

ALASKA LEGISLATIVE COMMISSION
1876 SCORE: MAR 75; FISH FARMING; 1990
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Soviet investigations could address the broader question of oceanic food limitation on salmon growth in those parts of the North Pacific that serve as the major feeding regimes.

(6) Several large federally funded and mandated studies of the atmosphere and ocean, responding to questions about global change, have components in the North Pacific. These programs (like the World Ocean Circulation Experiment [WOCE], and the Coastal Ecology Program) will provide data that should contribute to a better understanding of nearshore ocean processes in relationship to the larger oceanic environment. The workshop recommends that, whenever possible, advantage be taken of these large-scale oceanographic and meteorological studies to build databases relevant to the issue of carrying capacity and wild and hatchery stock interactions in Alaska and elsewhere.

Summary

Workshop participants evaluated several examples where the time-series of the size of both wild and hatchery salmon in the Gulf of Alaska suggested that food-limited density-dependent modification of adult size is occurring. Although a theoretical evaluation of the effects of present levels of fry feeding (wild and hatchery) on forage stocks in Prince William Sound demonstrated only minor apparent effects (Cooney, abstract in this report), this assessment was based on several untested assumptions.

Workshop participants agreed that salmon production in the North Pacific at some as-yet-to-be-determined level will be limited by food stocks in coastal, shelf, and oceanic environments. The level at which this will occur cannot be predicted from present information. However, Japanese chum salmon appear to be approaching a size limitation that is seriously impairing their reproductive potential, condition factor, and market value. This has not been observed for wild or hatchery salmon in Alaska, although record or near-record returns of pink salmon to most regions of Alaska last year were characterized by unusually small individuals. Much smaller than average red salmon have been observed recently in Bristol Bay.

This workshop recommends several courses of action to establish a framework for monitoring the growth environment and sizes of Pacific salmon. These efforts will track the carrying capacity issue and provide information to the management and enhancement sectors for mitigative purposes should that become necessary in the future.

C.
MANAGEMENT

Management of Mixed Stock Fisheries

O. A. Mathisen

THE BASIC PHILOSOPHY GOVERNING SALMON MANAGEMENT in Alaska is to separate the harvest by individual stocks. In practice this is difficult to achieve and there are all degrees of mixed fisheries. Until recently the high seas salmon fisheries intercepted large numbers of all species and stocks of North American and Asian origin. The next level of mixed fishery is harvest along the migratory path of adult salmon. A classical example is the False Pass fishery in western Alaska. There are many "cape" or outside fisheries both in southeast Alaska and Prince William Sound and elsewhere which operate on mixed stocks. Even in the estuaries of many large rivers fishing is on the mixed stocks belonging to that river or watershed or adjacent ones.

Mixed fisheries may not be detrimental as long as the different stocks have approximately the same survival rates. Otherwise the weaker races will decline with time. This is especially true in fisheries where enhanced stocks represent a strong and dominant component. If enhancement is successful the survival of the progeny to the larval or smolt stage is usually several percent higher than for the progeny from natural stocks, as demonstrated for pink salmon in Prince William Sound (Cooney abstract). Consequently, the fishing mortality which can be imposed on enhanced stocks for full utilization in a mixed fishery is higher than the natural stocks can sustain and they decline in numbers. This has happened in Sweden and Norway with the Atlantic salmon (Heggberget and Eriksson abstract), in the Columbia River and other Washington and Oregon coastal rivers for chinook and coho salmon (Washington abstract), and it may happen in Robertson Creek chinook hatchery in British Columbia if production there is expanded beyond its current level.

Larger escapements seem to be warranted for the natural runs of pink salmon in Prince William Sound according to the presented data (Eggers abstract), which implies that the present harvest rate on mixed stocks will have to be reduced to protect the weaker stocks of wild pink salmon.

Mixed stock harvest conflicts could have been avoided to a large extent if the planning process of enhancement installations had considered the distinctive biological requirements of the salmon populations being enhanced, and especially the timing of the returning adults. If enhanced stocks and natural runs overlap in space and time, mixed fisheries must be limited to an exploitation rate which the weakest of the natural stocks can tolerate while delaying the harvest of enhanced stocks until they reach the terminal areas. This of course is undesirable for pinks and chums whose truncated maturation process reduces their quality in the terminal areas. Thus, without sufficient biological criteria on the interaction of wild and hatchery fish, the management philosophy of "weakest run" provides at least a conservative if not the "best" criteria for predicting the limit for enhancement programs.

In other Alaskan fisheries, the chinook and coho fisheries of southeast Alaska, the harvest of mixed stocks is common rather than the exception. The absence of adverse effects is attributed to the relatively minor contribution of enhanced stock to the average harvest of

these two species, 10.2% and 8.1%, respectively, since 1985 (Amend, this workshop). Were these percentages to increase, the situation might change drastically.

There is no reason not to believe that the two factors, survival rate and abundance relative to the natural stocks, will operate differently for any species of salmon. Management of enhanced stocks therefore reverts back to setting a rate of exploitation in mixed fisheries compatible with what the natural runs can tolerate and harvesting the excess enhancement production in the terminal areas. Because of the deterioration of the quality of the fish during the maturation process in pinks and chums, the exploitation rate on the weakest natural runs in the mixed fishery will ultimately determine the limits of the production of enhanced stocks, if wild stocks are to survive and preserve their genetic integrity.

Another alternative is to manage for enhanced stocks. One might successfully argue for this in light of our success in domestication and hybridization of terrestrial animals. However, this involves the risk of losing the production of enhanced stocks, if a calamity like diseases should decimate them one year. It might be difficult to rebuild such stocks unless there are sufficient wild stocks left to restore production. Whether Alaska is ready to embark on such a management strategy requires a very careful and cautious analysis.

For the enhancement installations already in operation an acceptable management strategy is to monitor the harvest in mixed fisheries and determine the contributions from enhanced and wild stocks and regulate the exploitation rate so that the desired escapement of wild fish can be secured. But this is a costly process involving extensive tagging or marking experiments combined with thorough recovery programs. Unfortunately, no explicit funding exists in the state's management budget or in the operational budgets of the hatcheries for such undertakings.

In future enhancement projects some of the problems discussed above can to a large degree be avoided by judiciously selecting sites and broodstocks which are in conformity with the life history strategies of the stocks of fish being enhanced.

Harvest Management of Mixed Stocks of Enhanced and Wild Pink and Chum salmon

D. D. Railey

AMPLE EVIDENCE EXISTS IN PACIFIC SALMON HARVEST MANAGEMENT that harvesting has occurred above their sustainable capacity. Hatchery production in many cases has been a response to low production caused in part by environmental factors aggravated by over-harvesting. Evidence also exists that wild stocks can be harvested beyond their sustainable capacity when mixed with the more abundant and more productive enhanced stocks.

Depending on their productivity, wild pink and chum stocks may be able to sustain harvest rates of 50-70% while enhanced stocks should be able to sustain harvest rates of 85-95%. In British Columbia where enhanced and wild stocks coexist, exploitation level is based on the lower wild stock productivity and often on the weakest stock. Additional harvest of enhanced stocks is then carried out in terminal harvest areas. This is the procedure used to manage the south coast of British Columbia chum stocks passing through Johnstone Strait.

Data on the productivity of wild stocks is important both annually and during the fishing season in order to adjust harvest to meet fixed escapement goals. In the above example pre-season estimates via test fisheries and catch sampling for marked enhanced stocks are critical for management to fixed escapement goals. Careful management is especially critical when productivity is low. Pink salmon productivity has been related to Gulf of Alaska air temperature (Tom Royer, pers. commun.), which would indicate that pink salmon production may be lower in the future. Changes in stream flows from logging on the watershed are also known to seriously reduce the freshwater productivity of wild pink and chum stocks. Harvesting the forests in Prince William Sound and lower marine survivals for all regions in Alaska have the potential to result in wide variability in wild pink and chum productivity.

In order to maintain or increase wild pink and chum populations while maintaining or increasing enhanced production and maximizing its harvest the following recommendations should be considered.

(1) Marking of enhanced and wild pink and chum salmon stocks, both juvenile and adult, could and should be used to design a harvest strategy to maximize harvest of enhanced stocks in mixed wild and enhanced areas while meeting escapement goals for wild stocks. Use this data during and after fishing season to estimate wild and enhanced components of the catch. Research into mass marking of juvenile salmonids should be funded.

(2) Institute test fisheries in various locations (catch to be used to pay for charter) throughout the fishing areas to evaluate their use in wild escapement management. Sample catches for marks. These charters could also be used for adult tagging for timing and migration studies.

(3) Study the freshwater productivity of wild stocks by estimating egg deposition and fry output in index streams. This is especially important if escapement goals are increased to determine if increased escapement results in higher fry output. This should also be carried out in streams before and after logging.

(4) Evaluate the effect of logging on egg-to-fry survival and spawning habitat capacity.

(5) Consider increasing the escapement goal to maximize wild productivity.

(6) Evaluate the timing and migration of wild stocks and use stocks which will minimize wild and enhanced mixed fishery interception.

(7) Evaluate future enhancement for site location and stocks selected to minimize wild stock interception. Manageability should be a major criterion in the permission process.

(8) Hold a small workshop of pink and chum management biologists from Alaska, British Columbia, and Washington to make recommendations for the management of enhanced and wild pink and chum stocks in Prince William Sound and southeast Alaska.

Can Wild and Enhanced Coho Stocks Coexist in Southeast Alaska?

D. Amend

THE ALASKA LEGISLATIVE MANDATE DURING THE DEVELOPMENT OF STATUTES and regulations for the Alaska enhancement program was to manage for the natural stocks while enhancing salmon to supplement natural production. The enhancement of coho salmon in southeast

Alaska started in the mid-1970s by the FRED division and the private non-profit operations started in the early 1980s. These programs have now matured and production has stabilized.

The average annual harvest of coho salmon from 1980 through 1988 was 1.71 million. The average harvest of enhanced coho from 1986 through 1990 was 8.1% of the total harvest, but the average in the future, based on current production, is expected to average about 16%.

Coho in southeast Alaska are harvested primarily by trollers but significant harvest occurs by the drift gillnet and seine fleets as a by-catch during the conduct of traditional fisheries. Although some coho are harvested from Canadian systems, most are produced from southeast Alaska systems. Because most of the coho harvested in southeast Alaska are from natural production, it is important to maintain the wild coho stocks.

Enhancement Strategy

The enhancement strategy in southeast Alaska follows three basic courses: (1) release from freshwater raceways as smolts into adjacent rivers, (2) release from marine net pens as smolts at remote locations following an imprinting period, and (3) release of fed fry into non-anadromous lake systems and the fish emigrate after rearing and smolting in the lake. Typically, broodstock were secured from local wild stocks and the fry reared in hatcheries located on non-anadromous systems which are not near natural producing stocks. Fish released as smolts are typically reared about 18 months in a hatchery, and the fish return after about 18 months at sea. Fish released as fed fry are reared to about a 1 gram size in the hatchery, but they complete the remainder of their life cycle similar to wild coho.

Threats and Concerns

There are both intraspecies and interspecies concerns. The intraspecies concerns include wild stock interactions due to straying or competition and management implications. Interspecies concerns primarily involve predation.

There have been no documented negative impacts of enhanced coho on wild coho in Alaska. Hatcheries in southeast Alaska are located on non-anadromous systems; therefore, the smolts do not compete with wild stocks in the freshwater phase after being released. Coho salmon imprint well to the site where they are released and there have been no documented straying problems. Consequently, there have been no documented genetic problems. Potential exists for future problems if hatchery stocks become inbred and significant straying occurs. Continued monitoring is required. In addition, research should better define minimum conditions for imprinting for remote release programs. Enhancement practices should continue to follow policies that would minimize inbreeding or increased straying.

The recent past average of 8% enhanced coho salmon in the harvest has not been a management problem. Even with production capacity at a maximum, the forecast is to average 16% of the harvest. All coho releases include a coded wire tagging program. This allows managers to account for the hatchery contribution to the harvest. Due to the low percentage of enhanced coho in the total harvest, there should be no future management concern. However, the coded wire or marking programs should continue to avoid potential problems of local abundance near hatchery sites.

The interspecies concerns are primarily coho smolts preying on pink fry and to a lesser extent on chum fry. The scientific literature well documents that coho smolts will eat pink fry and in preference to chum fry. In areas where there is a high abundance of coho smolts, the potential exists for the coho to have a significant impact on pink salmon populations. Whether coho are a limiting factor overall to pink salmon abundance is a much broader question which can only be answered by resolving the overall predator-prey relationship among all predators. The coincidence of coho and pink abundance cycles appears to argue against coho limiting pink abundance. However, this does not resolve the concern of high coho abundance near hatcheries where wild pink fry are migrating.

Several studies have been conducted in southeast Alaska to answer concerns about coho preying on pink salmon fry. The results were inconclusive. Pink fry were occasionally found in the stomachs of coho fry, but the problem could not be fully resolved. Early life histories of pink salmon fry showed that they typically spend a short time in the inter-estuaries and 90% of them migrate offshore by late May. In order to minimize the impact period, hatchery releases of coho smolts have been delayed to after June 1. Although this is not considered to be the optimum release time for coho (mid-May would be better), satisfactory survival rates for coho have occurred. This appears to be a satisfactory compromise in order to reduce the concerns of high abundance of hatchery coho negatively impacting pink populations.

Conclusions and Recommendations

Enhanced coho stocks can coexist with wild coho stocks as long as current policies and practices are maintained. Coho hatcheries should not be located on anadromous systems or near major coho producing systems. Hatchery practices should be followed to minimize inbreeding and practices which would increase straying should be avoided. The current level of production should not be a management concern but tagging programs should be maintained to resolve concerns of local abundance. Research is needed to better define the conditions for optimum imprinting and the predator-prey relationship between coho smolts and pink fry should be better defined. The coho enhancement program in southeast Alaska appears to be meeting the original legislative intent of supplementing the harvest of coho salmon while not negatively impacting wild stocks.

Can Abundant Wild and Enhanced Stocks of Chinook Salmon Coexist in Southeast Alaska?

W. R. Heard

CHINOOK ARE THE LEAST ABUNDANT SALMON IN ALASKA but are among the most highly prized and are often at the center of controversial fishery issues. Coastwise declines in the wild chinook stocks, especially in Washington, Oregon, and British Columbia, along with mixed stock ocean-troll fisheries in both countries, were among the major factors leading to the Pacific Salmon Treaty between Canada and the United States.

One reason for the focus on chinook in the treaty was oceanic migration patterns of many stocks that migrate in a northwesterly direction along the U.S. and British Columbia

coastlines. Many stocks of chinook become vulnerable to distant area fisheries. The troll fishery in southeast Alaska was especially important because it caught large numbers of non-Alaska chinook originating from southerly stocks. Among other things, the treaty called for limiting such interceptions of chinook between countries and states and for initiating a coordinated rebuilding program of depressed stocks along the coast. Other treaty provisions include a limited quota on numbers of chinook that could be caught in certain fisheries and an option for developing new stocks or groups of enhanced fish that could be harvested by the country or state of origin in addition to fish counted under the quota.

Chinook salmon hatcheries and significant related enhancement programs in southeast Alaska increased from two in 1976 to fifteen in 1990. New hatchery add-on provisions of the treaty were a major incentive for much of this development and the basic goal of this effort was to provide more chinook of local origin for southeast Alaska fisheries. The primary targeted user groups for chinook salmon in this region are the commercial troll and marine recreational troll fisheries.

Most hatcheries in the region were developed with principles to have minimal impacts of hatchery fish on endemic wild stocks of chinook. Alaska Fish Genetic and Pathology Policy statements were important guidelines for selecting chinook hatchery sites, brood stocks, and enhancement practices. Unlike chinook hatcheries in many other regions, none were built on extant wild chinook streams. Most are located on islands 50 km to 200 km distant from wild stocks that are, with one exception, on the mainland. Four primary hatchery stocks, derived from regional wild stocks, are in use in different parts of southeast Alaska. Three other stocks have been involved in supplemental enhancement of their depressed natal runs. Chinook brood stock selection for use in hatcheries and other enhancement efforts in this region is important because of differences in ocean migration patterns that result in different fishery contribution potentials for target fisheries. Upriver stocks from larger transboundary rivers (Taku, Stikine, Alsek) tend to have longer, more distant ocean migrations than stocks from shorter coastal streams. Movement of eggs between hatcheries is carefully regulated based on stock, disease history and location of hatchery.

A formal interagency chinook plan for the region, with an annual annex update, provides oversight guidance on hatchery and other chinook enhancement activity within the region. The Chinook Plan Team and Plan Annex also serves as an annual monitor of individual hatchery broods relative to stock performance, fishery contributions, and marine survival. Production from both hatchery and wild stocks of chinook salmon in southeast Alaska has steadily increased in recent years. Regional hatchery contributions to southeast Alaska fisheries have grown from an average annual catch of about 5000 fish (1980-85) to an actual estimated catch of 79,546 fish in 1991. After pre-treaty hatchery fish and risk factor adjustments are made, the hatchery add-on allowance for 1991 becomes 65,546 fish. One long-term goal of enhancement in southeast Alaska is to provide 100,000 add-on chinook to the commercial troll fishery. Total estimated escapements of wild chinook stocks in the region have doubled from an average of 43% of target goal (1975-80) to 84% (1986-90). Target escapement goals for several wild chinook stocks within the region are increasing as better knowledge of spawner distributions within river systems becomes available.

