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United States Department of the Interior

NATIONAL BIOLOGICAL SURVEY

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Please find enclosed the manuscript "Studies of Alaska's Wild Salmon Stocks: Some Insights for Hatchery Supplementation" by Leslie Holland-Bartels, Carl Burger, and Steven Klein. This paper is to presented at the March North American Wildlife and Natural Resources Conference in the "Role of hatcheries and genetics in fisheries management" session. I have forwarded a copy of the document to the Institute as well.

Sincerely,

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Chief Marine Mammals and Fisheries Branch

2/12/94

Studies of Alaska's Wild Salmon Stocks: Some Insights for Hatchery Supplementation

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Introduction

"To characterize management of wild stocks as controversial would be a considerable understatement...one thing upon which we agree is that these valuable resources have been taken for granted for too long...both managers and scientists have many commitments to make and promises to keep before anyone can feel comfortable with the fate of our wild fish" (Walton and Houston 1984). A decade has passed since these and other similar concerns were voiced at forums such as the "Olympic Wild Fish Conference" (Walton and Houston 1984) and the "Wild Salmon and Trout Conference" (Washington Environmental Foundation 1983) where concerns for wild salmonid stocks (Oncorhynchus sp.) in the Pacific Northwest were brought to focus. Since then, the body of literature associated with wild stocks has grown exponentially, but we still see serious declines in populations. Konkel and McIntyre (1987) found that 13 percent of Pacific anadromous salmonid stocks declined between 1968 and 1984. Eighty-four percent of declining stocks were located in Washington, Oregon and California. The American Fisheries Society (Nehlsen et al. 1991) lists 214 native stocks of Pacific salmon, steelhead, and sea-run cutthroat as depleted, with 101 at high risk of extinction.

Restoration or enhancement of wild stocks through use of hatcheries has a long history in the Pacific Northwest (Kelly et al. 1990). However, this strategy is under an active debate in the fisheries profession (Martin et al. 1992, Hilborn 1992), centered around documented or suspected impacts of hatchery activities on wild stocks. Recommendations have been made to consider genetic diversity of wild stocks and genetic-based approaches to management (Kapuscinski and Philipp 1988, Waples et al. 1990) and, in part, implemented through various state policies as reviewed by Kelly et al. (1990) for the Pacific Northwest.

Salmonid populations of Alaska represent a different picture from much of the Pacific Northwest with respect to status of wild stocks, history of hatchery influence, and management agency perspectives, but the wild stock issue still exists (Thomas and Mathisen 1993). Five species of Pacific salmon occur naturally--pink (O. gorbuscha), sockeye (O. nerka), chum (O. keta), chinook (O. tshawytscha), and coho (O. kisutch). Only six percent of the 489 Alaska stocks analyzed by Konkel and McIntyre (1987) showed decreasing escapement trends, although a new effort to define stocks at risk is underway (Tim Baker personal communication: 1994). Alaska has many wild stocks that have had limited hatchery influence. Also, an active state genetics program supports genetics policies established in 1985 (ADFG 1985). As such, characteristics of these stocks may provide valuable insights for efforts to reestablish viable salmon populations in other parts of their range or identify areas of caution in applying hatchery techniques. We summarize the history of hatcheries in Alaska, outline the federal resource management perspective, highlight scientific concerns, and present examples where local adaptations of salmonids have and have not been reflected in measured genetic variation.

Historical Perspective

Efforts to "enhance" natural production of salmon in Alaska commenced over 100 years ago (Roppel 1982). However, most early attempts failed because of a poor understanding of the unique life history requirements of salmon. Federal hatcheries operated through the 1920's, but closed in the 1930's, with one experimental hatchery operated through the 1950's (Kelly et al. 1990).

In the 1970's, the State of Alaska initiated an enhancement program and began permitting private nonprofit salmon hatcheries. The State currently leads North America in production of artificially propagated salmon (Holland et al. 1993). As of 1989, Alaska had 41 aquaculture facilities, many of which are located on, adjacent to, or enhancing wild salmon stocks originating from federal lands (Figure 1). Production of salmon by aquaculture facilities has increased steadily since the mid-1970's with releases now approaching 1.4 billion fish annually (Seeb 1993).

