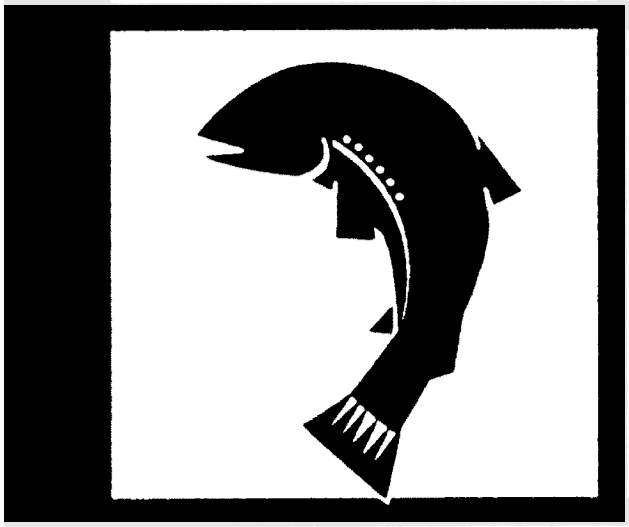
Diminishing Returns:

Executive Summary



Salmon Decline and Pesticides

A publication of the
Oregon Pesticide Education Network (OPEN)

- Oregon Environmental Council
- Northwest Coalition for Alternatives to Pesticides
- OSPIRG Foundation
- Institute for Fisheries Resources

We gratefully acknowledge the support of:

- The Pew Charitable Trusts
- The Bullitt Foundation
- Turner Foundation
- The Tides Center
- Rockefeller Family Fund
- True North Foundation
- The Educational Foundation of America

as well as numerous individuals who have supported the work of the Oregon Pesticide Education Network.

We sincerely appreciate the special contributions that the following individuals made to this report: Jeff Allen, Lev Anderson, Robie Honeyman-Colvin, Caroline Cox, Georgia Ewing, Lita Furby, Norma Grier, Neva Hassanein, Jacob Kann, Maureen Kirk, Becky Long, Kay Rumsey, Glen Spain, and Laura Weiss.

We also value the following individuals and agencies who contributed photos and graphics that are reproduced here with permission: Nancy Allen of Corvallis Environmental Center, K. Born, Andy Duncan and Lynn Ketchum of OSU Extension and Experiment Station Communications, Institute for Fisheries Resources, Kathryn Kostow, Tom and Pat Leeson, Oregon Dept. of Environmental Quality, Oregon Dept. of Fish and Wildlife, Public Interest GRFX, Oregon Sea Grant, Ana Soto, Steve Stone of National Marine Fisheries Service, and the US Fish and Wildlife Service.

Copies of this report can be found at:
http://www.pond.net/~fish1ifr/salpest.pdf

Diminishing Returns: Salmon Decline and Pesticides

By Richard D. Ewing, PhD
February 1999

Executive Summary

TOAM AND PAT LEESON

About the Author:

Richard D. Ewing is a native Oregonian who graduated from Reed College in 1962, and received his Ph.D. in cellular and molecular biology from the University of Miami at Coral Gables in 1968. After conducting research at Oak Ridge National Laboratory and at Oregon State University, Dr. Ewing joined the research team at the Oregon Department of Fish and Wildlife where he worked as a physiologist and hatchery specialist from 1975-1992. He left ODFW to form Biotech Research and Consulting, Inc., a Corvallis-based consulting company that specializes in hatchery operations and chemical analyses relating to fisheries. Dr. Ewing has published widely in professsional journals and written many reports for the Oregon Department of Fish and Wildlife.

Executive Summary

Pacific salmon are in serious trouble. The enormous runs of migratory salmon of the past have slowly diminished to the trickle of adult spawning salmon that presently inhabit western rivers. Although salmon recovery efforts are underway, scientists, policy makers, and interest groups have thus far given insufficient attention to the role that pesticide contamination of our watersheds may play in salmon decline. Accordingly, the purpose of *Diminishing Returns: Salmon Decline and Pesticides* is to review scientific literature on the effects of sublethal concentrations of pesticides on salmonids (see full report for documentation and references). The report places special emphasis on how pesticides can alter the biology of fishes in subtle ways that decrease their chances for reproduction and survival.

