Special Publication No. 18-12

Salmon Hatcheries in Alaska – A Review of the Implementation of Plans, Permits, and Policies Designed to Provide Protection for Wild Stocks

by

Danielle F. Evenson

Christopher Habicht

Mark Stopha

Andrew R. Munro

Theodore R. Meyers

and

William D. Templin

October 2018

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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SALMON HATCHERIES IN ALASKA – A REVIEW OF THE IMPLEMENTATION OF PLANS, PERMITS, AND POLICIES DESIGNED TO PROVIDE PROTECTION FOR WILD STOCKS

by

Danielle F. Evenson, Mark Stopha and Theodore R. Meyers
Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau

and

Christopher Habicht, Andrew R. Munro, and William D. Templin
Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

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Danielle F. Evenson and Mark Stopha
Alaska Department of Fish and Game, Division of Commercial Fisheries,
1255 W. 8th Street, Juneau, AK, 99811 USA

and

Christopher Habicht, Andrew R. Munro, and William D. Templin
Alaska Department of Fish and Game, Division of Commercial Fisheries,
333 Raspberry Road, Anchorage, AK, 99518 USA

and

Theodore Meyers
Alaska Department of Fish and Game, Division of Commercial Fisheries,
3333 Glacier Highway, Juneau, AK, 99811 USA

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ABSTRACT

The salmon hatchery program in Alaska was initiated in the 1970s to rehabilitate depleted salmon fisheries. Learning from problems encountered with the robust hatchery programs in place in the Pacific Northwest, Alaska's program was envisioned and proactively designed to protect wild salmon stocks. Here we build upon a previous review of the precautionary plans, permits, and policies that have guided salmon enhancement in Alaska in a manner that protects wild stocks. These consist of development of rigorous permitting processes that includes genetics, pathology, and fishery management reviews; policies that require hatcheries to be located away from significant wild stocks; use of local brood sources; laws that give priority to wild stocks in fisheries; provisions for marking of hatchery fish; and as necessary, requirements for special studies on hatchery/wild stock interactions. Now that statewide annual production has largely stabilized, and amid rising concerns for effects on wild salmon populations, a review of the implementation of Alaska's precautionary approach is both timely and warranted. In this paper we explore procedures, practices, fishery management, and stock assessment relevant to the hatchery program for consistency with State of Alaska policies using two case studies—Southeast Alaska Chinook salmon and Prince William Sound pink salmon.

Key words: precautionary, hatchery, Pacific salmon, Chinook salmon, pink salmon, Prince William Sound, Southeast Alaska, private nonprofit, policy

INTRODUCTION

Salmon hatchery programs in North America have been a topic of continuous discussion for much of the past 50 years because they entail the need to balance the benefits against the risks associated with production of salmon in aquaculture. There are many reasons to develop and maintain hatchery production of salmon, usually for economic and cultural benefits to communities or to mitigate harm to natural production from other sources (Flagg 2015). The benefits are usually easy to observe and measure in terms of numbers of fish and economics, whereas potential harms to natural systems are difficult to observe and measure and are usually stated in theoretical terms (e.g., the need to protect wild stocks) that are only recently being investigated. The unevenness of the support informing the discussion increases the complexity, making it difficult to come to resolution. However, while the conversation continues, hatchery programs are in place, public benefits are being accrued, and natural systems remain potentially at risk. In Alaska, this situation influences decisions made when permitting hatcheries (e.g., the State), considering proposed regulatory changes (e.g., the Alaska Board of Fisheries), operating hatcheries (e.g., aquaculture associations), certifying fisheries as sustainable (e.g., Marine Stewardship Council), and participating in public processes (e.g., stakeholders). It is unclear whether the debating entities fully understand how fisheries and hatcheries are being managed in the modern era and how the various management tools are integrated to maximize conservation and use of Alaska's valuable salmon resources (adapted from Trushenski et al. 2018). The intent of this document is to provide the reader with an understanding of the policies, plans, and permits that govern Alaska's hatchery program, and the ways they are implemented to benefit the people of Alaska while protecting the natural resource in context of current scientific information.

Alaska's contemporary hatchery program was initiated in the early 1970s in response to historically low salmon abundance. The purpose of most salmon hatcheries in Alaska is to supplement, not supplant, wild stock abundance for public benefit (McGee 2004). These hatcheries increase salmon production by increasing the survival of young salmon through the early life history stages where most mortalities occur, producing large numbers of fry or smolts that are released into marine waters where they are subject to the same conditions as their wild cohorts. Unlike fish farms (finfish farming is prohibited in Alaska), hatcheries do not rear fish to adulthood; rather, they act as a nursery to incubate fertilized eggs and to imprint and release the resulting progeny. Under hatchery conditions, developing embryos are protected from the vagaries of natural environmental conditions, such as low stream flows, freezing, gravel scouring from floods, and predation.

Little is known about the actual effects of hatchery fish on wild populations in Alaska, but potential effects have been proposed and reviewed (e.g., Grant 2012) and are often inferred from scientific studies on hatchery/wild interactions in the Pacific Northwest and elsewhere—even though they operate under different guidance than Alaska hatcheries. There are inherent genetic, pathological, and ecological risks to wild stocks from enhancement programs. Releases of hatchery fish have the potential to (1) change the genetic diversity of wild populations when hatchery and wild fish interbreed (Waples 1991; Utter and Epifanio 2002; Naish et al. 2007; Grant 2012), (2) reduce fitness of wild populations (Araki et al. 2009), (3) increase risk of disease transmission to wild stocks (Elliott et al. 1997), (4) increase competition with wild fish in freshwater and marine environments (Beamish et al. 1997; Daly et al. 2012; Ruggerone et al. 2012), and (5) result in over-harvest of wild stocks in mixed stock fisheries (Beamish et al. 1997; Hilborn 1985; Unwin and Glova 1997). In Alaska, salmon hatcheries are involved with the egg-to-smolt life stages and the returning adult life stage, thus providing the opportunity to mitigate risks associated with genetic, pathological, and fisheries management interactions. Ecological risks can occur when the presence of hatchery fish affects how wild fish interact with their environment or with other species—such as predator–prey interactions and competition with wild fish for food or habitat (Kostow 2009, 2012; Rand et al. 2012). However, quantifying the effects of ecological interactions in the natural environment is difficult (Rand et al. 2012; HSRG 2014).

Alaska's enhancement program was envisioned and designed to protect wild salmon stocks from its inception in the 1970s (McGee 2004). Alaska had the benefit of being able to review the practices and results of salmon enhancement programs that existed elsewhere and thereby plan the Alaska enhancement program in a manner that minimized risk to wild populations. Accordingly, the Alaska Department of Fish and Game (ADF&G) worked with a broad consortium of expertise at other regulatory agencies, veterans of Pacific Northwest hatcheries, the University of Alaska, and fisherman's associations to formulate guidelines and policies for the hatchery programs in the mid-1970s–1980s (reviewed in McGee 2004). In Alaska, the state constitution requires natural resources to be managed sustainably (Article 8, Section 4). A framework of statutes, regulations, and policies has been developed to guide the growth of the Alaska hatchery program with the intent to minimize risk to wild stocks.

ADF&G recognized the need to minimize the effects that enhancement could have on wild stocks and adopted standards with respect to hatchery location, genetic and disease policies, culture techniques, monitoring, data collection, and management. For example, hatcheries generally use stocks taken from close proximity so that any straying of hatchery returns will have similar genetic makeup as the stocks from nearby streams. Alaska hatcheries do not selectively breed salmon. Large numbers of broodstock are used for gamete collection to maintain genetic diversity, without regard to size or other characteristics.

Formally adopted in 2000, the *Policy for the Management of Sustainable Salmon Fisheries* (SSFP; 5 AAC 39.222) includes in regulation the principles and practices already in place. It calls for a precautionary approach in the face of uncertainty such that salmon stocks, fisheries, artificial propagation, and essential habitats are managed conservatively (5 AAC 39.222(c)(5)). The SSFP outlines a precautionary approach as follows:

…involving the application of prudent foresight that takes into account the uncertainties in salmon fisheries and habitat management, the biological, social, cultural, and economics risks, and the need to take action with incomplete knowledge, should be applied to the regulation and control of harvest and other human-induced sources of salmon mortality; a precautionary approach requires

(i) *consideration of the needs of future generations and avoidance of potentially irreversible changes;*
(ii) *prior identification of undesirable outcomes and of measures that will avoid undesirable outcomes or correct them promptly;*
(iii) *initiation of any necessary corrective measure without delay and prompt achievement of the measure's purpose, on a time scale not exceeding five years, which is approximately the generation time of most salmon species;*
(iv) *that where the impact of resource use is uncertain, but likely presents a measurable risk to sustained yield, priority should be given to conserving the productive capacity of the resource;* and
(v) *appropriate placement of the burden of proof, adherence to the requirements of this subparagraph, on those plans or ongoing activities that pose a risk or hazard to salmon habitat or protection.*

At the time that the SSFP was being developed, the United Nations (UN) was also developing principles with respect to precautionary reference points and a precautionary approach (United Nations 1995, Article 6 and Annex 2). The UN explicitly focused on reference points, monitoring, and development of alternative management as a part of the approach. Later, the UN's Food and Agriculture Organization (Garcia 1995) defined the precautionary approach as

A set of agreed cost-effective measures and actions, including future courses of action, which ensures prudent foresight, reduces or avoids risk to the resources, the environment, and the people, to the extent possible, taking explicitly into account existing uncertainties and the potential consequences of being wrong.

While developing and implementing the policies and regulations for salmon fishery enhancement in Alaska (McGee 2004), ADF&G used principles similar to those later defined by the UN.

Alaska's private nonprofit (PNP) salmon enhancement program differs markedly from many of the Pacific Northwest hatcheries, which were designed to mitigate habitat loss, or more recently to supplement weak stocks (Lichatowich 1999; HSRG 2009). In the Pacific Northwest, hundreds of hatchery facilities are operated by federal, state, tribal, and local governments, with limited coordination among them. Many of the existing facilities have been in operation for over 100 years and until recently have been operated with little understanding of the risks that hatchery practices may have on long-term productivity and fitness of wild populations. It is now widely recognized that the use of traditional mitigation hatchery programs has been a contributing factor to the overall decline of wild populations (HSRG 2004). Subsequently, U.S. Congress authorized the Hatchery Reform Project in 2000 and costly hatchery reform efforts have been taking place over the last decade or so to minimize impacts on wild stocks (HSRG 2014). Many of the requirements put in place for the development of the hatchery program in Alaska are now being used by the Hatchery Scientific Review Group (HSRG) to reform hatcheries in the Pacific Northwest (HSRG 2004; McGee 2004). This scientific review panel made the following recommendations: (1) take a regional approach to hatchery programs, (2) measure success in terms of contributions of adult fish to fisheries rather than production of juveniles, (3) require regular monitoring programs, (4) use locally adapted broodstocks, (5) take eggs throughout the run to maintain run timing, (6) develop specific spawning protocols, and (7) take into account both freshwater and marine carrying capacities in determining production goals. These practices have largely been in place in Alaska for more than 30 years.

The Marine Stewardship Council, a seafood sustainability certification body, reviews fisheries every 5 years. A condition of certification was to "establish and implement a mechanism for periodic formal evaluations of each hatchery program for consistency with statewide policies and prescribed management practices" (Chaffee et al. 2007; Knapman et al. 2009). Subsequently, ADF&G began evaluating PNP hatcheries for consistency with state policies and regulations in 2011. These evaluations have been completed for nearly all hatcheries.[1] Although these evaluations are an important systematic assessment of the hatcheries, there have been no comprehensive reviews of Alaska's salmon fishery enhancement program and its relation to wild stock production on a regional scale.

Although Alaska's salmon fishery enhancement policies clearly constitute a precautionary approach to meet the mandates of sustained yield and conservation of salmon resources under the Alaska State constitution and the legislation enabling the enhancement programs, success of enhancement efforts depends on implementation of the system and ensuring policies are followed. In this report, we explore the implementation of Alaska's precautionary approach using 2 case studies, Southeast Alaska (SEAK) Chinook salmon (*Oncorhynchus tshawytscha*) and Prince William Sound (PWS) pink salmon (*O. gorbuscha*) and describe the current configuration of each for consistency with policies using the best available current scientific information on hatchery risks to wild stocks.

HISTORY OF SALMON HATCHERIES IN ALASKA

Heard (2011) reviewed the history of hatcheries in Alaska and the origin of the contemporary program. The first hatcheries in Alaska were built in 1891 on the Karluk River on Kodiak Island and on Katlaku (a.k.a. Kutlaku) Creek in SEAK for the production of sockeye salmon (*O. nerka*; Roppel 1982). By the early 1900s, about a dozen more hatcheries were built, some by the U.S. Bureau of Fisheries, again primarily for sockeye salmon. A lack of knowledge of salmon life history and poor hatchery practices resulted in little success in terms of returning adults and eventually led to hatchery closures by the 1930s.

Prior to statehood in 1959, when fisheries were under federal fisheries management, there was a pronounced decline in the harvests of salmon. Harvest in Alaska averaged 90 million fish annually in the 1930s but fell to 25 million fish in 1959 (Figure 1). Gaining local control of the management of the Alaska's fisheries was a major impetus for pursuing statehood. The fisheries were important enough that the Alaska State constitution mandated its fishery resources "be utilized, developed, and maintained on the sustained yield principle" (Article 8, Section 4); the enhancement program was developed with that as foundational guidance. The Alaska State constitution also declares that fish in their natural state "are reserved to the people for common use" (Article 8, Section 3) and that "No exclusive right or special privilege of fishery shall be created or authorized" (Article 8, Section 15).

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[1] See Stopha (2017) for a bibliography of Alaska hatchery evaluations completed to date.

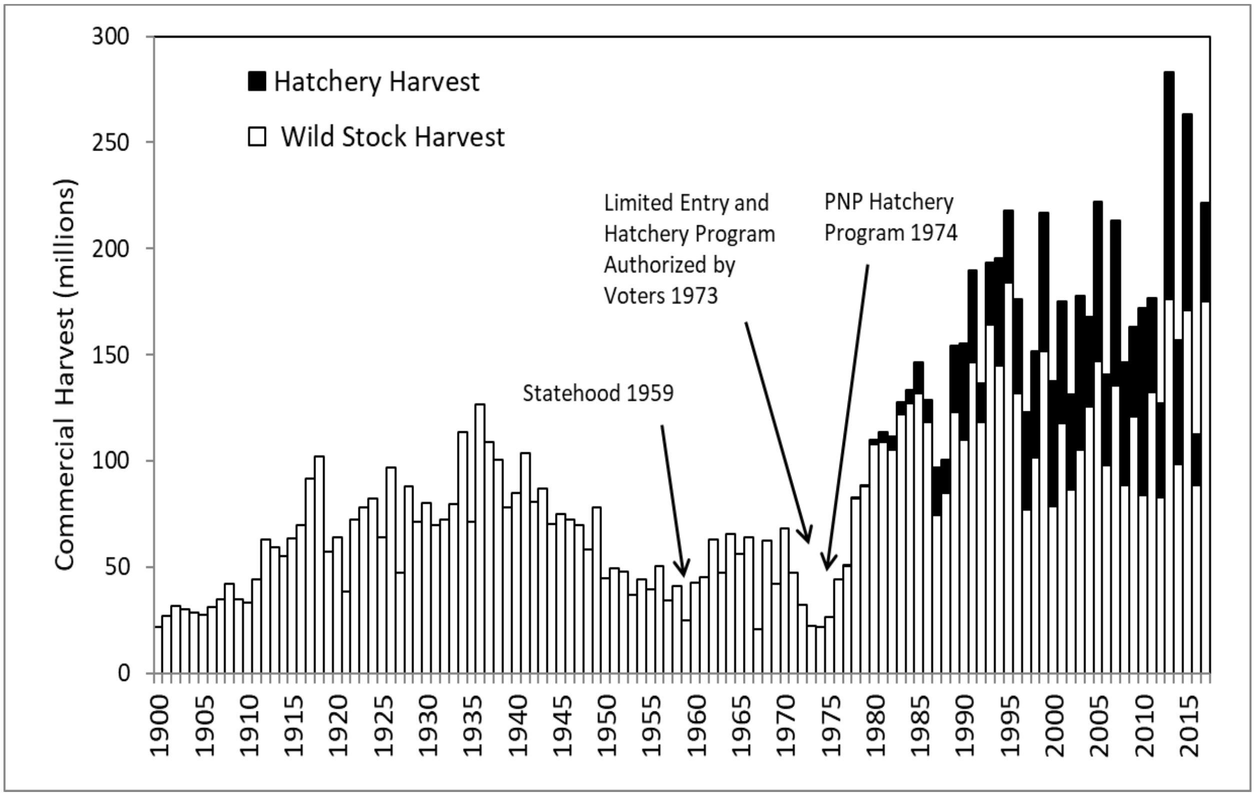

Figure 1.–Alaska commercial salmon harvests, in millions of fish, 1900–2017.

Source: Stopha 2018.

After statehood, salmon harvests in the 1960s remained above levels seen in the 1950s (except for 1967), averaging 50 million fish annually, but the early 1970s saw an extended period of low salmon harvests throughout the state; in 1973 and 1974, statewide harvest was only 22 million fish. The declines in abundance and harvests was particularly acute for PWS pink salmon; many stocks were severely impacted by the 1964 earthquake. Access to some spawning grounds in PWS was completely eliminated by tectonic uplift, while other habitats became available for colonization (Roys 1971). Harvests of pink salmon in PWS averaged nearly 8 million fish annually in the 1940s, but were less than half that in the 1960s, and were less than 1 million in 1972 and 1974.

In response to this dismally low abundance, Alaska designed an enhancement program to increase salmon harvest, while maintaining the sustainability of wild salmon. Alaska voters approved a constitutional amendment to Article 8, Section 15, in 1972 providing for an exemption enabling limited entry to Alaska's state fisheries

> *to prevent economic distress among fishermen and those dependent upon them for a livelihood and to promote the efficient development of aquaculture in the State.*

Implementing language from the Alaska Legislature authorized private nonprofit (PNP) corporations to operate salmon hatcheries:

The program shall be operated without adversely affecting natural stocks of fish in the state and under a policy of management which allows reasonable segregation of returning hatchery-reared salmon from naturally occurring stocks.

Alaska's contemporary salmon hatchery program was developed under this authority in the early 1970s. Because the low returns were not a consequence of habitat destruction (the vast majority of salmon habitat in Alaska is still in pristine condition), the focus was to enhance—not replace—wild production for public benefit. This is in marked contrast to many of the hatchery programs in the Pacific Northwest, which had been developed to mitigate for the impacts of salmon habitat loss.

The Alaska Legislature created the Division of Fisheries Rehabilitation, Enhancement and Development (FRED) in ADF&G to be responsible for developing the state's salmon hatchery system. The primary responsibilities of FRED (AS 16.05.092) included (1) develop a comprehensive, coordinated state plan for the orderly rehabilitation, enhancement and development of the state's fisheries; (2) encourage investment by private enterprise in the technological development and economic use of the fisheries resources; and (3) through rehabilitation, enhancement, and development programs do all things necessary to ensure perpetual and increasing production and use of the food resources of state waters and continental shelf areas. The overarching goal of the program was to provide fishery enhancement while minimizing adverse impacts on wild stock production. In practice, FRED (1) encouraged, sponsored, and conducted research on the basic problems inhibiting the sound development of hatcheries, and (2) implemented enhancement programs. By the time FRED was established, salmon hatcheries were already located at Kitoi Bay, Deer Mountain, Little Port Walter, Fire Lake, Fort Richardson, and Crystal Lake. Kitoi Bay and Little Port Walter were situated on small salmon spawning streams from which the broodstock was taken.

Initial FRED facilities were mostly located away from wild stocks, but not all. The Sikusuilaq, East Creek, Big Lake, Crooked Creek, Gulkana River, Klawock River, Cannery Creek, Tutka Bay Lagoon, and Russell Creek hatcheries were located on the systems from which broodstock were taken. The FRED Division was dissolved in 1994 and the FRED facilities have since either been closed or have had their operation contracted out to PNP corporations. Some of the pre-FRED facilities remain, and include the Kitoi Bay, Little Port Walter, Deer Mountain and Crystal Lake hatcheries. Additionally, some early FRED facilities built on streams with salmon populations remain, including Cannery Creek, Klawock River, and Tutka Bay Lagoon.

The Alaska Legislature also wanted to ensure participation of the private sector in enhancement efforts. To accomplish that, the Legislature passed the *Private Nonprofit Hatchery Act*. This act provided for private groups and associations to build and operate hatcheries or conduct other types of enhancement projects (lake fertilization, fish passage improvement, etc.). It also provided for the formation of Regional Aquaculture Associations (RAAs) to function as nonprofit corporations and provide stakeholder oversight of salmon fishery enhancement activities within their respective regions. By 1990, there were 45 hatcheries operating in Alaska, including 18 operated by the State of Alaska (Stopha 2018). This number declined as ineffective hatcheries were closed. Most of the state hatcheries were contracted for operation by the RAAs or adjacent nonregional PNP aquaculture associations. Currently, there are 29 hatcheries operating in Southeast Alaska, PWS, Cook Inlet, and Kodiak (Figure 2). Of the 29 hatcheries now in operation, 14 are owned and operated by PNPs; 11 are state-owned and operated by PNPs; 2 are state-owned and operated by ADF&G Division of Sport Fish; 1 small research facility is operated by a Federal agency; and 1 hatchery is owned and operated by a tribal entity, but is not subject to State of Alaska oversight because it is located on the Metlakatla Indian Community Annette Island Reserve.