Enhancement has taken various forms in Alaska, including habitat rehabilitation and lake fertilization. New runs have been established through introductions using non-indigenous broodstock that can be self-perpetuating (Blackett 1979). In some cases "terminal" fisheries are created where salmon are imprinted to a non-natal area for "complete" harvest (Clark et al. 1993). Either native or non-native cohorts can be used to supplement production where returns are weak. However, the most common method used in Alaska, and in compliance with the State's genetics policy (ADFG 1985), is the use of native broodstock. Eggs are taken from returning adults, incubated in hatcheries, and released as fry to their natal area.

Unlike the rest of the Pacific Northwest, no federal hatchery program exists in Alaska, but federal lands provide critical spawning and nursery areas. For example, almost 70 percent of the sockeye salmon in Cook Inlet originate on U. S. Fish and Wildlife Service or Forest Service lands. These salmon are an international resource with young migrating into the Gulf of Alaska and mingling with fish from British Columbia, Washington, and Oregon.

A Federal Perspective in Alaska

The federal perspective on preservation of wild stocks is multifaceted, but in Alaska focuses primarily on a land management and research role.

The Land Manager

Conservation and management of salmonid resources in Alaska exist in a framework forged by Alaska's unusual land ownership patterns and recent legislative history. Federal holdings of about 245 million acres ($\approx$1 million km^2) are managed primarily by the U. S. Fish and Wildlife Service (31 percent); National Park Service (22 percent), Bureau of Land Management (37 percent), and U. S. Forest Service (9 percent). Many of these holdings were created or expanded by the Alaska National Interest Lands Conservation Act of 1980, amended 1988 (Public Law 96-487). The U. S. Fish and Wildlife Service and the National Park Service received guidance significant to the wild stock issue, such as to conserve fish and wildlife populations and habitats in their natural diversity and to protect populations of fish and wildlife and their habitats. In addition, both agencies have national policies to consider the natural abundance, diversity, and ecological integrity of native animals.

National Biological Survey

In 1993, the Secretary of Interior consolidated research components of several agencies and established the National Biological Survey (NBS). With this action, Alaska is included in the "Western Ecoregion," with Hawaii, California, Oregon, Washington, and Idaho. This change encourages the study of Alaska's wild stocks to address restoration issues elsewhere in the Pacific Northwest, as well as for their inherent value in maintaining the integrity of various Alaskan ecosystems.

The Hatchery vs Wild Stock Issue

Potential interactions between propagated and wild salmon are well known (Hindar et al. 1991, Krueger and May 1991, Waples 1991). Genetic alterations, increased competition and predation, high exploitation of wild salmon in mixed-stock fisheries, and disease introduction are several issues of concern (Table 1). We will concentrate on the first three issues.

Genetic Alterations

It is widely accepted that wild salmon have evolved traits over many generations that adapt them to specific environments. Stock transfers (especially those using non-native broodstock) result in intraspecific gene flow that may lead to reduced genetic variability (Waples 1991), lower fitness and survival (Reisenbichler and McIntyre 1977), and outbreeding depression (Gharrett and Smoker 1991). For example, hybrid vigor is often reported in F1 generations of animal matings, but outbreeding depression (poor fitness in F2 and subsequent generations) may be a factor in the decline of some salmonid populations. Even when within-drainage, local broodstock are used, selection may occur within the hatchery over time or during the egg takes (selection of early returners, large females, etc.) which may result in a once wild gene pool permanently altered or lost (Waples 1991). Other concerns include "founder" effects (when small numbers of parents are used) and lowered disease resistance in wild stocks from reduced genetic diversity (Hindar et al. 1991). Hemmingsen et al. (1986) found that stocks of coho salmon exhibit a genetically based variance in their resistance to pathogens. It is possible that donor stocks can transmit lowered disease resistance to wild fish.

