COMMENCEMENT BAY NATURAL RESOURCE TRUSTEES SEDIMENT CLEANUP GOALS FOR ACTIVE NATURAL RESOURCE RESTORATION PROJECTS

In developing restoration projects for natural resources injured by releases of hazardous substances, the Commencement Bay Trustees are pursuing strategies that include restoration and enhancement of habitats degraded by human activities as well as preservation of existing habitat values and functions. As a result of the history of development in the industrial tideflats area of Commencement Bay, habitat manipulation activities undertaken in connection with active restoration and enhancement projects may expose fish and wildlife to potentially harmful levels of pre-existing soil, sediment or ground water contamination. Consequently, the Trustees frequently are faced with the prospect of deciding whether, and to what extent, existing contamination must be remediated to ensure an acceptable likelihood of success for the proposed restoration project.

Trustee decision making on active restoration projects (projects involving manipulation of existing habitat features) is guided in part by the following assumptions:

Active restoration projects are intended to attract fish and wildlife and to increase the use of the project area by fish and wildlife.

Active restoration projects should generate a net gain in ecosystem function and must avoid increasing the potential for natural resource injuries.

Decision making on active restoration projects should be guided by the best available scientific evidence. The need to achieve timely restoration of natural resource species, habitats and services requires the Trustees to make decisions and move forward with restoration projects even where the state of scientific knowledge is changing or incomplete. Because the goal of active restoration projects is to result in net environmental improvements, uncertainties about the benefits and detriments of alternative approaches or decision criteria should be resolved in favor of protecting and enhancing natural resources.

Applying these assumptions to active restoration projects involving pre-existing sediment contamination presents special challenges. Existing sediment cleanup regulatory standards are based primarily on observed effects of hazardous substances on benthic species and generally do not address the bioaccumulative impacts of persistent toxic compounds. Authoritative technical guidance on what level of sediment contamination is protective of fish and wildlife is not available for all frequently encountered contaminants. Consequently, the Trustees need to determine the sediment goals they will follow in making decisions on active restoration projects.

To provide notice to interested parties and consistency in decision making, the Trustees have determined to adopt the following sediment cleanup goals for active natural resource

restoration projects in Commencement Bay:

Total polynuclear aromatic hydrocarbons (PAHs)	2,000 ppb dry wt.
Polychlorinated biphenyls (PCBs)	200 ppb dry wt.
Tributyltins (TBTs)	6,000 ng/g OC

The above goals are the result of a review by technical experts of the results of numerous field and laboratory investigations of toxic effects in fish and wildlife related to sediment contamination, and have been developed in connection with the assessment and resolution of natural resource damages. The attached information summarizes the factors considered in arriving at these numbers. Pending the development of other specific goals, for other contaminants the Trustees will apply the lower of the Washington State Sediment Management Standards' sediment quality standards (SQS) or the sediment quality objectives (SQOs) of EPA's Commencement Bay Nearshore/Tideflats Superfund Site Record of Decision.

These goals are based upon the best currently available information on contaminant effects and may change as further information is developed. While the application of these goals will to some extent depend upon site conditions, it is the Trustees' intent that they will serve as the default goals for sediments at all active restoration projects.

Estimation of injury level for chinook salmon--PCBs as toxicant

- 10 studies reviewed, both lab and field-based. Data used to determine tissue levels of PCBs associated with injury. Injury endpoints included mortality, impaired growth, reduced disease resistance and immune function, impaired endocrine function.

- Tissue concentrations associated with injury were as low as 140 ppb wet weight, and as high as 22 ppm wet weight. Lower end of range tended to be associated with field investigations of salmon in Puget Sound.

- Assumptions made in estimating sediment concentrations required to give tissue concentrations were: whole body lipid levels--2% in field, 4% in lab; BSAF--1.7 (higher BSAF leads to lower allowable sediment concentrations. BSAFs for PCBs and chinook salmon in Puget Sound estuaries range as high as 5.2. BSAF of 4.0 increasingly supported in scientific literature).

- Overall effects level for the wide range of endpoints averaged 390 ppb in sediment, dry wt basis (8 studies total included). Lower levels (100 ppb or less) supported by field data for chinook salmon in Puget Sound. Best professional judgement is to use a safety factor of 2 applied to overall effects level (EPA generally supports a factor of 10), resulting in sediment injury level of 195 ppb dry wt. Rounded to 200 for settlement purposes.

- Detailed laboratory investigations with Puget Sound chinook salmon are not done (e.g. Round 3). However, it is estimated that the levels determined from this approach will be at or below 200 ppb.