In view of the general increases in both hatchery and wild chinook production in southeast Alaska and taking into account the conservative approaches used in development of the chinook enhancement program, there do not appear to be major problem areas of adverse hatchery stock-wild stock interactions in this region. The only known possible exception involves small numbers of adult hatchery chinook recovered in non-natal areas. The majority of these known chinook strays have been recovered from areas without natural chinook runs, although a few hatchery fish have been found in some wild chinook streams. There is some concern for the specific stock presently used for hatchery and enhancement activity in the greater Juneau area because of the proximity of the Taku River and possibility of hatchery strays into that system. Steps are in progress to use a more suitable hatchery stock in this area. In other regions of Alaska where there are chinook hatchery and enhancement activities, including Cook Inlet, there also are no known major adverse enhanced stock-wild stock interactions.

Management of Mixed Enhanced and Wild Salmonids in British Columbia

D. D. Bailey

MIXED SPECIES AND STOCKS IN BRITISH COLUMBIA salmon management have been a problem since the Department of Fisheries first began to actively manage the fisheries. Overfishing, habitat destruction from forestry, industrial, and urban expansion, and poor marine survival all combined to seriously depress stocks in the 1960s and early 1970s.

The Salmonid Enhancement Program (SEP) was designed to double salmon catches in two phases starting in 1977 over a span of about 15 years. Fishery management plans were also devised to rehabilitate depressed stocks through conservation and enhancement. This paper will address enhanced and wild fishery management for chum salmon throughout British Columbia and for coho salmon in Georgia Strait.

SEP projects were planned to minimize species and stock management problems by selecting sites where terminal harvests were possible and where all stocks and more than one species were usually enhanced. Because of the high value of chum salmon roe in the late 1970s this species was the most enhanced in the early phases of SEP. Chinook were also enhanced because of the severely depressed state of many of the stocks. Species such as sockeye and pink salmon were enhanced at a lower rate particularly in the North and Fraser until international management treaties were negotiated.

SEP is still a bit player in enhancement with only 10% of the 1985 to 1989 mean catch of enhanced origin (Table 1). Except for chum at 33%, the catch of enhanced salmon for all other species is less than 15% of the total catch.

SEP has 11 major chum salmon facilities producing 90 million fed fry and 100 million unfed fry annually. Fed fry are produced from Japanese style hatcheries and unfed fry from spawning channels. An additional 5 million fed fry and 25 million unfed fry are produced from small facilities, mostly improved side channels.

TABLE 1.—SEP production, 1985–89 average.

Species	Total Catch (millions)	SEP Catch (millions)	% SEP	Technology
Sockeye	9.3	1.1	12	Lake fert./channel
Chinook	0.9	0.1	11	Hatchery
Coho	4.2	0.6	14	Hatchery
Pink	18.4	0.4	2	Hatchery/channel
Chum	4.3	1.4	33	Hatchery/channel
Total	37.1	3.6	10	

SEP chum enhancement maintains the genetic integrity of each stream and only releases fry into the stream of origin unless the stream is barren or has reached a very low level. It also attempts to utilize all portions of the run, although there is a tendency to enhance the early to middle portion of the run because of the tendency to ensure the project reaches its egg target. Because a hatchery works with a number of stocks, broodstock collection is a mix of enhanced fish and naturally spawning stocks.

Fishery Management of Enhanced Stocks

Pre-season estimates of returns for enhanced stocks are supplied by SEP to management biologists based on past survival of the enhanced stock and average age composition of return. Because of the high variability of survival and age of return, pre-season estimates are of limited reliability. In-season management through test fisheries and biological sampling are critical for management of enhanced and natural stocks.

At Pallant and Kitimat, where enhanced chum presently make up less than 20% of the total catch in the major fishing area (Table 2), total abundance of all stocks drives the fishing plan. Snootli chum were originally enhanced to buffer the high harvest rate on chum during the harvest of Area 8 pinks. Snootli hatchery has been so successful that its stocks make up only about 8% of the Area 8 chum escapement yet have risen to comprise 40% of the Area 8 chum catch. Harvesting of these enhanced stocks has increased harvest rates from the pre-enhanced average of about 8% to 76% between 1985 and 1989.

"Harvesting this very productive enhanced stock in the mixed stock traditional fishing areas at a high harvest-rate suitable for the enhanced stocks results in an excessive harvest rate on the less productive natural stocks. . . . The significant benefits of enhancement can be realized without serious loss of enhancement only if excess production is assessed through scientific index fisheries and harvested terminally to protect natural chum stocks." (Central Coast SSMP Report, DFO Internal Report 1991)

At Conuma and Nitinat, virtually all the chum stocks have been enhanced and the fishery is managed to achieve escapement goals for the mixed enhanced and wild stocks returning to the native streams. At both sites the fishery is conducted terminally with minimal interception of passing stocks.

Clockwork Strategy

In the Johnstone Strait Fraser River Study Area (i.e., all streams on the east coast of Vancouver Island and on the adjacent mainland plus the Fraser River) a plan was initiated in 1983 to try to rebuild the depressed chum stocks to historic levels in 12 to 15 years by limiting fishing to a predetermined harvest rate schedule. Wild escapement levels would be raised from the previous 10-year average of 1.2 million to 1.8 million in the 1983 to 1986 period and then in stages every four years to 2.5 million in 1995. For 1987 to 1990 the total stock would have to be greater than 3.0 million (i.e. 2.0 million wild escapement goal and 0.9 million enhanced production plus 0.1 million U.S. production) before fishing would take place. Depending on stock size, harvest rate could increase to a maximum of 40% when stock size was over 5.2 million (Table 2).

TABLE 2.—Clockwork harvest rate schedule for Johnstone Strait, 1987-90.

Wild Stock (millions)	Total Stock (millions)	Harvest Rate (%)
0-2.0	0-3.0	10
2.0-2.7	3.0-3.7	20
2.7-4.2	3.7-5.2	30
over 4.2	over 5.2	40

Early season (third week of September) commercial fisheries and all-season test fisheries in Johnstone Strait are used to estimate total run size. Analysis of mark returns from in-season sampling of chum catches is used to estimate enhanced production.

As a result of this strategy, harvest rates of East Coast of Vancouver Island chum (Puntledge, Big Qualicum and Little Qualicum) and Fraser chum (Inch, Chehalis, and Chilliwack) in Johnstone Strait totaled only 21% and 29%, respectively, from 1984 to 1989 (Table 3).

An additional terminal harvest for East Coast Vancouver Island stocks has raised harvest rates to 64% for these stocks. A minor terminal harvest in the Fraser River increased the total Fraser harvest rate to 35%. The late timing Fraser enhanced stocks have had a lower harvest rate because of a late timing component which misses being harvested. In 1985, a new strategy was put in place to select eggs from those portions of the escapement of the component stocks which migrate in the middle portion of the Fraser timing. Weather problems and market quality make late Fraser fisheries undesirable. Harvest of early timing Fraser chums conflicts with the valuable migration of North Thompson steelhead. We are just starting to evaluate the success of this strategy of selecting the mid timing.

As a result of these low harvest rates on Fraser enhanced chum excess escapements have occurred chiefly to Chehalis Hatchery. In 1989 Chehalis had a surplus of 27,000 chums. Because of the depressed nature of many of the stocks, these surpluses have increased the natural spawning escapement.

TABLE 3.—Production of enhanced chum salmon, 1984–89 total.

Hatchery	Catch Area	Enhanced Catch	Exploitation Rate (%)	% of Catch Enhanced
Pallant	Area 2E	273,656	54	20
Kitimat	Area 6	42,620	29	9
Snootli	Area 8	990,569	89	40
Conuma	Area 25	218,858	46	55
Nitinat	Area 21	3,099,608	74	72
ECVI	Johnstone Strait	627,539	21	18
	Area 14	1,341,795	44	70
	Total	1,969,334	64	
Fraser	Johnstone Strait	372,507	29	10
	Area 14	15,896	1	2
	Fraser	70,473	5	37
	Total	458,876	35	
ECVI + Fraser	Johnstone Strait	1,000,046	23	28
	Area 14			72
	Fraser			37
Total		7,053,521	65	

Georgia Strait Coho Problem

Declining coho stocks in the Strait of Georgia are believed to have been caused by overfishing and habitat loss. Currently, about 40% of the Georgia Strait troll and sport catch is made up of Canadian enhanced salmon. Exploitation rates have averaged 80% (1985 to 1988) compared to the 65–70% considered acceptable for wild coho stocks.

Management of the Georgia Strait coho stocks is complicated by the fact that they are harvested in troll, net, and sport fisheries, both inside and outside Georgia Strait. A consultation process has been occurring through which options for rebuilding can be developed and evaluated with all interested parties. These include habitat protection and restoration, enhancement, and harvest restrictions.

One of the most interesting proposals is for all hatchery fish to be marked and sport regulations would set a higher bag limit for marked than for unmarked fish. Wild fish would be conserved, while hatchery benefits would increase. Fewer enhanced coho would return to the hatcheries where their market value is low. The catch of enhanced Georgia Strait coho averaged 578,000 for the 1985 to 1989 period. Hatchery coho surpluses average approximately 100,000 for the same period. Commercial harvest limitation is complicated by the fact that many Georgia Strait coho are caught incidental to large sockeye, pink, and chum fisheries. Whatever options are chosen, the decision will not be an easy one.

D.

INTERACTIONS BETWEEN WILD AND CULTURED SALMON IN NORWAY AND SWEDEN

T. G. Heggberget and T. Eriksson

ATLANTIC SALMON SMOLTIFY AND LEAVE FRESHWATER at sizes between 12 and 17 cm. The smolt ages vary between 1 and 6 years, depending on growth conditions during the presmolt freshwater period. The salmon return to freshwater to spawn after 1–4 years, at sizes from 1 to 25 kg.

Some significant life history variations between stocks exist. Examples of variations between stocks are: timing of spawning, timing of emergence of fry, timing of smolt migration, timing of return migration, and age and size at maturity. Atlantic salmon in Norway are genetically distinct from the Baltic salmon.

Norway

In Norway there are three main sources of cultured fish (1) presmolt salmon released for general enhancement of stocks, (2) smolts released to compensate negative effects due to hydropower development and ocean ranching along the coast, and (3) escapees from pen farms along the coast.

There are about 500 streams with natural stocks of salmon in Norway. The production of farmed salmon in Norway was about 150,000 tonnes in 1991, while the natural production was about 2000 tonnes.

A number of problems have occurred. Due to pen farming activities a great number of farmed salmon have escaped and are now mixing with the wild stocks. Proportions of cultured fish in spawning populations have increased during the last decade, and now exceed 80% of the total number of spawners in some streams. Parasites and diseases introduced with import of smolts from other countries have been transferred to wild stocks with some dramatic effects; high mortality of wild salmon has occurred both due to the parasitic monogenean *Gyrodactylus* and due to furunculosis. Ecological interactions—for instance, competition during spawning and presmolt stages—between wild and cultured fish have been observed. Interbreeding may result in erosion of local adaptations in wild stocks of Atlantic salmon in Norwegian streams. As well, ocean ranching increases fishing pressure on wild stocks.

Several attempts to minimize the negative effects of interactions between cultured and wild fish have been or are being tried: conversion from pen farming to land-based salmon farming; minimizing numbers of strayers from ocean ranching to wild stocks; releasing in connection to rivers, not directly in the sea; harvesting ocean-ranched fish apart from wild stocks; releasing away from important salmon streams; emphasizing locally and regionally based salmonid aquaculture and not transporting live fish material between regions; and practicing effective and intensive health control of release material.

Sweden

The Baltic stocks of Atlantic salmon have been exploited by humans for many centuries. At the end of the 19th century salmon spawned in 60–70 rivers in the Baltic. From 1940

onwards many of the large salmon rivers were dammed and destroyed as spawning habitats. To compensate for the losses hatcheries were established at the rivers used for hydroelectric power production.

Several problems persist. Most of the natural populations have disappeared due to human activities in the rivers. Today between 80 and 90% of the catches in the fishery have a hatchery origin. The catches are dominated (80-90%) of offshore catches on mixed stocks and represent a high exploitation rate on wild stocks. Wild stocks are unable to cope with the present exploitation rate while the reared stocks can, due to high egg-to-smolt survival in the hatcheries. Thus only about 20-25% of the production potential in the natural rivers is actually met today. Management plans are proposed, including a reduction of the offshore fishery.

V.
ABSTRACTS

A.
GENETIC CONSIDERATIONS

Conservation of Salmonid Fishes: Why, What, and How

F. W. Allendorf

Three questions must be addressed before we can develop objectives and methods for conserving salmonid fishes: (1) Why should we preserve salmonid fishes? (2) What should we attempt to preserve? and (3) How should we conserve salmonid fishes? It is important to address the issue of why we want to conserve salmonids in order to unify our efforts and to obtain the resources that are necessary to do it. The question of what we should be preserving is an important and perhaps surprisingly difficult one. Loss of local salmonid populations is occurring throughout the world. We cannot halt this ongoing process; that is, we cannot conserve all local salmonid populations. Therefore, choices and compromises must be made. How do we best use our limited resources to conserve genetic diversity in salmonid fishes? Our first priority should be to protect extant wild populations and their habitat. The loss of genetic diversity is usually irreversible. Therefore, our primary efforts should be to prevent such losses.

**Do Culture Conditions of Hatchery-Reared Salmon
Affect Return and Straying of Adults?**

S. O. E. Ebbesson

Available data indicate that caution should be exercised in rearing certain species of salmon under accelerated growth regimes; additional research is needed to determine if such regimens result in straying. We know from our experience in Alaska with accelerated rearing programs for chinook salmon, for example, that the result is significantly lower returns of adults and returns characterized by a high percentage of jacks. The reasons for this are unknown, but a better understanding of factors affecting smolt transformation and development in general are likely to lead to augmentation of current rearing strategies which will result in better developed smolts. Recent studies have revealed the importance of thyroid hormones on olfactory imprinting and development in general.

Studies comparing saltwater survival of yearling and zero-age coho salmon have showed differential rates of survival related to the timing of release into salt water and to the timing and extent of the plasma thyroid hormone surge. In a 1982 study by Dickhoff and others, about 5 times as many yearling smolts survived as compared to zero-age smolts. Those data, taken together with the information that the thyroid hormone surge (T_4) during smolt transformation in the zero-age fish was half the amplitude of the yearlings', indicate that in addition to poor survival as postsmolts, some zero-age fish may not imprint properly on the stream where they are released. The reason for that is that thyroid hormones play an

essential role in olfactory imprinting. Our studies on brain chemistry and brain circuitry changes during smolt transformation revealed sequential surges of select neurotransmitters before, during, and after the plasma T_h surge. Irregularities in any of these surges may result in inadequate imprinting or lead to inadequate brain development, which in turn could affect subsequent behavior and survival.

There is to my knowledge no direct evidence for straying of zero-age fish, but research in this area should, in my view, be carried out before accelerated rearing programs are implemented.

Adaptive Importance of Genetic Infrastructure in Salmon Populations

A. J. Gharrett and W. W. Smoker

Genetic differences among populations of Pacific salmon are well known, both for neutral biochemical traits and to a lesser extent for quantitative, ecologically adaptive traits. This knowledge is the basis for present day genetic policy which seeks to conserve the genetic variation which underlies that variability. There is increasing evidence of adaptively important genetic variability within populations; that is, genetic infrastructure. In Auke Creek pink salmon, for instance, there is genetically based variability of timing of anadromous migration that is important to the survival of offspring. The adaptability and productivity of commercially important populations are dependent on that infrastructure and rational resource management should seek to conserve it.

Homing, Straying, and the Interaction Between Wild and Hatchery-Produced Salmon

T. P. Quinn

This paper reviews studies on the patterns of straying of adult salmonids from their river or hatchery of origin, with an emphasis on Pacific salmon. The prevalence of straying varies greatly among populations. In general, introduced populations and salmon whose rearing history involves displacement or changes in water source may stray more than native stock and those reared and released on-site. Normal hatchery practices do not necessarily increase the tendency of salmon to stray, although evidence indicates that this may occur. While a generalized estimate of the proportion of salmon that stray would be useful, none seems appropriate because rivers and hatcheries vary so greatly in their tendency to produce and attract strays. There is evidence that the offspring of hatchery-produced salmon may be less viable than those from local wild fish, hence straying between hatcheries and spawning grounds is cause for concern. Whether or not strays actually affect local gene pools depends not only on the prevalence of straying but on the degree of assortative mating and differential survival between populations. At present, fundamental gaps in our understanding of the genetic and environmental factors influencing straying hinder accurate prediction of the levels and consequences of straying.

Complementary Uses of Ecological and Biochemical Genetic Data in Identifying and Conserving Salmon Populations

F. M. Utter, J. E. Seeb, and L. W. Seeb

This paper addresses the need to define distinct population segments within species of salmonid fishes. The focus is on identifying the smallest detectable population with unique sets of characters (i.e., a "species" under the phylogenetic species concept); such units require identification prior to any subsequent groupings under which individual populations may ultimately be managed. The inability of stream distances between populations to identify ancestral discontinuities excludes such measurements as a basis for estimating relationships. The requirement for genetic information in distinguishing populations has been met through characters reflecting ancestral lineages (including adequate biochemical genetic surveys and some meristic information), and those reflecting local adaptations (such as timing of migration and spawning, and distinct temperature tolerances). These different types of genetic information comprise complementary data sets for distinguishing populations because they reflect different evolutionary processes and time scales. Within distinct ancestral groupings defined by biochemical genetic data (supplemented with some meristic information) may exist adaptively distinct populations that cannot be distinguished in the absence of life history and ecological information. Examples are summarized in which a logical process has been applied for distinguishing populations including an initial survey focusing on identifying ancestral groupings followed by a systematic search for adaptive distinctions within these groupings.