Competition and Predation

Introduction of salmon into streams not previously colonized can cause competition with native fishes, increased predation on resident populations, and population instability. Ishida et al. (1993) suggest that density dependent factors, resulting from intensive enhancement of Japanese chum salmon, may be linked to observed reductions in fish size in the North Pacific Ocean and that wild stocks might be adversely affected. Where stock supplementation is made to revitalize depressed salmon populations, hatchery-incubated brood fry are often fed prior to release, with the larger hatchery fry in a position to outcompete wild cohorts.

Exploitation Rates

Overexploitation of wild stocks in a mixed fishery can occur. For example, Wright (1981) suggests that hatchery stocks of coho salmon can support a catch-to-escapement rate of 19:1, while wild stocks only a 3:1 rate. In addition, when a new fishery is created, other stocks or species in the fishing area may experience high incidental harvest.

Where Ecological Diversity and Genetics Converge

Often, ecologically distinct forms of salmon can be separated with genetic tools (Wilmot and Burger 1985). "Stream" and "ocean" chinook salmon in British Columbia spawning in three parts of a drainage could be distinguished by enzyme polymorphisms (Carl and Healey 1984). Variation in body morphology among certain chum salmon stocks (Beacham and Murray 1987) has a genetic component (Beacham et al. 1985). In Alaskan sockeye salmon populations, ecological differences in spawning area, time (Gard et al. 1987), and swimming orientation of emergent fry exist between lake outlet and tributary spawning sites (Raleigh 1967). Such behavioral patterns have a hereditary basis (Raleigh 1967).

Allozyme and mitochondrial DNA patterns of various Alaskan salmonids provide support that certain phenotypic traits have a significant genetic component. For example, Yukon River chum salmon exhibit differences among allozymes between early- and late-running stocks (Wilmot et al. in press).

Evidence exists for genetic uniqueness among stocks where formally only one population was expected. Early-running fish spawned in tributaries of each the Kenai and Kasilof rivers (Figure 2), but late-running fish spawned in main-stem waters (Burger et al. 1985, Faurot and Jones 1990). Both spatial and temporal segregation was supported by genetic analyses: late-running salmon in each of the rivers have an mtDNA haplotype found in only about eight percent of early-running fish (Adams et al. in press). Tustumena Lake sockeye salmon demonstrate similar differences: 50 percent of the late-running salmon sampled from spawning areas in the lake's outlet possessed an mtDNA haplotype not found in early-running tributary or lake shoreline spawners (Carl Burger, unpublished data). For both chinook and sockeye salmon, these differences are highly significant, yet spawning areas of the two runs averaged <30 km apart and, in some cases, were <10 km apart (Figure 2). Although fishery managers often consider geographically adjacent populations as good candidates for donor stocks in restoration plans, proximate stocks may differ substantially in phenotypic and genotypic characteristics.

A genetic basis exists for differences in egg development rates found among Alaskan chinook salmon stocks having different run and spawning times (Carl Burger, unpublished data). Each population appeared adapted to the unique temperature regime of its home stream. Early-running salmon spawned mid-July in tributaries where waters were coldest, while late-running salmon spawned late-August in main-stem rivers warmed by lakes. Eggs also hatched at different times (mid-September versus early November), but fry emerged at similar times the next May. The gentic basis of such differences has a major implication for managers because artificial selection can alter traits if sampling of a donor stock is temporally biased (Gharrett and Smoker 1993).

We See a Difference but What About Genetics?

The literature is replete with examples of ecological differences between populations whose environmental or genotypic basis has yet to be substantiated through genetic tools. Should phenotypic traits be considered during enhancement efforts? Available evidence suggests yes. In many cases (such as in the examples above), genetic techniques improve and subsequent application of these techniques corroborate ecological findings. Therefore, in some cases it may be prudent to conservatively define stocks as discrete based on consistent phenotypic differences until our understanding of the environmental or genetic basis of variability is improved.