Study	Tissue concentration for effect µg/g wet	µg/g dry	Lipid % wet	Lipid % dry	BSAF	Tiss conc. µg/g lip	Predicted Sedoc µg/g OC	Sed conc µg/g dry	Salmonids Sediment conc µg/g dry	Salmonids Sediment conc (adjusted) µg/g dry	Reason
Mayer et al. 1977	0.59	2.95	4	20	1.7	15	8.7	0.17	0.17	0.17	
Ndayibagira et al. 1995	5.0	25.0	4	20	1.7	125	73.5	1.47	1.47		only one dos
Fisher et al. 1994	1.1	7.17	4	20	1.7	36	21.1	0.42	0.42	0.42	
Gruger et al. 1975	3.5	17.5	3.8	19	1.7	92	54.2	1.08	1.08	1.08	
Bengtsson 1980	7.0	35.0	4.5	22.5	1.7	156	91.5	1.83			
Chen et al. 1986	1.5	7.5	4	20	1.7	38	22.1	0.44	0.44	0.44	
Schimmel et al. 1974	22.3	111.5	4.5	22.5	1.7	496	292	*5.83*	*5.83*	0.58	mortality
Arkoosh et al. 1998	0.14	0.68	2	10	1.7	6.8	4.0	0.08	0.08	0.08	
Broyles and Noveck 1979	3.60	18.0	2	10	1.7	180	106	*2.12*	*2.12*	0.21	mortality
Varanasi et al. 1993	0.16	0.8	2	10	1.7	8	4.8	0.10	0.10	0.10	
Lipid for Schimmel from Bengtsson		ACR=	0.1		dry/wet=	0.2		1.35	1.30	0.39	Mean
Bold lipid values are estimated.		TOC 2%			TOC=	2		1.74	1.84	0.33	sd
Lipid values (whole body) for lab studies can be approx. 4% wet, liver always higher								0.55	0.61	0.12	sem
Lipid for number 9 assumed to be 2% because of life stage								10	9	8	n
Lipid in Gruger et al. 1975 measured. High lipid diet from fish pellets leads to high lipid levels											
Liver lipid for Arkoosh = 4.5% wet., whole body prob 2%											
Lipid measured in Duwamish fish (7/98). Whole body wt = 0.97%									Safety Factor	**0.19**	0.5 x Mean
Lipid (whole body) for Hylebos2 lab study = 4.5% (stdev=2.0%), n=10.									of 2		
Lipid in liver for field caught chinook off SF Bay = 4.5% (stdev 1.3%), r=9											
BSAF based on EPA 1989 Record of Decision for the Hylebos.											
PCBs in liver for Arkoosh (0.27 µg/g). Value here times 0.5 to adjust to whole-body value									Predicted Injury Level Sediment Conc.		
Adjusted sediment concentration. Factor of 0.1 for minimum acute to chronic ratio										**193**	ng/g dry wt.
Varanasi, tissue conc. mean of 14 composites (5 - 10 fish per composite).									Tissue Conc.	821	ng/g dry wt.
Arkoosh study used fish from Duwamish median sed conc in Duwamish = 84 ng/g									(for 2% TOC sed and 5% lipid)		

Estimation of injury level for bird species--PCBs as toxicant