Genetic Stock Identification Study of Yukon River Chum and Chinook Salmon

R. L. Wilmot, W. J. Spearman, R. Everett, and R. Baccus

The United States and Canada opened negotiations in 1985 concerning the allocation of Yukon River chum and chinook salmon. Approximately 90% of the in-river harvest is by U.S. fishermen. An unknown proportion of this catch would have returned to the Canadian portion of the Yukon Drainage. In order to negotiate an equitable treaty between the two countries, it is necessary to determine what proportion of the U.S. harvest is of Canadian origin. In 1987, the U.S. Fish and Wildlife Service began a genetic stock identification (GSI) study in the Yukon River to address this problem.

Tissue samples were taken from 34 chum salmon populations and 30 chinook salmon populations and genetically characterized using enzyme electrophoresis. Nineteen variable characters were used to analyze the population structure of Yukon River chum salmon, and 22 variable characters in chinook salmon. Genetic separation between the summer run and fall run of chum salmon was very good as determined using simulations of stock mixtures of given contributions of each stock. Separation between U.S. fall run stocks and Canadian fall run stocks was also good. Estimates down to the stock level are not reliable for management purposes at this time. Resolution of an additional known 14 variable characters, and the use of mtDNA variation, may allow reliable estimates to the stock level. Genetic separation between U.S. and Canadian chinook stocks was very high as determined by simulations.

Separation was also very good for subgroups within both the U.S. and Canadian groups. Accuracy down to the stock level is substantially better for chinook salmon than for chum salmon, but is still not reliable for management purposes. Resolution of an additional 13 variable characters, and use of mtDNA variation, may allow discrimination to the stock level.

Samples have been taken from the mixed-stock fishery at the mouth of the Yukon River and estimates of stock contribution were calculated for the years 1987-90. Due to legal problems concerning management of the Yukon River fishery, these results will not be released until a thorough peer review of the data.

B.

OCEAN CARRYING CAPACITY

A Theoretical Evaluation of the Carrying Capacity of Prince William Sound, Alaska, for Juvenile Pacific Salmon

R. T. Cooney

Present levels of feeding on zooplankton resources by wild and ocean-ranched juvenile Pacific salmon in Prince William Sound are estimated to be between 1% and 4% of the annual macrozooplankton production in the region. When annual fry losses to early ocean mortality are taken into account, the feeding demand associated with growth rates averaging 3-4% of the body weight per day fall to 0.4-1.6% of the total herbivore production and 1.5-5.0% of the macrozooplankton production. Uncertainties associated with the numerous assumptions used in this analysis are discussed in relation to what is understood about the biology and ecology of salmon in Prince William Sound and elsewhere.

Density Dependent Changes in Chum Salmon, *Oncorhynchus keta*, Returning to Iwate Prefecture, Japan

H. Ida

In the last two decades in Iwate prefecture, Japan, hatchery operations were prolonged in order to overcome several problems: (1) to reduce natural mortality in early life stages, (2) to supply food for increased numbers of fry from hatcheries, and (3) to adjust the time of release from the hatchery, where fry hatch much earlier than in the natural beds because of higher temperature of incubating water in the hatchery.

Release after feeding of chum fry started in the early 1970s in Iwate, and the method prevailed throughout the prefecture in the later seventies. In addition to this feeding in freshwater, feeding of fry in cages set close to shore started in the early eighties. The rate of return of adults to Iwate for brood year 1970 was 0.82%; for 1975 it was 1.52%; and for 1985, 3.50%. Thus, the rate of return increased serially. In the earlier stages of this change, feeding or prolonged hatchery operations seemed to accelerate maturation, especially in males; the number of precocious 2-year-old males ("jacks") reached 25-30% in some rivers. There was a tendency toward decreased mean age and mean size, but this lasted only a few years.

Size of fry at the time of release was increased from about 1 gram in the 1970s to several grams in the early 1980s. Mean age and weight of adults returned were as follows.

	1975	1980	1985	1990
Mean age	3.3	3.90	4.47	4.27
Mean weight (kg)	3.42	3.39	3.54	3.12

On the whole, the effort of raising chum fry up to a certain size seemed to increase the survival rate of their early life history stages in coastal areas. At the same time, the number of fry released from Iwate prefecture increased from 30 million in 1970 to 400 million in 1990. Both of these efforts accelerated the biomass of chum salmon originating from Iwate, and as a result growth was stunted and the mean age at maturity was increased.

Factors Affecting Marine Growth of Bristol Bay Sockeye Salmon

D. E. Rogers and G. T. Ruggerone

Growth of Bristol Bay sockeye salmon in freshwater and in the last few months at sea, had been shown to be dependent on their density (higher density, poorer growth) and temperature (colder temperature, poorer growth). In both 1990 and 1991, the sockeye salmon returning to Bristol Bay was unusually small; i.e., for a given age and sex the fish were smaller than expected from the number of fish in the run and the prevailing spring temperatures. The pronounced increase in North Pacific salmon catches in recent years combined with the small size of sockeye in Bristol Bay prompted a reexamination of the factors influencing marine growth. We estimated the annual runs of sockeye and chum salmon in the North Pacific (central and western Alaska plus Asia) and compiled air and water temperature statistics for southwestern Alaska from 1952 to 1991. We estimated the annual mean lengths and weights of adult sockeye in Bristol Bay runs during 1959-91 and marine growth was estimated from scale measurements on samples from Nushagak sockeye catches during 1959-89. We used data plots, linear correlation, and step-wise multiple correlation analyses to relate the various measures of abundance (Bristol Bay, western Alaska, Asia, sockeye and chum) and measures of temperature (air and water for various monthly combinations).

The inclusion of numbers of sockeye and chum salmon from other areas did not improve on the inverse correlation between numbers of Bristol Bay sockeye and the mean lengths in the run. The inclusion of sea surface temperatures during late winter improved the multiple correlation (only April-May had been used before); however, the overall correlation with Bristol Bay lengths was poorer with the addition of the 1990 and 1991 observations. Scale radii measurements of Nushagak sockeye during each year at sea (1956-88) indicated that growth was positively related to temperature during the first (ages 1.2 and 1.3) and second (age 1.3 only) years at sea. Growth during the last year at sea of age 1.2 and 1.3 sockeye was not correlated with sea surface temperature nor salmon run size. Scale growth during the first and second years at sea was not correlated with adult length; however, growth during the third year (age 1.3) was positively correlated with adult length. These data indicate that abundance of Bristol Bay sockeye most affects their growth in the final months before their return, which is a time when they are probably most concentrated.

Table: PWSAC Adult Pink Salmon Weight Relative to PWS Return

J. Olsen

PWS PINK RETURN	YEAR	AFK		WNH		CCH	
		LB.S	KG	LB.S	KG	LB.S	KG
15,723,637	1980	3.30	1.50			?	?
22,085,837	1981	3.50	1.59			?	?
23,051,963	1982	3.20	1.45			?	?
16,696,998	1983	3.00	1.36			?	?
26,476,567	1984	3.40	1.55			?	?
28,254,589	1985	3.30	1.50			?	?
12,771,529	1986	3.40	1.55			?	?
31,544,027	1987	3.60	1.64	3.65	1.66	?	?
13,126,476	1988	3.10	1.41	3.48	1.58	?	?
24,157,149	1989	3.30	1.50	3.45	1.57	3.65	1.66
43,831,188	1990	3.00	1.36	2.99	1.36	2.97	1.35
38,354,826	1991	2.40	1.09	2.33	1.06	2.43	1.10
	1992						
	1993						
	1994						
	1995						
	1996						
	1997						
	1998						
	1999						
	2000						
24,672,899	AVG						
	1980-91	3.21	1.46	3.18	1.45	3.02	1.37
	1980-90	3.28	1.49	3.39	1.54	3.31	1.51
	MIN	2.40	1.09	2.33	1.06	2.43	1.10
	MAX	3.60	1.64	3.65	1.66	3.65	1.66

Regression Output:

Constant	3.51
Std Err of Y Est	0.31
R Squared	0.14
No. of Observations	12.00
Degrees of Freedom	10.00
X Coefficient(s)	-0.00001
Std Err of Coef.	0.00001

Interactions and Environmental Carrying Capacity Limitations of Natural and Artificial Stocks of Salmonids

P. M. Washington

Artificial propagation of salmonids has been practiced for more than a century. In theory, this practice allows the production of almost unlimited amounts of fish. The practice was developed and used to mitigate losses of smolts formerly produced in natural habitats, and evolved to reduce the high mortality of the early freshwater life of anadromous salmonids. Stocks used in hatcheries were selected to produce more easily handled fish. Short pulsed hatchery runs currently provide the basis for many coastal net fisheries.

Artificial facility releases can produce salmonids up to ocean carrying capacity. Oceanic salmonid yield potential is limited by both density-dependent and -independent factors. Monoculture has produced localized density limiting production, but actual production limitation may not be approached until the use of all niches and niche subsets approaches maximum.

Fisheries precluding individual stock management should be terminated before extinctions of wild stocks result. Harvest policies can no longer be to the detriment of wild stocks. Artificial propagation based policy has reduced genetic diversity, manipulated adult size and age downward, and had profoundly negative impacts upon wild stocks.

C.

MANAGEMENT

Overview of Salmon Enhancement Programs in Southeast Alaska

D. F. Amend

All five of the Pacific salmon species are being enhanced by hatcheries in southeast Alaska. Non-hatchery enhancement is not included in this report. Hatcheries are operated by the FRED Division of the Alaska Department of Fish and Game, the Northern and Southern Southeast Regional Aquaculture Associations, and private non-profit corporation. Hatcheries played a minor role in the commercial harvest prior to 1985. Since 1985, the average annual harvest of enhanced chum salmon has been 695,700 (31.2%), chinook 19,590 (10.2%), coho 195,650 (8.1%), sockeye 58,480 (2.4%), and pink 475,000 (2.1%). At full production the percentage of enhanced salmon in the commercial harvest is expected to be about 66.4% chum, 32.5% chinook, 18.2% sockeye, 16.2% coho, and 5.8% pinks. The annual value to the commercial fleet has averaged \$8.4 million annually and at full production is expected to average \$36.8 million annually. The annual 3% enhancement tax paid by fishermen has averaged \$2.39 million. Cost recovery is conducted only by the two regional aquaculture associations and the private non-profit corporations. The annual revenue generated from cost recovery is estimated to be about \$2 million.

The Perpetual Oversight of Hatchery Programs

E. L. Brannon

A major concern of fisheries biologists and managers has been the perception that hatchery fish are inferior to wild fish, and the belief that hatchery fish tend to degrade natural populations. These perceptions are not without foundation, but the problems are the fault of how we have managed hatcheries, and not with either concept or the potential which hatcheries can offer. The perpetual oversight that we have demonstrated consistently throughout our history of fisheries management has been to ignore the fact that fish populations are an integral component in a complex environmental system. If we neglect the requirements that populations have, and hence the traits they possess to synchronize their life history with specific environmental constraints, failure is guaranteed. Although appropriate technology is the key in producing healthy fish, the absolute critical component for success of the hatchery concept is the seed stock used for propagation. Synchrony between stock characteristics and the environment cannot be sacrificed, which means that every possible effort must be extended on working with the native gene pool and avoiding contamination from other brood sources. Adherence must be given to the stock concept in the use and management of hatcheries.

Trends in Abundance of Hatchery and Wild Stocks of Pink Salmon in Cook Inlet, Prince William Sound, and Kodiak, Alaska

D. M. Eggers, L. R. Peltz, B. G. Bue, and T. M. Willette

Trends in pink salmon (*Oncorhynchus gorbuscha*) abundance, production, and average weight of hatchery and wild stock catches, were examined for the years 1960 through 1990 for the lower Cook Inlet, Prince William Sound, and Kodiak Island areas. The abundance of wild pink salmon was the sum of catches and escapement, which were aerial survey index counts expanded by a life expectancy factor. Abundance of hatchery stock was the sum of the estimated contribution of stocks to catches and the returns to the stock. Production estimates were calculated as stock returns from fry released and wild stock returns from escapement. Hatchery runs have increased since the late 1970s and currently exceed wild stock runs. The total central Gulf of Alaska runs of pink salmon have increased and average weights have decreased since the early 1970s. Since the construction of hatcheries, wild pink salmon runs in Kodiak and Cook Inlet have not declined; however, in Prince William Sound a marked decrease in wild stock runs has coincided with the increase in hatchery runs. Return per spawner for wild stocks and survival of releases for hatchery stocks were similarly affected by ocean temperatures. The recent decline in Prince William Sound wild pink salmon runs is believed to be the result of lower wild stock escapement levels due to the heavy exploitation of weak to moderate wild stock runs.

Gene Frequencies, Risk Assessment, and the Management of Hatchery Production of Pacific Salmon

J. E. Seeb

The legislative mandate of the Alaska Department of Fish and Game (ADFG) is the "enhancement and development of all aspects of the state's fisheries for the perpetual use, benefit and enjoyment of all citizens" (Alaska Statutes Title 16). The legislature accompanied this mandate with the requirement that enhancement of crucial native stocks should only be undertaken if careful consideration indicated that they can be conserved in the presence of hatchery management (Title 16; ADFG Genetics Policy).

Native stocks of salmon are important because they not only are the mainstay of the Alaska fisheries economy, but they also represent thousands of years of adaptive evolution. Reproductive isolation, through homing, leads to between-population genetic differences. This component of genetic variation is responsible for adaptive fitness to diverse environments, a factor which permits different stocks of salmonids to thrive under different environmental regimes; and it is the factor that provides for optimal sustained production of wild stocks given the vagaries of environmental variation.

Hatchery production of enhanced fish can relax many of the pressures of selection on a population. While such a stock may thrive in a hatchery and produce fish for harvest, after several generations it may lose some of the genetic traits that made it optimally fit for response to the natural environment. Thus it is important that hatchery fish only be used to truly enhance harvests, and they must be kept from replacing the important wild stocks from which they were derived.

Of paramount concern (this symposium) is the loss of genetic integrity of the isolated salmon populations that can result if hatchery practices lead to increased straying of hatchery fish (and their interbreeding with the native populations). As a part of its effort to protect wild stocks, ADFG is conducting (and proposing) genetic research such as: (1) genetic stock identification (GSI)—genetic screening to determine stock boundaries, provide GSI data to identify hatchery and wild stocks in mixed stock fisheries, genetic marking to monitor straying of hatchery fish; (2) risk assessment and genetic monitoring—evaluation of the genetic consequences of new or increased hatchery production during phased-in expansion, monitoring of changes in fitness and possible effects on wild stocks, conducting long-term monitoring of hatchery and wild stock genetic diversity, modifying hatchery strategies if called for; and (3) use of best possible breeding practices to maintain fitness and genetic variability.

The ADFG believes that this recommendation of a conservative hatchery management strategy incorporating genetic monitoring will facilitate responsible development of the fishery resource. Strict adherence to this strategy will help ensure that hatchery enhancement does not cause any genetic alteration resulting in the loss of these important wild stocks.

Population Genetic Structure of Chum Salmon: Identification of Wild and Hatchery Fish in Mixed Fisheries

L. W. Seeb

The control and management of mixed-stock harvest of chum salmon is one of the most difficult problems facing salmon managers today. Interception of chum salmon exacerbates allocation issues and may contribute to conservation problems in certain areas. Genetic stock identification (GSI) is the primary tool which is being implemented to address these mixed-stock interception issues. Through GSI analyses, scientists can identify the origin and amounts of the different stocks harvested in mixed-stock areas. These values can be used both in-season and post-season to insure conformance to international treaties, to allocate future harvests by nation and user group, or to separate hatchery from wild stocks. They can also be used to adjust harvest areas or times to protect important depleted stocks, the extinction of which would represent an irreversible loss of distinct population segments of the species.

Genetic data from chum salmon have been collected for over a decade by many state, federal, and provincial agencies along the Pacific Rim. These data show that chum salmon subdivide genetically not only into large regional groups, but also one a finer scale into local genetic races. Federal and state agencies have invested considerable resources in the collection of data from stocks originating from Washington, southeast Alaska, Russia, and Japan; the Canadians have likewise gathered extensive data from British Columbia populations. Yet, with the exception of stocks inhabiting the Yukon River and Bristol Bay, no database currently exists for the remaining Alaskan stocks which comprise approximately 40% of the chum salmon production of North America. Many of these stocks have not been sampled because they inhabit remote areas difficult to access. The Alaska Department of Fish and Game has placed a high priority on obtaining genetic data from these stocks.

Further development of the Prince William Sound chum salmon genetic database would allow for identification of wild stocks adjacent to hatchery installations. The current chum salmon broodstock in Prince William Sound is a heterogenous group originating from multiple sources and timings. The effect of hatchery stocks on the wild stocks within Prince William Sound could be monitored through GSI techniques to insure the continued health of these important wild stocks.

D.

ATLANTIC SALMON

Status of Wild and Hatchery-Propagated Swedish Salmon Stocks After 40 Years of Hatchery Releases in the Baltic

T. Eriksson and L-O. Eriksson

The Baltic stocks of Atlantic salmon have been exploited by humans for many centuries. Especially during the last century, salmon populations have been subjected to dramatic changes in spawning stream access, fishing patterns, and fishing pressure.