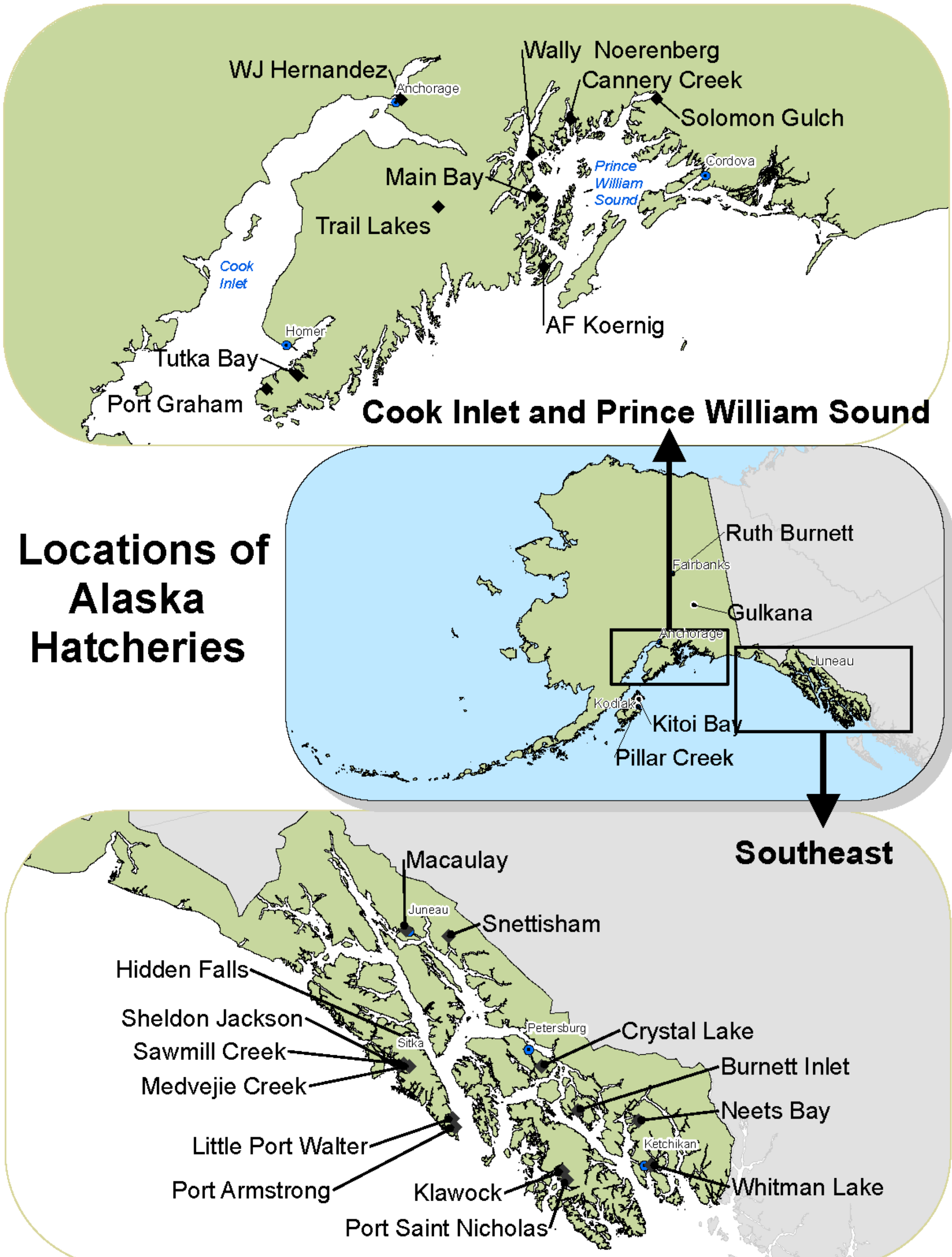

Figure 2.–Salmon hatcheries currently operating in Alaska.

Note: Tamgas Creek Hatchery, owned and operated by the Metlakatla Indian Community, is not shown.

Statewide harvests of salmon have increased remarkably since the early 1970s (Figure 1). Harvests now consistently exceed 100 million fish annually, and in 2013 reached an all-time record 283 million fish, of which there was a record harvest of both wild (176 million) and hatchery (107 million) fish. Since the volume of hatchery releases largely stabilized in 1997, approximately 34% (range: 21–51%) of the total common property harvest is from enhancement operations, primarily pink and chum salmon (*O. keta*; Stopha 2018). The hatchery return is composed primarily of the harvest in the fisheries and the broodstock from which eggs are collected for hatchery production. Most (95%) of the hatchery harvest occurs in the commercial common property fisheries (78%) and the cost recovery fisheries (17%), which collectively make up the commercial harvest. Sport, personal use, and subsistence fisheries harvest about 1% of the return. The remainder (4%) is broodstock, escapement, and estimated unharvested returns.

Overview of Policies and Practices

Numerous mandates and policies for hatchery operations were specifically developed to minimize potential adverse effects to wild stocks (McGee 2004). Recognizing that interactions between hatchery-produced and wild salmon are unavoidable, precautionary policies, plans, and practices were developed to guide hatcheries through the following: (1) rigorous permitting processes that includes genetics, pathology, and fishery management reviews; (2) selection of release sites away from significant wild stocks; (3) use of local brood sources; (4) prioritization of wild stocks in fishery management; (5) provisions for marking/tagging of hatchery fish; and (6) as necessary, requirements for special studies on hatchery/wild interactions.

The Alaska Board of Fisheries set policies that reflect the hatchery program's role in sustainable fisheries. These policies include the management of mixed stock salmon fisheries; the management of sustainable fisheries; individual management plans for terminal harvest areas; and allocation of salmon, including hatchery production, for harvests.

A variety of statutes, regulations, and policies guide the permitting of salmon fishery enhancement projects. They include the *Genetic Policy* (Davis et al. 1985), *Regulation Changes, Policies, and Guidelines for Fish and Shellfish Health and Disease Control* (Meyers 2014), *Permits for Salmon Hatcheries* (AS 16.10.400), *the Sustainable Salmon Fisheries Policy* (5 AAC 39.222) and *Mixed Stock Salmon Fishery Policy* (5 AAC 39.220). Using this guidance and a comprehensive permitting and planning process, ADF&G fishery managers, geneticists, pathologists, and the ADF&G commissioner continually review hatchery operations to assess genetic, health, and fishery management issues. For details see the *Consistency with Policy* section.

Hatchery Plans and Permits

In Alaska, salmon may be propagated by the public under 2 types of permits—a PNP salmon hatchery permit or an aquatic resource permit. Aquatic resource permits have a scientific or educational objective and are issued for small-scale projects, including salmon research, vocational programs, and the extensive *salmon in the classroom* program conducted in schools across the state. Private nonprofit hatchery permits have a fishery enhancement objective and are issued for production-scale fishery enhancement projects.

Salmon fishery enhancement efforts are guided by regional comprehensive salmon plans (CSP) for each region—in a public process—and are based on the needs of fishery user groups and communities of the region (AS 16.10.375, 5 AAC 40.300). The plans are developed by regional planning teams (RPT), which are composed of 6 voting members: 3 appointed by the ADF&G

commissioner and 3 appointed by the RAA board of directors. RPTs hold public meetings to make recommendations to the ADF&G commissioner regarding issuance of new hatchery permits and changes to existing hatchery operations (5 AAC 40.170, 5 AAC 40.840, 5 AAC 40.850) and the plans are periodically reviewed and updated to meet changing needs. Thus, the RPT process also serves as a mechanism for close coordination and cooperation within regions. These plans are implemented upon approval by the ADF&G commissioner. According to McGee (2004),

> *Regional comprehensive planning in Alaska progresses in stages. Phase I sets the long-term goals, objectives and strategies for the region. Phase II identifies potential projects and establishes criteria for evaluating the enhancement and rehabilitation potentials for the salmon resources in the region. In some regions, a Phase III in planning has been instituted to incorporate Alaska Board of Fisheries approved allocation and fisheries management plans with hatchery production plans.*

RAAs operate most of the PNP hatcheries statewide. Each RAA has a board of directors whose membership is composed of commercial salmon fishing permit holders and representatives of other stakeholder groups such as sport and subsistence harvesters, processors, and city officials providing public oversight of operations (AS 16.10.380). Nonregional aquaculture associations operate PNP hatcheries as well. Private nonprofit aquaculture association boards of directors establish hatchery production goals and oversee business operations, including PNP staff. PNP staff work with ADF&G to comply with state permitting and planning regulations.

ADF&G Sport Fish hatcheries in Anchorage and Fairbanks produce fish specifically for sport fisheries and are not subject to PNP hatchery permit and oversight requirements, although they do generally adhere to them. The hatcheries are primarily funded from the federal excise tax on fishing-related equipment under the Dingell-Johnson Sport Fish Restoration Act. The funding, policy, and planning for these hatcheries is described in the current Statewide Stocking Plan (http://www.adfg.alaska.gov/index.cfm?adfg=fishingSportStockingHatcheries.stockingPlan).

HATCHERY PERMITTING PROCESS

Acquisition of a PNP hatchery permit is an extensive process (AS 16.10.400–10.430; 5 AAC 40.110–40.230; Figure 3). A hatchery application consists of production goals, hatchery site information, water flow, water chemistry data, land ownership, water rights, hatchery design, initial proposed broodstock for the hatchery, and a staffing and financial plan. ADF&G staff draft a fishery management feasibility analysis for the proposed hatchery. ADF&G staff review the application with the applicant, who addresses any deficiencies in an iterative process.

Public participation is an integral part of the PNP hatchery system (Figure 3). The RPT reviews hatchery permit applications within their region in public meetings to determine if the hatchery operation is compatible with the regional salmon plan (AS 16.10.375). The RPT also makes a recommendation on the permit to the ADF&G commissioner. Following review by the RPT, a public review and comment period, including a public hearing, is held before a hatchery is permitted for operation (AS 16.10.410). The applicant describes the proposed hatchery plan, and ADF&G staff present the basic management plan (described below) for the hatchery. Public testimony and questions follow the presentations. The ADF&G must respond in writing to any specific objections to the proposed permit.

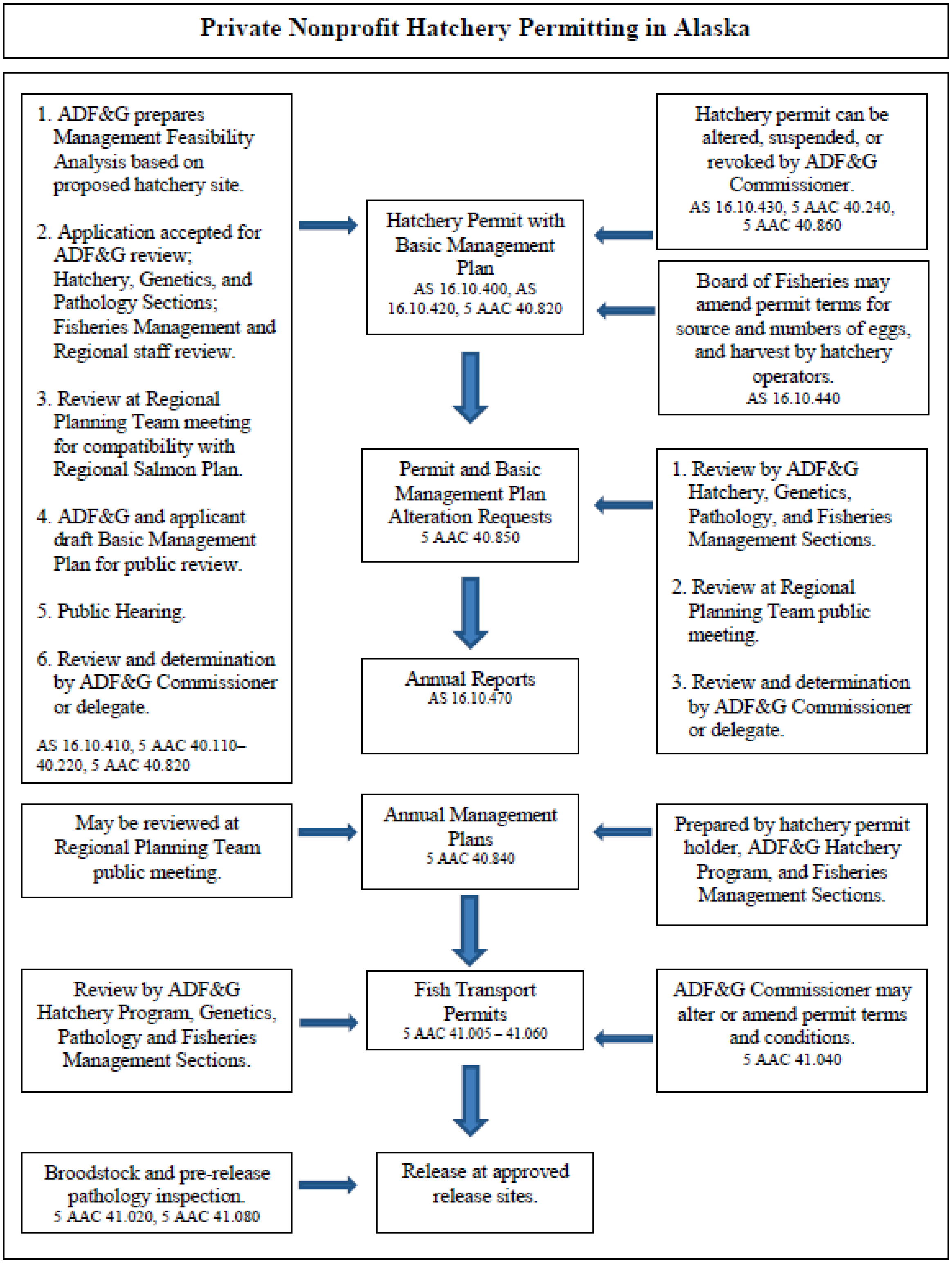

Figure 3.–Flowchart illustrating the regulation of Private Nonprofit hatcheries by ADF&G.

The application is then sent to the ADF&G commissioner for final review. By regulation (5 AAC 40.220) the commissioner's decision is based on consideration of the following: (1) the suitability of the site for making a reasonable contribution to the common property fishery, not adversely affecting management of wild stocks, and not requiring significant alterations of traditional fisheries; (2) the operation of the hatchery makes the best use of the site's potential to benefit the common property fishery; (3) the harvest area at the hatchery is sufficient in size to provide a segregated harvest of hatchery fish of acceptable quality for sale; (4) proposed donor sources can meet broodstock needs for the hatchery for the first cycle; (5) water sources for the hatchery are secured by permit and are of appropriate quality and quantity; and (6) the hatchery has a reasonable level of operational feasibility and an acceptable degree of potential success.

Hatchery permits cannot be transferred. When hatcheries change operators, a new permit must be issued by the process described above.

ADF&G Hatchery Oversight

There is a codified plan for oversight and regulation of the PNP hatcheries in Alaska that gives ADF&G complete authority over the program, and each hatchery is permitted separately. The PNP hatcheries operate under 4 documents required in regulation (5 AAC 40.110–990 and 5 AAC 41.005–100) and statute (AS 16.10.400 and AS 16.10.470): (1) hatchery permit with basic management plan (BMP), (2) annual management plan (AMP), (3) fish transport permit (FTP), and (4) annual report.

The hatchery permit authorizes operation of the hatchery and specifies the species permitted to be produced. The BMP, an addendum to the hatchery permit, specifies the maximum number of eggs of each species that a facility can incubate, the authorized release locations, and may identify stocks for broodstock. Hatchery permits remain in effect unless relinquished by the permit holder or revoked by the ADF&G commissioner. Hatchery permits and BMPs may be amended by the commissioner through a permit alteration request by the permit holder. Requested changes are reviewed by ADF&G staff, and by the RPT in public meetings, and recommendations are sent to the ADF&G commissioner for consideration.

The AMP outlines operations for the current year regarding production goals, broodstock development, and harvest management of hatchery returns and is cowritten by ADF&G and PNP hatchery staff. Typically, AMPs include the current year's egg-take goals, juvenile releases and remaining live fish inventory, expected adult returns, harvest management plans, FTPs (described below) required or in place, production strategies, and evaluation plans. The AMP must be consistent with the hatchery permit and BMP. Final approval of the plan is made by the ADF&G commissioner.

An FTP is required for egg collections, transports, and releases. The FTP authorizes specific activities described in the hatchery permit and management plans—including broodstock sources, gamete collections, and release sites—and must be consistent with the PNP permit and BMP. FTP applications are reviewed by the ADF&G fish pathologist, fish geneticist, regional resource development biologist, and other ADF&G staff as delegated by the ADF&G commissioner. Reviewers may suggest conditions for the FTP. Final consideration of the application is made by the ADF&G commissioner. An FTP is issued for a fixed time period. When an FTP is renewed or amended, the FTP application goes through the same process as the original FTP, providing an ongoing review of all PNP hatchery projects over time.

Each hatchery is required to submit an annual report documenting egg collections, juvenile releases, current year run sizes, contributions to fisheries, and projected run sizes for the following year. Information for all hatcheries is compiled into an annual ADF&G report to the Alaska Legislature as required by AS 16.05.092 (e.g., Stopha 2018).

The administration of hatchery permitting, planning, and reporting requires regular communication between ADF&G staff and hatchery operators. The serial documentation from hatchery permit/BMP to AMP to FTP to annual report necessarily spans generations of hatchery and ADF&G personnel, providing an important history of each hatchery's species cultured, stock lineages, releases, returns, and pathology.

CONSISTENCY WITH POLICY

The policies governing Alaska's enhancement programs were divided into 3 categories for this review: genetics, fish health, and fisheries management. The key elements of the policies in each of those categories are summarized in Table 1–3. These tables were used when constructing case studies of Southeast Alaska Chinook salmon and PWS pink salmon enhancement programs to provide examples of the application of the policy elements.

GENETIC POLICY

The State of Alaska ADF&G *Genetic Policy* (Davis et al. 1985; Davis and Burkett 1989) sets out restrictions and guidelines for stock transport, protection of wild stocks, and maintenance of genetic variance. Policy guidelines include (1) banning importation of salmonids from outside the state for enhancement (except U.S./Canada transboundary rivers); (2) restricting transportation of stocks between the major geographic areas in the state (Southeast, Kodiak Island, PWS, Cook Inlet, Alaska Peninsula,[2] Bristol Bay, Arctic-Yukon-Kuskokwim, and Interior); (3) requiring the use of local broodstocks and broodstocks with appropriate phenotypic characteristics; (4) maintaining genetic diversity among hatchery stocks by limiting the number of hatchery stocks derived from a single donor stock; and (5) maintaining genetic diversity within hatchery stocks by use of large broodstock sizes collected across the entire run.

The *Genetic Policy* also discusses the identification and protection of *significant and unique* wild stocks: "Significant or unique wild stocks must be identified on a regional and species basis so as to define sensitive and non-sensitive areas for movement of stocks." Davis and Burkett (1989) suggest that RPTs are an appropriate body to designate significant and unique stocks and this has been the practice of the ADF&G. It is important to note that although several *Genetic Policy* guidelines relate to hatchery stock effects on significant and unique wild stocks, there is nothing in statute or regulation authorizing or requiring the RPTs to designate them. To date, significant stocks have only been designated in the Cook Inlet Region (Cook Inlet Regional Planning Team 2007). The absence of significant stock designations elsewhere in the state adds uncertainty to the enhancement review process when applying standards set out in the *Genetic Policy*. In practice, if significant and unique stocks are not identified, the principal geneticist treats persistent spawning aggregates or groups of related spawning aggregates as significant stocks for implementation of the *Genetic Policy*.

Designation of stocks as significant or unique is interrelated with other restrictions and conditions of the *Genetic Policy*, including the following: (1) hatchery stocks cannot be introduced to sites

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[2] Alaska Peninsula is not specifically identified in the ADF&G *Genetic Policy*.

where the introduced stock may interact with, or impact on significant or unique wild stocks; (2) a watershed with a significant stock can only be stocked with progeny from the indigenous stocks; and (3) fish releases at sites where no interaction with, or impact on significant or unique stocks will occur, and which are not for the purposes of developing, rehabilitation of, or enhancement of a stock (e.g., releases for terminal harvest or in landlocked lakes) will not produce a detrimental genetic effect.

In addition, the *Genetic Policy* suggests that drainages be established as wild stock sanctuaries where no enhancement activity is permitted except for gamete removal for broodstock development. The wild stock sanctuaries were intended to preserve a variety of wild types for future broodstock development and outbreeding for enhancement programs. Davis and Burkett (1989) suggest that RPTs are an appropriate body to designate wild stock sanctuaries. To date, no wild stock sanctuaries have been designated.

Table 1 outlines the key elements of the *Genetic Policy* that are relevant to salmon hatcheries and enhancement.

Table 1.–Key elements of the ADF&G *Genetic Policy* by section.