- A steady state biomagnification analysis performed by the U.S. Fish and Wildlife Service in 1996 modeled sediment levels of 30 ppb, 150 ppb, and 450 ppb total PCBs for predicting injury to marine birds in Commencement Bay.

- This analysis looked at total PCB concentrations in eggs as the most sensitive and predictive endpoint in determining the potential for injury to birds. Injuries, including egg lethality and embryonic deformities, were determined as Lowest Observable Adverse Effects Levels (LOAELs) and were based on both laboratory and field studies (Ludwig et al., 1993)

- Field investigations of great blue herons in Commencement Bay suggest a potential for bird species feeding in the Bay to be impacted. This conclusion is based in part on the levels of PCBs found in heron eggs, together with observations of feeding behavior and local feeding site fidelity.

- Using best professional judgement, incorporating existing information and current field studies, an injury level for marine birds in the Commencement Bay environment is estimated to be in the 150-200 ppb range for PCBs in sediment.

Factors supporting an estimated injury level of 2000 ppb total PAHs, dry wt, in sediment

- Developed for a single species, English sole

- Based entirely on field data

- Data collected over more than 10 years, from more than 30 sites

- Geographic coverage from northern California through Alaska, with most sampling occurring in Puget Sound

- Liver lesion threshold estimates are from Horness et al., 1998 (peer reviewed). This is a statistical approach, encompassing a sophisticated toxicological approach.

- Liver lesion thresholds range from 230 to 2800 ppb total PAHs in dry sediment, with an average threshold of approximately 1200 ppb. This average leaves out one of the more sensitive endpoints, for which a threshold could not be statistically determined at an alpha level of 0.05. The threshold estimate for development of any lesion (including the most sensitive lesion) is 620 ppb total PAHs.

- Reproductive endpoints were overlaid on the plots of liver lesion data, again all field based data, and for English sole collected in Puget Sound. These data were from Johnson et al. 1998 and Collier et al. 1998.

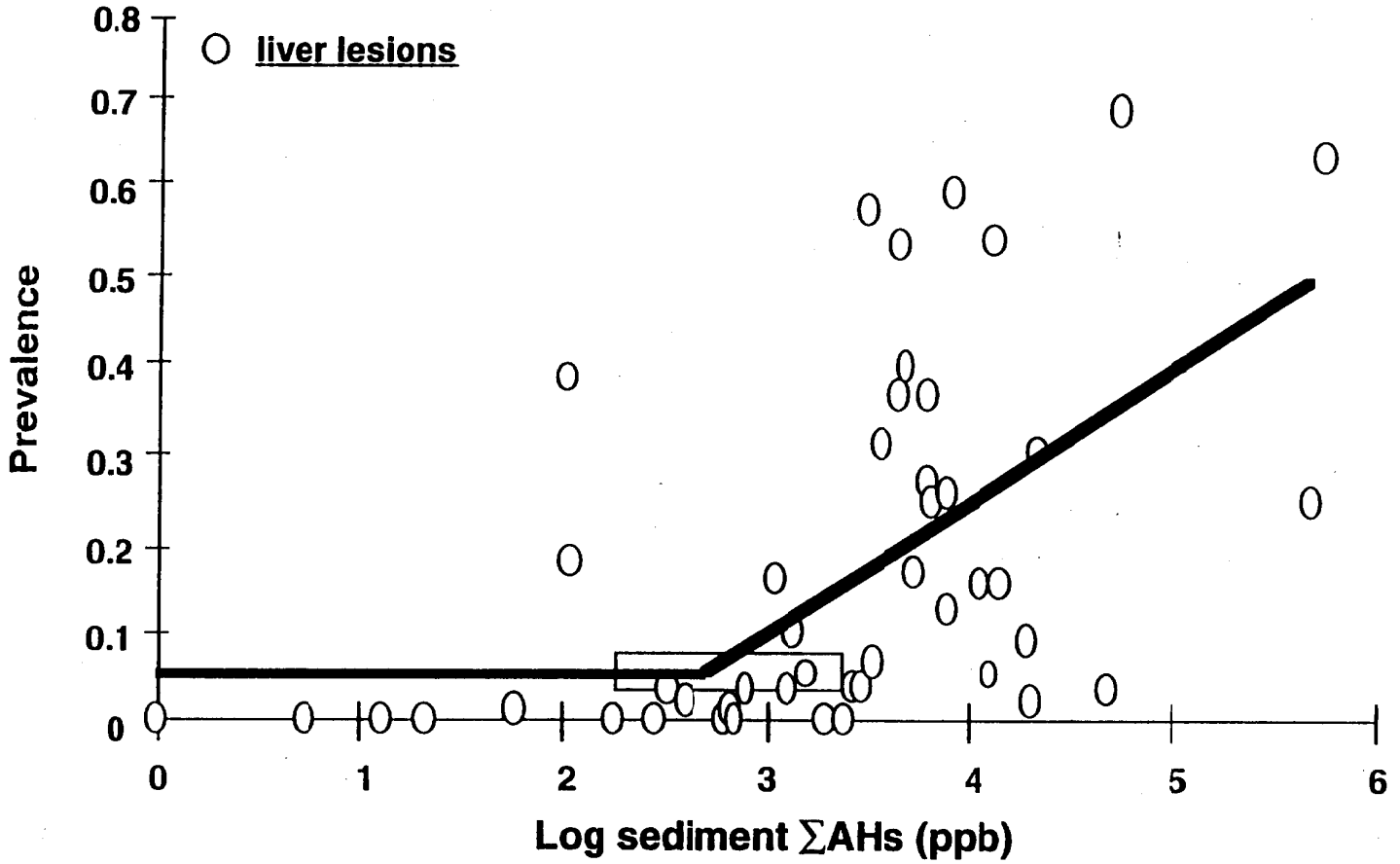
- Reproductive dysfunctions included failure to mature,