At the end of the 19th century salmon spawned in 60-70 rivers in the Baltic proper. From 1940 onward, many of the large salmon rivers were dammed, most of them below the lowest spawning rapids for salmon. Methods for rearing salmon up to the smolt stage were developed and the first smolt releases were around 1950. The number of smolts released in Swedish rivers gradually increased to between 2 and 2.5 million by the middle of the 1980s. During the last 10 years other countries have started salmon release programs, resulting in an annual release of about 3 million smolts. The smolt releases have been successful, showing high survival rates of stocked fish. Today, only about 20 rivers, most of them in Sweden, are attainable for natural spawning runs. The runs are very weak.

Before the second world war the Baltic salmon fishery mainly consisted of coastal and river catches of spawning migrators ascending the rivers. After the war an offshore drift gillnet fishery developed, nowadays making up the major part of the total catch. As a consequence, the spawning runs of wild salmon have decreased dramatically. One hundred years ago the natural production of salmon smolts from the Baltic salmon rivers was around 7-8 million smolts annually. In the early 1970s the wild smolt run to the Baltic was about 2 million. At present, only about 0.5 million wild smolts are released to the whole Baltic proper, which is only about 20% of still remaining smolt carrying capacity of the rivers.

The offshore fishery on mixed populations in the central Baltic proper leads to an extremely high fishing pressure on the Baltic salmon stocks. Stocks are unable to cope with the present exploitation rate. As a result, the number of spawners in natural streams gradually diminishes. In the absence of a compensatory program, a reduction in stock size of the magnitude shown by wild salmon in the Baltic would decrease catch per unit effort to such a degree that a salmon fishery would be meaningless. At present, however, about 90% of the salmon smolts leaving Baltic rivers are of hatchery origin. Depending on extremely high egg-to-smolt survival rates the reared stocks can withstand this high exploitation. It is concluded that the success of hatchery enhancement programs in combination with the lack of effective regulations allowing a high catch per unit effort in the offshore fishery, explains a major part of the sad fate of the remaining wild salmon stocks in the Baltic.

A biologically sound management program for the Baltic salmon is bound to include a stop (or strict regulation) of the offshore fishery on mixed stocks. Salmon stocks should be exploited in relation to the carrying capacity of individual populations, by a more terminal fishery at the coast, or in rivers.

However, an established offshore fishery in the main Baltic, including (at least) seven nations, has so far made any kind of regulations difficult. A recent and, hopefully, more accessible management program is a compromise, suggesting a ban on salmon fishing outside 24 nautical miles from the coast. The fishery closer to the coast will be supported by net-pen delayed releases of salmon at selected areas along the coast of the Baltic main basin. The proposed offshore fishery regulation would increase escapement considerably, while total catch (in tons) would remain unchanged. If the proposal is accepted, we estimate that most wild salmon stocks would have a possibility to recover within 3-4 generations. If not, we believe that the fate of all the wild salmon stocks in the Baltic is extinction within a few additional salmon generations.

Interactions Between Wild and Cultured Atlantic Salmon: A Review of the Experience in Norway

T. Heggberget

About 500 streams in Norway support Atlantic salmon. Most of the Norwegian salmon populations are characterized by small numbers of fish. Physical conditions, for instance water flow and temperature regimes, vary significantly along the Norwegian coast. Analyses of age and size at maturity, timing of spawning, and timing of smolt migrations clearly support the hypothesis of ecological adaptation to different physical environments. The differences in life history patterns are results of different selection pressures on salmon under varying physical conditions.

Proportions of cultured salmon have increased together with the rapid growth of the Norwegian salmon farming industry, and a maximum of 80% cultured fish in spawning populations have been observed. The sources of cultured salmon in Norwegian streams are fish released for general enhancements of stocks, ocean ranching, and escapees from the fish farming industry. Escapees from closed pen operations are the main source of cultured fish in nature.

The most striking effect of the increasing numbers of cultured fish so far has been the introduction of parasites and diseases. In recent years more than 30 populations of salmon have been completely wiped out by the monogenean *Gyrodactylus*, and high mortality of adult salmon due to furunculosis has been observed in some streams. The long-term effects of genetic interbreeding might result in extra mortality of wild fish due to erosion of local adaptations.

VI. ACKNOWLEDGMENTS

This workshop was sponsored by the Prince William Sound Science Center (PWSSC) and the School of Fisheries and Ocean Sciences (SFOS), University of Alaska Fairbanks. Co-chairpersons were Dr. Ole A. Mathisen, SFOS, and Dr. Gary L. Thomas, PWSSC. The list of contributors includes Pew Charitable Trust, University of Alaska Fairbanks, Alaska Department of Fish and Game, Pacific Seafood Processors Association, Prince William Sound Aquaculture Association, and Sealaska Corporation. We want to extend special thanks to Ms. Nancy Bird and Ms. Penelope Oswalt for their efforts to make the workshop a success.

VII.
AGENDA
Workshop on the Biological Interactions of Natural and Enhanced
Stocks of Salmon in Alaska

Saturday, November 9

Participants arrive during the day.

Sunday, November 10 *Open to the public*

First Morning Session - 8:30-10:00 a.m.

Opening remarks:

1. Gary L. Thomas, Director Prince William Sound Science Center
2. Goals of the Conference - Ole A. Mathisen, Univ. of Alaska-Juneau
3. Prince William Sound Aquaculture Corporation - John McMullen, President
4. State Genetic Policy - James E. Seeb, Alaska Dept. of Fish & Game

Session 1 -- Ocean carrying capacity

10:30-12:00

1. *A theoretical evaluation of the carrying capacity of Prince William Sound, Alaska for juvenile Pacific salmon.* R. Ted Cooney, School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks
2. *Density dependent changes in chum salmon, *Oncorhynchus keta*, returning to Iwate Prefecture, Japan.* Hitoshi Ida, Kitasato University School of Fisheries Sciences, Sanriku-cho, Kesen-gun, Japan
3. *Factors affecting marine growth of Bristol Bay sockeye salmon.* Donald E. Rogers, Fisheries Research Institute, University of Washington, Seattle, Washington
4. *Interaction in natural carrying capacity limitations for natural and enhanced stocks of salmon.* Percy M. Washington, GAIA NW, Inc., Seattle, Washington
5. *The carrying capacity of the North Pacific Ocean.* William G. Pearcy, Oregon State University, Corvallis (Summary)

Session 2 -- Management of mixed stocks

1:30-3:00 p.m.

1. *Trends in abundance of hatchery and wild stocks of pink salmon in Cook Inlet, Prince William Sound and Kodiak, Alaska.* Doug M. Eggers, Chief Fisheries Scientist, Alaska Department of Fish & Game, Juneau, Alaska
2. *Management of mixed enhanced and wild salmonids in British Columbia.* Don D. Bailey, Salmon Enhancement Division, Department of Fisheries and Ocean, Vancouver, Canada

3. *Gene frequencies, risk assessment and the management of hatchery production of Pacific Salmon.* James E. Seeb, Alaska Department of Fish & Game, Anchorage, Alaska

Session 3 -- Summary and general discussion
3:30-4:30 p.m.

Monday, November 11 *Open to the public*

Session 4 -- Basic Genetic Structure
8:30-10 am Session Chair: James E. Seeb

1. *Conservation of genetic diversity in salmonid fishes: why, what and how.* Fred W. Allendorf, Division of Biological Sciences, Missoula, Montana
2. *The predictive value of stream distances for estimating genetic relationship in salmonid species.* Fred M. Utter, National Oceanic and Atmospheric Administration (NOAA), Seattle, Washington
3. *Population genetic structure of chum salmon: identification of wild and hatchery fish in mixed fisheries.* Lisa W. Seeb, Alaska Department of Fish & Game, Anchorage, Alaska
4. *The importance of fine genetic structures in natural populations.* Anthony Gharrett, School of Fisheries and Ocean Science, University of Alaska, Juneau, Alaska

Session 4 continued
10:30-12:00

5. *Quantitative genetic variation of life history traits in pink salmon.* William Smoker, School of Fisheries and Ocean Science, University of Alaska, Juneau, Alaska
6. *Genetic stock identification of Yukon River chum and chinook salmon.* Richard L. Wilmot, U.S. Fish & Wildlife Service, Anchorage, Alaska
7. *Genetic relationships among Pacific salmon of the Bristol Bay area of Alaska.* Rebecca J. Everett, U.S. Fish & Wildlife Service, Anchorage, Alaska

Session 5 -- Straying
1:30 - 2:00 pm

1. *Homing, straying and the interaction between wild and enhanced stocks of salmon.* Thomas P. Quinn, Fisheries Research Institute, University of Washington, Seattle, Washington
2. *Do culture conditions of hatchery reared salmon affect return and straying of adults?* Sven Ebbesson (abstract only)

Session 6 -- Long Term Case Histories

2:00-3:00 pm

1. *Interactions between wild and cultured Atlantic salmon -- A review of the experience in Norway.* Tor G. Heggberget, NINA, Norsk Institutt for Naturforskning, Trondheim, Norway
2. *The status of wild and hatchery propagated Swedish salmon stocks after 40 years of hatchery releases in the Baltic rivers.* Torleif Eriksson, Swedish University of Agricultural Sciences, Department of Aquaculture, Umea, Sweden

Session 6 continued

3:30-5 pm

3. *The perpetual oversight of hatchery programs.* Ernest Brannon, University of Idaho, Moscow, Idaho
4. *The Soviet experience in the field of salmon interactions.* Mikhail Glubokovsky, Institute of Marine Biology, Far East Branch, Vladivostok, USSR
5. General discussion

Tuesday, November 12

Field trip to Wally Norenberg Hatchery at Esther Island (western Prince William Sound) --

Wednesday, November 13

Session 7 -- Interactions in Prince William Sound

8:30-10 am

1. *Overview of Ocean Ranching in Prince William Sound,* Jeff Olsen, Operations Manager, Prince William Sound Aquaculture Corporation, Cordova, Alaska

Session 7 continued

10:30-12 noon -- *Interactions in Prince William Sound*

Session 8 -- Interactions in Southeast Alaska

1:30-3 pm Session Chair: Ole Mathisen

1. *Southeast Alaska Chinook; Fisheries, management, enhancement, wild stocks and treaties.* William R. Heard, National Marine Fisheries Service, Auke Bay Laboratory, Auke Bay, Alaska
2. *An Overview of the Pink, Chum and Coho Enhancement programs in Southeast Alaska.* Donald F. Amend, Southern Southeast Aquaculture Association, Ketchikan, Alaska

Session 8 continued

3:30-5 pm -- ***Interactions - General discussion***

Thursday, November 14

Session 9 -- Interactions regarding other species, especially sockeye

8:30-10 am

Session 9 continued

10:30-12 Noon

Session 10 -- The Working Party: Writing sessions divided into sub-groups

1:30-5:00 pm Session Chairs in charge of each group

Friday, November 15 *Open to the public*

Session 11 Concluding Session

Session Chair: Gary Thomas

8:30-10 am Session leaders will present a short discussion of the findings of their working group followed by an open discussion session and approval of reports and documents.

10:30-noon Open discussion session continues.

Afternoon Departures

VIII.
LIST OF MANUSCRIPTS SUBMITTED

R. T. Cooney

A Theoretical Evaluation of the Carrying Capacity of Prince William Sound, Alaska, for Juvenile Pacific Salmon

T. Eriksson and L-O. Eriksson

Status of Wild and Hatchery-Propagated Swedish Salmon Stocks after 40 Years of Hatchery Releases in Baltic Rivers

A. J. Gharrett and W. W. Smoker

Adaptive Importance of Genetic Infrastructure in Salmon Populations

T. G. Heggberget

Interactions Between Wild and Cultured Atlantic Salmon: A Review of the Experience in Norway

T. P. Quinn

Homing and Straying of Wild and Hatchery-Produced Pacific Salmon

D. E. Rogers and G. T. Ruggerone

Factors Affecting Marine Growth of Bristol Bay Sockeye Salmon

F. M. Utter, J. E. Seeb, and L. W. Seeb

The Predictive Value of Stream Distance for Estimating Genetic Relationship in Salmonid Species

P. M. Washington

The Interactions and Environmental Carrying Capacity Limitations of Natural and Artificial Stocks of Salmonids

IX.
LIST OF PARTICIPANTS

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Stocks of Salmon in Alaska
November 9-15, 1991—Cordova, Alaska**

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News Release

FOR IMMEDIATE RELEASE
October 27, 1989
(89-164)

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FISH KILL REPORT RELEASED

OLYMPIA--The August fish kill in the Black and Chehalis rivers was caused by pollution not natural environmental conditions, according to a report released today by the Department of Ecology.

"Although water quality in the Black and Chehalis rivers was not ideal for salmon, trout and whitefish in early August, this fish kill was not caused by the ambient river conditions," said Ecology Director Chris Gregoire. "However, on and after the afternoon of August 8, the day the fish kill was reported to Ecology, our investigators were not able to find physical evidence of pollutants actively entering the Black River."

Gregoire said the investigation is continuing and Ecology is taking action to tighten pollution requirements for fish farms and other wastewater dischargers located on the Black River.

"We are not closing the book on this case, nor are we saying that enforcement actions won't be taken at a later date. The report we are issuing today summarizes the results of the investigation to date and actions we feel are necessary to prevent future problems."

Gregoire said Ecology, the departments of Fisheries and Wildlife, and the Chehalis Tribe conducted one of the most exhaustive investigations ever of a fish kill in Washington.

Gregoire said it appears that something toxic entered the Black River about August 6 nine miles upstream from the confluence of the Black and Chehalis rivers. Ecology was notified and responded to the incident on August 8.

"Although our spill responders were on the scene shortly after being notified on August 8, they failed to take water samples that day," Gregoire said. "However, water samples collected by Fisheries and private citizens were analyzed by Ecology."

Gregoire said the agency should have also notified the Chehalis Tribe of the fish kill. "This was a unique event because a second fish kill occurred downstream several days after the initial kill. From now on, we will put out a widespread warning during all fish kill incidents."

Gregoire said Ecology learned a lot from the incident and the experience will be used to improve response should there be future fish kills of this kind.

During the investigation, Ecology inspected four fish-farms, several dairies, a blueberry farm, a turf farm and several businesses that handle chemicals. Several tips about possible illegal dumping of chemicals into the river were also investigated.

"Numerous samples of water, sediments and fish were collected by Ecology and analyzed for literally hundreds of pollutants," Gregoire said.

Eleven people who reported stinging eyes while swimming in the river on August 7 and 8 were also interviewed.

According to the report, all fish in a nine-mile stretch of the Black River were assumed to be killed.

Fisheries estimates show that 320 adult chinook salmon, 100,000 coho salmon fingerlings, 16,500 cutthroat trout, 118,000 forage fish (sculpins, dace, shiners, suckers and lampreys), 320 mountain whitefish, and 3 adult steelhead trout were killed.

The report concluded that facilities along the river need to have their wastewater discharge permits upgraded.

The Global Aqua facility is receiving special attention because it is the largest fish-rearing facility on the Black River and is located where the fish kill began.

The report also identified several corrective actions that are needed. Among the actions underway or being considered are:

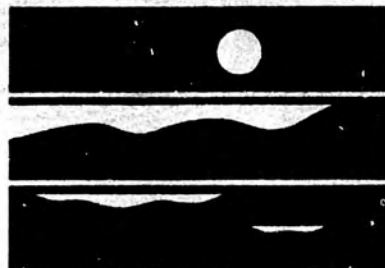
- o a short-term cooperative water quality monitoring study by Ecology and the Chehalis Tribe;
- o an immediate increase in inspections of water pollution sources in the greater Chehalis River watershed to get a better idea of what pollutants are getting into the water and to ensure that facilities have the required permits;
- o an assessment of whether an intensive Ecology water quality study is needed in the Black River; and
- o an assessment of whether an ambient water quality monitoring station on the Black River should be established by Ecology.

Ecology has also been working for the past year on a new general permit for fish-rearing facilities. Ecology is drafting the permit with the help of governmental agencies, environmental organizations, the aquaculture industry and the public.

--over--

Gregoire said the incident highlighted the need for investigators to receive notification of fish kills and spills as soon as possible.

"It is essential that people call Ecology immediately when they see a spill occur or if they observe an unusual number of dead fish."



WASHINGTON STATE
DEPARTMENT OF
E C O L O G Y

The Black River Fish Kill Report

October 1989
89-54

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- 5 Ecology and WDF Black River Shoreline and River Surveys on August 8-11, 1989
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- 2 Chehalis Water Data
- 3 Dave Seiler, WDF Fish Carcass Survey Report
- 4 Lab Data Sheets: General Chemistry, Metals, Organics
- 5 Ecology Facility Inspection & Miscellaneous Reports
- 6 Hallock Aquatic Plant Report
- 7 Chehalis Indian Nation Report
- 8 Dave Seiler, WDF, Report on Loss of Coho Salmon
in the Black River Fish Kill.

1.0 SUMMARY

Between August 6 & 7, 1989, a fish kill occurred in the Black River and on August 10th & 11th in the Chehalis River in southwest Washington State. Evidence indicates a toxic agent(s) entered the Black River in the vicinity of river mile 9.2 on about August 6, 1989 and moved downstream entering the Chehalis River near Oakville on about August 11, 1989, resulting in a substantial fish kill. In addition, in the Black River, in the vicinity of the fish kill and downstream of it, plant nutrients such as ammonia, nitrites, nitrates and phosphates were measured in elevated amounts. Increased amounts of these nutrients can cause increased algae and rooted plant growth which can at high concentrations, in turn, reduce the amount of oxygen available for fish and other aquatic organisms.

Based on the apparent conditions of carcasses and indications of residents and witnesses, a discharge likely occurred around August 6. The Department of Ecology was notified and responded to the fish kill on August 8. There are a variety of industrial and commercial enterprises in this vicinity of the Black River where the fish kill occurred. Virtually all possible pollutant sources were investigated. This report discloses all the significant findings regarding water chemistry and upland activities surrounding the fish kill event.