Dynamics of Pesticides in the Environment

Pesticides include a broad class of chemical and biological agents that are purposefully introduced into the environment to kill or damage organisms, including insecticides, herbicides, and fungicides. Once applied, pesticides move into streams and rivers throughout watersheds and may pose problems far from the site of application. Movement often occurs through the medium of water, thereby exposing all aquatic organisms during this transport. Where water quality monitoring has been done, a great variety of pesticides are typically found in salmon habitat. Federal and state agencies have established few criteria or standards for the protection of aquatic life from short-term (acute) and long-term (chronic) exposure to pesticides.

Pesticides do not necessarily disappear with time. They transform into other compounds that may be less toxic, of equal toxicity, or of greater toxicity than the original compound. The toxicity of these breakdown products is not well understood, and in general how they affect aquatic life has not been studied. All the while, fish and other aquatic organisms must continue to cope daily with pesticides (and their breakdown products), some of which are no longer used but remain in watersheds.

Although pesticides are diluted by transport in rivers and streams, a number of mechanisms concentrate the chemicals, often to toxic levels. In a process known as bioaccumulation, pesticides absorbed into plant and animal tissues may become concentrated and reach levels many times higher than those in surrounding water.

Pesticide detections in the western United States as measured by the U. S. Geological Survey NAWQA program.

State, region	# Pesticides Examined	# Pesticides Detected	# Exceeding Aquatic Life Criteria[1]	# For Which Aquatic Life Criteria Are Available
Oregon				
Willamette Basin[2]	86	36	4	22
Washington				
Puget Sound Basin[3]	NA	23	4	NA
Central Columbia River Plateau[4]	84	45	5	18
California				
San Joaquin Basin[5]	83	49	7	16
Idaho				
Snake River Basin[6]	80	36	2	17

NA, not available.

[1] Aquatic life criteria set by the National Academy of Sciences and National Academy of Engineering or by the Canadian Council of Resources and Environment Ministers.
[2] Data from Anderson et al. (1997).
[3] Data from Bortleson and Davis (1997).
[4] Data from Wagner et al. (1996).
[5] Data from Dubrovsky et al. (1998).
[6] Data from Clark et al. (1998).

Fish Kills and Acute Toxicity of Pesticides to Salmon

Pesticides are capable of killing salmon and other aquatic life directly and within a short period of time. For example, in 1996 the herbicide acrolein was responsible for the death of approximately 92,000 steelhead, 114 juvenile coho salmon, 19 resident rainbow trout, and thousands of nongame fish in Bear Creek, a tributary of the Rogue River. Deaths of threatened and endangered species from accidental contamination of waterways are of grave concern. The loss of each individual in a sensitive population makes recovery efforts that much more difficult. Fortunately, these deaths are relatively infrequent.

Behavioral Effects of Pesticides at Sublethal Concentrations

In contrast to dramatic fish kills, the effects of sublethal concentrations of pesticides are more subtle and go largely unseen and unregulated. Sublethal concentrations of pesticides do not cause immediate death, but can interfere with the biology of the organism in other ways and can ultimately impact the survival of the species. Laboratory studies show that sublethal concentrations of pesticides can affect many aspects of salmon biology, including a number of behavioral effects:

- Long-term exposure to certain pesticides can increase stress in juvenile

salmonids and thereby render them more susceptible to predation.

• Certain pesticides can alter swimming ability, which in turn can reduce the ability to feed, to avoid predators, to defend territories, and to maintain position in the river system.

• Many pesticides interrupt schooling behavior, a critical tactic for avoiding predation during salmon migration. Disruption of schooling behavior is thought by some researchers to be a classic method for examining sublethal effects of pesticides because the effect is so common.

• Several pesticides (and other pollutants) have been shown to cause fish to seek suboptimal water temperatures, thus subjecting them to increased dangers of disease and predation.

• Some herbicides have been shown to inhibit normal migration to the sea, resulting in severe disruption of the life cycle. There is a dearth of research looking at this effect for common insecticides.