For example, Burger and Finn (1993) compared the spawning distribution of sockeye salmon at Tustumena Lake, southcentral Alaska. As previously mentioned, the lake outlet-spawning component was genetically unique. Preliminary mtDNA studies suggested additional genetic differences between the tributary spawners and salmon spawning along the lake's shoreline (beach spawners). Ecological evidence that the beach spawners are a unique subpopulation comes from comparisons of run timing between beach and tributary spawners ($p < 0.0001$) and from spawning time ($p < 0.02$), yet genetic analyses to date are inconclusive. However, recently diverged populations may not be detectable by molecular genetic procedures (Utter et al. 1993). Based on glaciation patterns (Karlstrom 1964), we believe that beach spawners could have only colonized the lake in the last 2,000 years and that these fish may be actively differentiating. Conservative management may be appropriate until a body of evidence is compiled. The implications for salmon enhancement in this situation are obvious since all Tustumena sockeye salmon were formerly thought to be a single run of fish.

Other questions exist. Different outmigration timing patterns of juvenile salmon may also be in synch with temperature and aquatic productivity of their rearing areas (Burger and Finn 1993). Such findings are reasonable, but are these characteristics genetically based? We have found that most adult sockeye salmon migrate in a clockwise direction around Tustumena Lake. Why? In the Kenai River, we do not know if offspring from the genetically distinct early- and late-running chinook salmon use different rearing habitats. If they do, is this heritable, conferring a selective advantage for survival? The significance to wild salmonids will remain unknown if stock transfers occur before thoughtful analyses are completed.

Conclusion

While it is clear to the engineer that a road culvert will fail if designed for last year's flow regime, that we must build for the future...the 100-year event, we as fishery managers have yet to agree on a similar perspective. Alaska is fortunate that it has lagged behind the "lower 48" in anthropogenic impacts and has a diversity of wild salmonid stocks. That is both lucky for Alaskans and for citizens of the rest of the Pacific Northwest who have lost much of their salmonid diversity and abundance. One of our best hopes for maintenance or restoration of wild stocks in the Pacific Northwest is development and implementation of clear genetic policy by all resource agencies. Many agencies, including federal, do not have such policies. However, we must also acknowledge that genetics is a rapidly evolving science, with tools of promise but also limitations. For example, most genetic surveys assess traits which alone, may be insufficient to quantify genetic variability in populations (Gharrett and Smoker 1993). Because we lack clear black and white answers, we must manage with patience to ensure the future integrity and continued multiple use of our wild stocks. Our recommendations are not new but warrant restating and are as follows:

1. Establish formal policies among resource agencies to address strategies to maintain identifiable genetic variability in wild stocks. To meet the "diversity" mandates described

above, we recommend that federal agency policies conservatively consider stock discreteness based both on genotypic and consistent phenotypic traits. When artificial propagation is considered, stocks must be monitored and evaluated to ensure that long-term changes do not occur. Threshold characteristics should be identified that would trigger project termination or modification.

2. Develop a partnership and protocol to assess the status and trends of salmonids in a refined enough manner that wild stocks can be adequately monitored. While Konkel and McIntyre (1987) compiled data for 893 Alaskan stocks, 45 percent of these stocks had insufficient data for trend analysis. Eighty-four percent of those stocks (340) were from Southcentral Alaska, an area where refuge and national park lands are abundant and where sport harvest of sea-run salmon has increased 87 percent between 1982 and 1992 (Mills 1993). Enhancement project-specific information should also be incorporated, such as 1) a tag/recovery program, with recovery efforts in fisheries, spawning areas, and proximal streams, 2) enumeration of escapement and outmigrants, 3) genetic sampling and monitoring, and 4) monitoring of fish and dependent wildlife populations within the study area.

3. Identify research needs and establish a partnership mechanism to encourage needed research on wild stocks. Such a cooperative framework could address the issues of stock identification, consequences of local adaptations, and phenotypic and genotypic variation in wild stocks as they relate to federal land and resource management options.

For the federal land manager, wild stocks are a trust resource. Selection of artificial propagation is an option to be approached in an informed and cautious manner to minimize risks to species, populations, and ecosystems. In 1994, we must still concur with Walton and Houston (1984) that "both managers and scientists have many commitments to make and promises to keep before anyone can feel comfortable with the fate of our wild fish."