Although the ambient water quality in the Black and Chehalis River was not ideal for salmon, trout, and whitefish in early August 1989, this fish kill event was not caused by ambient river conditions. However, on and after the afternoon of August 8 (the date of the first fish kill report and investigation), investigators were not able to find physical evidence of pollutants being actively discharged into the Black River.

2.0 BACKGROUND

The Black River starts at Black Lake near Olympia and flows southwest to the Chehalis River which empties into the Pacific Ocean. The Black River has a shallow gradient (about 5 feet/mile). It slowly meanders through marshes and swamps over much of its course. The water is discolored black by organic material from which its name is derived.

According to Washington Department of Fisheries, Washington Department of Wildlife, and Chehalis Indian Nation fisheries biologists, the Black River supports significant populations of coho salmon, cutthroat trout, bass, sunfish, and forage fish (suckers, dace, shiners, sculpins, etc.). Salmon and trout spawning is primarily in tributary creeks such as Waddell Creek (r.m. 17.3). Those anadromous fish rear in the tributaries and the river and migrate to sea. The bass, sunfish, and forage fish are resident fishes and spawn and rear throughout the watershed. The river contains unique and valuable habitat for those species.

The river and shoreline from about r.m. 15.5 to r.m. 10 is a slough surrounded by swamp. This area has been designated as a conservation zone and habitat management area by State and County governments (Figure 1). The area is a unique habitat characterized by large pond lilies and osprey nests along the shoreline which takes on the appearance of a southeastern United States swamp.

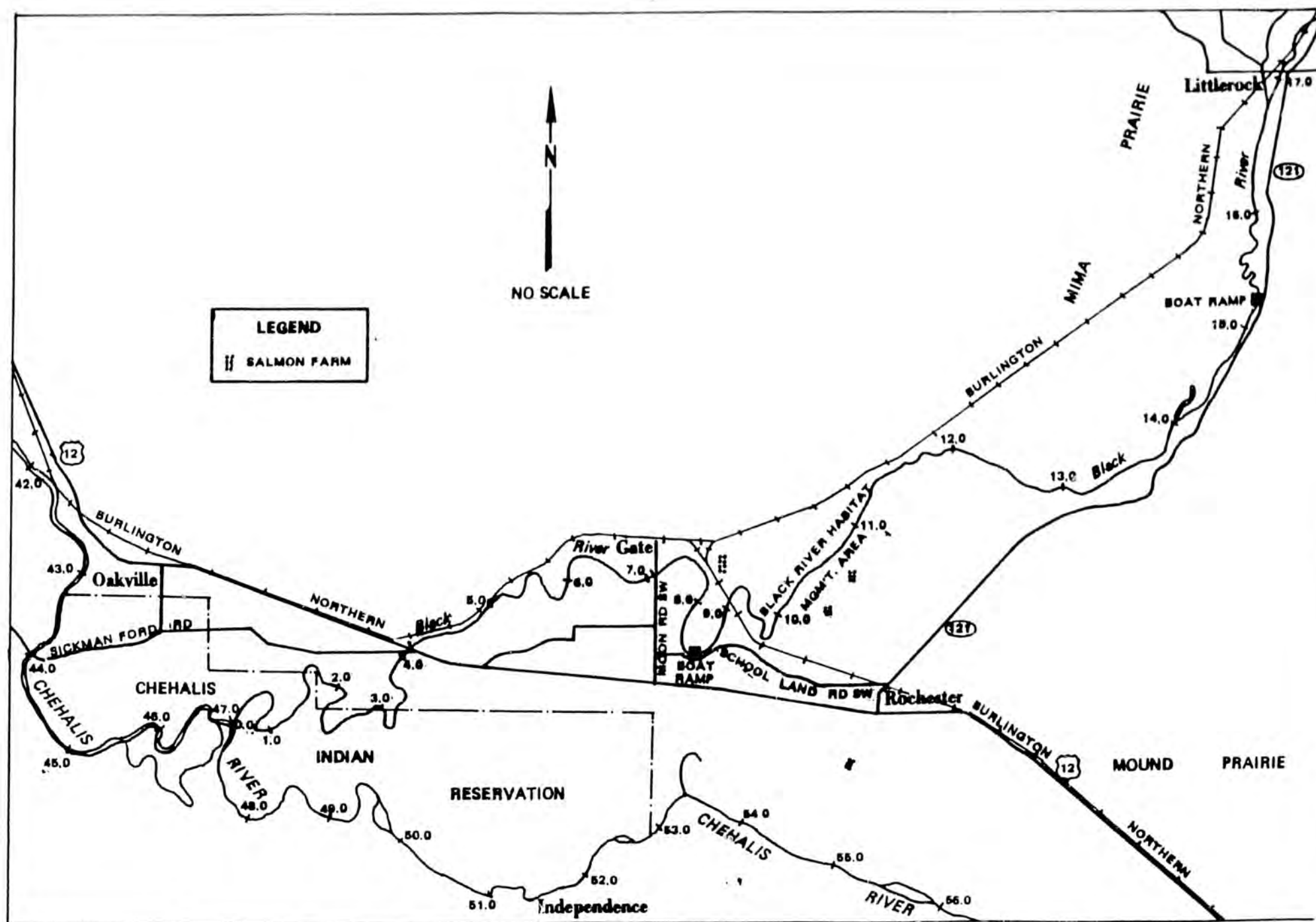


Figure 1. LANDMARKS ASSOCIATED WITH THE BLACK RIVER FISH KILL, AUGUST 6-7, 1980.

Four aquaculture facilities discharge into the Black River below r.m. 10.5, near Rochester: Swecker, Carlson, Steelhammer, and Global Aqua (Figure 2). Steelhammer discharges to the river through Rochester Slough at r.m. 9.6 (a tributary flood channel). Swecker and Carlson discharge to the river through channels in a swamp at r.m. 10.5 and r.m. 10.3 respectively. Global Aqua discharges to the river through springs from r.m. 9.3 to r.m. 7.8. In this reach, the channel becomes weed choked and navigation is impossible in some areas.

Other commercial enterprises include the Black River Ranch (Dairy) (r.m. 13), Weyerhaeuser Tree farm (r.m. 14), Drew's Blueberry farm (r.m. 7.2), and Emerald Turf farm (r.m. 7.0). While these operations do not have direct discharges to the river, they may exert some influence on the river through nonpoint discharge and/or groundwater.

Water quality data are almost nonexistent for the Black River. The Chehalis Indian Nation (the CIN) has collected water temperature data at the School Land Road boat launch (r.m. 8.5) in July and August from 1985 to 1989 (the data are presented in Attachment 2). Temperature ranges from 15 degrees Celsius to 18.5 degrees Celsius. The average temperature for August was 15.5 degrees Celsius (59.9 degrees Fahrenheit). According to WDF those temperatures in the Black River were ideal for salmon and trout and the Black River does not have a history of fish kills.

The Chehalis River from the City of Chehalis to the Satsop River (tidal influence point) is also a shallow stream gradient similar to the Black River and supports similar fish species.

Unlike the Black River, the Chehalis River in this reach has a history of fish kills associated with high temperatures and low dissolved oxygen (D.O.). Those kills in the Chehalis River are annual events and severity of kill is flow and weather dependent.

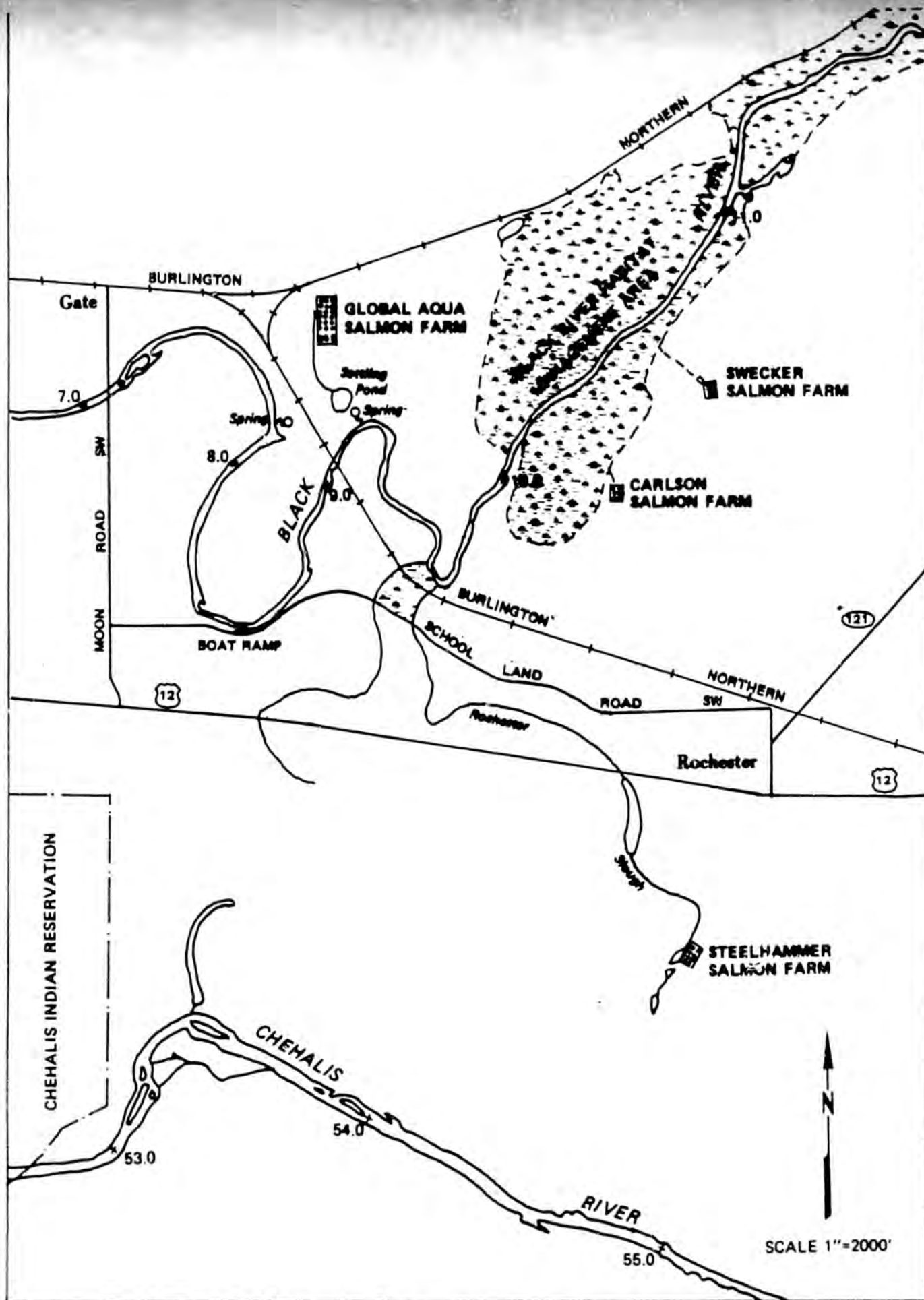


Figure 2. LANDMARKS ASSOCIATED WITH THE BLACK RIVER FISH KILL, SALMON FARMS, AUGUST 6-7, 1989.

3.0 INVESTIGATIONS/INSPECTIONS/SURVEYS DESCRIPTIONS

During the course of this incident, several investigations were conducted by Washington Department of Ecology (Ecology), Washington Department of Fisheries (WDF), and the Chehalis Indian Nation (CIN). This section describes those investigations/-inspections. Section 4.0 will describe the results/findings of those investigations. The subsections of Section 3.0 correspond numerically to related subsections in Section 4.0. Section 3.0 describes investigation methods, and Section 4.0 provides the related findings.

3.1 Ecology Complaint Investigations - Ecology received several leads concerning the fish kill. Reports typically involved suspected dumping or illegal discharges into the river. Each lead was followed up with an investigation. Ecology personnel conducted numerous investigations and interviews. Their purpose was to determine who or what was responsible for the fish kill. Investigators looked for abnormal operating procedures, discharges, chemical usage, and made other relevant observations.

3.2 WDF Stream Fish Carcass Surveys - WDF conducted stream surveys on August 8 & 9, 1989, noting carcasses and general stream conditions. Their objective was to determine the severity and the starting point of the fish kill. They waded and drifted the river noting carcasses, fish activity, and made other relevant observations.

3.3 Chehalis Indian Nation (CIN) Field Surveys - The CIN conducted daily field surveys starting on August 10, 1989 and ending on August 20, 1989 on the Black and Chehalis Rivers noting fish activity, carcasses, and making other relevant observations. Their purpose was to determine the number of salmon and trout mortalities in the Black River and Chehalis River.

3.4 Ecology Shoreline and Stream Fish Carcass Surveys - Ecology conducted stream surveys on August 11 and 13, 1989, noting carcasses and general stream conditions. Their objective was to determine where the fish kill started and find a responsible party. They walked the shoreline and drifted the river noting carcasses, fish activity, and other relevant observations.

3.5 Ecology Aquaculture Facility Inspections - Ecology conducted inspections at aquaculture facilities from August 11-21, 1989. Aquaculture facilities along the Black river discharge directly to the river. Water and sediment samples were collected at the locations described in Table 1.

Table 1. Washington Department of Ecology Aquaculture Facility Inspection Sample Locations. Ecology. Black River Fish Kill, August 6-7, 1989.

Date	Facility	Matrix	Location
8/17	Steelhammer	W	Rochester Slough at School Land Road.
8/18	Steelhammer	S	Discharge channel south of Tanglewood Trailer Park.
8/18	Steelhammer	W	Rochester Slough at School Land Road.
8/18	Carlson	W	Source well at Carlson Salmon Farm.
8/18	Carlson	W	Effluent channel
8/18	Swecker	W	Drainage channel near duck blind access road.
8/18	Swecker	S	Drainage channel below last rearing pond.
8/18	Swecker	W	Black River at Swecker duck blind.
8/10	Global Aqua	S	Settling Pond.
8/11	Global Aqua	W	Source Well.
8/11	Global Aqua	W	Standing water in raceway discharge.
8/11	Global Aqua	W	Standing water in settling pond.
8/11	Global Aqua	S	Settling Pond.
8/16	Global Aqua	W	Standing water in discharge channel.

NOTE: Matrix S = sediment
Matrix W = water

Water samples were analyzed by the Ecology Manchester Laboratory for the following parameters: pH, conductivity, alkalinity, hardness, chemical oxygen demand (COD), total organic carbon (TOC), total ammonia as nitrogen (NH₃-N), nitrite-nitrate (NO₂+NO₃-N), ortho-phosphate (O-PO₄-P), total phosphate (T-PO₄-P), and total chloride (T-Cl).

Selected water and sediment samples were analyzed for the following elements antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), copper (Cu), lead (Pb), nickel (Ni), selenium (Se), silver (Ag), thallium (Tl), zinc (Zn); and the following classes of organic chemicals, acid/base-neutral organics, volatile organics (VOA), pesticides/PCB, organo-phosphate pesticides, and herbicides. A complete list of the latter is in Attachment 3. Standard methods were used to analyze samples.

In addition to sample collection, investigators looked for abnormal operating procedures, discharges, chemical usage, and made other relevant observations.

3.6 Ecology Black River Ambient Water Quality Surveys - Black River water quality investigations were conducted by Ecology from August 16-18, 1989. The purpose of those investigations was to collect ambient water quality data upstream and downstream of the fish kill and determine if the kill was caused by natural conditions or other factors. Water and sediment samples were collected at Little Rock (r.m. 17.2), the boat ramp on highway 121 (r.m. 15.3), near Mima (r.m. 13.0), Black River habitat management area (r.m. 11.0), near Carlson fish farm (r.m. 9.8), Global Aqua (r.m. 9.3), the railroad bridge (r.m. 9.2), Big Rock (r.m. 7.8), Moon Road SW bridge, Gate (r.m. 7.1).

Water samples were analyzed for the same parameters as in section 3.5. Dissolved oxygen (D.O.), temperature, pH, conductivity, and barometric pressure were collected in the field.

Selected water and sediment samples were analyzed for the same metals and pesticides mentioned in section 3.5.

In addition to sample collection, investigators noted carcasses, aquatic vegetation, and made other relevant observations.

3.7 Ecology Chehalis River Ambient Water Quality Survey - A Chehalis River receiving water survey was conducted by Ecology on August 15, 1989. The purpose of the survey was to gather ambient water quality data and determine whether a toxic plume was moving down the Chehalis River. Water and sediment samples were collected at Montesano (r.m. 14.0), Keys Road (r.m. 21.0), Porter (r.m. 33.0), and Sickman Ford Bridge (r.m. 44.0).

Surface water samples were analyzed for the same parameters as in section 3.5. Dissolved oxygen (D.O.), temperature, pH, conductivity, and barometric pressure were collected in the field.

Selected water and sediment samples were analyzed for the same metals and pesticides mentioned in section 3.5.

In addition to sample collection, investigators noted carcasses, aquatic vegetation, and made other relevant observations.

Ecology also collected surface D.O. samples at the Sickman Ford bridge. Their purpose was to determine if oxygen was being depleted in the Chehalis River during night time hours.

4.0 RESULTS

Data indicate the Black River was highly nutrient enriched (eutrophic) and ambient water quality conditions in the Black River prior to the kill were approaching stressful levels for mountain whitefish, salmon, and trout. These fish species are temperature and dissolved oxygen (D.O.) sensitive. These fish require temperatures below 20°C and D.O. levels above 8.0 ppm to maintain healthy populations. Daytime temperatures were approaching 20°C and night time D.O.'s were below 8.0 ppm indicating stressful conditions, but not acute conditions.