Sublethal effects of selected pesticides found in the Willamette River Basin Study by USGS.[1]

	Herbicides		Insecticides		
	Atrazine	Simazine	Malathion	Chlorpyrifos	Carbaryl
Negative Effects on:					
Food Supply	+[2]		+[3]	+[4]	+[5]
Growth	+[2]		+[6]	+[7]	+[8]
Reproductive success	+[2]			+[9]	+[10]
Bone Abnormality			+[11]	+[12]	+[13]
Endocrine Disruptor			+[14]		+[13,14]
Immune System			+[15]		
Behavior		+[16]	+[17,18]	+[12,17]	+[12]
Schooling					+[19]
Predator Avoidance	+[20]		+[18]		

Plus indicates a detectable response from sublethal concentrations of pesticide. Blanks indicate that studies were not found analyzing these effects. Superscripts are references.

1. Anderson et al. 1997.
2. Macek et al. 1976.
3. Naqvi and Hawkins 1989.
4. Washino et al. 1972.
5. Burdick et al. 1960.
6. Hermanutz 1978.
7. Brazner and Kline. 1990.
8. Arunachalam and Palanichamy 1982.
9. Jarvinen et al. 1983.
10. Carlson 1971.
11. Weis, P. and J. S. Weis. 1976.
12. Holcombe et al. 1982.
13. Weis, J. S. and P. Weis. 1976.
14. Bruckner-Davis 1998.
15. Plumb and Areechon. 1990.
16. Dodson and Mayfield. 1979b.
17. Hansen 1969.
18. Hansen 1972.
19. Weis, P. and J. S. Weis. 1974.
20. Lorz et al. 1979.

• Several studies suggest that certain pesticides can impair salmonid's ability to transition from freshwater to seawater. There is a need for further research in this area, placing particular emphasis on the critical period of transition that takes place in the estuary.

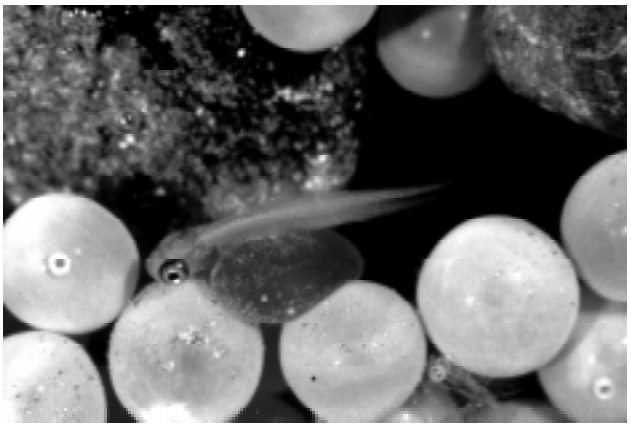
• Adult salmon adjust their migration patterns to avoid polluted areas, resulting in delayed spawning.

Compromised Immune Systems

In addition to changes in behavior, exposure to relatively low concentrations of pesticides can disrupt the immune system of salmon. Evidence for these effects in salmonids is not as extensive as for disruption of behavior, but the data available suggest that pesticides can have serious negative impacts on the immune system. Such disruption results in the onset of disease and even death.

OREGON DEPT. OF FISH AND WILDLIFE

Pesticide exposure at the fry stage can cause feminization of male fish or even sterility.



OREGON DEPT. OF FISH AND WILDLIFE

During early development, fish are especially vulnerable to pesticides that can mimic natural hormones.

Endocrine Disruptors

Fish and other organisms are especially vulnerable to endocrine-disrupting effects during the early stages of development. Pesticides at low concentrations may act as mimics or blockers of sex hormones, causing abnormal sexual development, feminization of males, abnormal sex ratios, and unusual mating behavior. The unique plasticity of sex differentiation in fish suggests that these animals may be very susceptible to disruption of sexual characteristics by pollutants. Pesticides can also interfere with other hormonal processes, such as thyroid functioning and bone development.

Indirect Effects of Pesticides on Salmon

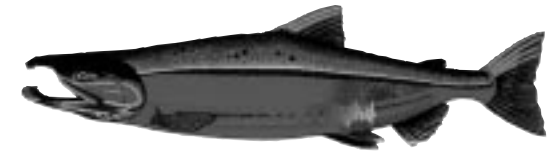
Pesticides can indirectly affect fish by interfering with their food supply or altering the aquatic habitat, even when the concentrations are too low to affect the fish directly. Such indirect effects greatly reduce the abundance of food organisms which in turn reduces the growth and probability of survival of the fish. In addition, removal of

aquatic vegetation can decrease habitat suitability and increase the salmon's susceptibility to predation. These indirect effects are subtle, but evidence suggests that in complex ecosystems indirect effects can be even more important than direct effects.

