of benthic macroinvertebrate communities could indicate food supplies available for certain migratory birds and fish, as well as effects of climate change. There is not sufficient information to characterize any long-term trends in these communities. For certain species, especially those commercially utilized, there is some information on trends of population size and distribution. For example, it is well known that a number of exploited species are severely reduced from historical numbers and distributions (e.g. Olympia oyster, several clam species). It was emphasized that there has been a loss of taxonomic expertise required to study communities of benthic invertebrates forming the food web base for migratory

birds. Further, the variability and patchiness in these communities constitute a formidable challenge given the resources available to carry out systematic studies of diversity.

* Sole, pacific cod, herring, pacific hake, and most other stocks of commercially important marine fish show fluctuations, but present population levels are well within historic levels of abundance and, with a few exceptions, stocks are in good shape. The exceptions include chinook salmon and ling cod in the Strait of Georgia, and coho, chinook, and steelhead in the Skeena. Some species and some stocks of salmon are decreasing and a number of others, such as Fraser sockeye, are at historic record levels. The community composition of finfishes is variable in space and time.

* Salmon numbers, size and age can be used to infer food conditions, effects of salmon enhancement, and availability of suitable habitat at various life stages. For some salmon species and stocks, there is an inverse relationship between density (and numbers of salmon released by enhancement projects) and body size.

* Increases have been documented in numbers and number of species of nesting marine birds in some areas. In some cases, the increases seem to be leveling off, indicating a possible limit in carrying capacity of the habitats utilized. Numbers and species composition changes in nesting marine birds may indicate changes in food supply conditions, human disturbance, and toxic contaminants.

* Marine mammal populations are generally increasing. There is anecdotal information on decreasing populations of harbour porpoise. However, there are no good quantitative data on the status of harbour porpoise populations. Harbour seal increases are also leveling off and this may also indicate a limit to the carrying capacity of the environment for this species. Although killer whales are below historic levels according to anecdotal information, there is a recent trend to increases in this species as well. Sea otter populations are increasing dramatically since they were re-introduced to the B.C. coast.

* Marine mammal populations, condition, and contaminant content of tissues can indicate food supplies, including effect of some fisheries, effects of anthropogenic disturbance, and effects of toxic contaminants and oil spills.

## SESSION 4 - PRIMARY PRODUCTIVITY AND NUTRIENTS

Panel Question: Is Primary Productivity Changing?

* Strong temporal and spatial variability is observed in the primary productivity of Hecate Strait, the West coast of Vancouver Island, and the Strait of Georgia. There is significant interannual and decade-scale variability in the West coast of Vancouver Island.

* Long-term trends in productivity are unknown. It is clear, however, that natural nutrient inputs are much greater than anthropogenic inputs and therefore the former are more likely to control productivity. Nevertheless, anthropogenic inputs can result in local eutrophication problems, especially in small, poorly-flushed areas. Factors thought to be important in controlling primary productivity include wind mixing, upwelling, grazing, river discharge, and temperature. Sunlight and temperature indices and models may allow useful predictions of primary and secondary production.

## SESSION 5 - INSTABILITY

Panel Question: Are There Indications of Long-Term Instability?

There are a number of indications of what is thought to constitute long-term instability.

* Fraser River runoff seems to be increasing over time. Catches of Fraser river coho, chinook, and chum seem to decrease when Fraser river runoff is high. There is a trend towards warming and a strong trend toward lower salinity in the sea-surface off B.C.. The resulting reduced density is very marked, and will reduce mixing and nutrient inputs from offshore areas. These trends are not observed as yet in shorter data records from inshore areas.

* With the possible exception of these temperature and salinity trends in offshore surface waters, for most sets of data available it is impossible to differentiate short-term state changes from long-term trends from long-period cycles. Further, in many cases, it is difficult or impossible to differentiate anthropogenic from naturally-induced changes due to climate, hydrology, or biological processes. This is especially true where human influence indirectly affects natural processes (e.g., climate change).

* In selected situations, for example in the case of certain contaminants, it has been possible to identify specific anthropogenic effects and to im1plement effective control measures.

## CLOSING REMARKS

*M. Bewers*

### WORKSHOP OBJECTIVES

The objectives of the Workshop can be summarized as:

1. To bring together the custodians of time-series marine monitoring data sets;

2. To design a network for coordinated monitoring and reporting of marine environmental quality on the Pacific coast of Canada;

3. To contribute to the design of the Canadian Marine Status and Trends Monitoring Network.

Objective 1 was met and exceeded in the sense that presentations dealt with more than merely time-series monitoring. Indeed, the meeting facilitated the presentation and discussion of a wide variety of projects involving the measurement of condition and trends in marine matrices.

Objective 2 is clearly an ambitious one. This meeting sought to capitalize on the opportunity to mesh together appropriate monitoring and survey activities into a more comprehensive and valuable framework for defining the state and trends within the Pacific coastal marine environment. The main text of these closing remarks addresses this objective and, by implication, Objective 3 which is a *sequitur* to Objective 2.

### STRATEGIC CONSIDERATIONS

In respect to objectives 2 and 3 above, there are a number of strategic considerations that need to be addressed. These are:

1. Define Objective(s): These must specify the purpose and application of the measurements;

2. Establish testable hypotheses consistent with the objectives;

3. Define measurement quality criteria necessary for testing the hypotheses (precision, accuracy; frequency of measurement);

4. Establish appropriate quality assurance procedures.

## OBJECTIVE 2

The context for Objective 2 can be outlined as follows, based on the presentations and discussion during the Workshop. The following is an attempt to draw some conclusions from the Workshop and express them hierarchically.