The data indicate a few fish were dying possibly of stress related diseases in the Black and Chehalis Rivers prior to the August 6-7, 1989 kill. According to WDF and CIN fisheries biologists, all but a few were surviving under the existing, somewhat stressful conditions.

4.1 Ecology Complaint Inspections

At 1400 on August 8, 1989, a complainant reported to Ecology Southwest Regional Office (SWRO), that his children had been swimming in the Black River at Big Rock (r.m. 7.8) on the previous day, August 7, and they had complained of irritated eyes and skin, and they had seen a few dead fish (Attachment 1). The report was passed on to SWRO spill response unit. At about 1445, the complainant was contacted to confirm the report.

Ecology responded to the scene at 1500, August 8, 1989. They inspected the Black River shoreline at the School Land Road boat launch (r.m. 8.5), Drew's blueberry farm (r.m. 7.2), Big Rock (r.m. 7.8), and from the Moon Road SW bridge (r.m. 7.1) (Figure 1). They did not see any stressed fish or fish carcasses along the shoreline. Their search was restricted to the shoreline because of the heavy aquatic weed growth. They were unable to search the open channels through the weed growth. Two children at the School Land Road boat launch told the Ecology inspectors, they had seen "a couple of dead fish a few days back". The Ecology inspectors returned to the SWRO at about 1700.

That evening and the following day (August 9) WDF employees using waders and a boat were able to conduct a closer search. They searched the clear channel (through the weeds) and found fish carcasses from r.m. 9.2 to 7.1. (see section 4.2).

On August 9, 1989, Ecology interviewed the owners of Drew's Blueberry Farm (Drew's) which is near the Moon Road SW bridge. According to Drew's, nothing had been sprayed on the fields for

about one month as they were harvesting blueberries. Water and sediments were tested for herbicides and pesticides and none were found.

Additional complaints were investigated by Ecology, SWRO. Those investigations are summarized in Table 2.

Ecology also interviewed eleven people that had been swimming in the river during the kill. The information is summarized in Table 3.

These swimmers indicated the river was cloudy which is unusual for the Black River. According to the swimmers, the Black River water is normally black and clear, not cloudy. These data indicate something abnormal was in the Black River between r.m. 8.5 and r.m. 7.0 on August 7 and 8, 1989. Ammonia ($\text{NH}_3\text{-N}$) found in the ambient water samples could have caused the irritation, provided the levels were higher.

Table 2. Washington Department of Ecology Complaint Report
Follow-up Investigation Summary. Black River Fish Kill
August 6-7, 1989.

Date	River Mile	Complaint Report	Findings
8/17	7.2	A site near Gate had been used to produce pesticides & had been used as a dump.	The underground pesticide storage tanks had been removed. No discharge found.
8/16	9.5	A company in Rochester was dumping solvent into storm drain.	The site has no drain leaving the site. No evidence of a spill.
8/16	?	A tree farm was spraying pesticides near Gate.	Information not adequate to find spray site.
8/18	14.0	A possible clandestine drug manufacturing operation was dumping waste into the river.	Referred to Sheriff. Sheriff was not aware of a lab operation in the area.
8/18	13.0	A Dairy was discharging manure into river.	Dairy was not discharging to the river.
8/18	14.0	A forklift punctured a pesticide container at a tree nursery near Gate.	No spill found, but containers of Pydrin, Dacolil 2787 and Benomyl on site.
8/23	14.0	A green truck near Dodd Road was seen dumping blue containers on 8/7/89.	No evidence of dumping found.
8/18	52.0 of the Chehalis River	Someone was dumping copper sulfate into Chehalis R. near Independence.	Found 36 barrels full of copper sulfate on site. No evidence of dumping found.

Table 3. Black River Swimmer Interview Summary. Black River Fish Kill, August 6-7, 1989.

Swimmer	Date-Time	Location	Description
#1	8/7-1300	Turf Farm Pump (r.m. 7.0)	Irritated eyes for 24 hours.
#2	8/7-1300	Turf Farm Pump (r.m. 7.0)	Irritated eyes for 24 hours. Upset stomach for for 36 hrs.
#3	8/7-1300	Below Moon Rd. (r.m. 7.0)	Irritated eyes for 18 hrs. Rash and sores on stomach.
#4	8/7-1300	Below Moon Rd.	Irritated eyes.
#5	8/7-1500	Big Rock (r.m. 7.8)	Irritated eyes.
#6	8/7-1500	Big Rock (r.m. 7.8)	Irritated eyes. River salty to taste.
#7	8/7-1500	Big Rock (r.m. 7.8)	Eyes okay, but wore goggles.
#8	8/8-1200	Below Moon Rd. (r.m. 7.0)	Irritated eyes for 24 hrs.
#9	8/8-1200	Below Moon Rd. (r.m. 7.0)	No Problems, but swim was brief.
#10	8/8-1600	Above School Land Rd. boat launch (r.m. 8.5)	Irritated eyes for 18 hrs. Eyes were light sensitive.
#11	8/8-1600	Above School Land Rd. boat launch (r.m. 8.5)	Irritated eyes for 18 hrs. Eyes were light sensitive

4.2 WDF Stream Fish Carcass Surveys August 8-9, 1989

WDF Stream Survey August 8, 1989 - At 1800 on August 8, 1989, a local resident reported several dead fish near his property (r.m. 6.5) to WDF. WDF responded and arrived on scene at about 1900. WDF waded a 200 yard reach of the river near r.m. 6.5. WDF observed hundreds of trout, coho salmon fry, juvenile lamprey, sculpin, and crayfish carcasses in channels and weed beds. The experienced investigators estimated the fish had been dead for 24 to 48 hours, fixing the fish kill date on August 6 or 7, 1989. They collected a subsample of trout, coho, and sculpin carcasses (Attachment 3).

WDF Stream Survey August 9, 1989 - On August 9, 1989, WDF conducted a carcass survey. WDF drifted the Black River from r.m. 10.3 to r.m. 7.2, Moon Road SW bridge. Their report says, in part, "At 10 a.m. WDF launched a canoe at r.m. 9.8 and paddled upstream to r.m. 10.3. At the launch point and upstream no dead fish were found, only live fish. They proceeded downstream and encountered the first dead fish just below the train trestle (r.m. 9.2). From this point down to r.m. 8.0 they found a few dead fish. The number of dead fish greatly increased below r.m. 8.0 and continued to increase through r.m. 7.2 where they pulled out (Table 5). Mortalities included the following species: coho salmon fry, trout fry (age 0+), cutthroat trout (up to 12"), sculpins, large scale suckers, lampreys, crayfish and freshwater clams. The only live fish observed below r.m. 8.0 were cyprinid fry (approximately 3/4 inches in length)" (see attachment 3). Cyprinids are resistant to many pollutants. These data suggest the fish kill started near r.m. 9.2.

WDF collected surface water samples at r.m. 9.7, 9.2, 8.0, and 7.5. The respective nutrient levels (NO₂+NO₃-N) were 1.08, 2.01, 1.17, and 1.30 ppm respectively. Those levels were significantly higher than levels found in the subsequent August 16-18 samples (.01 ppm to .70 ppm) although the data are somewhat compromised by sample preservation and holding time problems. They do indicate an unusually enriched condition probably existed in the river on August 9, 1989.

4.3 Chehalis Indian Nation (CIN) Stream Surveys - On August 10, 1989, CIN fishery technicians, drifted the Black River from the School Land Road boat launch (r.m. 8.5) to the Highway 12 bridge boat launch (r.m. 4.1). From r.m. 8.5 to r.m. 7.1 (Moon Road SW bridge), they found the following carcasses: 3 coho salmon fingerlings (avg. 3 in.) and 1 squawfish (16 in.). From r.m. 7.1 to r.m. 4.1, they found the following carcasses: 4 native sea-run cutthroat (12 -14 in), 1 sucker (18 in.) and 1 red-sided shiner. They noted the water was murky and aquatic plants were very thick throughout the river.

At 1045, on August 10, 1989, CIN technicians noted live fish at the Howanut bridge (r.m. 1.1), but the water was starting to get murky indicating conditions were changing. CIN also visited the Moon Road SW bridge and observed several stressed lamprey larvae and numerous fish carcasses. A detailed accounting is included in Attachment 6.

On August 11, 1989, CIN fisheries technicians drifted the Chehalis River from the Sickman Ford bridge (r.m. 44.0) to the Oakville boat launch (r.m. 42.2). They found 31 adult Chinook carcasses and 16 stressed adult Chinook. The mortalities were concentrated near the Sickman Ford bridge.

From August 11 to August 21, 1989, CIN collected 240 adult carcasses. The gill tissue from two fish were analyzed for copper and zinc. Those analyses revealed no significant difference between adult Chinook salmon upstream (control) and Chinook carcasses within the kill area (test). The results are shown in Table 4.

Table 4. Adult Chinook salmon gill tissue copper and zinc analysis results. Values are wet weight. Black River Fish Kill, August 6-7, 1989.

Fish	Location	Cu	Zn
		(ug/Kg)	(ug/Kg)
Control	Chehalis R. near Independence (r.m. 50.0)	0.7	33.3
Test	Chehalis R. near Sickman Ford Bridge (r.m. 44)	0.7	27.2

4.4 Ecology Shoreline and Stream Fish Carcass Surveys - On August 11, 1989, Ecology surveyed the shoreline of the Black River, in the vicinity of the kill. It was suspected the carcasses were not visible from the shore. Needing a view from bank to bank including midstream sections, Ecology drifted the Black River on Sunday, August 13, 1989 from the Highway 121 boat launch to the School Land Road boat launch searching the river from shore to shore. The observations are summarized in Table 5. The purpose of the trip was to determine the kill starting point.

Following an intensive mid channel search from a drift boat, Ecology found no fish carcasses above r.m. 9.2, but found carcasses from r.m. 9.2 to 8.5 (see Table 5). Those carcasses were found along the clear channel between the heavy shoreline weed growth. They did not find any carcasses along the shoreline

explaining why previous shoreline searches had not yielded carcasses. Further, Ecology's findings corroborate WDF's boat survey of August 9, 1989. It is possible that scavengers had eaten many of the dead fish by the time Ecology investigators completed this survey.

4.5 Ecology Aquaculture Facility Inspections - Ecology inspected Swecker Salmon Farm (August 18 and 21), Carlson Salmon Farm (August 9 and 18), Steelhammer Salmon Farm (August 17, 18 and 21), and Global Aqua (August 9, 11, 16 and 18). Detailed inspection reports are included in Attachment 4. Ecology's inspections revealed all farms except Global were operating normally.

Table 5. Washington Departments of Ecology and Fisheries Black River Shoreline and River Surveys on August 8-11, 1989. Black River Fish Kill, August 6-7, 1989.

Type	Location	Date	Observation
B	Little Rock bridge - ECY (r.m. 17.2)		8/13 No dead fish or plants.
S	Highway 121 Boat launch near Little Rock - ECY (r.m. 15.3)		8/11 Water clear, small fish dimpling water surface. Live fish & aquatic insects present. No carcasses.
S	Highway 121 Canoe Rental Shop - ECY (r.m. 14.2)		8/11 Same as above.
B	Highway 121 Canoe Rental Shop - ECY (r.m. 14.2)		8/13 No dead fish or plants.
B	Swecker aqua- culture facility ECY (r.m. 10.5)	8/13	No dead fish or plants.
B	r.m. 10.3 - WDF		8/9 No dead fish.
B	r.m. 9.8 - WDF	8/9	No dead fish.
S	Across from Goodrich Farm - ECY (r.m. 9.5)		8/11 No carcasses. No fish seen live aquatic insects along shoreline.
S	Goodrich Farm - ECY (r.m. 9.5)		8/11 Area choked with aquatic plants. Live small fish and aquatic insects present along shoreline.
S	Drainage ditch along upstream boundary of Global Aqua - ECY (r.m. 9.4)	8/11	No carcasses nor live fish or aquatic insects found.

Table 5 - Continued

Type	Location	Date	Observation
S	Near Global Aqua well - ECY (r.m. 9.3)		8/11 No carcasses nor live fish or aquatic insects found along the shoreline.
B	Global Aqua aquaculture facility upstream end - ECY (r.m. 9.3)		8/13 No dead fish or plants.
S	Railroad bridge - ECY (r.m. 9.2)		8/11 Area choked with aquatic plants. No fish present. Live aquatic insects seen along shoreline.
B	Railroad bridge - ECY (r.m. 9.2)		8/13 One sculpin carcass 200 ft. upstream of bridge.
B	Below RR bridge - WDF (r.m. 9.1)		8/11 Dead fish.
S	School Land Rd. boat launch - ECY (r.m. 8.5)		8/11 Area choked with aquatic plants. No fish present. Two earthworm carcasses.
B	School Land Rd. boat launch - ECY (r.m. 8.5)		8/13 One sculpin carcass.
B	r.m. 8.0 - WDF 8/9 r.m. 7.2.		Dead fish density same as
S	Big Rock - ECY 8/11 (r.m. 7.8)		Five live sculpin observed. No fish carcasses along shoreline.
B	r.m. 7.2 - WDF 8/9		Dead fish density increased significantly.
S	Moon Road SW bridge - ECY (r.m. 7.1)	8/11	Area choked with aquatic plants. No fish present.
W	r.m. 6.5 - WDF 8/8		Numerous dead trout, sculpins, lamprey and mussels.

NOTE:

S = Shoreline Survey
 B = Boat Survey
 W = Wader Survey

ECY = Wash. Department of Ecology
 WDF = Wash. Department of Fisheries

Several factors suggested Global Aqua warranted a further look. These factors include the farm's proximity to fish carcasses, the fact that the hatchery had been shutdown at the time of the fish kill (an abnormal situation), and the observation that the last of the cleanup water moving through the facility had percolated into the ground through its drainage channel and settling pond prior to seeping into the Black River.

On August 9, 1989, Ecology returned to the fish kill site and visited Global Aqua (Global). The facility had recently ceased fish rearing operations and was shutdown. According to Global, the facility had been shutdown because of disease problems (Frunculosis). The hatchery is permitted to use up to 12 million gallons of well water daily. According to Global, the water had been shut off on August 2 and the entire system allowed to drain through a series of rearing and holding ponds eventually discharging through a drainage channel and into a 5 acre settling pond.

According to Global, the tanks were cleaned and flushed as follows. The water was shutoff on August 3, 1989. Fish remaining in the rearing tanks were allowed to suffocate. The fish suffocation would have reduced oxygen in the tank water to a low level because the fish would have respired the oxygen. After a time, this anoxic water plus the residual fish sludge and feces were flushed into the drainage channel. Those sludges and feces typically have very high NH₃-N, total organic carbon, and chemical oxygen demand levels.

Water from the drainage channel and settling pond percolates rapidly into the ground. Under normal operating conditions the channel and pond percolate several million gallons per day into the ground and do not have an overland discharge to the river. It is accepted that Global's discharge enters the river through springs located at r.m. 9.3 and 7.8. Ecology conducted an inspection tour with Global and found the settling pond empty and no evidence of an overland discharge to the river.

Aerial photographs taken on August 6, 1989 revealed the Global settling pond was one-half full indicating the springs along the riverbank from r.m. 9.3 to 7.8 which are fed by Global's drainage channel and settling pond water was probably discharging during the August 6 to 7 kill. See "springs" in Figure 2.

According to a local resident, flows from the springs near r.m. 7.8 dropped significantly on August 4, 1989 and flows declined until they stopped on August 7, 1989. The timing of those observations correlate with the water shutoff at Global (Table 6) and the aerial photo data, and also corroborate the groundwater link between Global and the Black River.

During Ecology's inspections, Global personnel stated Global's shutdown started on July 27, 1989 and was completed by August 9, 1989. Again, the shutdown of several million gallons per day of well water flowing through the facility meant that as these flows diminished, the final effluent to the drainage channel and settling pond would be concentrating during the warm sunny days. Table 6 summarizes the shutdown operation.

Ecology also noted opened and used drums and bags of "Paracide - F", sodium thiosulfate, "Pentahydrate", formaldehyde, and chlorine on site.

Global records indicate chlorine had been used on three occasions from July 1 to August 4, 1989 to disinfect tools and the resulting chlorinated water had been neutralized with sodium thiosulfate (a substance which can deplete oxygen) prior to discharging the water into the settling pond. Ecology tested the settling pond and the Black River at r.m. 7.2 on August 9 for residual chlorine on the off chance that a residual remained and found no residual chlorine. The chances of finding a chlorine residual 24 hours after a discharge are unlikely.

Table 6. Summary of Events Relating to Global Aqua operation shutdown July-August, 1989. Black River Fish Kill August 6-7, 1989.

Date	Sequence of Events
7/27	Shut off pump on one of two wells reducing flow to about 3 million gallons/day (Global).
8/3	Shut off remaining fresh water well pump. Removed remaining fish from site (Global).
8/4	Flow from springs into Black River near r.m. 7.8 reduced by one half (Local Long-Time Resident).
8/6	Aerial photos show water in settling pond, about 1/2 full (Ecology).
8/7	Swimmers from r.m. 8.0 - 7.0 experience eye and skin irritation, and see murky water conditions, fish carcasses.
8/7	Flow from springs into Black River near r.m. 7.8 has ceased (Local Resident).
8/9	Settling pond dry (Ecology).

NOTE: Comments from local residents confirm Ecology's understanding that the springs are hydraulically connected to Global Aqua's drainage channel and settling pond. Springs only flow when Global Aqua is operating.