I. Stock Transport	
Use of appropriate local stocks	The policy prohibits interstate (except for transboundary rivers) or inter-regional stock transports and uses transport distance and phenotypic characteristics as criteria for judging the acceptability of donor stocks within regions.
II. Protection of wild stocks	
Identification of significant or unique wild stocks	Significant or unique wild stocks must be identified on a regional and species basis so as to define sensitive and nonsensitive areas for movement of stocks. The RPTs should establish criteria for determining significant stocks and recommend such stock designations.
Interaction with or impact on significant wild stocks	Priority is given to protection of significant wild stocks from harmful interactions with introduced stocks. Stocks cannot be introduced to sites where they may interact or impact significant or unique wild stocks.
Stock rehabilitation and enhancement	A watershed with a significant wild stock can only be stocked with progeny from the indigenous stocks. The policy also specifies that no more than 1 generation of separation from the donor system to stocking of the progeny will be allowed.
Establishment of wild stock sanctuaries	Wild stock sanctuaries should be established on a regional and species basis. No enhancement activities would be allowed, but gamete removal would be permitted. The sanctuaries would serve as gene banks of wild type variability for broodstock development.
III. Maintenance of genetic variance	
Maximum of 3 hatchery stocks from a single donor stock	A maximum of 3 hatchery stocks can be derived from a single donor stock. Offsite releases, such as for terminal harvest, should not be restricted by this policy if the release sites are selected so that they do not impact significant wild stocks, wild stock sanctuaries, or other hatchery stocks.
Minimum effective population size	The policy recommends a minimum effective population (i.e., broodstock) size of 400 fish. It also recognizes that small population sizes may be unavoidable with Chinook salmon and steelhead.
Incorporating all segments of the run for establishing hatchery stocks	Egg takes should occur on a sliding scale representative of all segments of the donor stock.
Protecting wild stocks from removals for establishing hatchery stocks	To ensure all segments of the run have the opportunity to spawn, sliding egg take scales for donor stock transplants will not allocate more than 90% of any segment of the run for broodstock.
Implementation of Policy	
Genetic review of permits (5 AAC 40.190 and 5 AAC 41)	
Review by geneticist	Each application is reviewed by the geneticist, who then makes a recommendation to either approve or deny the application. The geneticist may also recommend terms or conditions to protect wild or hatchery stocks.

FISH HEALTH AND DISEASE POLICY

The *Alaska Fish Health and Disease Control Policy* (5 AAC 41.080) is designed to protect the health of wild and cultured fisheries resources through regulatory oversight of finfish/shellfish pathogens, and to develop disease policies and apply technical expertise to prevent, detect, and treat fish diseases in cultured situations or wild fish and shellfish in Alaska (Table 2). The policy and associated guidelines are discussed in *Policies and Guidelines for Alaska Fish and Shellfish Health and Disease Control* (Meyers 2014), which includes policy guidelines for fish transports, broodstock screening, disease histories, and transfers between hatcheries. Previous suggested regulation changes published in an earlier description of the Alaska hatchery program (Meyers 2010) have since been codified into state regulations in Title 5 of the Alaska Administrative Code[3] in February 2011. As with the *Genetic Policy* for geneticists, these regulations and guidelines are used by ADF&G fish pathologists to review hatchery plans and permits.

Table 2 outlines the key elements of these fish health and disease policies that are relevant to salmon hatcheries and enhancement.

Table 2.–Key elements of Alaska's policy and regulations pertaining to fish health and disease.

Fish Health and Disease Policy (5 AAC 41.080)	
Egg disinfection	Within 48 hours of taking and fertilizing live fish eggs or transporting live fish eggs between watersheds, all eggs must be treated with an iodine solution. This requirement may be waived for large scale pink and chum salmon facilities where such disinfection is not practical.
Hatchery inspections	According to AS 16.10.460, inspection of the hatchery facility by department inspectors shall be permitted by the permit holder at any time the hatchery is operating, and inspectors must have an American Fisheries Society/Fish Health Section (AFS/FHS) fish health specialist certification (AS 16.05.868). Inspections are every other year or longer depending on physical plant and fish health issues of each hatchery.
Disease reporting	The occurrence of fish diseases or pathogens listed in 5 AAC 41.080(d) must be immediately reported to the ADF&G Fish Pathology Section and, if necessary, may require the destruction of diseased fish to protect wild and other hatchery stocks.
Disease history	Applications for FTPs require all hatchery broodstocks to have either a complete disease history of the stock or a broodstock inspection and certification if the disease history is not available. Fish stock disease histories are maintained in a statewide database dating back to the 1980s and each stock disease history is updated every 3–4 years or sooner if warranted.
Isolation measures	Applications must list the isolation measures to be used during transport, including a description of containers, water source, depuration measures, and plans for disinfection.
Implementation of Policy	
Pathology review of permits (5 AAC 40.190 and 5AAC 41)	
Review by pathologist	Each application is reviewed by the pathologist, who then makes a recommendation to either approve or deny it. The pathologist may also recommend to the commissioner terms or conditions to the permit to protect fish health. Transports of fish between regions are discouraged.

[3] http://www.legis.state.ak.us/basis/folioproxy.asp?url=http://wwwjnu01.legis.state.ak.us/cgi-bin/folioisa.dll/aac/query=%5bJUMP:'Title5Chap41!2C+a!2E+3'%5d/doc/%7b@1%7d?firsthit

FISHERIES MANAGEMENT POLICIES

ADF&G manages mixed stock and mixed species fisheries where hatchery stocks can sometimes outnumber wild stocks. Consequently, stock identification programs are central to management success, which is gauged in terms of sustained yield of wild stocks. A fishery manager must balance (1) wild stock escapement requirements, (2) hatchery cost recovery and broodstock needs, and (3) an orderly common property harvest of the highest possible quality. Paramount to these is the requirement to sustain the long-term health and yield of the Alaska's wild stocks of salmon. These requirements are promulgated in several policies and regulations.

The *Alaska Policy for the Management of Sustainable Salmon Fisheries* (5 AAC 39.222) mandates protection of wild salmon stocks in the management of salmon fisheries. Other applicable policies include the *Policy for the Management of Mixed Stock Salmon Fisheries* (5 AAC 39.220), the *Salmon Escapement Goal Policy* (5 AAC 39.223), and local fishery management plans (5 AAC 39.200). These regulations require biologists to consider the interactions of wild and hatchery salmon stocks when reviewing hatchery management plans and permits. It is important to note that several of these policies overlap in prioritizing the protection of wild stocks from the potential effects of fisheries enhancement projects and do not specify or mandate how to assess those effects. These policies provide principles and priorities, but not specific direction, for decision making.

Table 3 outlines the key elements of these fishery management policies that are relevant to salmon hatcheries and enhancement.

Table 3.–Key elements of Alaska fisheries management policies and regulations relevant to salmon hatcheries and enhancement.

Mixed Stock Salmon Fishery Policy (5 AAC 39.220)	
Wild stock conservation priority	The conservation of wild stocks consistent with sustained yield is the highest priority in management of mixed stock fisheries.
Sustainable Salmon Fishery Policy (5 AAC 39.222)	
Management for sustained yield of wild stocks	Management for sustained yield requires the establishment of scientifically based wild stock escapement goals, appropriate stock assessment programs and management plans or strategies to achieve goals.
Harvest management plans	Management plans are developed to guide common property salmon fisheries inclusive of gear type, time and area. For hatcheries, AMPs are required for each PNP hatchery which outline the methods for broodstock collection, a plan for cost recovery, and a plan for utilization in common property fisheries.
Establishment of management objectives	Management objectives should be established in harvest management plans, strategies, guiding principles, and policies, such as for mixed stock fishery harvests, fish disease, genetics, and hatchery production, that are subject to periodic review.
Assessment of wild stock interaction and effects	As a management principle, the effects and interactions of introduced or enhanced salmon stocks on wild stocks should be assessed. Wild stocks should be protected from potential adverse impacts from artificial propagation and enhancement efforts.
Salmon Escapement Goal Policy (5 AAC 39.223)	
Establishment of escapement goals	Management of fisheries is based on scientifically-based escapement goals that result in sustainable harvests.
Implementation of Policy	
Fishery Management review of permits (5 AAC 40.190 and 5AAC 41)	
Review by management staff	All proposed FTPs are reviewed by the regional supervisors for the Divisions of Commercial Fisheries and Sport Fish, the deputy director of Commercial Fisheries, and the local Regional Resource Development Biologist before consideration by the commissioner of ADF&G. Department staff may recommend approval or denial of the permit, and recommend permit conditions.

CASE STUDY #1: SOUTHEAST ALASKA CHINOOK SALMON

PROGRAM OVERVIEW

Most of the state's Chinook salmon hatchery production occurs in Southeast Alaska (SEAK; Figure 4). Chinook salmon hatchery production was largely developed after the Pacific Salmon Treaty (PST) was signed in 1985. The PST included funding for Chinook salmon hatchery production in SEAK to mitigate harvest concessions made in the treaty. Chinook salmon, wild and enhanced, are targeted year-round by the commercial troll and sport fleets and are harvested in the summer months by the net fleets. Harvest of Alaska hatchery-produced Chinook salmon is incentivized, as most do not count towards the PST all-gear harvest limit. Eleven facilities are currently producing Chinook salmon, and 7 conducted egg takes in 2017 (Table 4). Combined, these 11 facilities produce over 7 million juveniles annually.[4] Of these 11 facilities, 2 are not PNP operated hatcheries—Tamgas Creek Hatchery is operated by the Metlakatla Indian Community and Little Port Walter facility is operated by National Oceanic and Atmospheric Administration (NOAA); as neither are PNPs, they are not subject to PNP statutes and regulations. Crystal Lake Hatchery located in Petersburg is a Sport Fish hatchery with operations contracted out to a PNP (Southern Southeast Regional Aquaculture Association).

From 1990 to 2017, the cumulative contribution of the SEAK hatchery program to the all-gear harvest was 1.8 million Chinook salmon, accounting for 20% of the total harvest of Chinook salmon on average. For the same time period, SEAK hatchery fish contributed on average 24,500 fish annually (range: 8,600–38,400) to troll fisheries, accounting for 12% (range: 5–27%) of the total Chinook salmon harvest (Randy Peterson and John Carlile, ADF&G, pers. comm.). In the net fisheries, SEAK hatchery fish have contributed an average of 22,140 fish annually (range: 8,700–39,700), accounting for 52% (range: 19–80%) of the Chinook salmon harvest. Southeast Alaska hatchery fish have contributed an average of 17,900 Chinook salmon to the sport fishery (range: 8,300–30,900) accounting for 28% of the harvest (range: 15–43%).

Juvenile Chinook salmon are generally reared for over a year at the hatchery and released as smolt during May of their second rearing year and are commonly referred to as yearlings or *one checks*. Some hatcheries have experimented with subyearling or *zero-check* releases which are released in late June to mid-July of the first rearing year. Subyearling releases are less space consumptive, less labor intensive, and more cost effective to produce, but often have lower survival to adulthood. Releases are generally in saltwater and occur either at the hatchery or in remote inlets and bays. In recent years, hatcheries have been experimenting with staggering releases in time and space in an attempt to minimize predation by burgeoning marine mammal populations (Hendrix et al. 2012).

[4] For details on specific hatcheries see Stopha 2014, 2015a, 2015b, 2015c, 2016a, 2016b, and 2017.

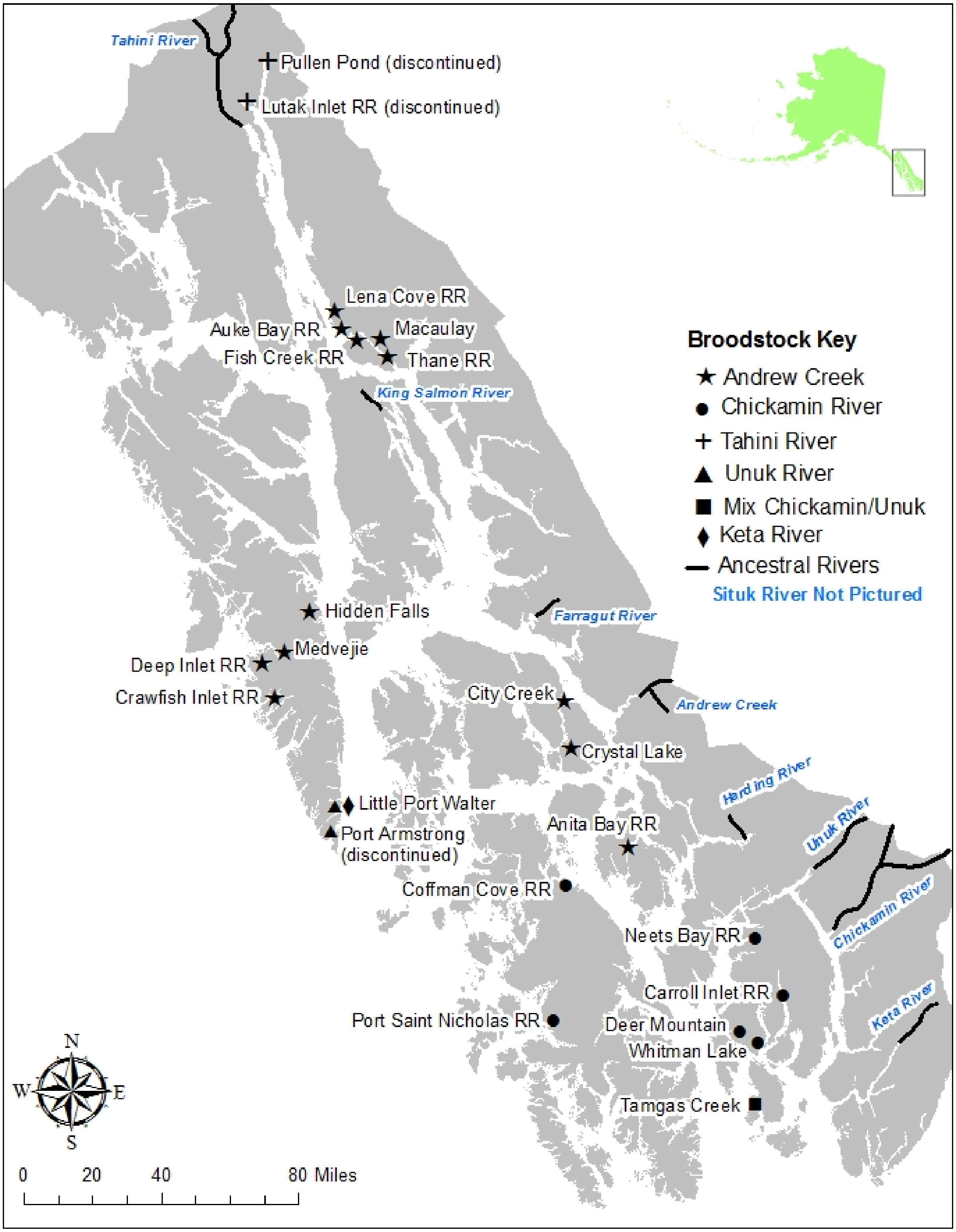

Figure 4.–Southeast Alaska Chinook salmon hatcheries, remote release sites (RR), and ancestral broodstock sources.

Table 4.–Southeast Alaska Chinook salmon permitted eggs and 2017 juvenile releases in millions by hatchery.

Operator	Hatchery	Permitted eggs	2017 release	# of release sites
Southern Southeast Regional Aquaculture Association	Crystal Lake[a]	4.00	1.12	4
	Neets Bay[b]	2.00	0.73	1
	Whitman Lake	2.10	0.91	2
	Deer Mountain[b]	0.60	0.07	1
	Port St Nicholas[c]	0.77	0.09	1
Northern Southeast Regional Aquaculture Association.	Hidden Falls	3.80	0.55	1
	Medvejie Creek	5.20	2.51	3
Armstrong-Keta, Inc.	Port Armstrong	2.00	0.00	1
Douglas Island Pink and Chum	Macaulay	1.25	0.89	7
National Marine Fisheries Service	Little Port Walter[d]		0.11	1
Metlakatla Indian Community	Tamgas Creek[e]		NA	2
Total		21.72	7.0	23

Source: Stopha 2018.

[a] Not a PNP permitted hatchery. Crystal Lake Hatchery egg takes and releases are regulated by ADF&G Division of Sport Fish.

[b] Egg take no longer occurs at Neets Bay or Deer Mountain hatcheries; eggs or fry are transferred from Whitman Lake Hatchery.

[c] No egg take occurs at Port Saint Nicholas; eggs or fry are transferred from Whitman Lake Hatchery.

[d] Little Port Walter is a federal NOAA research facility whose production is regulated through an ADF&G aquatic resource permit.

[e] Tamgas Creek is operated by Metlakatla Indian Community and is not regulated by ADF&G.

Regional Comprehensive Salmon Plan

Three phases of Regional Comprehensive Salmon Plans (CSP) have been developed to date in SEAK. Phase I[5] set goals for salmon production in SEAK. The Phase II CSP provided planning to achieve the goals of the Phase I CSP. The Phase III CSP (Duckett et al. 2010) focused on integrating hatchery production increases with natural production to sustainably manage fisheries.

The long-range (year 2000) harvest objectives for the Phase I CSP were to increase the harvest in SEAK by 537,000 Chinook, 2.1 million sockeye, 2.65 million coho (*O. kisutch*), 30.0 million pink, and 9.7 million chum salmon. After considering current Chinook salmon hatchery production and harvest increases associated with better management, it was determined that hatchery harvest would need to increase by 134,000 to meet the long-range goals.

Phase II CSP planning identified projects and plans to meet the Phase I harvest objectives, and the RPTs for Northern and Southern SEAK developed separate plans. The Northern SEAK CSP Phase II was issued in 1981[6] and the Southern SEAK CSP Phase II was issued in 1983.[7] Subsequent Phase II CSP plan updates were issued yearly through 1996 for Southern SEAK and yearly from

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[5] Joint Southeast Alaska regional planning teams. 1981. Comprehensive salmon enhancement plan for Southeast Alaska: Phase I. Unpublished document obtained from Lorraine Vercessi, ADF&G PNP coordinator, Juneau.

[6] Northern Southeast Regional Planning Team. 1981. Comprehensive Salmon Plan, Phase II: Northern Southeast Alaska. Unpublished document obtained from Lorraine Vercessi, ADF&G PNP hatchery coordinator, Juneau.

[7] Comprehensive Salmon Plan, Phase II: Southern Southeast Alaska, by the SSERPT. September 1983. Unpublished document obtained from Lorraine Vercessi, ADF&G PNP hatchery coordinator, Juneau.

1986 through 1996 for Northern SEAK. In the initial Phase II CSP, hatchery opportunities were prioritized from A (high priority) to B (medium priority) to C (lower priority). Priorities were based on such things as feasibility, wild stock management concerns, and potential for harvest in the commercial fisheries.

With the maturation of the enhancement program, the harvest target objectives and programs in the Phase I and Phase II CSPs were replaced in the Phase III CSP with objectives that supported an overriding goal to enhance the salmon fishery while minimizing the impact of enhancement on wild stocks (Duckett et al. 2010). These new objectives included (1) minimizing the impact of hatchery stocks on wild stocks, (2) maintaining existing production potential for wild and enhanced stocks, (3) assuring that increases in hatchery production are consistent with regionwide goals and allocation plans, and (4) updating the RPT process periodically to provide status reports and recommendations in a timely manner.

The Phase III CSP provided *best practice* guidelines for enhancement planning to provide a systematic approach to project formulation and the decision-making process. Guidelines were developed for fishery supplementation, wild stock supplementation, and colonization. Four standards are to be documented in developing a fishery supplementation project: (1) the release site has an adequate freshwater supply for imprinting and is not in close proximity to significant wild stocks, (2) fish are adequately imprinted to the release site, (3) releases are marked and contribute to the harvest without jeopardizing the sustainability of wild stocks, and (4) the terminal area enables harvest or containment of all returning adults. These standards were to meet the *Policy for the Management of Sustainable Salmon Fisheries* (5 AAC 39.222) developed by the Alaska Board of Fisheries and ADF&G.

The Phase III CSP provided a stock appraisal tool for assessing the *significance* of stocks for assessment of projects with regard to the significant stock references in the *Genetic Policy* (Davis et al. 1985). The Phase III CSP states that *significance* is more complex than a simple production number because some of the region's most viable fisheries depend on aggregates of wild stocks, each of which is not very large.

The Phase III CSP also provided a framework for assessment of new projects:

> *All projects will have an approved evaluation plan to assess impacts and measure success. This plan will describe how the project benefits will be measured and include a method for detecting negative or unintended impacts. An evaluation plan includes (A) fish identification (marking) method to be used; (B) mark–recovery plan for common property and terminal site harvests; (C) identification of potential ecological and genetic impacts that might warrant evaluation, a strategy to detect them, and criteria to determine when measured impacts would warrant project modification; (D) a description of how impacts to fishery management will be evaluated; and (E) a plan for dispersing information about the project.*

Chinook Salmon Plan for Southeast Alaska

The Chinook Planning Team was established under the direction of the ADF&G commissioner to address Chinook salmon enhancement in SEAK from a regional stock rebuilding perspective. The team's members represent Chinook salmon producers and ADF&G staff. The Chinook Planning Team developed the *Chinook Salmon Plan for Southeast Alaska* (Holland et al. 1983) as an annex to the *Comprehensive Salmon Plan for Southeast Alaska, Phase I.*[8] This annex was updated annually through 2005 (e.g., Farrington et al. 2004; Pryor et al. 2009) and serves as a comprehensive source of historic information on enhanced Chinook salmon production and harvest in SEAK.