failure to spawn, failure to produce fertile eggs, and production of abnormal larvae.

- Both statistical and visual interpretation of the lesion and reproductive function data indicate that there may be injuries to this species occurring at sediment FAH levels considerably lower than 1000 ppb, but there is an apparent increase in both types of injuries at approximately the 2000 ppb level. Thus a level of PAH contamination which is thought to afford reasonable though not complete, protection to English sole is 2000 ppb total PAHs, based on dry weight of sediment. The PAHs included in this total are as listed in Collier et al, 1998.

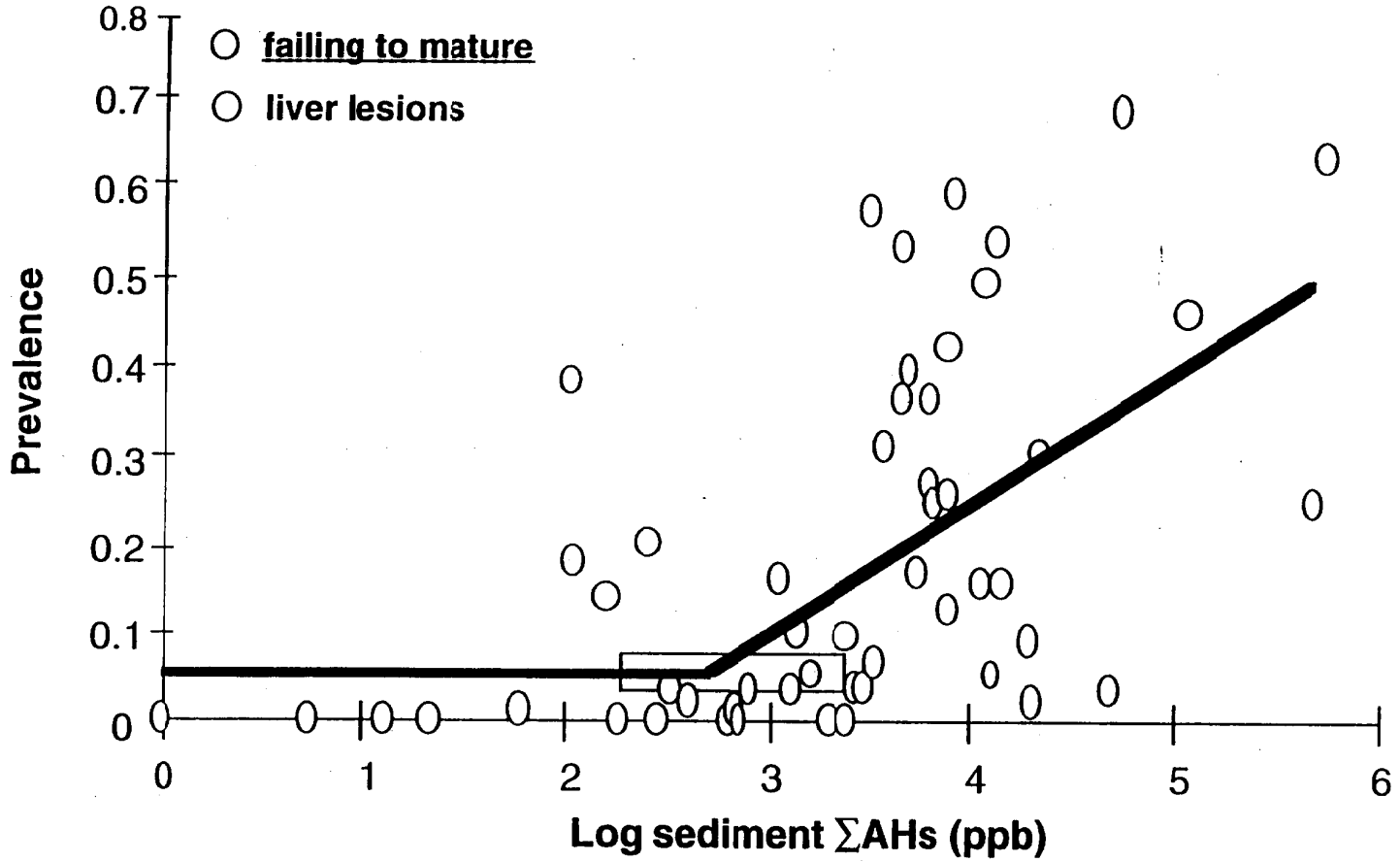
English sole

liver lesions -vs- sediment AH concentrations



English sole

prevalence that fail to undergo gonadal maturation -vs- sediment AH concentrations