Global records indicate formaldehyde (a toxic substance and a carcinogen) was used on six occasions from June 20 to July 13, 1989 to treat eggs for disease problems and was not used in August. Residual formaldehyde was found in sediment samples taken in the channel between the rearing tanks and settling pond on August 10, 1989 at 0.10 ppm and 12.74 ppm, respectively, indicating the formaldehyde had not completely degraded 27 days after the last reported use.

Water samples collected at r.m. 7.8 and 7.1 were analyzed for formaldehyde on August 9 in the off chance that formaldehyde could be found and none was found. Like chlorine, the chances of finding formaldehyde 24 hours after a discharge to a flowing stream are unlikely.

On August 16, 1989, Ecology collected a water sample from the drainage channel between Global's fish rearing tanks and their settling pond. Ten days after the fish kill and thirteen days after the water was shut off, this water had an extremely high ammonia concentration (703 ppm). This channel water was not only very high in ammonia, but also very high in organic matter (total organic carbon value, 2190 ppm; chemical oxygen demand, 11,000 ppm). The toxicity of total ammonia as nitrogen (NH₃-N) is dependent on pH and temperature. Total NH₃-N would have been acutely toxic at 12 ppm in the Black River using a pH of 7.5 and temperature of 19 degrees Celsius (66.2 F°) which were the averages measured during the Black River ambient water quality survey (Table 7). Total NH₃-N would have been toxic at 3.7 ppm in the Chehalis River using a pH of 8.2 and a temperature of 19.5 degrees Celsius (67.1 F°) which were the averages found during the Chehalis River ambient water quality survey (Section 4.7).

Table 7. Washington Department of Ecology Black River Ambient Water Quality Survey Temperature and Dissolved Oxygen Data, August 17-18, 1989. Black River Fish Kill August 6-7, 1989.

R.M.	Date-Time	Depth (m)	Temp. (°C)	D.O. (ppm)	% Sat.	Barom. (in. Hg)	Cond. (uMHOS/cm)
17.2	8/17-1630	0.0	19.2	7.3			125
	8/18-0545	0.0	18.4	6.7	70.3	30.12	116
	8/18-0755	0.0	17.9	6.5	67.5	30.12	93
15.3	8/18-0820	0.0	14.7	6.3	61.2	30.18	99
13.0	8/18-1020	0.0	18.8	11.1	117.1	30.20	100
		5.0	10.7	2.6	23.1	30.20	100
11.0	8/18-1125	0.0	17.8	11.8	122.2	30.20	89
	-1125	5.0	15.6	6.0	59.3	30.20	100
9.8	8/17-1340	0.0	18.8	8.0			110
	-1330	B		<1.1			118
9.3	8/17-1425	0.0	18.1	8.9			115
	-1415	B		3.9			119
	8/18-0522	0.0	18.1	9.4	98.1	30.12	100
	-1210	0.0	19.5	11.2	120.2	30.20	100
	-1210	2.5	18.4	9.4	98.4	30.20	100
7.7	8/17-1530	0.0	19.2	8.8			125
7.1	8/18-0505	0.0	17.4	6.7	68.9	30.20	100
	-1305	0.0	19.8	9.5	102.8	30.03	113
4.0	8/18-0453	0.0	17.8	8.6	89.2	30.20	100

NOTE: B = Bottom
Cond. = Conductivity
Barom. = Barometric Pressure

Water of the quality found in the drainage channel would, if discharged into the Black River in sufficient quantity, result in both ammonia toxicity and anoxia in the river. Minimum dilution ratios of roughly 60:1 for $\text{NH}_3\text{-N}$ plus 1,000:1 for chemical oxygen demand, would be required to prevent severe impacts to the river. An additional dilution ratio of roughly 500:1 would be required to prevent severe impacts downstream from the nitrogenous oxygen demand of the total $\text{NH}_3\text{-N}$ as it oxidized to NO_3 (nitrate). The quantity of water, and therefore the concentration of pollutants, discharged to the Black River through the channel and settling pond during the Global shut down and cleaning operation is unknown.

4.6 Ecology Black River Ambient Water Quality Surveys - The results of the Black River ambient water quality surveys are presented in this section.

Temperatures - Surface water temperatures within the Black River study area ranged from 14.7 degrees Celsius (58.5 $^{\circ}\text{F}$) to 19.8 degrees Celsius (67.6 $^{\circ}\text{F}$) (Table 7).

Dissolved Oxygen (D.O.) - Surface D.O. levels within the Black River study area varied with location, ranging from 6.3 ppm to 11.8 ppm (Table 7).

At r.m. 13, 9.8, and 9.3, D.O.'s near the bottom of the river (5m) were very low (2.5, <1.1, and 3.9 ppm respectively). D.O. at these concentrations is inadequate to support healthy fish populations. The water temperature and D.O. data indicate the water column was stratified, with a low D.O. layer near the bottom typical of eutrophic lakes.

Ecology collected D.O. samples in the Black and Chehalis River just before daylight (4:53 a.m. to 5:45 a.m.) to determine if the respiration and decay of aquatic plants and algae were depleting the oxygen and causing fish kills. The data indicate surface D.O.'s were not depleted significantly and were adequate to support fish (Table 7). Trout and salmon are supported by oxygen levels above 5 ppm. Thus it was concluded, natural D.O. depletion did not cause the fish kill.

Nutrients - Based on nutrient data collected during the Black River surveys (see Table 8), and despite a spike at r.m. 15.3, total nutrient concentrations (nitrite, nitrate, ammonia and phosphates) increase an average of about three-fold below r.m. 10 (Figure 4).

Total phosphate concentrations above r.m. 10 average 0.06 ppm (range 0.05 to 0.08 ppm); while concentrations downstream from r.m. 10 average 0.13 ppm (range 0.08 to 0.19 ppm) (Figure 5).

Similarly NO₂+NO₃-N concentrations increase dramatically: a mean of 0.18 ppm above r.m. 10 increasing to 0.51 ppm downstream of r.m. 10 (Figure 3). NH₃-N (ammonia) concentrations increase significantly at r.m. 9.3 (Figure 6).

This three-fold increase in nutrient concentrations (Table 8) (Figure 3-5) correlates with a clear increase in density of rooted aquatic plants and algae. Ecology Environmental Investigation/Laboratory Services summarized the aquatic plants in this reach of the Black River (Attachment 5).

Table 8. Washington Department of Ecology Black River Ambient Water Quality Survey Temperature and Nutrient Data, August 17-18, 1989. Black River Fish Kill August 6-7, 1989.

R.M.	Date-Time	Depth m	Temp (°C)	pH	Nutrients			
					NO ₂ + NO ₃ -N ppm	NH ₃ -N ppm	O-PO ₄ -P ppm	T-PO ₄ -P ppm
17.2	8/18-0755	0.0	17.9	7.3	0.01	0.02	0.02	0.06
15.3	8/18-0820	0.0	14.7	7.1	0.41	0.03	0.02	0.06
13.0	8/18-1020	0.0	18.8	7.5	0.02	0.01	0.01	0.05
11.0	8/18-1125	0.0	<u>17.8</u>	<u>7.4</u>	<u>0.29</u>	<u>0.01</u>	<u>0.02</u>	<u>0.08</u>
	<u>Averages</u>		<u>17.3</u>	<u>7.2</u>	<u>0.18</u>	<u>0.02</u>	<u>0.02</u>	<u>0.06</u>
9.9	8/17-1340	0.0	18.8	8.0	0.51	0.01		0.11
9.3	8/17-1425	0.0	18.1	7.3	0.70	0.09		0.11
	8/18-1210	0.0	19.5	7.4	0.52	0.04	0.04	0.19
7.8	8/17-1530	0.0	19.2	7.3	0.70	0.05		0.08
7.1	8/18-1305	0.0	<u>19.8</u>	<u>7.6</u>	<u>0.64</u>	<u>0.02</u>	<u>0.02</u>	<u>0.15</u>
	<u>Averages</u>		<u>19.1</u>	<u>7.5</u>	<u>0.51</u>	<u>0.04</u>	<u>0.03</u>	<u>0.13</u>

BLACK RIVER FISH KILL August 6-7, 1989

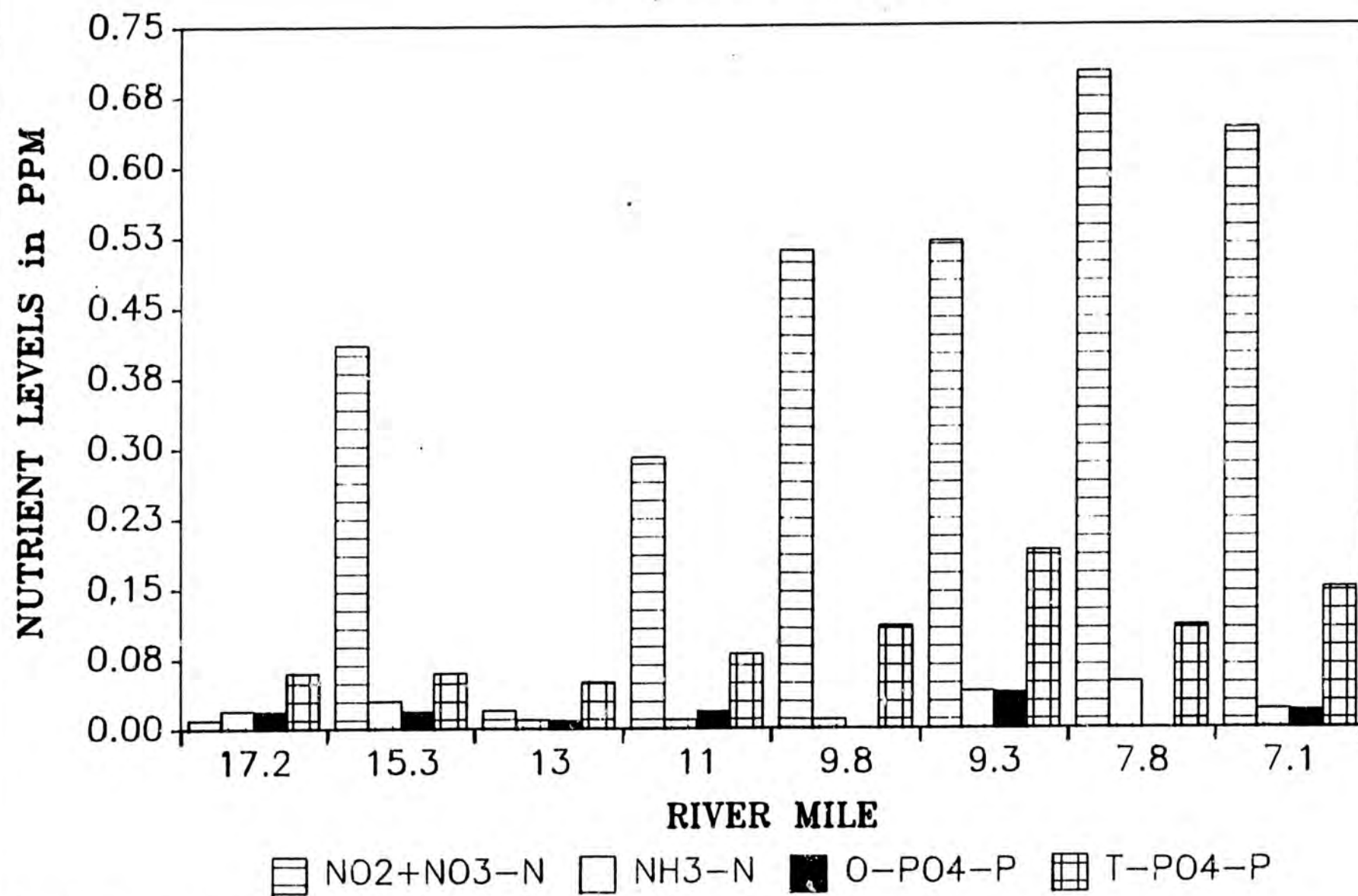


Figure 3. Black River Surface Water
Nutrient Data
Black River Fish Kill, August 6-7, 1989

BLACK RIVER FISH KILL AUGUST 6-7, 1989

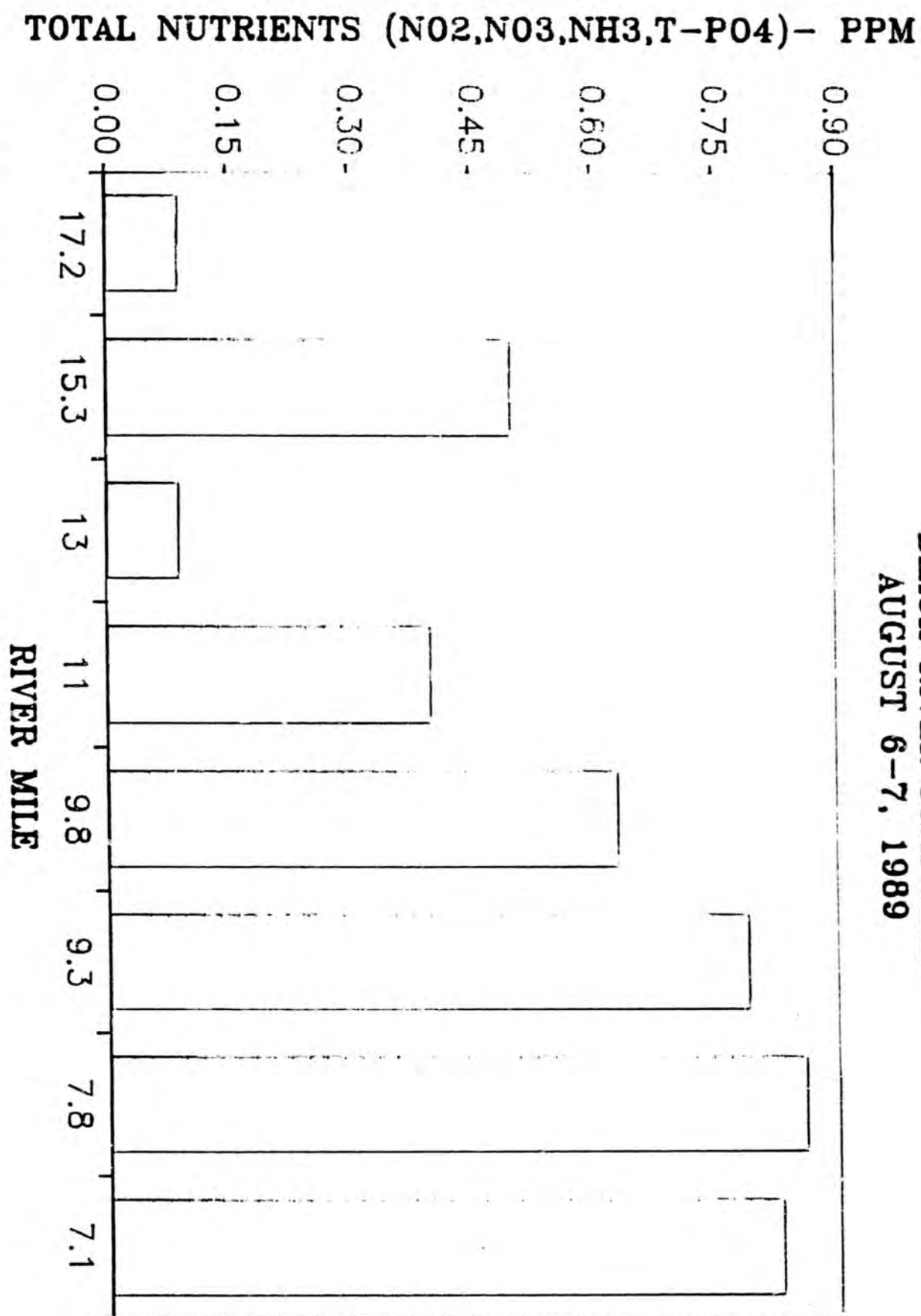


Figure 4. Black River Surface Water
Total Nutrient Data.
Black River Fish Kill, August 6-7, 1989