Once the PST was signed in 1985, annual harvest limits were imposed on the Alaska harvest of "treaty" fish, defined as any Chinook salmon *not* of Alaska hatchery-origin and originating from areas within the geographic scope of the PST (i.e., from Cape Suckling in northern SEAK to Cape Falcon in Oregon). Alaska hatchery Chinook salmon production is exempt from the PST harvest limits, except for a preexisting level of 5,000 fish and a "risk adjustment" penalty for not marking 100% of the hatchery production and not sampling 100% of the harvest. The risk adjustment averages 2,500 fish annually (John Carlile, ADF&G, pers. comm.). Therefore, hatchery production that can be harvested in discrete areas where the interception rate of non-Alaska and wild Alaska fish is low has become important to the fishing industry, particularly to the troll and recreational fleets. Thus, in 1985 significant changes in hatchery production occurred due to the PST. From 1986 to 1992, $20 million of funding was made available for fishery enhancement projects to mitigate the harvest restrictions imposed on SEAK fishers by the Treaty agreement. Enhancement from PST mitigation funds initially focused on hatchery production of Chinook salmon.[9]

The compilation of data in each annex of the *Chinook Salmon Plan for Southeast Alaska* assisted Chinook salmon producers and managers with plans to maximize benefits to Alaskan user groups while staying within the annual harvest limit of the PST. Each annex describes actions taken to implement the policies and achieve the goals described in the *Chinook Salmon Plan for Southeast Alaska*. Annexes also contain broodstock allocation plans and recommendations for the current year, and summarize current issues in Chinook salmon enhancement discussed at the Chinook Planning Team meeting each spring.

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[8] Joint Southeast Alaska regional planning teams. 1981. Comprehensive salmon enhancement plan for Southeast Alaska: Phase I. Unpublished document obtained from Lorraine Vercessi, ADF&G PNP hatchery coordinator, Juneau.

[9] Comprehensive Salmon Plan for Phase II: Northern Southeast Alaska: Northern Southeast Regional Planning Team, revised January 1986. Unpublished document obtained from Lorraine Vercessi, ADF&G PNP hatchery coordinator, Juneau.

PROGRAM CONSISTENCY WITH STATE POLICIES

For this case study, the alignment of the SEAK Chinook salmon enhancement program with the relevant policy elements is provided in Tables 5–7. Criteria used to assess each policy element are provided in Tables 1–3.

Table 5.–A summary review of the current Chinook salmon fisheries enhancement program in Southeast Alaska and its consistency with elements of the ADF&G *Genetic Policy*. (See Table 1.)

I. Stock Transport	
Use of appropriate local stocks	All Chinook salmon broodstock has been locally sourced from SEAK. In nonsensitive zones more distant stocks were utilized, which was appropriate given the anticipated lack of interaction with or impact on wild populations.
II. Protection of wild stocks	
Identification of significant or unique wild stocks	Significant or unique stocks were considered, but none were specifically identified in the comprehensive salmon plans by the RPT. However, a stock appraisal tool has been developed to address this element of the policy. In practice, all persistent wild spawning aggregates are considered significant stocks.
Interaction with or impact on significant wild stocks	Stocks were introduced to sites where it was anticipated that they would not interact with, or impact on, significant or unique wild stocks.
A. Interaction[10]	Variable hatchery proportions were found in several wild streams. In the most recent study, overall hatchery proportions in fish examined in 10 Chinook salmon drainages was 0.5%. It is unlikely that the straying hatchery fish are introgressing genes in most streams, given the hatchery proportions observed and the deep population structure of Chinook salmon in SEAK. However, in the Farragut River, where hatchery proportions observed were 11%, further evaluation is warranted to better assess hatchery proportions (the hatchery proportion is based on the observation of 10 tags) and potential genetic interaction.
B. Impact	Because impact cannot occur without introgression, it is likely that populations in most streams are not experiencing impact. However, in the Farragut River, further evaluation may be warranted.
Stock rehabilitation and enhancement	No watersheds with significant wild stocks are stocked with non-indigenous stocks.
Establishment of wild stock sanctuaries	No specific wild stock sanctuaries are designated within SEAK. However, the Chinook Salmon Plan delineates a *sensitive* and *nonsensitive* zone for stock selection and transport considerations based on whether wild spawning populations are present. Additionally, some areas are inherently wild stock sanctuaries owing to land status (i.e., National Park).

-continued-

[10] For the purposes of this assessment, in areas where significant stocks have not been identified, persistent wild spawning aggregates or groups of related spawning aggregates are considered significant stocks.

Table 5.–Page 2 of 2.

III. Maintenance of genetic variance	
Maximum of 3 hatchery stocks from a single donor stock	Andrew Creek is being used as the donor stock for 4 hatcheries; this is currently being addressed via the development of a new broodstock from Keta River.
Minimum effective population size for establishing and maintaining hatchery stocks	Establishing broodstocks within hatcheries with adequate genetic variance has been challenging for Chinook salmon in SEAK because of relatively very low wild stock size as contrasted with other species. This challenge was anticipated, and the authors of the *Genetic Policy* acknowledged that sometimes this guideline may not be obtainable in some Chinook salmon enhancement operations and provided for exceptions. Despite this, development of some broodstocks approach or exceed this guideline, and 1 stock (Chickamin) was intentionally limited for experimental purposes. Once hatchery stocks are established within hatcheries, all Chinook salmon hatcheries in SEAK maintain effective population sizes of 400 fish.
Incorporating all segments of the run for establishing hatchery stocks	Donor gametes are collected during peak spawn timing of the run. Chinook salmon may have a protracted freshwater entry timing but tend to have a narrow window for spawning within streams such that all segments of the run are believed to spawn concurrently.
Protecting wild stocks from removals for establishing hatchery stocks	No more than 90% of any segment of the run was used to establish any of the hatchery broodstocks. To achieve minimum effective population sizes for hatchery stocks while protecting wild stocks, multiyear broodstock collections were needed.
Implementation of Policy	
Genetic review of permits (5 AAC 40.190 and 5AAC 41)	
Review by geneticist	All applications for permits and plans are reviewed by the geneticist.

Table 6.–A summary review of the current Chinook salmon fisheries enhancement program in Southeast Alaska and its consistency with elements of the *Alaska Fish Health and Disease Control Policy*. (See Table 2.)

Fish Health and Disease Policy (5 AAC 41.080; amended by Meyers 2014)	
Egg disinfection	Eggs are disinfected as necessary according to ADF&G regulations and guidelines.
Hatchery inspections	Hatchery inspections were conducted regularly from at least 1987 to present, with some dating back to the late 1970s.
Disease reporting	There are no significant disease issues at the hatcheries. Reports from the ADF&G pathology lab indicate that diseased fish have been sent to the state lab as necessary for diagnoses.
Pathology requirements for FTPs (5 AAC 41.010)	
Disease history	Samples were submitted to the pathology lab as necessary for disease history.
Isolation measures	Isolation measures to control for disease are described in the FTPs.
Implementation of Policy	
Pathology review of permits (5 AAC 40.190 and 5AAC 41)	
Review by pathologist	All proposed plans and permits were reviewed by the pathologist.

Table 7.–A summary review of the current Chinook salmon fisheries enhancement program in Southeast Alaska and its consistency with elements of Alaska fisheries management policies and regulations relevant to salmon hatcheries and enhancement. (See Table 3.)

Mixed Stock Salmon Fishery Policy (5 AAC 39.220)	
Wild stock conservation priority	Chinook salmon escapement is monitored annually, and most escapement goals have been met except in recent years. Beginning in 2007, there has been a regionwide decline in productivity affecting both wild and hatchery-origin stocks.
Sustainable Salmon Fishery Policy (5 AAC 39.222)	
Management for sustained yield	Escapements are monitored for 11 SEAK wild stocks and mostly expressed in terms of large fish (>28 inches).
Harvest management plans	The fishery is managed for PST obligations and under Board of Fisheries approved management plans. Additionally, AMPs are submitted annually for each PNP hatchery and outline the methods for broodstock collection and a plan for cost recovery and common property fisheries.
Establishment of management objectives	Objectives are established in all fishery management plans, hatchery permits, and hatchery AMPs.
Assessment of wild stock interaction and effects	A range of approximately 8% to 12% of PNP hatchery releases are marked and coded-wire-tagged. Four of 34 known wild stocks are coded-wire-tagged.
A. Fishery	The commercial and sport fisheries are sampled at a rate of ≥20%. The sampling rates produce estimates with accompanying measures of uncertainty. The Alaska hatchery contribution to the fisheries is assessed inseason and the estimates are used to calculate the hatchery add-on provision of the PST.
B. Escapement	Spawning grounds for 11 of the 34 wild Chinook salmon producing streams are annually sampled. For most of the 11 streams, only a few hatchery-origin coded wire tags have been recovered in freshwater.
Salmon Escapement Goal Policy (5 AAC 39.223)	
Establishment of escapement goals	ADF&G has established biological escapement goals for 11 of 34 stocks in SEAK that account for approximately 85% of the total production. The escapement goals are regularly reviewed and updated.
Implementation of Policy	
Fisheries management review of permits (5 AAC 40.190 and 5AAC 41)	
Review by management staff	All proposed plans and permits are reviewed by appropriate management staff.

Genetic Policy

Stock transport

Southeast Alaska hatchery sites, remote release sites, and broodstock sources were carefully selected to minimize the potential for returning hatchery stocks to mix with wild stocks (Holland et al. 1983; Farrington et al. 2004). All Chinook salmon broodstock has been locally sourced from SEAK. With few exceptions, Chinook salmon hatcheries are located on islands at or near tidewater and away from any endemic stock (Heard et al. 1995; Heard 1996; Figure 4). The Chinook Salmon Plan delineates a *sensitive* and *nonsensitive* zone for stock selection and transport considerations based on the potential to affect wild stocks (Figure 5; Holland et al. 1983). Sensitive zones contain wild spawning populations, whereas nonsensitive zones do not. In nonsensitive zones, more distant stocks were used; this was appropriate given the anticipated lack of interaction with or impact on wild populations. Within the sensitive zone, movement of Chinook salmon stocks is limited, and enhancement stock needs must be met with the closest feasible stock. In the nonsensitive zone, enhancement stock needs may be met by any stock in the region approved through the ADF&G review process.

Protection of wild stocks

In response to the *Genetic Policy* element regarding designation of significant stocks (Section II A), the Chinook Plan Team developed a *Stock Appraisal Tool* to identify criteria to be used by the RPTs and ADF&G biologists when evaluating the significance of a wild stock that may potentially interact with a hatchery release. The Stock Appraisal Tool attempts to inject as much objectivity as possible in determining the significance of a potentially impacted stock. In this context, significance is defined as “the importance of a stock in maintaining the overall viability and sustainability of the wild salmon resource as well as the importance of the stock in meeting fishery needs” (Duckett et al. 2010). The Stock Appraisal Tool is modeled after one developed by the HSRG for use in the Pacific Northwest (HSRG 2002). The tool identified the 6 characteristics of consideration: wildness, uniqueness, isolation, population size, population trend, and the stock’s economic and/or cultural significance. Essentially, this tool splits viability into population size and population trend and adds a criterion that addresses the human use pattern.

Significant or unique stocks were considered, but none were specifically identified in the comprehensive salmon plans by the RPT. However, the Stock Appraisal Tool is used each time a permit application comes up for review to evaluate risk to nearby stocks. In practice, when applying the *Genetic Policy*, all persistent wild spawning aggregates are considered significant stocks.

No specific wild stock sanctuaries are designated within SEAK. However, the sensitive zone identified in the Chinook Salmon Plan was delineated based on the presence or absence of wild spawning populations. Additionally, the National Park Service and U.S. Forest Service prohibit enhancement activities in lands/drainages classified as *wilderness*, therefore the Southeast RPT considered this land designation a *de facto* sanctuary (Ducket et al. 2010).

Several studies have documented variable hatchery proportions in wild systems. Hard and Heard (1999) examined hatchery straying from fish produced at the Little Port Walter facility from adult recoveries at 25 locations in Alaska and British Columbia between 1981 and 1989. Of the over 22,000 Little Port Walter-origin fish recovered, 98.8% were collected at Little Port Walter. Of 264 fish recovered elsewhere, 64.4% were within 25 km of the facility. No Little Port Walter-origin fish were recovered from the ancestral rivers, but 9 fish were recovered from rivers supporting wild Chinook salmon.

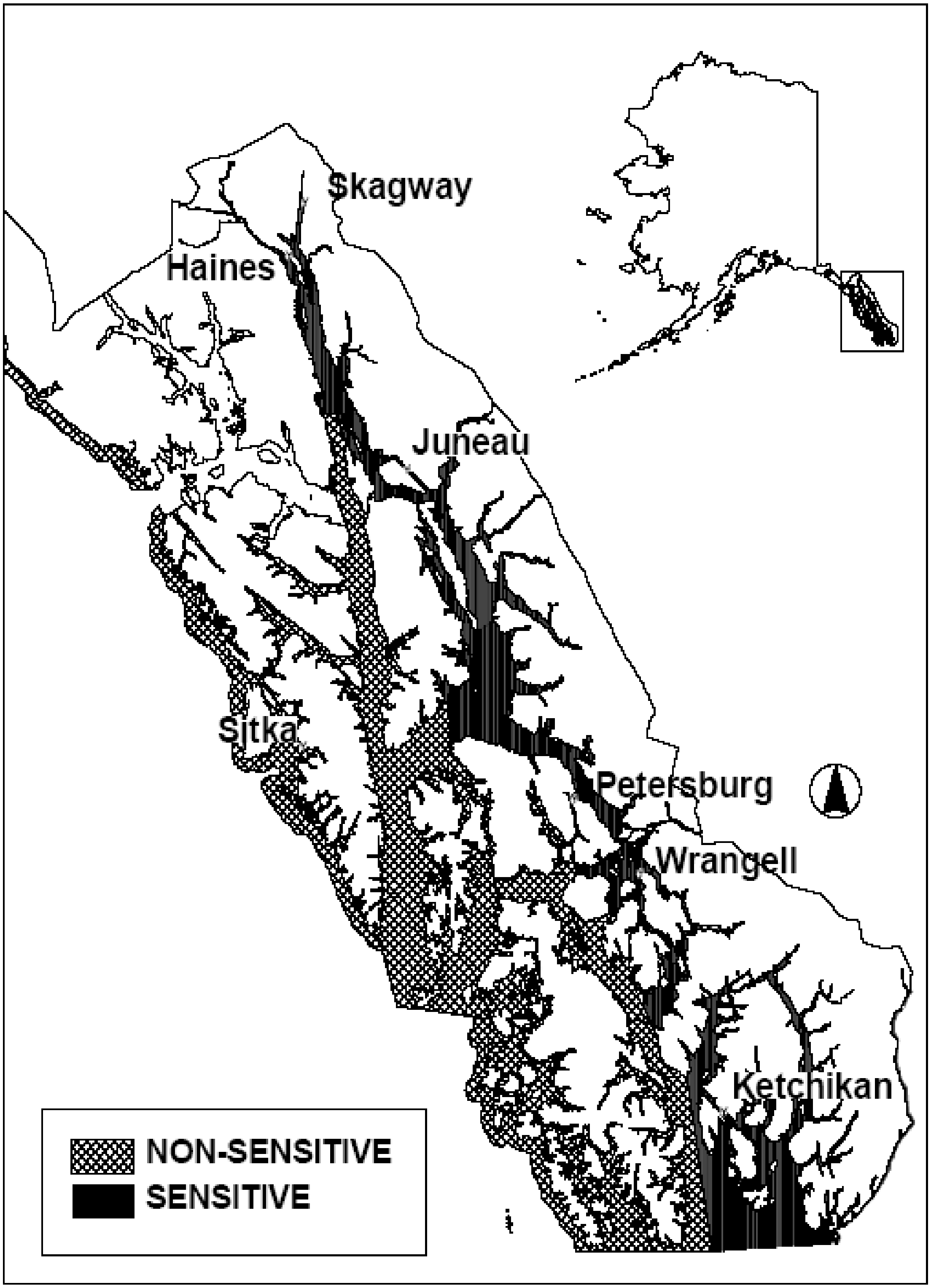

Figure 5.–Chinook salmon sensitive and nonsensitive areas in Southeast Alaska.

Following up on previous work (Heard et al. 1995), Heard (2011) summarized the incidence of hatchery strays in 10 wild stock rivers in SEAK from 1983 to 2007. Out of the 180,260 fish examined, only 493 were determined to be hatchery fish from coded wire tag expansions[11] for an overall contribution of 0.3%. Hatchery proportions were generally under 1% across all rivers and years with the exception of the Farragut River where the portion of spawners that were hatchery strays was 8.5% over the 8 years (1983–1985; 1989; 1991–1993, 2007) for which data were available.

More recent data are available through the ADF&G Mark, Tag, and Age Laboratory database (Table 8; https://mtalab.adfg.alaska.gov/). These data, which do not include all the early years from Heard (2011), indicate that overall hatchery proportions in examined fish in more recent years was 0.5%. Most rivers have had average stray fractions less than 2.0% in examined fish, with several less than 0.5%. The exceptions were Andrew Creek (4.3%), Blossom River (2.7%), and Chilkat River (2.1%). Recent data have not been collected for the Farragut River; for the 3 years of data in the database, 10 tags were recovered which yielded an estimate of 14 hatchery fish that represented 10.8% of the sampled fish. Most strays into Andrew Creek during that time period were from releases of Andrew Creek stock at Earl West Cove; releases at this site, which is approximately 32 km from the mouth of the Stikine River, have been moved to Neets Bay as of 2001 (Farrington et al. 2004). The change in release site of Andrew Creek stock in 2001 reduced the number of strays into Andrew Creek; only 2 hatchery coded wire tags have been recovered over the years that sampling has occurred since that time (2004, 2005, 2007, 2008, 2010, 2015, and 2016) resulting in a 1.3% average hatchery-origin proportion.

Table 8.–Incidence of hatchery strays in 10 wild stock streams in Southeast Alaska.

System	Years Examined	Total No. Years	Number Examined	Hatchery Tags	Hatchery Fish	% Hatchery
Blossom R.	1998–2008, 2012	12	1,758	5	48	2.72%
Chickamin R.	1987–1990, 1995–1996, 1999–2014, 2016	22	12,783	21	221	1.73%
Chilkat R.	1989–2001, 2006–2007, 2009–2018	25	6,872	139	144	2.09%
Farragut R.	1993, 2007–2008	3	125	10	14	10.80%
Keta R.	1998–2000, 2002–2003, 2005–2009, 2012, 2014, 2016	13	2,409	2	44	1.83%
King Salmon R.	2000, 2004–2005, 2007–2008	5	219	1	1	0.46%
Taku R.	1984–1986, 1988, 1990, 1994–2018	30	78,132	9	36	0.05%
Unuk R.	1986, 1988–1990, 1992–2017	30	27,211	18	101	0.37%
Stikine R. [a]	1984, 1995–1996, 2000–2008, 2010–2016, 2018	20	23,225	1	1	0.00%
Andrew Cr.	1997–2005, 2007–2008, 2010, 2015, 2016	14	3,342	15	144	4.32%
Total			156,076	221	754	0.48%

Source: https://mtalab.adfg.alaska.gov/.
[a] Excludes Andrew Creek.

[11] Coded-wire tag recoveries are expanded based on the proportion tagged of the total release group at the hatchery.

Information from wild stock tagging programs in SEAK provide some context for the observed hatchery-to-wild stray proportions. Smolt from 4 wild stock rivers (Chilkat, Taku, Stikine and Unuk rivers) were externally marked with an adipose fin clip and were coded-wire-tagged. Carcass recovery efforts in 2 of these rivers documented straying between wild rivers. In the Taku River, 4 out of 606 tags (0.7%) recovered over the period 1994 through 2013 were wild strays (Ed Jones, ADF&G, pers. comm.). Likewise, 8 out of 872 tags (0.9%) recovered from the Unuk River between 1996 and 2014 were wild strays (Phillip Richards, ADF&G, pers comm.). It is difficult to compare stray rates for the various wild and hatchery Chinook salmon in SEAK since not all are coded-wire-tagged, and marked fractions vary.

Genetic interaction of hatchery fish with wild fish occurs when hatchery-origin fish spawn with wild fish, introgressing genes into wild populations. Thus, straying is a prerequisite for genetic interaction and can act as an initial measure of its potential to occur. Genetic impact of hatchery fish on wild fish occurs when hatchery-origin fish introgress genes that impact wild populations. These impacts include effects on fitness within wild populations and effects on genetic variation among wild populations. The potential for genetic introgression and impacts is tied to population structure of the species within the geographic area of interest.

Population structure of Chinook salmon throughout the species range is intermediate relative to other Pacific salmon species (Utter et al. 1989; Beacham et al. 2006a, 2006b, 2009; Templin et al. 2011). The geographic expanse of SEAK, along with the discontinuous distribution of Chinook salmon spawning areas and variation in Chinook salmon life histories throughout SEAK (Halupka et al. 2000), has resulted in large genetic distances among wild populations (Gharrett et al. 1987; Guthrie and Wilmot 2004). This deeper structure is thought to stem from lower natural straying among spawning aggregates (Keefer and Caudill 2014) leading to smaller genetic interaction among wild populations than is found in other Pacific salmon species such as pink and chum salmon. This deeper population structure, driven by life history differences, provides larger barriers to introgression (Bugert et al. 1995, reviewed in Utter 2001), with the associated risk that introgression will more likely lead to larger reductions in genetic variation among populations (e.g., Hess et al. 2011). Although interaction is inherently difficult to demonstrate, given the hatchery proportions observed in most streams and the deep population structure of Chinook salmon in SEAK, there is no clear evidence of genetic interaction. The effect of straying and introgression on fitness is not straightforward or predictable (reviewed in McClelland and Naish 2007).