**Subject**: Coordinated Monitoring and Reporting.

**Context**: Environmental Quality of Pacific Marine Coastal Area.

**Argument**: There is no *a priori* reason to exclude research.

**Rationale**: Many possible measurement series are not yet at a stage of development that qualifies them as monitoring tools because:

a) there is inadequate specification of achievable signal-to-noise;

b) there is inadequate quality assurance;

c) relevance to issues of MEQ concern has not been adequately demonstrated.

## ENVIRONMENTAL CONDITION AND CHANGE

Assuming that the title of this section encapsulates the focus of the intended monitoring framework for status and trends, it is useful to examine the driving forces that demand information that might be derived from the programme.

**Driving Forces**:
Public Interest
Sustainable Development
Environmental Protection
Coastal Zone Management
Resource Utilization/Economics

The objectives of the programme relate to the identification and quantification of change in conditions both for examining hindcasting coherence and for prediction (e.g., early warning of adverse trends).

What then are legitimate foci of measurements made within the proposed programme framework? In my view these are:

**Relevant topics**:
contamination;
biological effects of contaminants;
production of (natural) toxins;
physical properties;
diversity of biological communities.

## MONITORING TYPES

What categories of monitoring might legitimately be considered for inclusion in the programme framework? Basically, monitoring focusses on changes in the environment and, for practical purposes, falls into the following categories: compliance, health protection, patterns and trends, and research. In the present context, the latter two categories can be combined under the heading of "environmental monitoring". Potential inclusions under the three chosen categories are shown below:

**Human Health Protection**

Seafood quality;
Bathing water quality;
Drinking water quality (if a relevant component).

**Compliance**

Dumpsite monitoring;
Discharge monitoring;
Runoff monitoring (for diffuse source aggregate if appropriate)

In relation to: Fisheries Act;
Canadian Environmental Protection Act;
Cumulative Environmental Impact Act;
Canadian Environmental Assessment Act;
Provincial Acts and Regulations.
(e.g., Compliance with any legislative standards)

**Environmental Monitoring** (Status and Trends)

- Down-core trend contaminant reconstruction;
- Environmental contaminant distributions (water, sediments, biota);
- Biological effects of contaminants;
- Toxin/nutrient measurements;
- Physical properties (solids, temp, salinity, etc.);
- Biological diversity;
- Habitat conditions;
- Health/condition of aquatic organisms;

Performance criteria for the measurement of contemporary condition are less stringent than criteria for temporal trend measurements.

In the context of the health/condition of marine organisms, the following measurements are relevant:

- Community structure;
- Contaminant exposure fields;

- Contaminant accumulation;
- Animal condition indices;
- Contaminant response indices (e.g., enzyme induction).

RELEVANT TRENDS

The following is a brief summary of potential trend measurements, their driving forces and purposes.

**Trends in Fisheries Resources/Stocks**

**Prime Driver**: Economic.

**Focus**: Trends in the abundance and distribution of exploitable species.

**Purpose**: Sustainable exploitation of renewable resources.

**Climate-Related Trends**

**Prime Driver**: Economic.

**Focus:** Trends in temperature, salinity, sea-level, insolation, etc.

**Purpose**: To project, through extrapolation, time trends for determining the need for, and nature of, policy responses.

**Contaminants in Seafood**

**Prime Drivers**: Public Health Protection;
Economic .

**Focus**: Contaminant levels in edible tissues of marine organisms.

**Purpose**: Ensure long-term health protection and to predict trends of contaminants in seafood for determining policy response.

Priorities may be assigned in relation to nature of suspected trend, relative toxicity, persistence and bioaccumulation properties of substances, and proximity of levels to regulatory standards/tolerances.

**Destruction of Habitat**

**Prime Drivers**: Sustainable Development; Biodiversity; Public Interest.

**Focus**: Distribution of different habitat types in relation to colonization by communities of organisms.

**Purpose**: To provide an indicator of progress towards sustainable development.

This topic has spatial and temporal components that relate to temporal trends.

**Contaminants in Avians and Non-Commercial Marine Biota**

**Prime Drivers**: Public Interest; Biodiversity.

**Focus**: Presence and levels of contaminants in tissues of non-commercial maritime organisms.

**Purpose**: Indicators of progress towards sustainable development and the maintenance of biodiversity.

In the cases of contaminants and organisms for which an adequate understanding of dose-response relationships exists, this activity also covers biological effects.

## TREND MEASUREMENT APPLICATIONS

For a measurement to have utility in trend measurement applications, it must meet specific criteria relating to:

- precision;
- an ability to control and compensate for extraneous sources of variance to the extent required for trend detection and quantification in amounts and with probabilities specified in the statement of objectives and testable hypotheses;
- frequency of measurement;
- quality assurance.

These criteria have been demonstrably met by:

- Climate-related measurements of temperature and salinity;
- Commercial fish population trends;
- Contaminant trend measurements in avian tissues;
- Certain river and atmospheric composition/flux measurements;
- Certain down-core trend measurements; and
- (implicitly) Trends in habitat loss.