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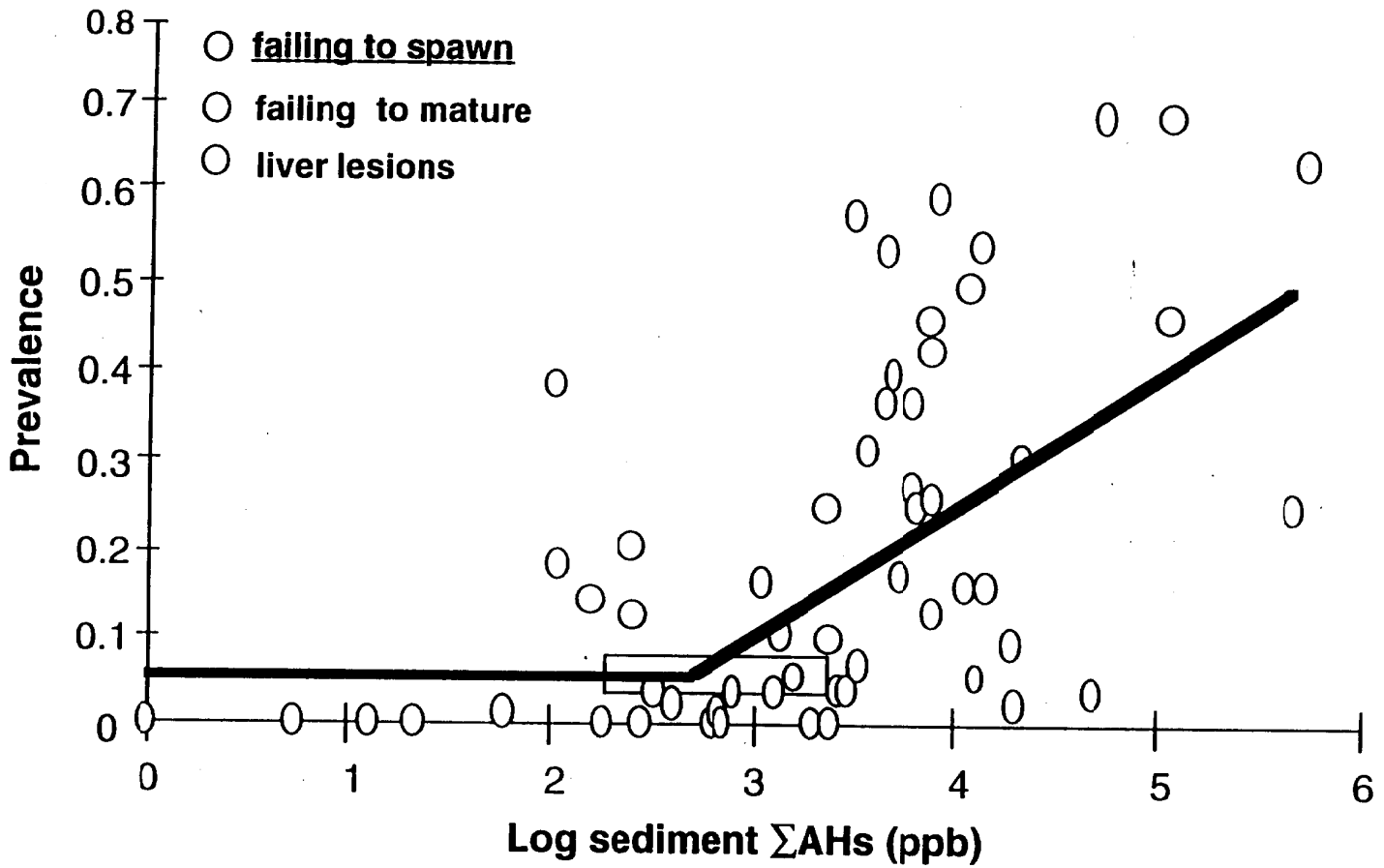
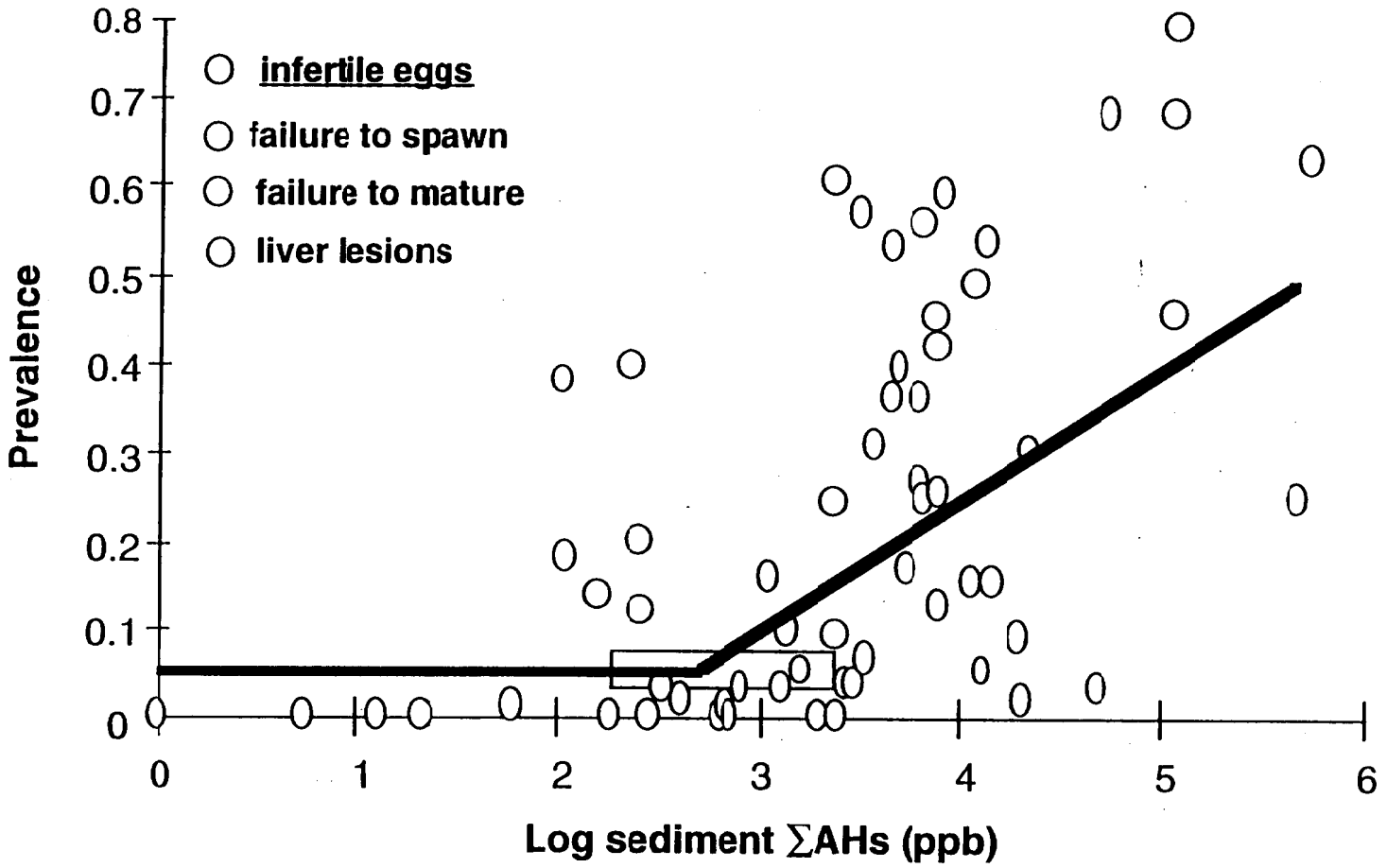
English sole