Maintenance of genetic variance

Donor sources currently in use at PNPs and the Little Port Walter facility include Andrew Creek, Chickamin River, Unuk River, and most recently, the Keta River. Andrew Creek is currently being used as the broodstock source for 4 hatcheries: Crystal Lake, Macaulay, Medvejie Creek, and Hidden Falls. This exceeds the *Genetic Policy* guideline of use of 1 stock at no more than 3 hatcheries. However, in 2019, Hidden Falls Hatchery will begin replacing Andrew Creek stock production with Keta River stock production, if surplus eggs are available from the Little Port Walter facility. This will bring the SEAK Chinook salmon enhancement program back into alignment with the maintenance of genetic variance elements of the policy. Production from other donor stocks have previously been attempted (e.g., Situk, Tahini [a tributary of the Chilkat River], Farragut, Harding, and King Salmon rivers stocks), but with limited success.

The SEAK Chinook salmon enhancement program sheds a spotlight on the need to further consider the *Genetic Policy*'s element restricting the use of a single stock to 3 hatcheries. This element was designed to build stock diversity into the hatchery system (Davis et. al 1989) to provide resilience for the collective hatchery program by establishing hatcheries with stocks that respond differently to disease and environmental conditions. However, the 3-hatchery restriction may not be the best metric to ensure the intent of the *Genetic Policy*. For example, more than 3 small hatcheries (using same broodstock) that account for a small proportion of the hatchery production within a region may be more in line with the objectives of the *Genetic Policy* than 3 or fewer large hatcheries (using the same broodstock) that produce a large proportion of the hatchery production within a region. This is one policy element that should be revisited to ensure that it is accomplishing the intent of the *Genetic Policy*.

Establishing broodstocks with adequate genetic variance within hatcheries has been challenging for Chinook salmon in SEAK because of the low wild stock size relative to other species. This challenge was anticipated, and the authors of the *Genetic Policy* acknowledged that this guideline may not be attainable in some Chinook salmon enhancement operations and provided for exceptions. Despite this challenge, development of some of the Chinook salmon broodstocks approach or exceed this guideline, and 1 stock (Chickamin) was intentionally limited for experimental purposes.

For all stocks, donor gametes were collected during peak spawn timing of the run. Chinook salmon may have a protracted freshwater entry timing but tend to have a narrow window for spawning within streams such that all segments of the run are believed to spawn concurrently. In no cases were more than 90% of any segment of the run used to establish any of the hatchery broodstocks. Multiyear broodstock collections were needed to achieve minimum effective population sizes for hatchery stocks while protecting wild stocks.

Andrew Creek Chinook salmon brood stock was developed at Crystal Lake Hatchery. Broodstock were collected over a period of 7 years (1976–1979, 1980–1983; Table 6 in Templin 2001) from a weir on the creek that was operated during July and August. Broodstock were taken on a schedule to match run timing as closely as practical. A total of 321 males and 433 females were taken over these 7 years that made up the founding hatchery broodstock, exceeding the ideal minimum effective population size guidelines in the *Genetic Policy* (400 fish).

Chickamin River broodstock was established as an experimental population at Little Port Walter facility from 6 females and 3 males in 1976 and from 5 females and 14 males in 1996 (Joyce et al. 2004). This stock was subsequently produced at Whitman Lake Hatchery. The effective population size (23 fish calculated as summed effective population sizes across years) for this stock departs markedly from the guidelines in the *Genetic Policy*.

Unuk River Chinook salmon brood stock were developed at Little Port Walter facility. Broodstock were collected over 6 years (1976–1981; Table 10b in Templin 2001). A total of 119 males and 128 females were taken over these 6 years that made up the founding hatchery broodstock. In 1998, gametes from an additional 9 males and 9 females were collected from the Unuk River and incorporated into this broodstock at the Little Port Walter facility. Within years, the ratio of males to females was fairly consistent. As a result, although this stock does not meet the guidelines for effective population size within the *Genetic Policy*, it represents reasonable founding numbers.

Keta River Chinook salmon brood stock is being developed at Little Port Walter facility. Broodstock have been collected over 5 years so far (2014–2018; Andy Gray, NOAA Fisheries, pers. Comm.). A total of 147 males and 74 females were taken over these 5 years that made up the founding hatchery broodstock. Within years, the ratio of males to females was fairly consistent. As a result, the effective population size for this stock is 154 fish (summed effective population sizes across years). Although this stock does not meet the guidelines for effective population size within the *Genetic Policy,* it represents reasonable founding numbers and additional donor stock collection is planned.

When considering the potential effects of the number of founders used and the potential divergence of hatchery broodstocks and their progenitor wild stock, the research facility at Little Port Walter provides a unique opportunity. For many years this facility handled 2 separate broodstocks (Chickamin and Unuk) with very different development histories, allowing comparison of hatchery stocks with progenitor wild salmon populations to evaluate differences in performance and life-history characteristics in common-garden experiments (e.g., Rodgveller et al. 2005). Research into domestication of these hatchery Chinook salmon stocks began in 1996 and results indicate the following differences: (1) maturation timing for females for both stocks, (2) fecundity for Chickamin, and (3) egg size for Chickamin (Joyce et al. 2004). These differences could be attributed to both the number of spawners used to establish the broodstocks and genetic changes associated with different selection regimes at the research facility and in the wild. The stock developed on the smallest number of founders (n = 28; Chickamin) appears to have diverged more than the stock developed with more founders (n = 247; Unuk). These findings are in line with findings from other researchers conducted outside Alaska on species with long hatchery residence life histories (reviewed by Christie et al. 2014).

Once broodstocks are established within hatcheries, all Chinook salmon hatcheries in SEAK maintain effective population sizes of 400 fish by spawning at least 50 pairs per year. At least 50 pairs per year are required to maintain an effective population size of 400 fish because Chinook salmon return at various ages.

Fish Health and Disease Policies

All FTPs were reviewed and recommended for approval by an ADF&G pathologist. Appropriate salmon culture techniques are implemented, and disease reporting and broodstock screening occur as required. Pathology records showed no inconsistencies with fish health and disease policies at any of the hatcheries. All hatcheries have been inspected regularly since at least the late 1980s, and no major health issues were reported. In general, the inspection reports have noted that most of the SEAK hatcheries are clean, well organized, and well run.

Most hatcheries have experienced some health issues at various times for Chinook salmon including *Trichodina*, bacterial coldwater disease, and bacterial kidney disease. The inspector indicated that staff had taken appropriate measures for isolating and treating the diseases.

Fishery Management Policies

Stock assessment

Standardized index escapement monitoring projects began in the early 1970s and by the late 1970s 11 of the 34 known Chinook salmon producing rivers in SEAK were surveyed annually, which include 3 transboundary river stocks: the Alsek, Taku, and Stikine River stocks. These 11 index systems represent roughly 85% of the assumed total production from SEAK including all of the major producers and 1 minor producer (production less than 1,500 fish; Clark et al. 2006). Over time, annual assessments have been modified to convert indices of escapement into total estimates of escapement. Biological escapement goals are in place for all 11 index systems and these goals are expressed in terms of large (i.e., ≥660 mm length from mid eye to fork, or approximately 28 inches in total length) fish, with the exception of the Alsek stock which also includes 2-ocean jacks. Biological data are collected annually to estimate escapement by age and length and to sample for genetics and coded wire tags, among other. Escapement goals have generally been met but production declines beginning in 2007 have resulted in recent poor runs and escapement goal performance. Available data show the declines are not due to freshwater production but rather are directly the result of a severe decrease in marine survival. This decline in productivity is both persistent and widespread and has affected both wild and hatchery Chinook salmon stocks. Despite the use of fishery management measures to modify harvests, this decline led to a regionwide failure to meet escapement goals in recent years, and ultimately led to the Board of Fisheries listing 3 stocks—the Chilkat, Unuk, and King Salmon rivers stocks as *Stocks of Concern* (Lum and Fair 2018a; 2018b).

Hatchery contribution

Robust sampling programs are in place for all fisheries to determine hatchery contributions in mixed stock fisheries. Because all hatchery broodstock is locally sourced, hatchery fish have the same run timing and ocean rearing distributions as their wild stock counterparts and are indistinguishable genetically. Therefore, coded wire tag recoveries from fisheries have been used to estimate the hatchery contributions to the fisheries since 1985. This, in large part, is due to the SEAK hatchery add-on provision of the PST. Southeast Alaska hatchery fish are currently marked and tagged at a rate of approximately 9% with the notable exception of the National Marine Fisheries Service's Little Port Walter facility which marks and tags up to 100% of its production. By comparison, the wild Chilkat and Unuk stocks of Chinook salmon are tagged at similar rates (~5–12%) and wild Taku and Stikine stocks are tagged at much lower rates (~1–3%). Release and recovery data are publicly available from ADF&G Mark, Tag, and Age Laboratory database (https://mtalab.adfg.alaska.gov/) which include recovery location, gear type, number of fish caught, and date, among other data. Because fisheries are generally sampled at rates greater than 20%, it is possible to assess hatchery contributions to fisheries both temporally and spatially with reasonable accuracy, though increasing the proportion of marked and tagged hatchery fish would provide greater certainty in estimates and improved management performance. The number of Alaska hatchery fish caught is estimated inseason providing fishery managers with information useful for regulation of SEAK fisheries.

Alaska-origin hatchery fish have contributed 20% of the total harvest of Chinook salmon on average since 1990 (Figure 6). The remaining 80% of the total harvest is composed of SEAK wild fish and wild- and hatchery-origin fish from British Columbia, Washington, and Oregon.

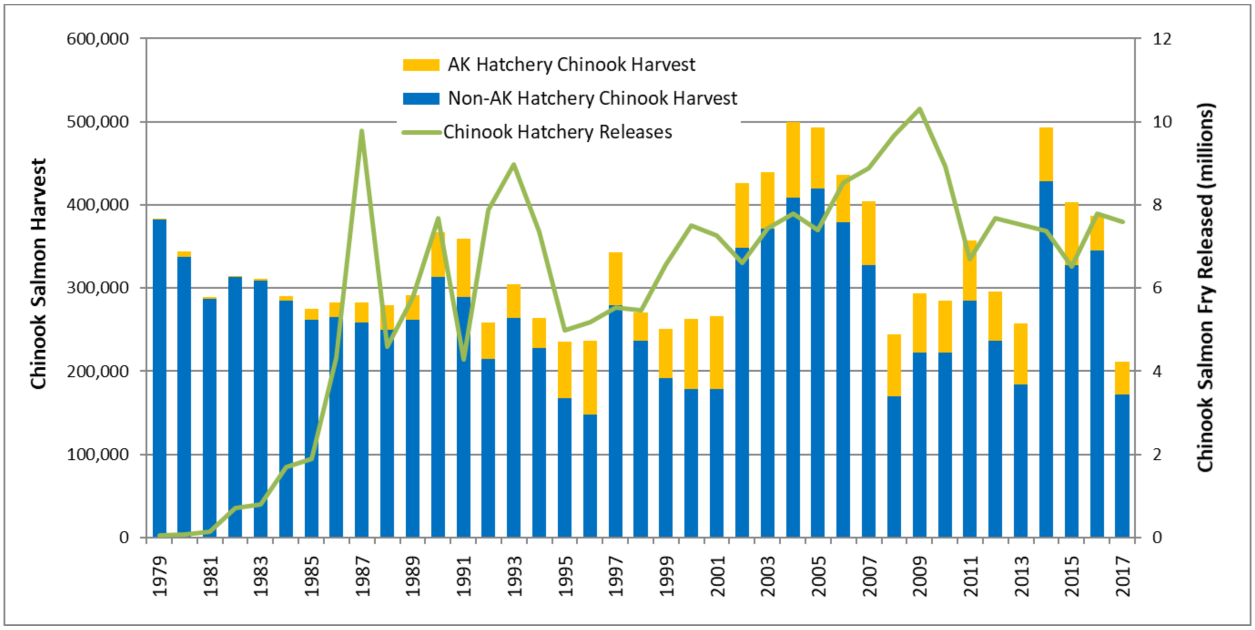

Figure 6.–Southeast Alaska Chinook salmon harvests and hatchery releases in millions, 1975–2016.

Chinook salmon management

The SEAK Chinook salmon fishery is largely a mixed stock fishery, composed of Chinook salmon originating from Alaska, British Columbia, and the Pacific Northwest. The commercial troll and net fisheries are managed for harvest limits inseason according to procedures outlined in gear-specific management plans and gear allocations as specified by the Alaska Board of Fisheries. Sport fishery bag and possession limits as well as annual limits are established prior to the season based on the PST preseason abundance index. In addition, the SEAK fishery is managed for the following:

(1) *Alaska hatchery add-on* provision of the PST, which stipulates that most SEAK hatchery Chinook salmon harvested in SEAK fisheries do not count against the annual harvest limit under the PST (CTC 1992), and exclusion of Chinook salmon catches in selected terminal areas;

(2) compliance with provisions established by the National Marine Fisheries Service in accordance with the US Endangered Species Act; and

(3) consistency with the provisions of the PST as required by the Salmon Fishery Management Plan of the North Pacific Fishery Management Council that was established by the Magnuson-Stevens Act.

The spring troll fisheries have a unique management plan among SEAK salmon fisheries to target Alaska hatchery fish. Although there is no ceiling on the number of Chinook salmon harvested in the spring troll fisheries, the take of PST Chinook salmon is limited according to the percentage of the Alaskan hatchery fish taken in the fishery. Non-SEAK hatchery fish are counted towards the annual PST harvest limit, while most of the Alaska hatchery fish are not.

SOUTHEAST CHINOOK SALMON RECOMMENDATIONS

On the whole, the Chinook salmon fishery enhancement program in SEAK is consistent with State of Alaska policies. The SEAK Chinook stock assessment program is adequate to provide a basis for some evaluation of the hatchery program in place. It provides quality data on harvest, escapement, and their compositions as well as a basis for monitoring hatchery straying.

Recommendations for actions to improve consistency with state policies for SEAK Chinook salmon and actions that could be taken to improve the state of knowledge include the following:

(1) Continued use of the Stock Appraisal Tool to identify significant and unique stocks (*Genetic Policy*).

(2) Identify wild stock sanctuaries (*Genetic Policy*).

(3) Consider implementing annual assessments of the Farragut River Chinook salmon stock including sampling to detect hatchery strays in the escapements.

(4) Encourage hatcheries to collect additional gametes from wild fish to supplement the genetic variation in the broodstocks being used in Southeast Alaska and especially for the Chickamin River and Keta River broodstocks (*Genetic Policy*).

(5) Encourage hatcheries to mark and coded wire tag a higher proportion of hatchery-origin Chinook salmon. Increasing the number of tagged hatchery-origin fish will improve the precision of hatchery contribution estimates to fisheries and escapements and provide an improved ability to detect hatchery strays.

CASE STUDY #2: PRINCE WILLIAM SOUND PINK SALMON

PROGRAM OVERVIEW

Prince William Sound facilities produce most of the hatchery pink salmon in the state. Pink salmon were, and continue to be, the most abundant species in PWS. The first contemporary PWS hatcheries were built in the 1970s in response to low runs. Pink salmon hatchery production was viewed as a way to aid recovery of the fishery, as pink salmon provided the quickest turnaround time from egg take to harvest and historic infrastructure for processing pink salmon was already in place (Prince William Sound Regional Planning Team 1983). The Prince William Sound Aquaculture Corporation (PWSAC) formed in 1974 to develop PWS hatcheries to optimize Alaska's wild salmon resources (www.pwsac.com). PWSAC, and their precursor, the Cordova Aquatic Marketing Association, also saw hatcheries as safeguards against potential impacts from oil development in the area (Yakutat and Yakutaga), as well as from the Trans-Alaska pipeline terminus in Valdez.[12] The first hatchery releases occurred in 1976 (Stopha 2013d).

Currently, 4 hatchery facilities and 2 operators produce pink salmon in PWS (Table 9; Figure 7).[13] A fifth facility, Main Bay Hatchery, raised pink salmon until 1989, but only sockeye salmon are raised there now. Collectively, these facilities are currently permitted for a total of 775 million pink salmon eggs (Table 9). The total release of pink salmon in 2017 was 659 million juveniles.

Table 9.–Prince William Sound pink salmon 2017 permitted eggs and juvenile release in millions.

Operator	Hatchery (acronym)	Permitted eggs	Release
Prince William Sound Aquaculture Corporation	Armin F. Koernig (AFKH)	190	137
	Cannery Creek (CCH)	187	149
	Wally Noerenberg (WNH)	148	131
Valdez Fisheries Development Association	Solomon Gulch (SGH)	250	242
Total		775	659

Source: Stopha 2018.
Note: All pink salmon were released on site.

Pink salmon eggs are collected from late-July through mid-August at Solomon Gulch Hatchery (SGH), which are an early returning stock. Stocks at the other PWS facilities are later run stocks, and eggs are collected from late August through mid-September. To ensure that the run timing is proportionally represented in broodstock, a collection schedule is implemented based on the historic even- and odd-year run timing percentages by date at each facility as described in each hatchery's annual management plan (AMP).

[12] Noerenberg, W. H. 1979. Biological Planning Document. Port San Juan and Esther Salmon Hatcheries, Prince William Sound, Alaska. Prince William Sound Aquaculture Corporation. Unpublished document that was part of the PNP Salmon Hatchery Application for AFKH obtained from the files of Lorraine Vercessi, ADF&G PNP hatchery coordinator, Juneau.

[13] For details on specific hatcheries see Stopha 2013a, 2013b, 2013c, and 2013d.

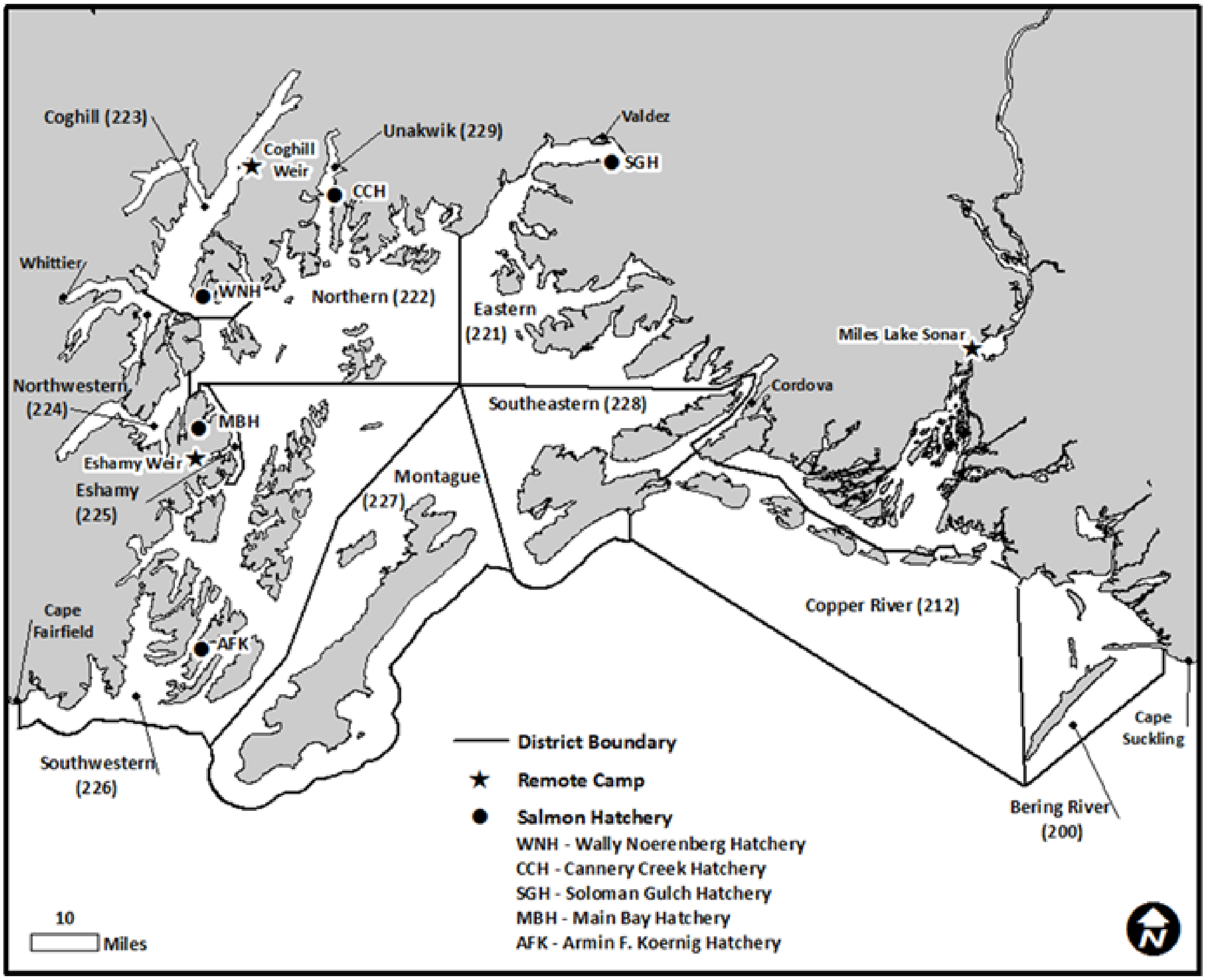

Figure 7.–Map of Prince William Sound fishing districts and pink salmon hatchery locations.

Note: Main Bay hatchery no longer produces pink salmon.

Fertilized pink salmon eggs are held overwinter in incubators, hatch in the winter, and are ponded in the spring. Water temperature is varied in a complex process over a several-day period during incubation to mark the fish's otolith with a particular mark unique to each hatchery. Fry are transferred to net pens and fed for up to 6 weeks and released into the spring plankton bloom. Egg incubation period and fry growth vary based on water temperature at each hatchery, and hatchery managers try to release fish into an abundant plankton bloom to maximize survival. For more detail, all hatchery practices are described in the PNP permit basic management plan and in annual management plans for each hatchery.

