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## Organochlorine Contaminants in Sea Otters: The Sea Otter as a Bio-Indicator

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Sea otters (Enhydra lutris) were once distributed throughout the North Pacific Rim from the Kuril Islands to Baja California, with estimates of the worldwide population between 150,000-300,000 individuals (Marine Mammal Commission 1992; see Anderson et al., this issue). Fur harvesting during the eighteenth and nineteenth centuries nearly exterminated the species, and by the early 1900s the total world population had been reduced to an estimated 1,000-2,000 individuals; the California population was estimated at fewer than 50 animals (Kenyon 1969). Since sea otters were legally protected in 1911 by the International Fur Seal Treaty these remnant colonies, and others established by relocations, have increased (Estes 1990).

The rates of recovery, however, have differed among areas or populations. The California sea otter population has increased at a rate of about 5% per year, compared with 17-20% per year for more northerly populations (Estes 1990). The explanation for the depressed rate of increase in the California sea otter population is ambiguous and most likely complicated. Potential factors are (1) emigration; (2) reduced fecundity; and (3) increased mortality, possibly caused at least partially by environmental contaminants (Estes 1990).

Although the effects of environmental contaminants on sea otters is unstudied, confamilial species, such as minks (Mustela vison) and ferrets (Mustela putorius furo), have been shown to be extremely sensitive to several of these compounds (Platanow and Karstad 1973; Jensen et al. 1977; Wren et al. 1987). For example, experimental exposure of mink to PCB levels as low as 0.64 parts per million (ppm) in their feed caused nearly complete reproductive failure (in these animals liver PCB levels averaged 1.2 ppm) (Platanow and Karstad 1973). Sea otter livers from central California were found to have levels of PCBs which exceed 1.2 ppm (Hofman and Risebrough 1985). PCBs have also been suggested as having a role in the decline of river otters throughout much of Europe (Mason 1989).

The purpose of this study was to determine if organochlorine contaminants could be contributing to the depressed rate of increase in the California sea otter population. Unlike most previous contaminant studies involving marine mammals, sea otters provide good subjects for ecotoxicological studies because they are non-migratory. Contaminant burdens in sea otters should reflect their local habitats, in combination with metabolic factors.

Our approach was to compare organochlorine contaminant levels in sea otter tissue among three separate populations across the North Pacific Rim to determine if California sea otters have significantly higher tissue organochlorine levels when compared with populations in Alaska. Liver tissue from sea otters in California, Southeast Alaska, and Aleutian Islands (Adak and Amchitka, Alaska) were analyzed for organochlorine pesticides (e.g., DDT and related compounds), polychlorinated biphenyls (PCBs) including non-ortho congeners (NOPCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and polychlorinated terphenyls (PCTs).

### Sample collection

Biologists affiliated with the California Department of Fish and Game located in Monterey, California routinely perform necropsies on sea otters. Mortality categories are assigned and tissue samples are collected and archived. Liver samples for this study were chosen according to the sea otter's sex, condition, year of death, and mortality category. California sea otter tissues were selected primarily from adult male sea otters in relatively good condition collected between the years 1988-1991, with one female sea otter included for comparison. Adult, male sea otters were chosen to reduce variability involved with reproduction and age when analyzing for organic contaminants in female marine mammals (Addison

1989). Seven sea otters died from uncertain causes, one was shark bitten, and one died of mating wounds.

Samples from Southeast Alaskan otters were acquired by Native Alaskan hunters at Middle Island, Sitka Sound and Ogden Bay, Alaska, during May 1991. Otters were shot, pelts removed, and tissue samples were taken within 8 hours of death. Samples were collected from adult male sea otters exclusively. Aleutian Island sea otter samples were obtained from beach-cast carcasses at Adak and Amchitka islands; one specimen was obtained in July 1992 from an individual who drowned during capture operations. Aleutian samples were collected during 1991-1992 and include 3 adult males and 4 female sea otters of varying ages.