prevalence that fail to spawn -vs- sediment AH concentrations



English sole

proportion of infertile eggs -vs- sediment AH concentrations



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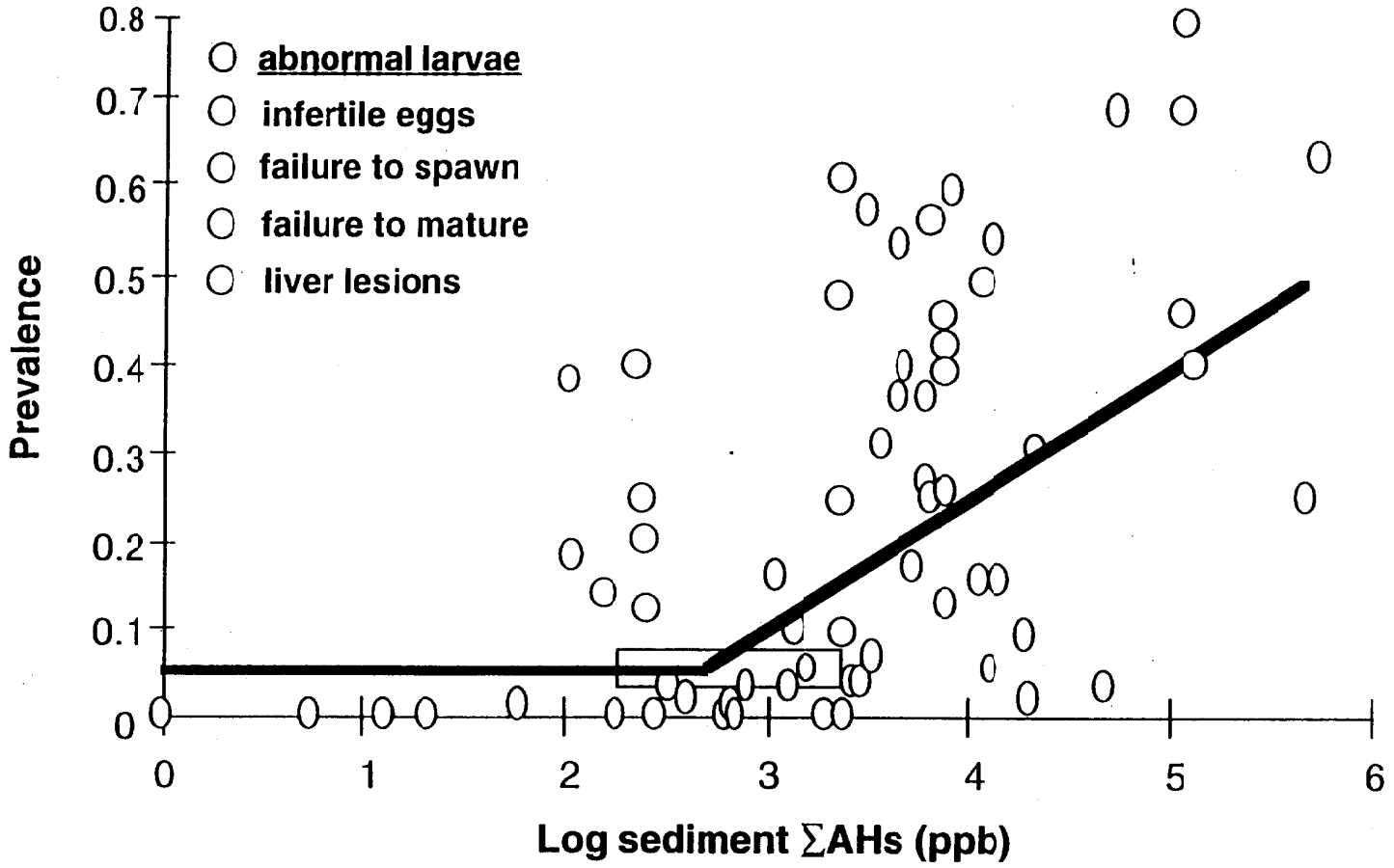
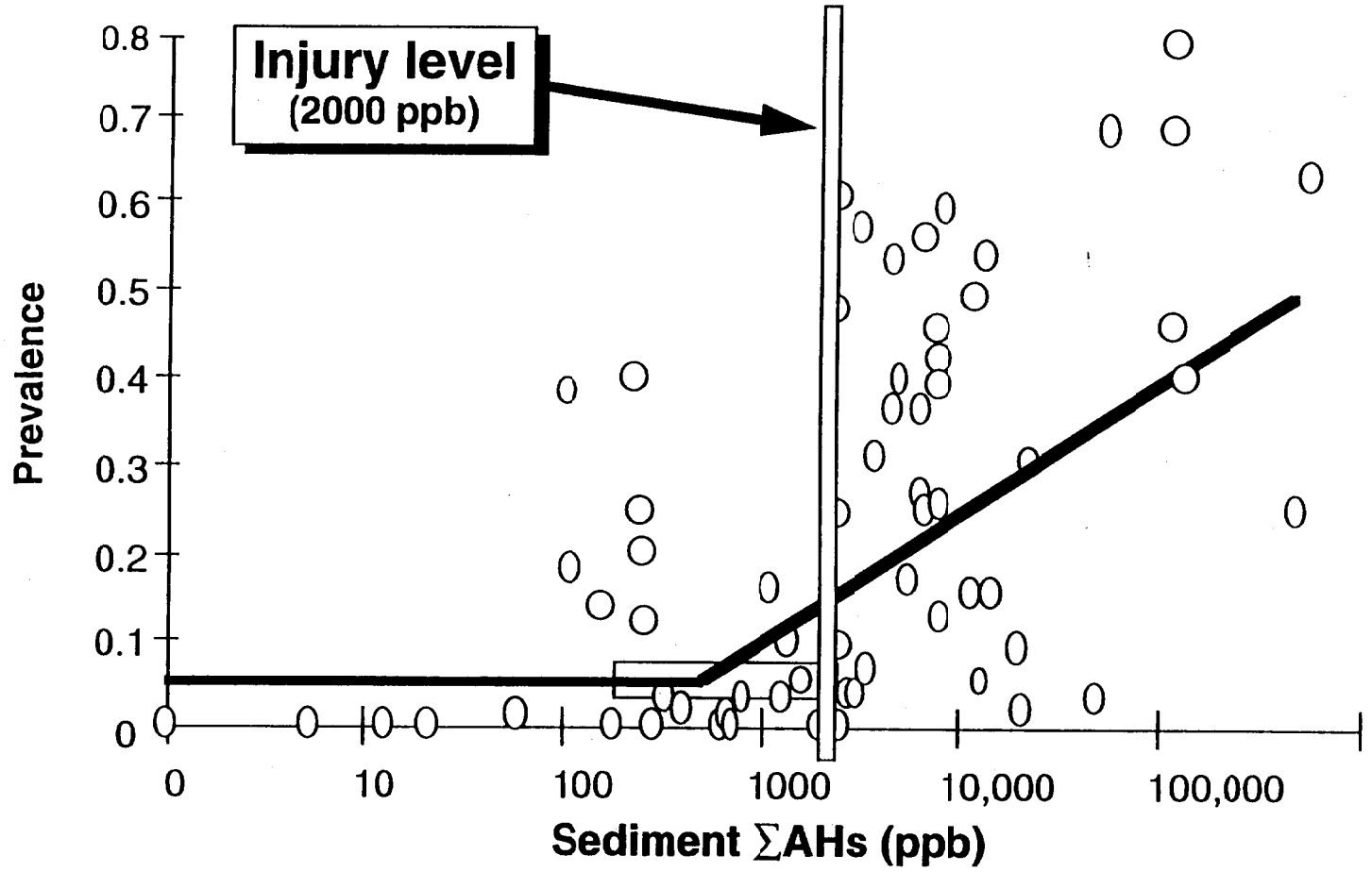
English sole