In 2017, about 23.8 million hatchery-produced pink salmon were harvested in the PWS common property commercial fisheries, accounting for 57% of the pink salmon harvest (Stopha 2018). Hatchery operators estimated that hatchery-produced pink salmon contributed 9,000 fish to the sport, personal use, and subsistence fisheries in PWS (Stopha 2018).

Regional Comprehensive Salmon Plan

The Prince William Sound/Copper River Comprehensive Salmon Plan (CSP) Phase I was approved in 1983 and served to assemble relevant information regarding the development and protection of salmon resources in the area (PWS Regional Planning Team 1983). The document assessed the region's commercial, sport, and subsistence fisheries resource needs, identified areas for enhancement and rehabilitation to meet those needs, and set 20-year goals for each fishery. The RPT conducted a survey as part of the Phase I CSP to ask the fishing community about their desires for enhancement and set priorities accordingly.

The CSP Phase II was approved in 1986 (PWS Regional Planning Team 1986). The purpose of the Phase II plan was to recommend 5-year goals to achieve the 20-year goals in the Phase I plan. The Phase II plan recommended production levels and completion of the Wally Noerenberg Hatchery (WNH), among other things.

The Phase III CSP was approved in 1994 (PWS Regional Planning Team 1994) with the purpose to "achieve optimum production of wild and enhanced salmon stocks on a sustained yield basis through an integrated program of research, management, and application of salmon enhancement technology, for the benefit of all user groups."

The Phase III plan recommended 4 biological and a single economic criteria as the hatchery program in PWS was developed. The first recommendation was that wild stock escapement goals must be achieved over the long term. This demonstrated support for the wild stock priority in management. The second recommendation, that straying of hatchery fish must remain below 2% of the wild stock escapement over the long term, was not well supported by research and the RPT recognized that more data were needed to improve understanding of interbreeding of hatchery and wild salmon. The third recommendation, that growth rates of juvenile salmon during the early marine period must be density independent over the long term, was an acknowledgement of the wild stock priority in regard to nearshore competition for food. The fourth recommendation, that abundance of juvenile salmon predators must be independent of juvenile salmon abundance over the long term, was acknowledgement of a potential negative effect of hatchery production on wild production, i.e., increasing predator population in response to increased prey. The fifth recommendation, that the long-term average cost of hatchery operations, management, and evaluation must remain below 50% of the value of hatchery production addressed the economics of operating a hatchery, is outside the purview and oversight of the State of Alaska (for information on economics see McDowell Group 2011; 2012; 2013).

Finally, the revised charter for the RPT under the Phase III Plan states that the RPT will update the Comprehensive Salmon Plan at least once a year and will provide an updated plan to the commissioner each year. Annual updates have not occurred since issuance of the Phase III Plan in 1994.

PROGRAM CONSISTENCY WITH STATE POLICIES

For this case study, the alignment of the PWS pink salmon enhancement program with the relevant policy elements is provided in in Tables 10–12.

Criteria used to assess each policy element are provided in Tables 1–3.

Table 10.–A summary review of the current pink salmon fisheries enhancement program in Prince William Sound and its consistency with elements of the ADF&G *Genetic Policy*. (See Table 1.)

I. Stock Transport	
Use of appropriate local stocks	All pink salmon broodstock has been locally sourced from PWS. When more distant stocks were selected, life history and run timing of donor stocks were appropriately selected to match to hatchery conditions and management needs.
II. Protection of wild stocks	
Identification of significant or unique wild stocks	Significant or unique stocks were considered, but none were identified in the comprehensive salmon plans by the RPT and no criteria for determining significant and unique stocks for any species has been established.
Interaction with or impact on significant wild stocks[a]	
A. Interaction	Multiple studies have documented hatchery fish in several wild streams. In the most recent study, weighted mean hatchery proportions using 32 streams was between 4% and 15% from 2013 to 2015. Hatchery proportions were also variable across districts, ranging from 0% to 90%. In addition, there is evidence that PWS hatchery fish are straying to streams outside PWS. Given the hatchery proportions observed and the shallower population structure of pink salmon relative to other Pacific salmon, it is likely that the straying hatchery fish are introgressing genes. Although genetic interaction is inherently difficult to demonstrate, a study is underway to detect and estimate rates of introgression for pink salmon in PWS.
B. Impact	Population structure of pink salmon throughout the species range is shallower than for other Pacific salmon species. This shallower structure is thought to stem from higher natural straying and greater genetic interaction among wild spawning aggregates. Similarity in life histories provides fewer barriers to introgression and reduced risk that introgression will lead to reductions in genetic variation among populations. The effect of straying and introgression on fitness in salmon is not straightforward or predictable. A study is underway to assess relative reproductive success between hatchery- and natural-origin fish in streams.
Stock rehabilitation and enhancement	No watersheds with significant wild stocks are stocked with nonindigenous stocks.
Establishment of wild stock sanctuaries	No wild stock sanctuaries are designated for pink salmon in PWS. In 2011, the RPT discussed them and chose not to designate.

-continued-

Table 10.–Page 2 of 2.

III. Maintenance of genetic variance	
Maximum of 3 hatchery stocks from a single donor stock	The stocks used at SGH are not used elsewhere. AFKH stock pink salmon were also used at MBH and WNH. Cannery Creek is the donor stock for Cannery Creek Hatchery (CCH) and was used at MBH.
Minimum effective population size for establishing and maintaining hatchery stocks	Broodstock for all stocks at all hatcheries were established and have been maintained with an effective population sizes that far exceed the 400 fish.
Incorporating all segments of the run for establishing hatchery stocks	Egg takes occurred on a sliding scale representative of most segments of the donor stock. Deviations from full representation of the run were sometimes due to logistical constraints and sometimes done purposely to provide temporal separation for fisheries.
Protecting wild stocks from removals for establishing hatchery stocks	No more than 90% of any segment of the run was used to establish any of the hatchery broodstocks. Strict escapement requirements were laid out and followed during the original egg takes.
Implementation of Policy	
Genetic review of permits (5 AAC 40.190 and 5AAC 41)	
Review by geneticist	All applications for permits and plans are reviewed by the geneticist.

[a] In areas where significant stocks have not been identified, persistent wild spawning aggregates or groups of related spawning aggregates are considered significant stocks for application of the *Genetic Policy*.

Table 11.–A summary review of the current pink salmon fisheries enhancement program in Prince William Sound and its consistency with elements of the *Alaska Fish Health and Disease Control Policy*. (See Table 2.)

Fish Health and Disease Policy (5 AAC 41.080; amended by Meyers 2014)	
Egg disinfection	At WNH, eggs are treated for fungus initially and then up to 3 times per week. Due to the large volume of eggs at SGH, pink salmon eggs are not disinfected, which is allowed under Alaska regulation (5 AAC 41.080 (b)) in large pink and chum salmon facilities where disease has not been a problem in returning stocks of fish. No egg disinfection is used at AFKH and CCH.
Hatchery inspections	Hatchery inspections were conducted regularly from 1980–2017 for SGH, from at least 1986–2017 for WNH, from at least 1977–2014 for AFKH, and from at least 1988–2017 for CCH.
Disease reporting	Reports from the ADF&G pathology lab indicate that WNH diseased fish have been sent to the state lab as necessary for diagnoses. ADF&G sent notice for SGH to report hatchery pathogens or diseases to ADF&G in 1983 and requested SGH provide descriptions of substantial moralities in pink salmon eggs in 1984, which they did. Disease reporting was timely after 1984. There have been no chronic disease issues at AFKH or CCH.
Disease history	The disease history is current through 2018 for all 4 hatcheries. Samples have been submitted upon request.
Isolation measures	Isolation measures to control for disease during transport are listed as necessary in approved FTPs. No physical transport occurs for onsite release at AFKH and CCH according to the FTPs.
Implementation of Policy	
Pathology review of permits (5 AAC 40.190 and 5AAC 41)	
Review by pathologist	All proposed plans and permits were reviewed by the pathologist.

Table 12.–A summary review of the current pink salmon fisheries enhancement program in Prince William Sound and its consistency with elements of Alaska fisheries management policies and regulations relevant to salmon hatcheries and enhancement. (See Table 3.)

Mixed Stock Salmon Fishery Policy (5 AAC 39.220)	
Wild stock conservation priority	Pink salmon escapement is monitored annually, and escapement goals have been met in most years.
Sustainable Salmon Fishery Policy (5 AAC 39.222)	
Management for sustained yield	Wild stock harvest estimates are assessed after each fishery opening via otolith samples from the harvest. This information is used inseason to regulate fishing periods by time and area to meet escapement goals. Escapement goal performance is assessed via aerial surveys.
Harvest management plans	The fishery is managed under Board of Fisheries approved management plans. Additionally, AMPs are required for each PNP hatchery and outline the methods for broodstock collection and a plan for cost recovery and common property fisheries near hatchery release sites.
Establishment of management objectives	Objectives are established in all fishery management plans, hatchery permits, and hatchery AMPs.
Assessment of wild stock interaction and effects	Hatchery-produced pink salmon are 100% marked in PWS.
A. Fishery	Otolith recoveries from marked fish provide accurate inseason estimates of hatchery and wild fish in the harvest. All available tenders from major processors participating in district-period strata are sampled systematically, using time intervals dependent upon delivery poundage and processing speed to sample the entire load in an unbiased manner on an approximately weekly basis.
B. Escapement	Escapement is indexed by aerial surveys. Studies have documented hatchery straying in PWS and more recently, out-of-region straying in Cook Inlet. Consistent annual sampling of streams to estimate the portion of escapement composed of hatchery-origin fish could be implemented, but would be very expensive and is currently beyond the ability of ADF&G to fund.
Salmon Escapement Goal Policy (5 AAC 39.223)	
Establishment of escapement goals	ADF&G has established sustainable escapement goals for 8 geographic districts in PWS. The escapement goals are regularly reviewed and updated.
Implementation of Policy	
Fisheries management review of permits (5 AAC 40.190 and 5AAC 41)	
Review by management staff	All proposed plans and permits are reviewed by appropriate management staff.

Genetic Policy

Stock transport

All donor stocks for PWS hatcheries were from PWS and were selected for appropriate life-history traits (Habicht et al. 2000). Solomon Gulch Hatchery (SGH) used even-year donor stock (1982) from Vlassoff and Gregorieff creeks (located in Jack Bay within Valdez Arm, 25 km from the hatchery) and odd-year donor stock (1981) from Siwash Creek (located in Port Valdez, 5 km from the hatchery). Armin F. Koernig Hatchery (AFKH) was approved to use wild stocks from western PWS, but due to low escapement in 1976, they were not pursued. Instead AFKH used even-year donor stocks mostly from Duck River and Millard Creek (Galena Bay; 145 km northeast of the hatchery), and from Larsen Creek (at the hatchery location). The Galena Bay stocks were selected because they were late-run timed stocks, and the Larsen Creek stock was selected because it was local. Run timing for Larsen Creek was described as middle-run. The AFKH used odd-year donor stock (1975 and 1977) from Ewan Creek (almost all in 1975 and less than 27% in 1977; 36 km northwest of the hatchery) and the rest from creeks near the hatchery location (Larsen Creek, O'Brien Creek, and Hardins Creek). WNH used AFKH hatchery broodstock as its founding broodstock. Cannery Creek Hatchery used even- and odd-year donor stocks (1978 and 1979) from Cannery Creek (at the location of the hatchery). Two hatcheries that no longer release pink salmon (Perry Island Hatchery and MBH) also sourced their donor stocks locally (Perry Island from within 20 km of the hatchery, and MBH from AFKH).

Protection of wild stocks

Three phases of the Prince William Sound/Copper River Comprehensive Salmon Enhancement Plans have been published by the RPT (PWS Regional Planning Team 1983; 1986; and 1994). The plan does not identify significant or unique wild stocks, nor does it establish criteria for determining significant and unique stocks. The Plan supports the wild stock priority by prioritizing wild stock escapement goals and early life marine survival of wild fish. It also provides 1 guideline related to genetic policy among the 5 biological and economic criteria described above: "the proportion of hatchery salmon straying into wild stock streams must remain below 2% of the wild stock escapement over the long term."

Studies have demonstrated that the 2% hatchery fraction in wild streams is being exceeded. This 2% threshold in wild streams is not set in state policy, but is provided in the plan as a criterion to assess the success of operations in PWS. The 2% maximum straying proportion of hatchery-origin fish was adopted based on a study of coho salmon on Vancouver Island in Canada (Labelle 1992); this can now be considered conservative, given that higher stray rates among wild pink salmon stocks have been estimated in more recent studies. Some studies could only measure stray-out rates—the proportion of wild fish that were detected in a nonnatal stream (range: 9–53%, Sharp et al. [1994]; range: 3–9%, Thedinga et al. [2000]; range: 4–7%, Mortensen et al. [2002]). Measuring the wild stray-in rate—the proportion of nonnatal wild fish observed in a stream—is more difficult to do in the absence of comprehensive marking of wild-origin fish reviewed in Keefer and Caudill (2014).

From 1997 to 1999, Joyce and Evans[14] looked at the incidence of hatchery-origin pink salmon in up to 30 streams. From samples collected twice a week over a 4-week period, they found that the incidence of hatchery strays in some areas of PWS (i.e., Eastern, Southeastern, and Montague

[14] T. Joyce and D. Evans, ADF&G, unpublished data from a 1998–1999 study.

districts) was generally less than 10% (25 of 31 sampling events) and 2 were greater than 25% (range: 0–98%). In other districts (Eshamy, Southwestern, and Coghill districts) the proportion of hatchery strays was consistently higher (range: 7– 88%). Across the years of study, they found that streams closest to release facilities generally contained higher proportions of hatchery pink salmon strays than was the case for streams further distant. They also found that the proportions of hatchery pink salmon strays in streams increased as the spawning season progressed.

In a subsequent study, Brenner et al. (2012) collected samples during 3 visits each year (early, middle, and late portions of the run) for up to 43 wild stock streams in PWS from 2008 to 2010 using a stratified sampling design based on distance from hatcheries. This study found similar results; there were more strays observed in some areas than others (range: 0–93%). Consistent with the results of Joyce and Evans,[15] lower percentages of hatchery-origin fish were found in Eastern and Montague districts (14 of 22 sampling events were < 10% and 2 were >25%; range: 0–98%), and higher percentages of hatchery-origin fish were found in the streams of Eshamy District (range: 5–80%) and Southwestern District (range: 10% to 82%). One finding of this study was that the proportion of hatchery fish present was associated with distance from a hatchery. As previously found by Joyce and Evans,[16] the relative proportion of hatchery-origin fish found in a stream increased as the season progressed.

A more recent hatchery–wild interaction study looked at the extent and annual variability in straying of hatchery pink salmon from 2013 to 2015 (Knudsen et al. 2015a, 2015b, 2016). Using a systematic random sampling design, the project sampled otoliths from spawned-out fish in representative pink salmon streams in PWS to estimate the hatchery fraction in natural spawning populations on a district scale. A maximum of 27 streams were sampled for otoliths to detect hatchery fish in both even- and odd-year runs. Straying of hatchery fish was documented in all streams in all years, but at varying levels. About two-thirds of pink salmon streams sampled in the 2 odd-years had lower proportions of hatchery-produced fish. For the entire PWS region, the percentage of hatchery pink salmon in all spawning streams was estimated to be between 4% and 15% among the 3 years of study, with hatchery proportions in the only even year being higher than the 2 odd years (Table 13). Consistent with earlier studies, hatchery fish contributed less than or equal to 2% of fish on the spawning grounds in Coghill, Eastern, and Southeastern districts, which represented 62% to 72% of the natural spawning population in 2013 and 2015. Again, the Eshamy District had the highest fraction of hatchery pink salmon (range: 81–90%); this district also had the lowest escapement in PWS, accounting for less than or equal to 1% of the overall sound and was represented by 1 study stream that had one of the highest straying fractions of all study streams (Table 13). The Southwestern district had the second highest straying fractions of hatchery pink salmon (range: 29–49%) and contributed less than or equal to 11% of the overall proportion of hatchery strays to PWS. The Eastern District, despite having one of the lower estimated hatchery fractions within a district (range: 1–5%), had the highest escapement in PWS overall, accounting for 22% to 30% of the overall sound. Hatchery proportions in streams for the single even-year collection (2014) were higher than in the 2 odd-year collections (2013 and 2015). Consistent with findings by the previous 2 studies, research associated with the study also found that the prevalence of hatchery-origin fish in streams increased throughout the season (Peter Rand, Research Ecologist, Prince William Sound Science Center, pers. comm.).

[15] Ibid.
[16] Ibid.

Table 13.–Estimated Prince William Sound pink salmon districtwide stream hatchery proportions, 2013–2015.

	Estimated hatchery proportions		
District	2013	2014	2015
Eastern	1%	5%	2%
Northern	5%	27%	17%
Coghill	2%	10%	0%
Northwestern	3%	7%	16%
Eshamy	87%	90%	81%
Southwestern	29%	49%	34%
Montague	11%	39%	16%
Southeastern	0%	4%	1%
Overall [a]	4.4%	14.8%	9.6%

Source: Knudsen et al. 2015a, 2015b, 2016.

[a] The aerial survey fraction for each district was used to weight the contribution of each district to estimate the overall proportion.

All 3 studies found similar patterns of occurrence of hatchery-origin pink salmon in the streams of PWS. However, more detailed comparison of results among these 3 studies is complicated by differences in the study designs and sampling approaches and is outside the scope of this case history.

More recently, sampling in lower Cook Inlet documented presence of PWS hatchery marked pink salmon in 17 streams in varying levels (Otis et al. 2018.). This pilot study was conducted from 2014 to 2017, because 2 pink salmon hatcheries were reopening in lower Cook Inlet and permitted to take 250 million green eggs and release resultant progeny. Baseline information was collected early in hatchery development to better understand future hatchery–wild interactions. The presence of *out-of-region* strays was unexpected, but given the proximity of Lower Cook Inlet to PWS combined with the propensity of pink salmon to stray it is not surprising. Otis et al. (2018.) sampled 17 streams and observed 0% to 87% of the sampled fish were of PWS hatchery origin in some stream/year combinations in all 4 years. The average proportion of PWS hatchery marks during sampling events in streams with 3 or more years of data exceeded 5% on 6 streams and exceeded 20% on 3 streams, though PWS hatchery proportions in samples from some systems were highly variable across years. Originally envisioned as a baseline study to determine the level of Tutka Bay Lagoon Hatchery marked fish in escapement index streams, this project closely followed the methods and procedures used by Brenner et al. (2012). Samples were collected during multiple site visits each summer from dead salmon without regard for the age of the carcass. A research plan is being developed to specifically evaluate the prevalence of hatchery-origin strays and add statistical validity using *a priori* sampling protocols.

Genetic interaction of hatchery fish with wild fish occurs when hatchery-origin fish spawn with wild fish, introgressing genes into wild populations. Thus, straying is a prerequisite for genetic interaction and can act as an initial measure of its potential to occur. Genetic impact of hatchery fish on wild fish occurs when hatchery-origin fish introgress genes that impact wild populations. These impacts include effects on fitness within wild populations and effects on genetic variation among wild populations. The potential for genetic introgression and impacts is tied to population structure of the species within the geographic area of interest.

Population structure of pink salmon throughout the species range is shallower than for other Pacific salmon species and genetic distinction is highly correlated with geographic distance (Tarpey et al. 2017). The small genetic distances among wild populations in PWS is consistent with previous findings, given the small geographic expanse of PWS (Seeb et al. 1999; Cheng et al. 2016). This shallower structure is thought to stem from higher natural straying among nearby spawning aggregates (Keefer and Caudill 2014) leading to greater interaction among wild populations than found in other Pacific salmon species. This shallower population structure, driven by similar life histories, provides fewer barriers to introgression (Bugert et al. 1995, reviewed in Utter 2001), and introgression is less likely to lead to reductions in genetic variation among populations (e.g., Hess et al. 2011). Given the hatchery proportions observed in most streams and the shallow population structure of pink salmon in PWS, it is likely that the straying hatchery fish are introgressing genes. The effect of straying and introgression on fitness in salmon is not straightforward or predictable (McClelland and Naish 2007). A study is underway—the Alaska Hatchery Research Project—to document hatchery proportions in streams, examine population structure, and assess relative reproductive success between hatchery- and wild-origin fish in streams (http://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.current_research).

Maintenance of genetic variance

SGH purposely collected eggs from the early part of the run for both even and odd years to produce an early-run stock at the hatchery with the goal of minimizing interception of later-returning wild salmon stocks (e.g., coho salmon) in Valdez Arm. Egg take collections times ranged from mid-July to early August, removed in proportion to the escapement in the system on a sliding scale (within the early part of the run) developed by ADF&G,[17] and included thousands of fish for both even and odd years.