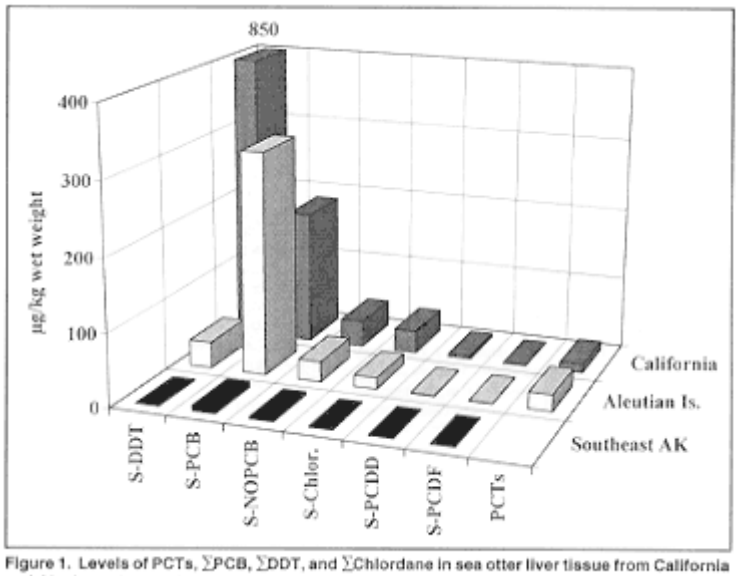

Figure 1. Levels of PCTs, ∑PCB, ∑DDT, and ∑Chlordane in sea otter liver tissue from California and Alaska, collected in 1988-1992.

**Results and discussion**

*Polychlorinated biphenyls*

Average total PCB levels (…PCB; sum of individual congeners) in sea otter livers were highest in the Aleutian Islands (310 µg/kg), intermediate in California (170 µg/kg), and lowest in Southeast Alaska (8 µg/kg) (see Figure 1). …PCB levels in both California and Aleutian sea otters were significantly higher than those in Southeast Alaska ($p<0.05$; all statistical results presented in this text based on one way ANOVA). Though Aleutian sea otters had the highest …PCB levels, this difference is not significant when compared to …PCB levels in California sea otters ($p>0.05$). …NOPCB levels were highest in sea otters from California (33 µg/kg), however, the three populations could not be shown to differ significantly ($p>0.05$).

The California sea otter population is located close to industrial activities. High levels of organic xenobiotics have been documented in the mid-latitudes of the northern hemisphere and reflect extensive use and production of these chemicals in these densely populated areas (Tanabe 1988; Bacon et al. 1992; Norstrom and Muir 1994). Otter populations at Adak and Amchitka were chosen for comparative study because of the extreme remoteness and presumably pristine nature of the western Aleutian Islands. Thus, the relatively high …PCB levels in otters from the Aleutians are surprising.

There are two potential sources of PCBs to the islands of Adak and Amchitka: (1) local contamination sources (point-source input), and/or (2) atmospheric and oceanic currents which supply the Aleutian

Islands. Both islands are located approximately 2,000 miles from the Alaskan mainland and 1,000 miles from the Kamchatka Peninsula of Russia, along the Pacific Ocean and Bering Sea division. Adak and Amchitka have a history of limited post-industrial revolution human activity, primarily serving as military bases during and since World War II. Portions of these islands are currently "restricted" because of the presence of explosives and chemicals, including PCBs. Therefore, the source of PCBs to Adak and Amchitka sea otters could be derived from local military activities.

*Organochlorine pesticides*

In contrast with PCBs, …DDT (p,p'-DDT+p,p'-DDE+p,p'-DDD) levels were highest in California sea otters (see Figure 1). Levels of …DDT in California otters (850 µg/kg) are significantly different ($p<0.05$) than those for Aleutian otters (40 µg/kg) and Southeast Alaska (1 µg/kg). Relatively high …DDT levels reported for California sea otters most likely reflect the extensive use and production of DDT in California during the 1950s through the early 1970s (MacGregor 1976; U.S. Fish and Wildlife Service 1993).

…DDT levels reported for California sea otters are not exceptionally high when compared to environmental levels in the literature. DeLong et al. (1973) associated …DDT levels in blubber of 820 ppm with premature births in California sea lions, and LeBoeuf and Bonnell (1971) reported extraordinary concentrations of DDT (911 mg/g wet weight) in blubber from the same species. Studies involving mink, however, have not conclusively demonstrated extreme reproductive effects related to DDT exposure. Minks exposed to large doses of DDT did not experience significant decreases in the number of whelps (Jensen et al. 1977).