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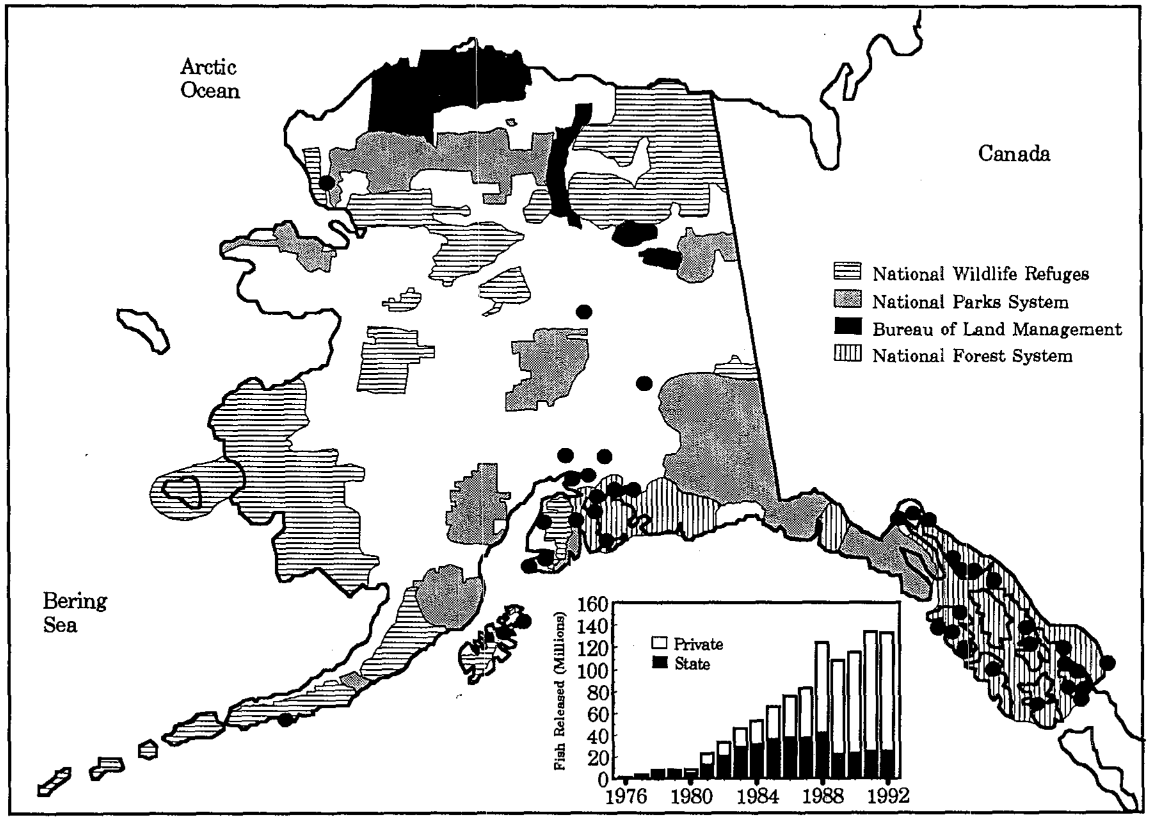
Table 1. Types of salmon enhancement used in Alaska and possible impacts and risks to wild stocks as synthesized from selected literature.