BLACK RIVER FISH KILL
August 6-7, 1989

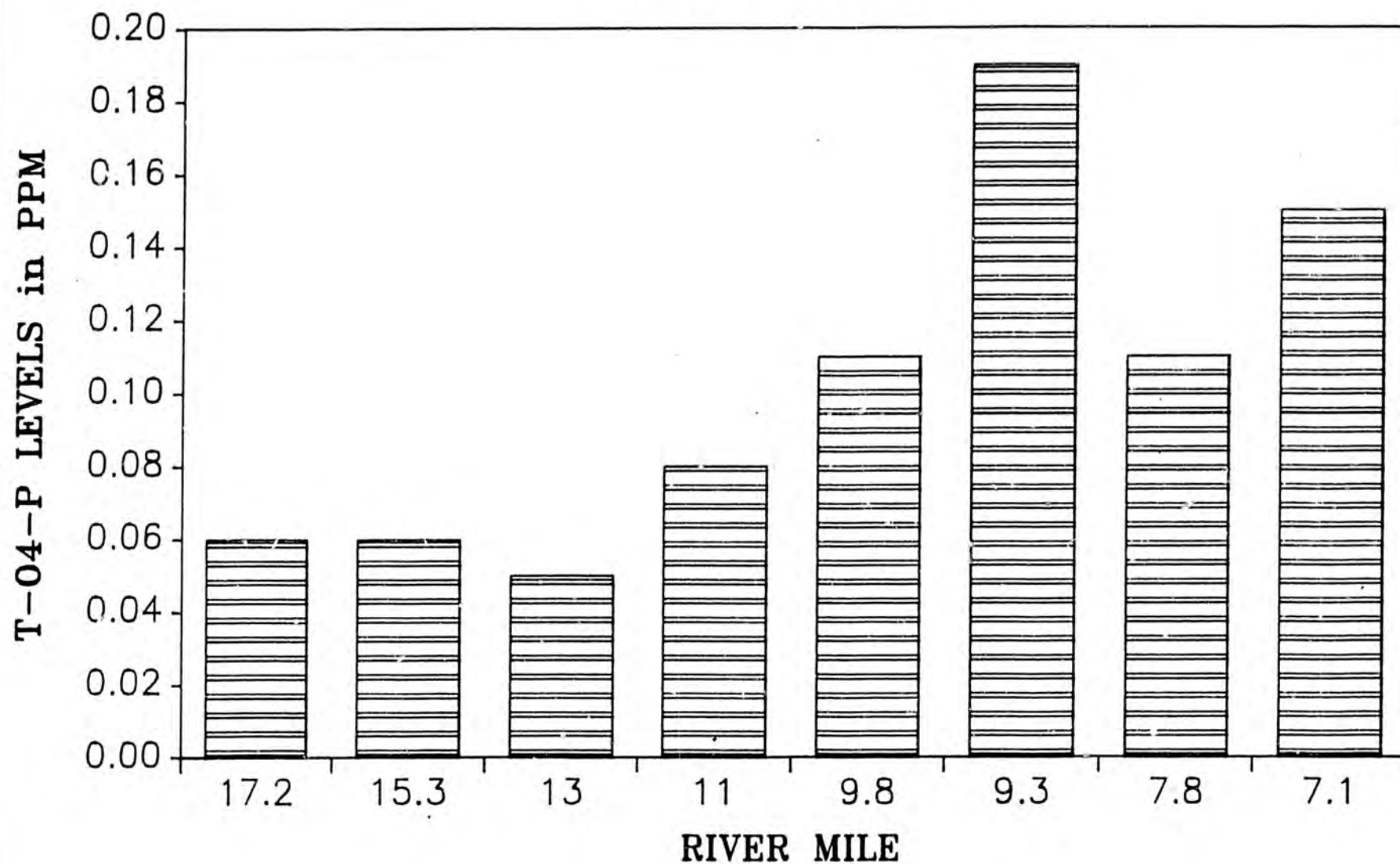


Figure 5. Black River Surface Water
Total Phosphate Data
Black River Fish Kill, August 6-7, 1989

BLACK RIVER FISH KILL
August 6-7, 1989

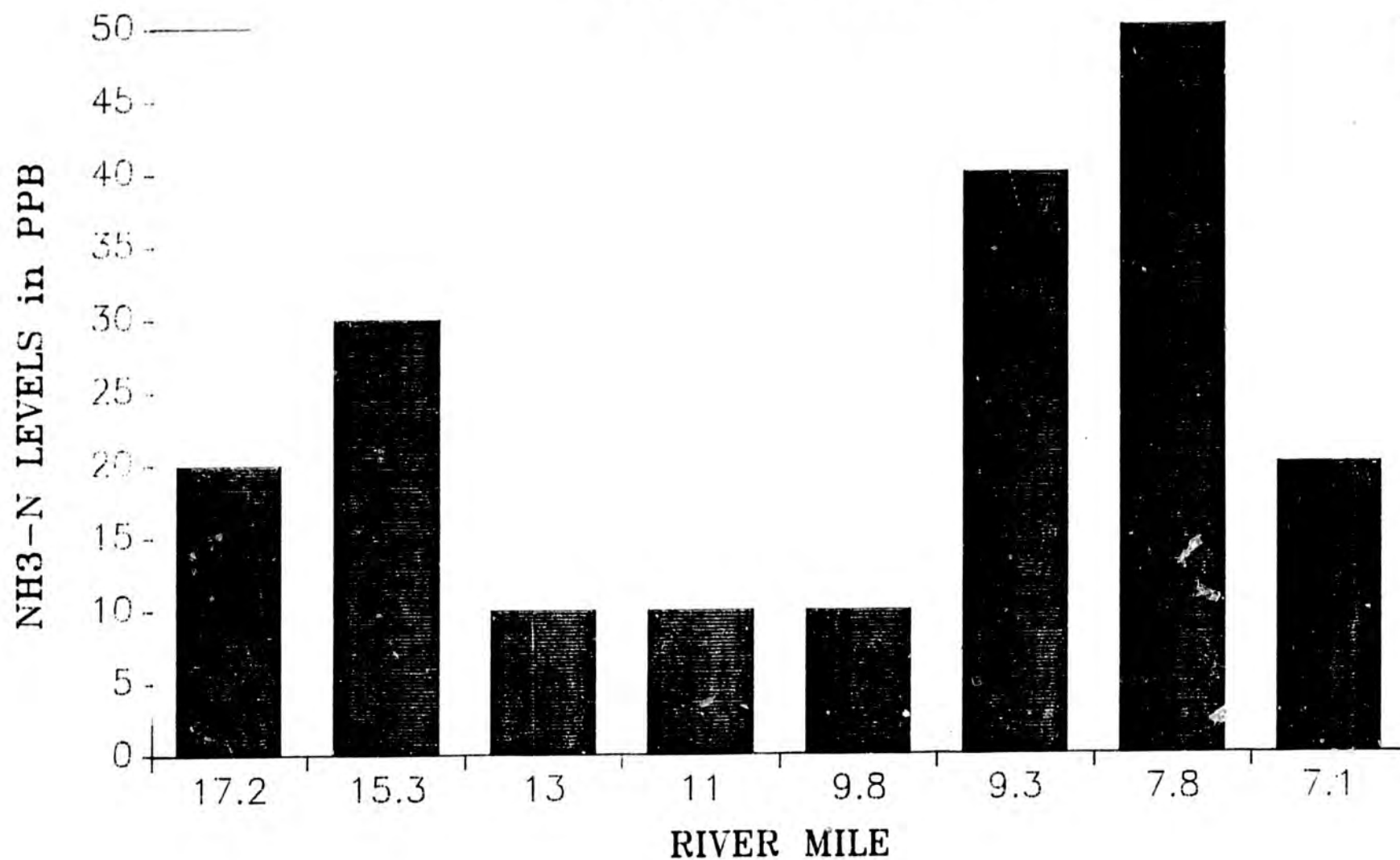


Figure 6. Black River Surface Water
Ammonia Data
Black River Fish Kill, August 6-7, 1989

The increase in nutrient concentrations and aquatic plant density below r.m. 10 is a problem which aggravates conditions in the river. High productivity typically leads to dramatic swings in oxygen concentrations. This is particularly troublesome in a stream like the Black River which has a very low velocity and thus little capacity for physical reaeration.

The combination of low river velocity, high nutrient concentrations, high productivity, and stratified pools is one which can put the lower Black River at risk to conditions which induce anoxia (Table 8).

It should be noted that while these nutrients, ammonia in low concentrations is quite a good plant nutrient, contribute to the degradation of water quality, they do not normally cause acute, widespread mortality as seen in this fish kill. Conversely, ammonia in adequate concentration, can be lethal.

Pesticides and Other Observations - No pesticides or herbicides were found in the Black River sediment samples and metals were below toxic levels.

One mountain whitefish carcass was found on August 18, 1989 near r.m. 13.0. Judging from the state of decomposition, the carcass was less than 48 hours old. This carcass indicates a limited summer kill was occurring which is normal.

On that same day, several freshwater clam carcasses were noted at r.m. 9.5 and r.m. 7.1. The carcasses at r.m. 9.5 were floating on the surface and were in an advanced state of decay. The clam carcasses were analyzed for metals and pesticide residuals. The analysis did not find significant metal concentrations or pesticides.

The data indicate ambient water quality in the Black River was adequate to support fish.

4.7 Ecology Chehalis River Ambient Water Quality Survey - On August 15, 1989, Ecology's Chehalis River study revealed surface D.O.'s of 10.2, 12.8, 11.7, and 11.6 ppm at river miles 14, 21, 33, and 44 respectively. The average surface water pH and temperature were 8.2 and 19.5 C°, respectively. These conditions were adequate to support fish and other aquatic life.

Ecology also noted one decomposing adult Chinook carcass near the Satsop River (r.m. 21.1) and several fresher Chinook carcasses upstream of Davis Creek (r.m. 42.5).

Analysis of the Chehalis River water and sediment samples did not find significant metal concentrations or pesticides.

Ecology's sample revealed a surface D.O. of 9.9 ppm at r.m. 44.0 (Sickman Ford bridge, Oakville). These data indicate surface D.O. in the Chehalis River was adequate during night time hours to support fish.

The data indicate ambient water quality in the Chehalis River was adequate to support fish and that the kill occurred in the reach of the Chehalis above Davis Creek.

5.0 FISH MORTALITY ESTIMATE

The fish mortality estimate and resource loss is discussed in this section.

5.1 Black River Fish Mortality Estimate

For the purposes of this report, it was assumed that 100% of the fish in the Black River from r.m. 9.2 to the mouth were killed.

WDF collected 16 fish: 3 coho salmon fingerlings, 3 resident cutthroat trout, and 10 forage fish (sculpins, dace, shiners, suckers, and lamprey) carcasses in about 200 yards. The reach was choked with aquatic vegetation hiding the majority of the carcasses making an accurate carcass count impossible.

WDF estimated about 100,000 coho fingerlings died as a result of the kill. Their estimate is based on WDF coho smolt trapping data collected over the last four years and applying fingerling survival rates to smolt production (Attachment 7).

For the purposes of this report, it was assumed by WDW that the density of cutthroat trout was about one per 7.1 square meters. The surface area of the affected reach was $118,422 \text{ m}^2$ (9.2 mi. x 1,609 m/mi. x 8m).

Applying the cutthroat density to the surface area provided a cutthroat mortality estimate ($118,422 \text{ m}^2 \times .14 \text{ fish/m}^2$) of 16,579 or roughly 17,000.

Again, for the purposes of this report it was assumed the forage fish density was one fish per square meter resulting in a forage fish mortality estimate of approximately 118,422.

5.2 Chehalis River Fish Mortality Estimate

The CIN counted 240 adult Chinook salmon carcasses and 1 adult steelhead trout carcass in the Chehalis River downstream from the Black River. Because of predation and fish size it was assumed by CIN 75% of the Chinook and 33% of the steelhead were collected resulting in a mortality estimate of 320 ($240/.75$) and 3 ($1/.33$) respectively (Table 9).

For the purposes of this report it was estimated that 320 mountain whitefish also died as a result of this incident.

Table 9. Chehalis River Fish Mortality Estimate. Black River Fish Kill, August 6-7, 1989.

Species	No. Fish Collected	Percent Collected	Mort. Est.
Chinook	240	75	320
Steelhead	1	33	3
Whitefish	Est.	NA	320

6.0 CONCLUSIONS

Based on the facts available, the Department of Ecology has concluded:

- o Although the ambient water quality in the Black and Chehalis River was not ideal for salmon, trout, and whitefish in early August 1989, this fish kill event was not caused by ambient river conditions.
- o The fish kill was caused by a pollutant(s) discharged to the river resulting in an acute mortality.
- o The fish kill in the Black River probably occurred on August 6, 1989 and began in the vicinity of river mile 9.2.
- o Subsequent to the kill, the Black River contained elevated levels of ammonia, nitrites, nitrates, and phosphorous. Lethal levels of an acutely toxic substance in either river could not be found due to the very rapid (usually within less than 24 hours) dilution, dissipation and evaporation of the pollutant(s).
- o On and after the afternoon of August 8 (the date of the first fish kill report and investigation), investigators were not able to find physical evidence of pollutants being actively discharged into the Black River.
- o Results of the Black River fish kill investigation indicate discharge permits in this area warrant upgrading (see Section 7.0 Corrective Actions).

7.0 CORRECTIVE ACTION

The investigation of the August fish kill revealed that chronic water quality problems associated with elevated levels of nutrients exist in the lower Black River. This situation presents a stressful environment for fish and other aquatic organisms especially during late summer and reduces the recreational/boating value of the river. However, limited information exists regarding flows and overall water quality of the entire Black River.

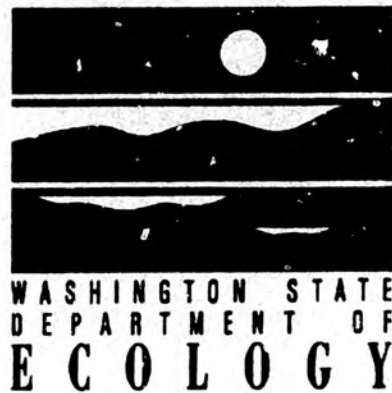
As a result of the extensive investigation, Ecology has identified several corrective actions that will provide better water quality information and better control potential sources of pollution. The following actions are currently underway or will be carried out as indicated:

1. Ecology and the Chehalis Tribe will conduct a short-term cooperative ambient water quality monitoring study. Water samples will be collected monthly by tribal members from October 1989 through June 1990 at two monitoring stations along the Black River. The samples will be sent to Ecology for analysis. Ecology will train tribal members in appropriate sample collection techniques and assist in selecting the two water monitoring stations.
2. Ecology will immediately increase inspections of point and nonpoint sources of water pollution in the greater Chehalis River watershed to identify the source and type of pollutants entering the water. Facilities identified as requiring wastewater discharge permits will be brought into the permit program. Facilities having wastewater discharge permits will be reviewed for compliance with current technological and water quality standards. If needed, these facilities will be required to upgrade their operations to ensure water quality in the Black and Chehalis rivers is protected.
3. Because wastewater from the Global Aqua fish-rearing operation is not monitored due to its ground discharge, the facility will immediately undergo a review and wastewater permit upgrade. Global Aqua is currently working cooperatively with Ecology to implement interim control measures prior to permanent facility modifications.

In a related action, Ecology has been working with the aquaculture industry to develop a policy regarding water quality requirements for fish production facilities. The purpose of the fin-fish discharge permit policy is to provide a consistent and predictable permitting process that ensures

environmental protection. All fish-rearing facilities on the Black River will be subject to any additional requirements that result from the new policy.

4. Upon completion of the short-term Black River water quality monitoring study, Ecology will assess the need for an intensive water quality study in the Black River. Pending an evaluation of priorities, the study would likely be conducted from mid-summer to early winter, 1990.
5. To provide a better understanding of water quality trends, Ecology will evaluate establishing an ambient water quality monitoring station on the Black River.



Appendices
to the Black River
Fish Kill Report

October 1989
89-57

ATTACHMENT 1

SWPO Complaint Tracking Form

DATE
753-1650

GP

4. Recorder ROBERT W. RYAN DEPARTMENT OF ECOLOGY ENVIRONMENTAL REPORT 1. ID number 10508

2. Date 8-8-89 3. Time 2:45 PM 5. Region SWR 6. County THURSTON 7. Waterway BLACK RIVER 8. WRIA _____

9. Repo address _____ city: RE wishes emergency _____

10. Incident location: ROCKMISTAKE / GATE
AREA, BLACK RIVER
city: GATE WA.

11. Alleged violator: UNKNOWN
address: _____
city: _____
contact person: _____
phone: _____

12. Media: ☐ A air ☐ GW grnd wtr ☐ S soil ☒ SW surf wtr ☐ O other _____

13. Material: ☐ G gas/particu ☐ H haz mat ☐ OP oil/polr ☐ SW sol wast ☐ WW waste water ☐ O other _____
chemical UNKNOWN quantity _____

14. Source: ☐ AG agricul ☐ AQ aqecul ☐ C commerc ☐ D domestic ☐ FP for pres ☐ M municip ☐ NP non-pt ☐ U unknown ☐ O other _____

15. Ecology referral: ☐ HC hazwast inspec/CU ☐ I industr ☐ SH shoreland ☐ SW sol haz wast ☐ S spill ☐ W waste red/recyc ☒ WQ water qual
☐ WR water res ☐ O other _____ section head _____ inspector CLAUDE date investigated _____

16. Outside referral ☐ A air auth ☒ CH co health ☐ CD conv dist ☐ CO coast ad ☐ EP ops ☐ O other DEPT. OF FISH & WILDLIFE
name: SUE DAVES phone: 754-4111 (DAVE STILLER)

17. Narrative (who, where, when)

CHILDREN OF HAD BURNING / SWALLOW EYES AFTER SWIMMING
IN THE BLACK RIVER MONDAY.

MR ALSO STATED HE HAD NOTICED DEAD FISH IN THE
RIVER. HE STATED THAT THE FISH FARMS MAYBE DISCHARGING
CHEM. INTO THE RIVER.

DOG SPILL TEAM RESPONDED AND TOOK PH. TEST ON WATER. SITE SHOULD
BE REVIEWED BY BOAT DURING CLEANSING / FLUSHING PROCESS OF FISH
TANKS / FACILITIES.

POSSIBLE SPILL / DISCHARGE OF UNKNOWN CHEM. INTO BLACK RIVER

ATTACHMENT 2

Chehalis Water Data

2.0

Water Temperature - 1510.5 h. - 1500 - 2.0

(Temps. late morning) J. K. S. 9 (0 Celsius) 1989

Day	July	1	2	3	4
1		1989	1988	1987	1986
2					1985
3					
4					
5					
6		150	150	160	
7					
8					
9					16.50
10					
11					
12					
13					
14					
15		15			
16					
17				180	
18					
19		160	160		
20					
21					
22					
23					
24					
25		180	180		
26					
27				170	
28					
29					
30					
31					



EFFICIENCY LINE • 22-208

180

13.50