Levels of Chlordane are very low in sea otters from both California and Alaska (see Figure 1); the levels are highest in California sea otters, then Aleutian, and lowest in the Southeast Alaskan sea otters.

*Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans*

Unlike PCBs or DDTs, dioxin and furan congeners occurred at very low to undetectable levels in otters from all three regions (see Figure 1). Levels of dioxin and furans were not significantly different between otters in California and the Aleutian islands ($p>0.05$). The Southeast Alaskan sea otter population was not included in statistical comparison since extremely low or undetectable levels of PCDDs and PCDFs are reported. These results are consistent with data showing that PCDDs and PCDFs are distributed differently than other organic contaminants in marine mammal samples from the Canadian Arctic (Norstrom et al. 1990).

*Polychlorinated terphenyls*

The mean PCT level in otters from California was about 1.3 times (46 µg/kg dry weight) that in the Aleutian Islands (35 µg/kg), however, these levels were not statistically significant ($p>0.05$) (see Figure 1). PCTs were not measured in the Southeast Alaska sea otters. Possible sources of PCTs to the environment involve either atmospheric/oceanic transport and/or point-source contamination. Risebrough et al. (1990) speculated that the source of PCTs in Winter Quarters Bay was local machine shops located at the military facility or machine shops on ships. Furthermore, de Lappe et al. (1989) associated PCT residues in San Diego Bay with local shipyards, and Gallagher et al. (1993) associated PCTs with a suspected outfall site in Chesapeake Bay.

Similar PCT levels in otters from California and the Aleutian Islands indicate similar atmospheric deposition to each environment, comparable point-source input, or a combination of the two factors. Similar PCT/…PCB and PCT/…Chlordane ratios indicate an atmospheric source of PCTs to California and the Aleutian Islands. Yet the islands of Adak and Amchitka have a history of military presence and PCTs have been associated with a military base (Risebrough et al. 1990); therefore, exposure at these islands could be local. The central California coast has substantial ship traffic, and since PCTs have been

associated with shipyards (de Lappe et al. 1989), the source of PCTs to the central California coast could be related to shipping activities.

## Conclusion

Though …PCBs are not significantly different among otter populations in Adak and Amchitka compared with California, they are still of concern to both California and Aleutian populations. Firstly, reproductive problems and reduced kit survival in minks have been correlated with PCB exposure at environmental levels. (Platanow and Karstad 1973; Aulerich and Ringer 1977; Jensen et al. 1977; Bleavins et al. 1980). Secondly, comparing PCB levels in Aleutian otters with those in California may be misleading because the possibility exists that the introduction of these compounds is comparatively recent to the Aleutian environment as opposed to California. Their introduction to the Aleutians may be so recent that population effects have not been fully recognized. Recent ecological data suggests that high pre-weaning pup mortality accounts for the impaired growth rate of the California sea otter population (Riedman et al. 1994). Furthermore, while sea otter populations in the Aleutian Islands appear healthy and thriving, Monson (unpublished data) has noted a high rate of pup mortality at Amchitka.

Lastly, in addition to PCBs, sea otters from both California and the Aleutian Islands had detectable levels of many other organochlorines which could be acting synergistically to impair the health of these otter populations. Synergistic effects of PCB exposure with compounds such as HCB and dieldrin, accompanied by environmental stresses (e.g., severe cold or food limitations) are documented in mink (Bleavins et al. 1984; Wren et al. 1987; Cobb et al. 1994).

We have shown that sea otters are valuable in the study of contaminants for several reasons. They are (when compared to other marine mammals) relatively sedentary, and tend to reflect localized contamination. As high level predators they tend to biomagnify ambient contamination, making detection easier. Their role as a "keystone species," and their relationship to mink (a species very sensitive to environmental contaminants) make the sea otter a species worthy of study as a bio-indicator.

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## Literature Cited

Addison, R.F. 1989. Organochlorines and marine mammal reproduction. Canadian Journal of Fisheries and Aquatic Sciences 46:360-368.

Aulerich, R.J., and R.K. Ringer. 1977. Current status of PCB toxicity to mink, and effects on their reproduction. Archives of Environmental Contamination and Toxicology 6:279-292.

Bacon, C. E., W. M. Jarman, and D. P. Costa. 1992. Organochlorine and polychlorinated biphenyl levels in pinniped milk from the Arctic, the Antarctic, California, and Australia. Chemosphere 24:779-791.