Enhancement Type	Possible Impact and Risk	Citation
Introductions	Increased competition with resident fishes.	Krueger and May 1991
	Increased predation on resident fishes.	Krueger and May 1991
	Unwanted gene flow (straying) from fry releases.	Unwin and Quinn 1993
	Unwanted gene flow (straying) from smolt releases.	Unwin and Quinn 1993
	Incidental harvest of other stocks.	Wright 1981
Supplementation:		
Non-Indigenous Stock	Intraspecific genetic change.	Waples 1991
	Outbreeding depression.	Gharrett and Smoker 1991
	Unwanted gene flow (straying) from fry releases.	Unwin and Quinn 1993
	Unwanted gene flow (straying) from smolt releases.	Unwin and Quinn 1993
	Decreased fitness from competition, disease.	Hemmingsen et al. 1986
	Increased exploitation of native fish.	McIntyre and Reisenbichler 1986
Indigenous Stock	Intraspecific genetic change.	Waples 1991
	Unwanted gene flow (straying) from fry releases.	Unwin and Quinn 1993
	Unwanted gene flow (straying) from smolt releases.	Unwin and Quinn 1993
	Decreased fitness from competition, disease.	Waples 1991
	Increased exploitation of native fish.	McIntyre and Reisenbichler 1986
Habitat Modification:		
Stream Rehabilitation	Change in stream dynamics.	Ryder and Kerr 1989
Lake Enrichment	Change in fish community balance.	O'Neill and Hyatt 1987

Figure Titles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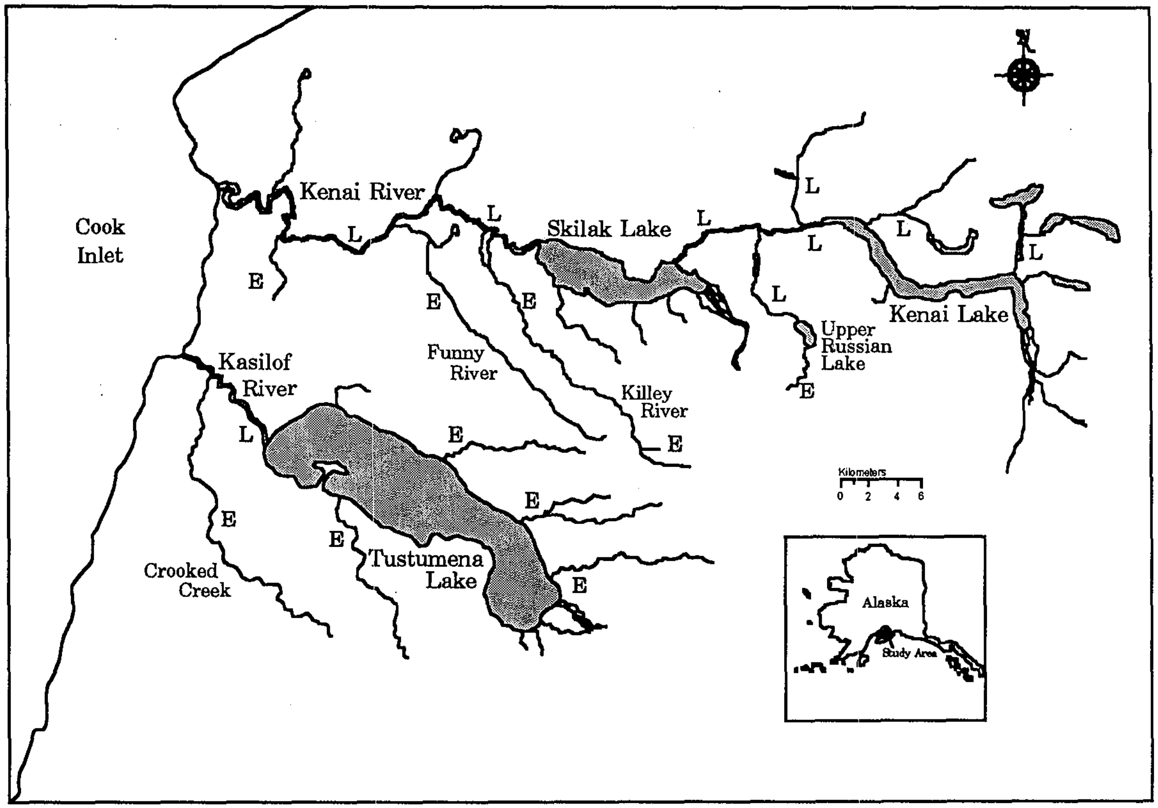

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