proportion of abnormal larvae -vs- sediment AH concentrations



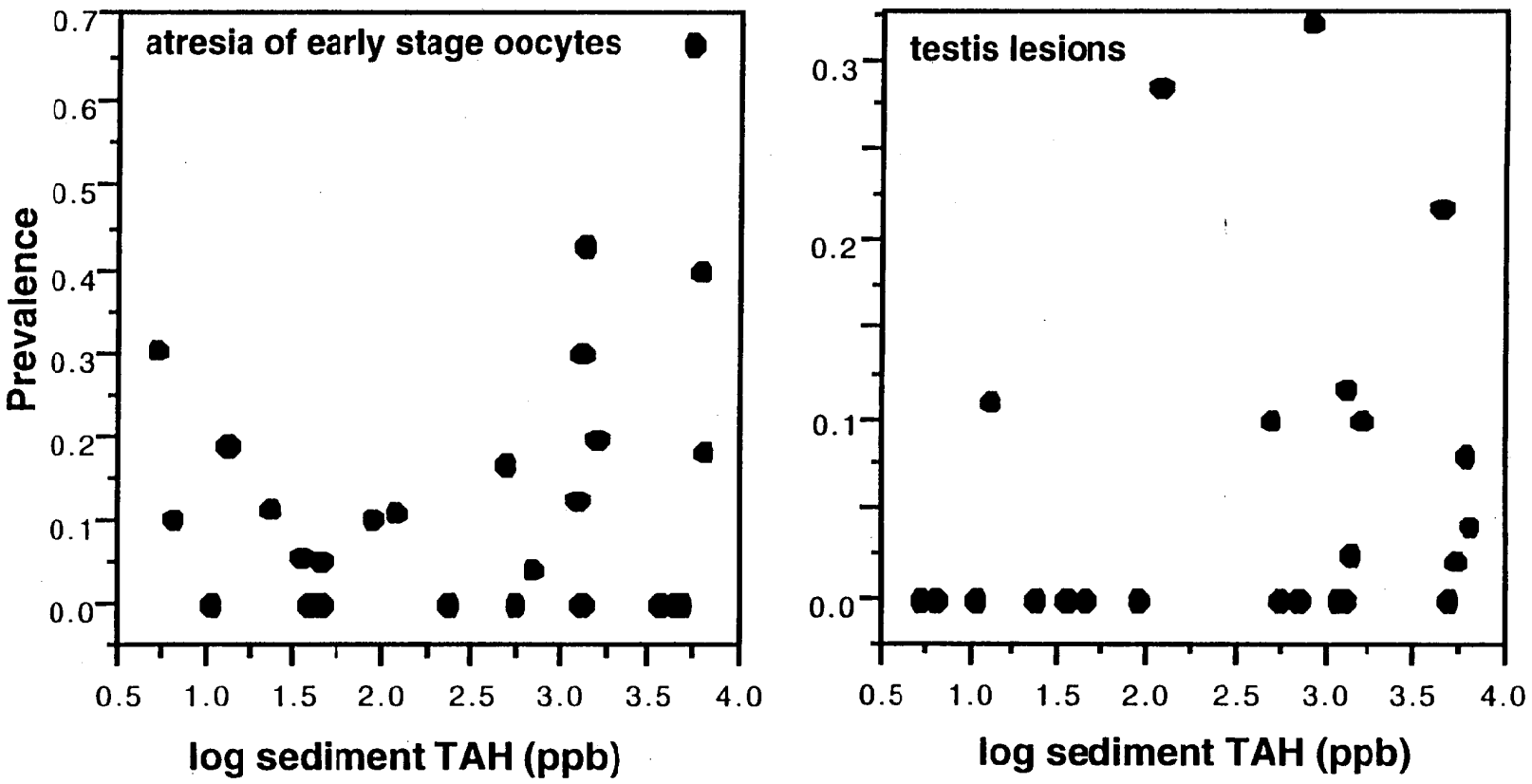
English sole

injury measures -vs- sediment AH concentrations



English sole

ovary and testis lesions -vs- sediment AH concentrations



Estimation of injury level for benthos-- TBT as toxicant

- Multiple studies reviewed, incorporated into report by Weston (1996) to the USEPA. Injury endpoint used was median water concentration for chronic effects as determined by this review, 0.24 ng TBT ion per ml.

- K_{OC} of TBT measured by Meador et al (1997) is 25,100. Application of this K_{OC} to the Weston value gives a sediment concentration for injury of ~6000 ng TBT/g organic carbon. Assuming an average TOC value of 2% in sediments from the Hylebos Waterway, an injury level of 120 ng TBT/g sediment (dry wt) is derived.

- Proposed water quality criterion by USEPA is 0.01 ng TBT ion per ml, which would result in much lower sediment values.

- Median TBT concentration in Hylebos Waterway sediment is 329 ng/g dry wt. This level is higher than the LC50 values for sensitive invertebrates such as the amphipod *Euhaustorius washingtonianus* (Meador et al., 1997)

- LC50 for starry flounder is 3.0 ng/ml water. Sublethal effects are expected at levels much lower than this.

The following are references associated with identifying Commencement Bay Natural Resource Trustee sediment restoration goals at sites being actively restored:

Arkoosh, M. R., E. Casillas, P. Huffman, E. Cleamons, J. Evered, J.E. Stein, and U. Varanasi. 1998. Increased Susceptibility of Juvenile Chinook Salmon from a Contaminated Estuary to *Vibrio anguillarum*. Trans. Am. Fish. Soc. 127:360-374.

Bengtsson, B-E. 1980. Long-term Effects of PCB (Clophen A-50) on Growth, Reproduction and Swimming Performance in the Minnow, *Phoxinus phoxinus.* Water Res. 14:681-687.

Bierman, V. J., Jr. 1990. Equilibrium Partitioning and Biomagnification of Organic Chemicals in Benthic Animals. Environ. Sci. Technol. 24(9):1407-1412.

Broyles, R. H. and M. I. Noveck. 1979. Uptake and Distribution of 2,4,5,2',4',5'-Hexachlorobiphenyl in Fry of Lake Trout and Chinook Salmon and Its Effects on Viability. Toxicol. Appl. Pharmacol. 50:299-308.

Chen, T. T., P. C. Reid, R. Van Beneden, and R. A. Sonstegard. 1986. Effect of Aroclor 1254 and Mirex on Estradiol-Induced Vitellogenin Production in Juvenile Rainbow Trout *(Salmo gairdneri).* Can. J. Fish. Aquat. Sci. 43:169-173.

Collier, T. K., L. L. Johnson, M. S. Myers, C. M. Stehr, M. M. Krahn, and J. E. Stein. 1998. Fish Injury in the Hylebos Waterway of Commencement Bay, Washington. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-36, 576 pp.