When developing the AFKH even-year broodstock, most of the egg take (95%) came from Duck River between August 23 and September 21, which accounted for the middle to the end of the run. Most of these eggs were fertilized from sperm collected at Duck River and Millard Creek, but about 2% of the eggs were fertilized by Larsen Creek fish. In addition, egg takes from Larsen Creek fish accounted for 5% of the eggs (fertilized by Larson Creek fish). Broodstock sizes were in the thousands of fish. Although the release of Larsen Creek stock fish was only about 5% of the total release in 1976, survival and contribution to the 1978 generation was estimated to be much higher such that the Larsen component of the stock is likely much higher than the percentage of eggs collected in the founding even-year broodstock at AFKH.[18] The AFKH used odd-year donor stock (1975 and 1977) from Ewan Creek (almost all in 1975 and less than 27% in 1977; 36 km northwest of the hatchery) and the rest from creeks near the hatchery location (Larsen, O'Brien, and Hardins creeks). These stocks were chosen because they were thought to be adapted to conditions at the hatchery site (similar temperature regimes due to watersheds with lowland lakes) and because they spawned above high tide and were therefore more suitable for the pure freshwater used in the freshwater hatchery incubation. Egg take collection times in 1975 were late due to

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[17] Solomon Gulch Hatchery 1981 Annual Report. Unpublished document obtained from Lorraine Vercessi, ADF&G PNP Hatchery Program Coordinator.

[18] Port San Juan Hatchery Annual Report for 1978, Armin F. Koernig, Prince William Sound Aquaculture Corporation. Unpublished document, Alaska Department of Fish and Game.

construction delays at the hatchery and ranged from late August to mid-September, included thousands of fish, and were allowed because the escapement was above the escapement goal. In 1977 most of the egg take came from fish returning to the hatchery (73%). Egg takes occurred late August through mid-September, largely because of the late arrival of the hatchery stock. WNH used broodstock from AFKH for both even and odd years.

When developing Cannery Creek broodstock, eggs were collected throughout the run and thousands of fish were used as broodstock for both even and odd years.

Fish Health and Disease Policies

All FTPs were reviewed and recommended for approval by an ADF&G pathologist. Appropriate salmon culture techniques are implemented, and disease reporting and broodstock screening occur as required. Pathology records showed no inconsistencies with fish health and disease policies at any of the hatcheries. All hatcheries have been inspected regularly since at least the late 1980s, and no major health issues were reported, with the exception of SGH.

SGH has had few health issues. During the initial start-up of the hatchery, there was some excessive mortality possibly associated with heavy siltation from glacial water or heavy metals. However, filtration cannot effectively be done due to the volume of water needed for incubation. The Valdez Fisheries Development Association tried UV filtration upon start up but it was determined that this was not practical and was discontinued in 1991 or 1992 (Mike Wells, Executive Director, Valdez Fisheries Development Association, pers. comm.). Personnel have been periodically sent to fish health and disease workshops to enhance job skills.

Apart from the occasional gas bubble disease, fish from WNH facility have had relatively few health problems."[19]

Fisheries Management Policies

Stock assessment

In PWS, pink salmon have been managed to meet certain levels of escapement since the early 1960s. The escapement targets have varied over time and were developed using different methodologies, varying number of index streams, and switching between district-specific and Sound-wide goals, thus making it challenging to do a simplistic evaluation. There have been 4 sets of escapement goals or management targets that span from the prehatchery period to present. Escapement targets or goals are all based on weekly aerial survey indexes of a subset of pink salmon spawning streams within PWS (Bue et al. 1998).

The first set of *desired escapement* ranges were established possibly as early as 1960 (Fried et al. 1994) and were district-specific targets. Until 1984, Coghill and Northwestern districts had a combined escapement range, as did Eshamy and Southwestern districts (Randall et al. 1984, 1985). The other goals were for Eastern, Northern, Montague, and Southeastern districts. In general, desired escapement ranges within each district were met or exceeded 50% to 60% of the time between 1960 and 1989, based on the escapement target and assessment at the time.[20] For some districts, escapements did not meet the lower end of the desired escapement range for multiple

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[19] Jayde Ferguson and Collette Bentz, Hatchery Inspection Report, 2012. Unpublished document obtained from Lorraine Vercessi, ADF&G PNP Hatchery Coordinator, Juneau

[20] Source data from Prince William Sound Annual Management Reports.

consecutive years. For example, the estimated escapement to Montague District did not meet the escapement target range between 1965 and 1970.

Formal biological escapement goals for PWS districts were first adopted in the early 1990s, after implementation of the first salmon escapement goal policy in 1992 (Fried et al. 1994). This was the first time separate even- and odd-brood year escapement goals were established. These goals remained in place until the *Policy for the Management of Sustainable Salmon Fisheries* (5 AAC 39.222) was implemented; the *Policy for Statewide Salmon Escapement Goals* (5 AAC 39.223) was updated in 2000; and the existing goals were reviewed in 2002. Between 1990 and 2002, escapement goals were met or exceed between 15% and 77% of the time within each district. Both Coghill and Northwestern districts met escapement goals less than 25% of the time (Coghill, 15%; Northwestern, 23%), with extended periods of not meeting the escapement goal (e.g., 1990–1998 for Coghill District and 1995–2000 for Northwestern District). Eastern, Southwestern, Montague, and Southeastern districts met or exceeded their escapement goals more than 60% of the time, based on the escapement goals and assessment at the time.

In 2003, new Sound-wide even- and odd-year sustainable escapement goals replaced district-specific biological escapement goals (Bue et al. 2002). At this time, district-specific *management target* ranges were also established that were proportional to the Sound-wide goals and were designed to maintain historical distribution of escapement. During the 9 years that the Sound-wide goals were in place, they were achieved every year except 2006 and 2008. Annually, the percentage of the 8 district-specific management targets that were met or exceeded ranged from 88% to 100% in odd years and 25% to 88% in even years. Within districts, management targets were met or exceeded between 56% (Southwestern District) and 89% (Coghill and Northwestern districts) of the time between 2003 and 2011 (i.e., 5 out of 9 years and 8 out of 9 years).

In 2012, district-specific sustainable escapement goals were established and replaced the framework of Sound-wide goals and management targets (Fair et al. 2011). Overall, between 2012 and 2017, pink salmon escapement goals within PWS have been met 89% of the time. Annually, the percentage of districts that met or exceeded their assessed escapement goals ranged from 88% to 100% in odd years and 63% to 100% in even years. In 2016, all of the escapement goals were met (2) or exceeded (3) in the districts in which escapement was adequately assessed (5 out of 8). Within districts, escapement goals were met or exceeded between 60% and 100% of the time during the past 6 years. Eshamy and Northern districts met their escapement goals less than 80% of the time. Eshamy District escapement index was below the lower bound of the escapement goal in 2 years (2012 and 2017), not adequately assessed in 2016, and over the upper bound in 2013 and 2014. Northern District escapement index was below the lower bound of the escapement goal in 2 years (2012 and 2014), met the escapement goal in 2016, and over the upper bound in all odd years (2013, 2015, and 2017).

It is difficult to discern trends in performance towards meeting escapement goals among the different escapement goal/management time frames because any such evaluation requires comparing across units of measurement. In addition to changing goals, the period prior to the advent of hatchery pink salmon (1960s to mid-1970s) was characterized by low returns of pink salmon and limited fishing in some years (Clark et al. 2006). This was followed by a period of large returns and high escapements from the late-1970s through the mid-1980s. These high escapements are believed to be the result of an ocean regime shift that began in 1977 resulting in high productivity of salmon (Mantua 2009). Consequently, any comparison of prehatchery era and hatchery era escapements is further complicated by the coincidence of this change in ocean productivity.

Escapements appear to have increased since the lows experienced in the 1960s and early to mid-1970s (prehatchery). We also know that performance since the establishment of the *Policy for the Management of Sustainable Salmon Fisheries* and the *Policy for Statewide Salmon Escapement Goals* has been generally good, with escapement goals being met 78% of the time between 2003 and 2011 and 89% during the most recent period (2012–2017).

Historically, total escapement and total run of wild-origin pink salmon in PWS has been difficult to accurately estimate because escapement has primarily been assessed by aerial observer counts and is an index of spawning fish present in a subset of streams. Most efforts to estimate total escapements and total run sizes in PWS relied on aerial survey index counts (e.g., Hilborn and Eggers 2000; Wertheimer et al. 2004; Amoroso et al. 2017). Resultant estimates, however, were highly variable due to the suite of assumptions each researcher used in their analyses, including those related to the aerial survey escapement indexes and partitioning out-fish origin. The Alaska Hatchery Research Project has provided a unique opportunity to estimate total escapements and total run sizes for both wild and hatchery-origin pink salmon in PWS from 2013 to 2015 that are largely independent of aerial surveys. Using information on harvests, the fraction of the total run composed of hatchery salmon and the fraction of escapement composed of hatchery fish in preliminary estimates for pink salmon wild and hatchery total escapements and total run sizes (with measures of uncertainty) were able to be estimated (Knudsen et al. 2016; Table 14).

Table 14.–Preliminary Prince William Sound pink salmon run size estimates, 2013–2015.

Year	Natural spawners	Hatchery strays	Total spawners	Natural run	Hatchery run	Total run
2013	15,698,000	701,000	16,399,000	33,096,000	69,888,000	102,985,000
2014	5,130,000	741,000	5,872,000	6,960,000	42,757,000	49,718,000
2015	37,972,000	4,009,000	41,981,000	63,531,000	77,335,000	140,866,000

Source: Knudsen et al. 2016.

Note: Hatchery-origin determined by presence of otolith marks.

Hatchery contribution

Annual estimates of wild and hatchery pink salmon in the harvest and escapement have been based on marking of hatchery fish. Hatchery pink salmon were marked early in the hatchery program (1977 to 1981) by fin clipping to study the effects of feeding versus not feeding released fry, release timing, and to assess straying to nearby streams.[21] From 1986 to 1991, hatchery fish were first coded-wire-tagged and marked with an adipose fin clip. Hatchery pink salmon were coded-wire-tagged at less than 0.2% because of the large number of fry released. Thus, it took a high sampling rate to identify the returning tagged hatchery pink salmon and to estimate survivals. Recovery of tags in the commercial harvest provided insight into timing and location of hatchery returns. Only a gross estimation of the hatchery contribution to the harvest was possible because only a small fraction of releases could be coded-wire-tagged due to logistics and costs (Sharr et al. 1996).

[21] San Juan Hatchery 1981 Annual Management Plan. Unpublished document from Lorraine Vercessi, PNP Coordinator, ADF&G.

A technique to thermally mark otoliths by alternating water temperatures in the hatchery during egg incubation or after hatching was developed (Volk et al. 1990), allowing 100% of hatchery releases to be marked. Since 1997, estimates of hatchery contributions based on otolith thermal marks have provided precise inseason estimates of hatchery fish in the harvest, as well as estimates of hatchery fish in the escapement. District-period strata include a systematic sample from major processors proportional to their harvest for that period. The number of wild fish in the harvest is determined by subtracting the estimated hatchery-origin catch from the total harvest.

Pink salmon hatchery returns began contributing to fisheries substantially by 1980 with a harvest of over 1 million pink salmon hatchery fish (inclusive of cost recovery) and by 1990, the harvest of hatchery fish exceeded 37 million (Figure 8). Since 1990, harvest of hatchery-origin pink salmon has ranged from 4 million fish in 1993 to 70 million fish in 2015 with an average of 32 million and accounting for 85% of the total harvest. The even-year harvests of hatchery-origin fish have averaged 28 million accounting for 88% of the total harvests, and odd-year harvests of hatchery-origin fish have averaged 36 million accounting for 82% of the odd-year total harvest.

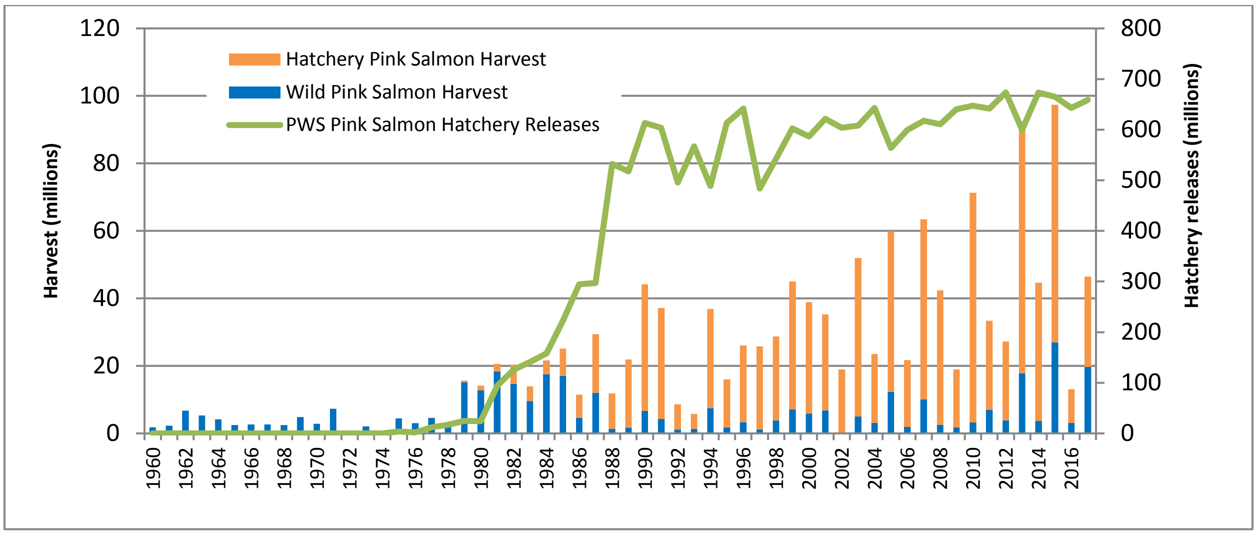

Figure 8.–Prince William Sound pink salmon hatchery releases and harvests in millions, 1960–2017.

Pink salmon management

At statehood, PWS was divided into 8 fishing districts based on topography and species of fish for management, and salmon fisheries were managed by emergency order in 3 discrete units. The Eshamy District was managed for sockeye salmon returning to Eshamy Lake. The Coghill and Unakwik districts combined were managed for similarly timed sockeye salmon returns to Coghill Lake and Miners Lake, respectively. The 6 remaining districts, called “the general purse seine districts” were managed for pink and chum salmon returns (Figure 7). Managers opened fishing periods based on harvest rates and escapement observed in index streams by aerial over-flight surveys. The pink salmon seine fishery usually opened in early or mid-July and when catches began to decline signifying that the peak of the return had passed, managers would close the fishery —usually by the middle of August (Pirtle 1980)—to fulfill escapement needs.

Low pink salmon returns in the early 1970s forced the closure of the PWS purse seine fishery in 1972 and 1974, with minimal fishing in 1973. In response, the first contemporary PWS hatcheries were built in the 1970s. It took several years for the hatcheries to see sufficient returns from the initial releases to meet broodstock goals before much targeted fishing could occur. As hatchery returns started to contribute to the fisheries in the early 1980s and increase over the decade, managers extended the fishing season later into August and eventually into September and provided numerous special openings to harvest surplus hatchery fish build ups. In addition, special closure areas were established in front of hatcheries to protect returning fish needed for broodstock and cost recovery.

In 1986, the harvest of hatchery-produced pink salmon exceeded the harvest of wild stocks for the first time. Fishery managers, fishermen, and processors were challenged to quickly and effectively adapt to the process of harvesting large numbers of hatchery fish while conserving wild stocks. The 1990 pink salmon hatchery release was the largest to date and set the benchmark for PWS releases over the course of the next 2 decades. During this time frame, releases remained relatively constant, but the harvest—particularly in odd years—steadily increased, with harvest records being consistently broken for both stronger odd-year and weaker even-year returns (Figure 8). In 1997, inseason stock information improved dramatically, when the first pink salmon with otolith marks returned to PWS (Morstad et al. 1998). Otolith recoveries from marked fish were immediately used to estimate hatchery and wild fish in the harvest to assess the relative abundance of hatchery and wild fish and to gauge run strength.

The 2003 season marked the beginning of 6 record harvest years during the next 12 years. Record years were during odd years in 2003, 2005, 2007, 2013 and 2015, as well as a record year in 2010 (Figure 8). The wild stock component of harvests in 2013, 2015, and 2017 were among the highest on record, but hatchery releases remained relatively constant. However, in 2016, the common property commercial fishery harvest was 8.7 million pink salmon—including 2.2 million wild fish—the second lowest harvest in the last 20 years, and 73% below the 31.6 million preseason harvest forecast.[22] Low returns and associated economic impacts across the Gulf of Alaska precipitated a pink salmon disaster declaration for 2016 under Section 312(a) of the Magnuson-Stevens Fishery Conservation and Management Act.

The prevalence of hatchery fish has complicated both fisheries management and stock assessment (Clark et al. 2006). Fishery managers had to adapt management approaches over time to target abundant hatchery fish but maintaining sustained yield of wild stocks. Current management practices were refined with the accurate, timely data made possible from otolith marking and management experience gained over time. Consistent with Board of Fisheries approved plans, general purse seine district openings are now determined inseason by gauging wild stock run strength through sampling the harvest and via weekly aerial escapement surveys. Targeted harvest of hatchery fish in subdistricts near each hatchery is based on hatchery stock run strength gauged by applying the proportion of hatchery fish in the harvest, the progression of cost recovery harvest and broodstock collection, and timing of the return based on the sex ratio of return over time at the hatchery. In years of strong wild stock returns, fishing time and area is liberalized; in cases where harvest of hatchery returns is high, managers may need to close areas near each hatchery to achieve cost recovery and broodstock goals. In years of weaker wild stock returns, fishing time and area

[22] 2016 Prince William Sound salmon season summary

in the general districts is more restricted and limited to hatchery subdistricts and terminal areas, with fishing time dictated by achievement of hatchery cost recovery and broodstock goals.

The Alaska Hatchery Research Project was also able to estimate harvest rates of hatchery and wild pink salmon. Knudsen et al. 2016 found that the rates of harvest on hatchery fish are approximately double that of wild fish for 2013 and 2015, and nearly 4-fold the harvest rates on wild fish for 2014 (Table 15). This demonstrates that the fishery is effectively managed to target hatchery fish and maintaining sustainable harvest rates on wild-origin stocks.

Table 15.–Estimated harvest rate of hatchery and wild pink salmon in Prince William Sound, 2013-2015.

	Estimated Harvest Rates	
Year	Hatchery	Wild
2013	99%	53%
2014	98%	26%
2015	95%	40%

Source: Knudsen et al. 2016.

PRINCE WILLIAM SOUND PINK SALMON RECOMMENDATIONS

Generally, the pink salmon fishery enhancement program in PWS is consistent with State of Alaska policies. There were 2 elements that were not consistent with guidance in the *Genetic Policy*: (1) identification of significant or unique stocks, and (2) establishment of wild stock sanctuaries. These 2 policy elements can be addressed within the existing process (see the recommendations listed below).

Further, the *Genetic Policy* concerning interaction with or impact on significant wild stocks vis-a-vis documented straying of hatchery origin pink salmon needs clarification. Genetic interaction is inherently difficult to demonstrate, but reasonably can only occur when hatchery and wild-origin pink salmon are present on the spawning grounds at the same time. If the proportion of hatchery-origin fish found on the spawning grounds is used as a proxy for potential genetic interaction, then it has been demonstrated that hatchery stocks are interacting (at least physically) with wild stocks. Genetic interaction can occur when hatchery-origin fish introgress genes into wild populations. Impacts can occur if these introgressed genes impart negative traits into the receiving wild population. Negative traits can include disruption of local adaptations and/or a reduction in genetic variation among spawning aggregates. It is possible to have genetic interaction without impact if the introgressed genes do not disrupt local adaptation or do not erode among-population genetic diversity.

Hatchery proportions documented in PWS pink salmon spawning streams over multiple studies exceed the criterion of 2% established by the Prince William Sound/Copper River Comprehensive Salmon Plan, especially within some Districts (Table 13). After discussions between the RPT and the principal geneticist and without much information available from straying studies, this criterion was established based on a contemporary and fairly broad coho salmon study conducted in British Columbia (Labelle 1992; Dr. Jim Seeb, University of Washington, pers. comm.). It is known that wild stray rates among spawning aggregates of Pacific salmon vary by species, region, and distance among spawning aggregates (reviewed in Keefer and Caudill 2014). The 2% criterion is not biologically appropriate for PWS pink salmon and this threshold criterion should be reconsidered when the Prince William Sound/Copper River Comprehensive Salmon Plan is updated. The State of Alaska does not have a specific policy criterion relative to straying rates overall, by species, by area, or otherwise. In the Policy for the Management of Sustainable Salmon Fisheries (5 AAC 39.222), a precautionary approach requires that "where the impact of resource use is uncertain, but likely presents a measurable risk to sustained yield, priority should be given to conserving the productive capacity of the resource." Based on current information, the simple presence of hatchery-origin fish on the spawning grounds is not directly by itself a measurable risk to sustained yield. However, the presence of hatchery fish intermingling with wild-origin pink salmon in PWS streams raises questions that need to be researched, and impacts on wild fish that may be occurring need to be documented.

Recommendations for actions to improve consistency with the state policies for PWS pink salmon and actions that could be taken to improve the state of knowledge include the following:

(1) Identify significant and unique stocks (*Genetic Policy*).

(2) Identify wild stock sanctuaries (*Genetic Policy*).

(3) Continue collecting information on contemporary and historical population structure of wild pink salmon spawning aggregates and comparing this structure to hatchery populations (*Genetic Policy*).

(4) Implement an annual sampling program of escapements of pink salmon in PWS to monitor and index hatchery stray rates.

(5) Finalize the study concerning relative reproductive fitness of hatchery- and wild-origin pink salmon spawning in the wild in PWS.

DISCUSSION

Alaska's salmon fishery enhancement policies constitute a precautionary approach to meet the mandates of sustained yield and conservation of salmon resources under the Alaska State constitution and the legislation enabling the enhancement programs. Alaska hatchery and fisheries enhancement programs are governed by a comprehensive permitting system designed to protect wild stocks and to provide increased harvest opportunities. The success of enhancement efforts depends on implementing that system and ensuring policies are followed.