Recommendations

From the evidence available at present, there is a plausible basis for considering pesticides to be one of the causes of declining salmon populations in the Pacific Northwest. Based on this review, we offer several policy recommendations and identify areas for further research:

1. Address the impacts of pesticides on salmon when developing and implementing recovery plans for threatened and endangered species. To date, efforts to recover salmon have devoted insufficient attention to pesticides as a contributing factor in salmon decline. We must act now using available information to formulate management strategies that will minimize the potential danger from sublethal concentrations of pesticides.



2. Conduct ecoepidemiological studies in critical salmonid habitat. Most of the effects of pesticides referred to in this report have been determined in experimental laboratories. In the field, however, environmental conditions are not controlled, and many factors interact to confuse the determination of direct relationships. Ecoepidemiological investigations in the Great Lakes have established the relationship between chlorinated hydrocarbons and the decrease in lake trout populations. An ecoepidemiological approach for salmon in the Pacific Northwest would be particularly valuable because it is designed to attribute causality to events occurring in real-world situations.

3. Create comprehensive pesticide tracking systems in the Pacific Northwest. To better understand the relationship between pesticides and salmon decline, we must have accurate, site-specific data on the patterns of pesticide use in the watersheds of the Northwest. State and provincial governments need to collect data on which pesticides are used where, when, and in what amounts. Such data can then be combined with watershed-specific information on indicators of salmon health. (Currently, California is the only state with Pacific salmon habitat where such information is collected.) Pesticide use information will also enable efficient instream monitoring for pesticide contamination.

4. Establish instream monitoring programs in critical salmon habitats. A systematic monitoring program for pesticides and their breakdown products needs to be undertaken. Not all pesticides can be tested for in all locations, but current testing is woefully inadequate for understanding the role of pesticides in salmon decline. In conjunction with pesticide use data, these analyses can be targeted to the

NEVA HASSANEIN

compounds of most concern. Such targeting can greatly improve the cost-effectiveness of monitoring.

5. Err on the side of caution when setting water quality standards for pesticides. There are few established criteria for the protection of aquatic life from pesticides. Moreover, evidence reviewed here shows that sublethal effects on salmonids have not been fully appreciated, that juvenile salmonids succumb more easily to toxins in the water, that laboratory studies do not reflect the natural life cycle of the fish, and that little is known about how pesticides affect aquatic ecosystems. These factors must be considered when setting standards, and a precautionary approach must be adopted.

6. Prevent pesticide contamination of salmonid habitat by reducing pesticide use. Once contaminated, water is difficult if not impossible to clean up. Therefore, pest management approaches that do not depend on pesticide use in agricultural and non-agricultural settings should be encouraged and further developed. There is ample evidence that ecologically sound and economically viable methods can be successfully implemented. The adoption of such alternatives can be encouraged through technical assistance, financial incentives and disincentives, demonstration programs, and information exchange opportunities.

7. Adopt state and provincial programs in the Pacific Northwest to phase out pesticides that persist and bioaccumulate in the environment. Numerous pesticides, including some that are no longer used and many that are currently used, are known to persist in the environment and to bioaccumulate in aquatic systems. Washington State's Department of Ecology is now considering a plan to end the release of such toxins, including certain pesticides, into the environment. To ensure salmon recovery, all state and provincial governments in the Pacific Northwest should adopt similar programs.

For more information...

Northwest Coalition for Alternatives to Pesticides
P.O. Box 1393
Eugene, OR 97440-1393
(541) 344-5044; fax (541) 344-6923
www.efn.org/~ncap

Oregon Environmental Council
520 SW 6th Ave., Suite 940
Portland, OR 97204
(503) 222-1963; fax (503) 222-1405
www.orcouncil.org

OSPIRG Foundation
1536 SE 11th Ave.
Portland, OR 97214
(503) 231-4181; fax (503) 231-4007
www.pirg.org/ospirg

Institute for Fisheries Resources
PO Box 11170
Eugene, OR 97440-3370
(541) 689-2000; fax (541) 689-2500
www.pond.net/~fish1ifr