Di Toro, D. M., C. S. Zarba, D. J. Hansen, W. J. Berry, R C. Swartz, C. E. Cowan, S. P. Pavlou, H. E. allen, N. A. Thomas, and P. R. Paquin. 1991. Technical Basis for Establishing Sediment Quality Criteria for Nonionic Organic Chemicals Using Equilibrium Partitioning. Environ. Toxicol. Chem. 10:1541-1583.

Fisher, J. P., J. M. Spitsbergen, B. Bush, and B. Jahan-Parwar. 1994. Effect of Embryonic PCB exposure on Hatching Success, Survival, Growth and Developmental Behavior in Landlocked Atlantic Salmon, *Salmo salar.* In: Environmental Toxicology and Risk Assessment: 2nd Volume. ASTM STP 1216. (Joseph W. Gorsuch, F. James Dwyer, Christopher G. Ingersoll, and Thomas W. La Point, editors). American Society for Testing and Materials, Philadelphia. Pp. 298-314.

Fisher, J. 1998. Unpublished data faxed to Jim Meador. 3pp.

Gruger, E. H., Jr., N. L. Karrick, A. I. Davidson, and T. Hruby. 1975. Accumulation of 3,4,3',4'-Tetrachlorobiphenyl and 2,4,5,2',4',5'- and 2.4.6,2',4',6'-Hexachlorobiphenyl in Juvenile Coho Salmon. Environ. Sci. Technol. 9(2):121-127.

Horness, B. H., D. Pl Lomax, L. L. Johnson, M. S. Myers, S. M. Pierce, and T. K. Collier. 1998. Sediment Quality Thresholds: Estimates from Hockey Stick Regression of Liver Lesion Prevalence in English Sole (*Pleuronectes vetulus).* Environ. Toxicol. Chem. 17(3):872-882.

Johnson, L. L., J. T. Landahl, L. A. Kubin. B. H. Horness, M. S. Myers, T. K. Collier, and J. E. Stein. 1998. Assessing the Effects of Anthropogenic Stressors on Puget Sound Flatfish Populations. J. Sea Res. 39:125-137.

Ludwig, J.P., H.J. Auman, H. Kurita, M.E. Ludwig, L.M. Campbell, J.P. Giesy, D.E. Tillitt, P.D. Jones, N. Yamashita, S. Tanabe, and R. Tatsukawa. 1993. Caspian Tern reproduction in Saginaw Bay ecosystem following a 100-year flood event. J. Great Lakes Res. 19:96-108.

Mackay, D. 1982. Correlation of Bioconcentration Factors. Environ. Sci. Technol. 16(5):274-278.

Mayer, F. L., P. M. Mehrle, and H. O. Sanders. 1977. Residue Dynamics and Biological Effects of Polychlorinated Biphenyls in Aquatic Organisms. Arch. Environ. Contam. Toxicol. 5:501-511.

McFarland, V. A. 1984. Dredging and Dredge Material Disposal. In: Proceedings of the Conference, Dredging '84. (R.L. Montgomery and J. W. Leach, editors). American Society of Civil Engineers. New York, NY. Vol. 1, pp. 461-466.

Meador, J. P., J. E. Stein, W. L. Reichert, and U. Varanasi. 1995. Biaccumulation of Polycyclic Aromatic Hydrocarbons by Marine Organisms. Rev. Environ. Contam. Toxicol. 143:79-195.

Meador, J. P., N. G. Adams, E. Casillas, and J. L. Bolton. 1997. Comparative Bioaccumulation of Chlorinated Hydrocarbons from Sediment by Two Infaunal Invertebrates. Arch. Environ. Contam. Toxicol. 33:388-400.

Musgrove, N., D. Hughes, and R. Sturim. 1996. Recommendations for a Screening Level for Tributyltin in Puget Sound Sediment. Prepared for the US EPA Region X Superfund Program by Roy F. Weston, Inc. Contract No. 68-W9-0046

Ndayibagira, A., M-J Cloutier, P. D. Anderson, and P. A. Spear. *1995.* Effects of 3,3',4,4'-tetrachlorobiphenyl on the Dynamics of Vitamin A in Brook Trout *(Slavelinus fontinalis)* and Intestinal Retinoid Concentrations in Lake Sturgeon *(Acipenser fulvescens).* Can. J. Fish. Aquat. Sci. 52:512-520.

Schimmel, S. C., D. J. Hansen, and J. Forester. 1974. Effects of Aroclor 1254 on Laboratory-Reared Embryos and Fry of Sheepshead *Minnows (Cyprinodon variegatus).* Trans. Am. Fish. Soc. 103(3):582-586.

Varanasi, U., M. Nishimoto, W. M. Baird, and T. A. Smolarek. 1989. Metabolic Activation of PAH in Subcellular Fractions and Cell Cultures from Aquatic and Terrestrial Species. In: Metabolism of Polycyclic Aromatic Hydrocarbons in the Aquatic Environment, (Usha Varanasi, editor). Chapter 6, pp. 203-251. CRC Press, Inc. Boca Raton, FL.

Varanasi, U., J. H. Stein, W. L. Reichert, K. L. Tilbury, M. M. Krahn, and S-L Chan. 1993 Chlorinated and Aromatic Hydrocarbons in Bottom Sediments, Fish and Marine Mammals in US Coastal Waters: Laboratory and Field Studies of Metabolism and Accumulation. In: Persistent Pollutants in Marine Ecosystems (Colin Walker and D. R. Livinstone, editors), Chapter 5, pp. 83-115. Pergammon Press.

Varanasi, U., E. Casillas, M. R. Arkoosh, T. Hom. D. A. Misitano, D. w. Brown, S-L. Chan, T. K. Collier, B. B. McCain, and J. E. Stein. 1993. Contaminant Exposure and Associated Biological Effects in Juvenile Chinook Salmon (*Oncorhynchus Tthawytscha)* under Urban and Nonurban Estuaries of Puget Sound. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-8, 112 pp.