Developing the table of policy attributes (Tables 1–3) proved somewhat challenging, particularly for some ADF&G *Genetic Policy* and fishery management policy elements for several reasons.

First, the guidance provided by these policies is sometimes very specific, and sometimes less so. For example, the *Alaska Fish Health and Disease Control Policy* (5 AAC 41.080) mandates the use of an iodine solution on salmon eggs transported between watersheds—a prescribed practice that requires little interpretation. In contrast, several policies prioritize the protection of wild stocks from the potential effects of fisheries enhancement projects without specifying or mandating how to assess those effects. These less explicit policies provide principles and priorities, but not specific direction for decision making.

Second, the overlap in the mandates for wild stock protection made it challenging to distinguish the various policy elements. For example, the *Mixed Stock Salmon Fishery Policy* states that "conservation of wild salmon stocks consistent with sustained yield shall be accorded the highest priority." The *Sustainable Salmon Fisheries Policy* contains a corresponding management principle that wild salmon stocks should be "maintained at levels of resource productivity that assure sustained yield." Similarly, the *Sustainable Salmon Fisheries Policy* contains the provision that salmon escapement goals "should be established in a manner consistent with sustained yield," wheareas the *Salmon Escapement Goal Policy* directs ADF&G to establish escapement goals.

Third, the ADF&G *Genetic Policy* recommends the identification and protection of *significant and unique* wild stocks and suggests that drainages be established as *wild stock sanctuaries* where no enhancement activity is permitted except for gamete removal for broodstock development. However, the policy does not provide any criteria or guidance for such designations. In their document, *Background of the Genetics Policy of the Alaska Department of Fish and Game,* Davis and Burkett (1989) state that one important task remained to be accomplished: developing an approach to the problem of identifying significant and unique wild stocks. They concluded that "any designation of stocks as significant or nonsignificant will be arbitrary. However, some means of defining these terms is critical to the successful application of the genetic policy and must be found." Because these stock designations have not been defined and are interrelated with several other restrictions in the ADF&G *Genetic Policy,* we expanded the criteria to include "persistent wild spawning aggregates or groups of related spawning aggregates" for the purposes of this evaluation, which better represents how this designation is treated in practice.

Finally, there are ambiguities in some of the policies which have led to competing interpretations and confusion. For example, the ADF&G *Genetic Policy* states that "To ensure all segments of the run have the opportunity to spawn, sliding egg take scales for the donor stock transplants will not allocate more than 90% of any segment of the run for broodstock" (III.B.2). In section B, "Genetic diversity within hatcheries and from donor stocks" could be interpreted to mean that the stipulation is trying to ensure diversity within the hatchery stock by not allowing it to be developed from only 1 segment of the run. Yet in the "Guidelines and Justifications" section, the interpretation is clearly intended to prevent cropping of early- or late-run segments of a donor stock.

As new information becomes available, the policies should continue to be reviewed and revised. The *Policies and Guidelines for Alaska Fish Health and Disease Control* were updated in 2014 (Meyers et al. 2014); the *Genetic Policy* has not been updated since 1985.

GENETICS

The mission of the Gene Conservation Laboratory is to protect genetic resources and provide genetic information and advice to department staff, policy makers, and the public to support management of resources consistent with the mission of ADF&G. The *Genetic Policy* provides the fundamental document for guiding decisions made to protect the genetic integrity of important wild stocks. Policy development began in the 1970s and was finalized in the 1980s and therefore benefitted from knowledge gained from mistakes made in the Pacific Northwest and from experience in agriculture. *Genetic Policy* acknowledged the limited information available and followed a conservative approach to protecting wild stocks and also providing opportunity for enhancement and rehabilitation.

The foundational premise behind the *Genetic Policy* guidelines is that populations of salmonids have adapted to their native habitat over long periods of time and have therefore maximized their fitness. The corollary to this premise is that disruption to these adaptations reduces the long-term fitness of populations. Adaptations among populations also provides increased resilience to variation in environmental conditions, a concept coined more recently as the *portfolio effect* (Figge 2004). These adaptations are genetically based, so to protect wild stocks *Genetic Policy* provides guidelines to reduce genetic divergence between hatchery and wild fish and to reduce gene flow from hatchery to wild fish.

The premise of the *Genetic Policy* continues to gain support in the literature, but some of the tasks that were outlined have not been completed and the lack of definition of some of the terms have led to divergent interpretations. The most critical unaccomplished task outlined in *Genetic Policy* is the task of identifying *significant and unique stocks*. Defining these stocks is fundamental to implementation of the *Genetic Policy* and allows consideration of permitted activities to focus on and prioritize these stocks. Without these stocks defined, the *Genetic Policy* is applied to all persistent wild spawning aggregates, thereby spreading effort over higher and lower priority stocks resulting in less focus on the most important stocks. This task is best accomplished by an RPT that understands local utilization and understands variation in wild population life histories within each region. The Gene Conservation Lab can play a role in moving this task forward by providing the RPTs with information and advice.

The definition of some of the terms in the *Genetic Policy* will lead to uncertainty in the application of the policy. As an example, consider the definition of the term *hatchery* used when implementing the restriction to allow only 3 hatcheries to use a single stock is unclear. Some have suggested that only hatcheries that conduct egg-takes should be included in this count, whereas others suggest that all hatcheries that use eggs from this stock (whether they receive their eggs from another hatchery or conduct their own egg take) should be counted. As a result, implementing this restriction is problematic. The intentions and applications of the guidelines and principles outlined in *Genetic Policy* should be updated and documented to reduce these types of ambiguities and reduce uncertainty in the interpretation of the policy.

FISH HEALTH AND DISEASE

The statewide fish/shellfish health program partially fulfills the mission of the ADF&G Division of Commercial Fisheries by ensuring aquaculture and mariculture activities are conducted according to established policies and regulations to prevent, detect, or control disease pathogens in cultured or wild finfish and shellfish stocks in Alaska. This program specifically addresses protection of wild stocks from exposure to disease agents potentially transported by release of hatchery fish, so there is much effort expended in the fish health oversight of the statewide hatchery programs. In Alaska, all hatchery fish diseases in the statewide fish disease database are indigenous and have originated from the donor Alaskan broodstocks of fish used in the hatchery programs. Importantly, the fish disease policy, in place and continually updated for the last 30 years, was designed to reduce disease agent amplification and prevent harmful introductions where these disease agents do not occur naturally. The bacterial and viral agents causing bacterial kidney disease (BKD) and infectious hematopoietic necrosis (IHNV) have been used as indicators of wild and hatchery fish interactions. The existing statewide disease history database has shown no increasing trend in the prevalence of these indicator pathogens due to hatchery interactions. Surveillance of broodstock for vertically transmitted BKD is done annually with the enzyme-linked immunosorbent assay (ELISA) on approximately 8,000 fish so that eggs from positive females can be destroyed. Although modest increases have occurred in the prevalence of IHNV (31% vs. 38%) and in the percentages of sockeye salmon with high virus titers (30% vs. 48%) over the last 30 years, there is no evidence that these increases are correlated with hatchery practices. This is further supported by the temporally low genetic diversity maintained by INHV in Alaska (Emmenegger et al. 2000; Meyers et al. 2003) and indications that hatchery practices have not caused the virus to adapt to other fish species beyond the natural sockeye salmon host, as has occurred in other areas of the Pacific Northwest (Black et al. 2016). Overall, interactions with hatchery-derived fish have not caused increased pathogen levels or prevalence among wild salmonid stocks (Meyers 2005).

The ADF&G fish/shellfish health program also provides surveillance of existing, emerging, and exotic aquatic animal pathogens. To this end, there is continued diagnostic testing of wild and hatchery fish and shellfish stocks for exotic or emerging new pathogens, either from importation (almost exclusively Pacific oysters, aquarium fish, and classroom invertebrates) or from the growing threat of aquatic animal range extension due to global warming. It is important to note that the long-term success of the fish health program is measured by the continued health of Alaska's wild finfish and shellfish resources with respect to the absence of significant diseases. Alaska's fish stocks and population numbers have not been (and currently are not) threatened by any known preventable infectious disease agent.

FISHERIES MANAGEMENT

Alaska's salmon fishery management system is among the most comprehensive and intensive of any fishery in the world (Chaffee et al. 2007). Area and regional fishery managers monitor (1) indicators of abundance, (2) escapements of wild fish to spawning areas, and (3) wild/hatchery composition of the harvest, and manage the harvest sector to increase the probability that escapement goals are attained. In addition to preseason, inseason and annual management and regulatory activity, ADF&G supports research activities to inform management decisions.

Fishery managers deal with mixed stock and mixed species fisheries where hatchery fish can outnumber wild stocks. A fishery manager must balance (1) wild stock escapement requirements, (2) hatchery cost recovery and broodstock needs, and (3) an orderly common property harvest of the highest possible quality. Paramount of these is the requirement to sustain the long-term health and sustained yield of Alaska's wild stocks of salmon. Management measures, as well as the stock assessment programs they are based on, have been tailored to accommodate the added complexity of hatchery-origin fish. Fisheries management practices have adapted through time as new information on hatchery vs. wild run distribution, timing, and abundance became available.

Both wild and hatchery returns are managed to meet wild stock escapement goals. Consequently, stock identification programs are now central to management success, which is gauged in terms of sustained yield of wild stocks. A sample of coded wire tags and/or otoliths are collected from fisheries and from fish on the spawning grounds, which are interpreted to estimate how many hatchery-origin fish are in the harvest and escapement, and which hatcheries the fish were released from. During the fishing season, the harvest is sampled to measure the magnitude of wild and hatchery stock returns, allowing fisheries managers to have improved information to manage for wild stock harvest and escapement goals. Coded wire tags and otoliths from spawned-out carcasses are collected during stream surveys to assess straying. In addition, coded wire tags and otoliths from immature salmon caught in high seas fisheries are used to determine origins and migration patterns.

In PWS, hatchery stocks of pink salmon return simultaneously with the wild pink salmon stocks they are derived from. All PWS hatchery-produced pink salmon are otolith marked. Otoliths are interpreted from samples of fish collected from the commercial fishery to apportion the harvest between hatchery and wild stocks during the season so that managers can conserve the wild stock return to the extent needed and pass them to the spawning grounds. In Southeast Alaska, a percentage of both hatchery and wild stocks of Chinook salmon are coded-wire-tagged. Tags are collected and read during the season so that managers can assess the wild and hatchery components of the return and tailor fisheries to better meet obligations of the PST.

In PWS, ADF&G manages the commercial fishery to achieve sustained yield of wild and hatchery stocks through time. Generally, commercial fishing period duration and areas opened are dependent upon wild stock escapement trends, which are assessed inseason by the aerial survey program. Hatchery cost recovery and broodstock are the management priority in hatchery subdistricts and terminal areas and are managed for both enhanced and wild stocks. Both Valdez Fisheries Development Association and Prince William Sound Aquaculture Corporation provide ADF&G with daily recommendations when managing enhanced stocks returning to their respective facilities. Timely inseason escapement monitoring, harvest trends, and the ability to distinguish between hatchery and wild stock contributions allows ADF&G staff to manage areas to improve the likelihood of achieving escapement objectives and also harvesting potential surpluses of wild and enhanced stocks within PWS.

EVALUATION AND PROTECTION OF WILD STOCKS

Hatchery Strays and Fishery Management

One concern is that hatchery strays into wild systems may muddle the ability of fishery managers to accurately assess the run strength and subsequent escapement of the wild component of the return. The number of hatchery strays is often related to the size of the release, the effectiveness of imprinting at the release site, management actions by ADF&G, and the abilities of the fishing fleet and the hatchery to harvest the returning fish.

It is important to recognize that straying of salmon is not just a hatchery phenomenon. Pink salmon are generally recognized as the species of Pacific salmon with the highest propensity to stray (Keefer and Caudill 2014). Sharp et al. (1994) found extensive straying of coded-wire-tagged wild pink salmon in PWS following the Exxon Valdez oil spill, ranging from 9% to 54%. Thedinga et al. (2000) documented higher stray rates for fish from a wild population with a high proportion of intertidal spawners relative to a wild population with predominately upstream spawners. Sharp et al. (1994), documented that in PWS, between 35% and 75% of the pink salmon spawned intertidally. Without straying, colonization of new areas such as Glacier Bay and newly accessible streams from the 1964 earthquake could not have occurred (Hendry et al. 2003).

Straying of hatchery-origin fish to wild stock systems has been monitored for many years. Hatchery Chinook salmon straying has been monitored on several SEAK systems for decades (Heard 2011; Ed Jones, ADF&G fishery biologist, personal communication). Hatchery-origin Chinook salmon have been detected on the spawning grounds in those monitored SEAK rivers.

Pink salmon straying has been documented in PWS (Joyce and Evans 2000; Brenner et al. 2012; Knudsen et al. 2016) and cross-regional strays have been documented in Cook Inlet (Otis et al. 2018). All 4 of these sources have documented hatchery-origin fish in streams (i.e., recipient straying as defined in Keefer and Caudill 2014). Pink salmon escapement is monitored by aerial surveys, during which fish origin cannot be determined. Because PWS hatchery-origin pink salmon are 100% marked, accurate assessments of hatchery-origin prevalence in streams is possible.

Hatchery Strays and Genetic Effects

A concern for hatchery impacts on wild stocks is that hatchery strays into wild systems may affect population structure and productivity of wild populations. Currently, a consortium of industry, PNPs, and ADF&G, with oversight from a science panel, is implementing a large-scale hatchery-wild interaction study, the Alaska Hatchery Research Project, to examine (1) genetic population structure, (2) hatchery proportions (straying rates) of pink and chum salmon in PWS and chum salmon in Southeast Alaska, and (3) an assessment of the relative fitness of hatchery strays and wild spawners of pink salmon in PWS and chum salmon in SEAK (Gorman et al. 2018). The project is a collaborative effort, funded by the State of Alaska, salmon processors, and fishermen through hatchery operators. The associated science panel (with broad expertise in salmon management, enhancement, and hatchery-wild interactions) designed the research plan and provides oversight and guidance to the research. Fieldwork is being carried out by the Prince William Sound Science Center and Sitka Sound Science Center under contract. The ADF&G Gene Conservation Lab in Anchorage is providing genetic analyses, and ADF&G's Mark, Tag and Age Laboratory in Juneau and the otolith mark recovery laboratory in Cordova are analyzing the otoliths for thermal marks (http://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.findings_updates).

Ecological Interactions Between Hatchery and Wild Fish

Potential interactions between wild and hatchery salmon can occur in both freshwater and marine environments. Ecological concerns from these interactions in freshwater center mostly on carrying capacity for species that have extended freshwater life cycles and competition for spawning habitat (e.g., Fleming and Gross 1992). ADF&G has conducted carrying capacity studies to determine appropriate stocking densities for species that have extended freshwater life cycles such as sockeye salmon (Kyle et al. 1997). Competition for spawning habitat can also be an ecological concern if hatchery-origin fish are less fit than wild-origin fish; for example, superimposition of hatchery fish redds over wild fish redds could reduce the productivity of the system. As noted above, the Alaska Hatchery Research Project is investigating fitness differences between hatchery- and wild-origin fish (Gorman et al. 2018). If a fitness effect is found, the Alaska Hatchery Research Project is not designed to identify the mechanisms (ecological vs. genetic).

Most PNP hatchery programs in Alaska do not release juveniles into freshwater, most ecological concerns are focused on the role of hatchery salmon in nearshore and open ocean marine environments. Studies of ecological interactions within the nearshore marine environment are primarily concerned with predation of returning adult salmon on juvenile salmon and nonsalmonid species (e.g., Sturdevant et al. 2013) or competition between hatchery- and wild-origin juvenile salmon (e.g., Sturdevant et al. 2011). The results of Sturdevant et al. (2011) suggested that the probability of competition between hatchery and wild chum salmon in Taku Inlet was reduced because hatchery release strategies were successful in promoting early spatial segregation and prey partitioning. However, co-occurrence of hatchery and wild-origin juvenile pink salmon does not mean that negative competitive interaction necessarily follows. Comparative studies of hatchery and wild-origin juvenile pink salmon in PWS and the North Pacific Ocean found that similar diets between the 2 groups could be the basis for competition, but similarity of gut fullness and energy content indicated a lack of competitive advantage of either group (e.g., Armstrong et al. 2008; Boldt and Haldorson 2004). Within the open ocean environment, there is concern around ocean carrying capacity and the resulting density-dependent effects on wild salmon, as well as potential trophic changes in the ocean driven by both increased biomass, competition, and climatic change.

The premise of *sea ranching* is that there are excess and unused resources in the marine environment that could support the additional biomass of hatchery-produced salmon. However, it is conceivable that under various scenarios and conditions, biomass could exceed the carrying capacity within large swaths of the North Pacific Ocean. Recent trends in salmon abundance, as indexed by commercial harvests, indicate population abundance is currently the highest on record and rising with no indication of a decline (Ruggerone and Irvine 2018; Irvine and Fukuwaka 2011), with hatchery salmon being a significant component of the increase. The concern is that as salmon biomass increases, density-dependent effects may begin to manifest themselves, especially during periods of low ocean productivity and future uncertainty due to global climate change. Interrelated with this is the concern over competition for limited resources that could result in top-down trophic effects on both salmonid and nonsalmonid species (e.g., Springer and van Vliet 2014).

Studies suggest that density-dependent interactions may be occurring, as evidenced by declines in age-specific size and weight of individuals (Lewis et al. 2015; Ohlberger et al 2018; Jeffrey et al 2017), decreasing age at maturity (Lewis et al. 2015), reduction in growth rate correlated with high salmon abundance (Ruggerone et al. 2012), and decreased survival, especially in pink, sockeye, and chum salmon—the most abundant Pacific salmon species (Azumaya and Ishida 2000, Ruggerone et al. 2005). These data suggest that carrying capacity limitations can occur for Pacific salmon in the North Pacific Ocean. Because hatchery and wild salmon populations from throughout the Pacific Rim coexist within the North Pacific Ocean, a frequently stated concern is that large and increasing releases of salmon from hatcheries exacerbate the potential problems associated with density-dependent interactions (Holt et al. 2008, Ruggerone and Irvine 2018).

Although it is possible that hatchery production of salmon could be associated with density-dependent effects, much of the support consists of correlation of some measured effect with salmon numbers or biomass. Generally, the mechanism or connections are posited, but not demonstrated. Given the complexity of the North Pacific Ocean ecosystem and the life history of Pacific salmon, a variety of environmental factors influence salmon growth and productivity, such as prey density, prey distribution, prey quality, inter- and intraspecies interactions (including nonsalmonid fishes, marine mammals, and seabirds), and water temperature. It is likely that there is no single cause for observed changes in salmon growth and productivity—including hatchery production. Differentiating relative effects of various contributing factors in the North Pacific Ocean is difficult. This ambiguity is made even more evident when reviewing the body of literature on density-dependent effects. It is not yet clearly demonstrated how and to what extent density-dependent interactions occur among populations of salmon in the North Pacific Ocean, whether they are always present or occur only under specific combinations of events, and whether these interactions are responsible for the observed declines in salmon size and weight. There are also myriad other factors that potentially influence salmon production, from fine scale nearshore environment effects to macro-scale climate change effects.

Despite the difficulty of demonstrating direct density-dependent interactions in the North Pacific Ocean and Bering Sea, and teasing apart the complexities associated with potential mechanisms behind those interactions, all habitats have inherent temporal and spatial limits to abundance of organisms they can support. For any level of ocean productivity, each ocean habitat will only support a certain biomass of fish and there is evidence that climate-related change in the coming decades could significantly alter ocean feeding regimes for salmon (Mantua 2009). It also seems likely that hatchery production of salmon, particularly for pink and chum salmon, will increase in the coming decades throughout the North Pacific Ocean. Indicators of adverse density-dependent biological impacts at all life history stages should be considered when weighing policy decisions about future hatchery production levels. However, quantification of ecological effects of hatchery fish on wild populations still remains an unresolved issue (HSRG 2014).

RECOMMENDATIONS

In general, our review of documents suggest that the implementation of Alaska's policies, plans, and permits for SEAK Chinook salmon and PWS pink salmon are largely consistent with a precautionary approach. The SEAK Chinook salmon stock assessment program is adequate for an evaluation of the hatchery program in place, which facilitates precautionary management. We found no elements of any of the policies that were particularly concerning for the SEAK Chinook salmon enhancement program, though a handful were identified as needing improvement and can be addressed with the recommendations provided. The PWS pink salmon enhancement program case study yielded some similar inconsistencies with state policies. There are questions concerning the possible effects of hatchery strays on wild populations of salmon in Alaska. However, the ongoing Alaska Hatchery Research Project initiated in 2012 is providing information to better understand interactions of wild and hatchery-origin pink and chum salmon and a similar research effort is underway for sockeye salmon in SEAK.

In addition to the region-specific recommendations provided in the case studies, we provide the following general recommendations:

1) Clarify the *Genetic Policy* and technical terms, specifically addressing the following:
    a. Add region(s) that encompass Alaska Peninsula areas.
    b. Define significant and unique stocks.
    c. Define remote release sites.
    d. Revisit the criteria designed to ensure adequate stock diversity among hatcheries.
    e. Provide clearer guidance for protection of donor stocks.
    f. Assist with criteria for wild sanctuary designation.

2) Improve communication of policies, plans, and processes to regulatory bodies and stakeholders.

3) Support basic research to better understand homing and the effects of straying.

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