Bleavins, M. R., R. J. Aulerich, and R. K. Ringer. 1980. Polychlorinated biphenyls (Aroclors 1016 and 1242): effects on survival and reproduction in mink and ferrets. Archives of Environmental Contamination and Toxicology 9:627-635.

‹. 1984. Effects of chronic dietary hexachlorobenzene exposure on the reproduction performance and survivability of mink and European ferrets. Archives of Environmental Contamination and Toxicology 13:357-365.

Cobb, G., D. Norman, and R. Kendall. 1994. Organochlorine contaminant assessment in great blue herons using traditional and nonlethal monitoring techniques. Environmental Pollution 83:299-309.

de Lappe, B. W., C. Younghans-Haug, J. Bott, and G. Ichikawa, editors. 1989. A Survey of Polychlorinated Terphenyls (PCTs) in San Francisco Bay, Los Angeles and San Diego Bay sediment and mussels. Trace Organics Facility, California Department of Fish and Game Long Marine Laboratory, U.C. Santa Cruz, Santa Cruz, California.

DeLong, R. L., W. G. Gilmartin, and J. G. Simpson. 1973. Premature births in California Sea Lions: association with high organochlorine pollutant levels. Nature 181:1168-1170.

Estes, J.A. 1990. Growth and equilibrium in sea otter populations. Journal of Animal Ecology 59:385-401.

Gallagher, K., R.C. Hale, J. Greaves, E.O. Bush, and D.A. Stilwell. 1993. Accumulation of polychlorinated terphenyls in aquatic biota of an estuarine creek. Ecotoxicology and Environmental Safety 26:302-312.

Hoffman, R.J. and R.W. Risebrough, editors. 1995. Accumulation patterns of heavy metals and chlorinated hydrocarbons by sea otters, Enhydra lutris, in California. Marine Mammal Commission, 1625 Eye St., NW., Washington, D.C. 20006.

Jensen, S., J. E. Kihlstrom, Olsson M, C. Lundberg, and J. Orberg. 1977. Effects of PCB and DDT on mink (Mustela vision) during the reproductive season. Ambio 6:239.

Kenyon, K.W. 1969. The sea otter in the eastern Pacific Ocean. North American Fauna 68:1-352.

Le Boeuf, B.J. and M.L. Bonnell. 1971. DDT in California sea lions. Nature 234:108-109.

MacGregor, J. S. 1976. DDT and its metabolites in the sediments off southern California. Fisheries Bulletin 74:27-35.

Marine Mammal Commission. 1992. Annual Report to Congress., Washington, D.C.

Mason, C.F. 1989. Water pollution and otter distribution: A review. Lutra 32:97-131.

Norstrom, R.J. and D.C.G. Muir. 1994. Chlorinated hydrocarbons contaminants in arctic marine mammals. The Science of the Total Environment 154:107-128.

Norstrom, R.J., M. Simon, and D.C.G. Muir. 1990. Polychlorinated-p-dioxins and dibenzofurans in marine mammals in the Canadian north. Environmental Pollution 66:1-19.

Platanow, N.S. and L.H. Karstad. 1973. Dietary effects of polychlorinated biphenyls on mink. Canadian Journal of Comparative Medicine 37:391-400.

Riedman, M.L., J.A. Estes, M.M. Staedler, A.A. Giles, and D.R. Carlson. 1994. Breeding pattern and reproductive success of California sea otters. Journal of Wildlife Management 58:391-399.

Risebrough, R., B. De Lappe, and C. Younghans-Haug. 1990. PCB and PCT contamination in Winter Quarters Bay, Antarctica. Marine Pollution Bulletin 21 No.11:523-529.

Tanabe, S. 1988. PCB problems in the future: foresight from current knowledge. Environmental Pollution 50:5-28.

U.S. Fish and Wildlife Service. 1993. Draft Addendum to the Pacific Coast and Rocky Mountain/Southwest American Peregrine Falcon Recovery Plans. U.S. Fish and Wildlife Service, Portland, Oregon.

Wren, C. D., D. B. Hunter, J. F. Leatherland, and P. M. Stokes. 1987. The effects of polychlorinated biphenyls and methylmercury, singly and in combination on mink. II:Reproduction and kit development. Archives of Environmental Contamination and Toxicology 16:449-454.

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