ICICLE

January 17, 2014

Mr. Glenn Haight, Executive Director
Boards Support Section
Alaska Department of Fish and Game
P.O. 1155526
Juneau, AK 99811-5526
Fax: 907-465-6094

ATTN: Board of Fish-Comments for Upper Cook Inlet Finfish

Dear Mr. Haight,

Icicle Seafoods, Inc. has a large presence in the state of Alaska with processing plants from Southeast Alaska to Bristol Bay. We started buying salmon in Upper Cook Inlet in 1977. We have been processing salmon in UCI longer than any of our competitors. The fishing season is much shorter than it used to be and the number of fishing days has dropped off dramatically. This short season, coupled with unpredictable opening schedules makes it very difficult to staff our buying stations and plants in UCI and increases costs. Less fishing time also condenses harvest, which can have a negative impact on quality.

It is important for our business to have regulatory stability. We understand and accept the biological risks. I believe we have excellent fish biologists and managers in Cook Inlet. It is crucial that they are allowed to manage the fisheries based on the best available science.

It is our hope that regulatory stability and historical allocation will be supported and continued in the future. This is essential for a healthy business and economy.

Thank you for your consideration,

John Woodruff
Icicle Seafoods, Inc.
Vice President Operations

Duff Hoyt
Icicle Seafoods, Inc.
UCI Manager, Homer, AK

RECEIVED
JAN 17 2014
BOARDS

Jehnifer Ehmann

BOF Public Comment

3rd Generation Alaskan - Born and raised in Palmer - Lifelong fisherman - President Greater Palmer Chamber of Commerce - Chair Mat Valley Fish and Game Advisory Committee - Member Matsu Borough Fish and Wildlife Commission - Co-Owner Ehmann Outdoors (Outdoor Education Business) - Organizer of Matsu Kids Ice Fishing Derby (Make-A-Wish Fundraiser) - Certified Hunter Education Instructor

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- **Achieving the lower end of all escapement goals shall take priority over not exceeding the upper end of any escapement goal.** (Proposal #103)

"I'm charging each one of you to make sure every stream in your district is filled to the maximum spawning capability. Now, if you allow an over-escapement, depriving the fisherman of their livelihood, you can expect to be criticized. But on a personal level, gentlemen, I want you to understand that if you allow an under-escapement, you can expect to be fired."

Andy Anderson, ADF&G's First Commissioner

Drift Gillnet Fishery Management

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- **Establish discrete harvest zones for mixed stock commercial fisheries. Restructure UCI management to be more similar to the Bristol Bay commercial fishery.**
- **Provide a mixed stock conservation corridor to allow Northern bound salmon to pass through Central District into Northern District.**

"(a) The purpose of this management plan is to ensure adequate escapement of salmon into the Northern District drainages and to provide management guidelines to the department. The department shall manage the commercial drift gill net fishery to minimize the harvest of Northern District and Kenai River coho salmon in order to provide sport and guided sport fisherman a reasonable opportunity to harvest these salmon stocks over the entire run, as measured by the frequency of in river restrictions."

The Central District Drift Gillnet Management Plan

- **Create a youth only King / Coho Fishing Opportunity at Eklutna Tailrace.**

Given the current state of our fisheries in the Northern District it is imperative that we provide a specific opportunity geared for children to participate. We must encourage our future generations to invest in our fisheries.

Proposal Support	Proposal Description	Author
323	Create a Youth Only King Fishery in Eklutna Tailrace	John and Butch Ehmann
376	Create a Youth-Only Coho Fishery in Eklutna Tailrace	John and Butch Ehmann
131	Close waters within one statute mile of the Little Susitna River to commercial fishing.	Mat Valley Fish and Game AC
138	Restrict drift gillnet fishery to the Expanded Kenai and Expanded Kasilof sections from June 19-Aug 10	Mat Valley Fish and Game AC
297	Adopt a King Salmon Management Plan	Mat Valley Fish and Game AC
300	Establish an optimal escapement goal (OEG) for Deshka River coho	Mat Valley Fish and Game AC
313	Adopt a sustainable escapement goal (SEG) established by the Department or establish an optimal escapement goal (OEG) for Little Susitna River sockeye Salmon	Mat Valley Fish and Game AC
315	Adopt a sustainable escapement goal (SEG) established by the department or establish an optimal (OEG) for Little Susitna River Chum Salmon.	Mat Valley Fish and Game AC
321	Adopt a sustainable escapement goal (SEG) established by the department or establish an optimal (OEG) escapement goal for Moose Creek King Salmon.	Mat Valley Fish and Game AC
132	Close waters within on statute mile of the Little Susitna River to commercial fishing.	Matsu Borough Fish and Wildlife Commission
139	Restrict drift gillnet fishery to the Expanded Kenai and Expanded Kasilof Sections.	Matsu Borough Fish and Wildlife Commission
292	Modify management plan to restrict commercial king salmon fishing in the Northern District if sport fishing in the Deshka River is restricted to artificial lures, or close commercial king salmon fishing in the Northern District if sport fishing is restricted to catch and release or closed in Susitna River tributary streams upriver from the Deshka River.	Matsu Borough Fish and Wildlife Commission
296	Adopt a Deshka River king salmon management plan	Matsu Borough Fish and Wildlife Commission
298	Allow use of bait in the Deshka River on June 1 instead of May 15.	Matsu Borough Fish and Wildlife Commission
301	Adopt a sustainable escapement goal (SEG) established by the department of establish an Optimal (OEG) escapement goal for Kashwitna River king salmon	Matsu Borough Fish and Wildlife Commission

Proposals Support	Proposal Description	Author
168	Liberalize the Kenai River sockeye salmon bag and possession limit when the run is forecasted to exceed 2.3 million fish.	KRSA
170	Increase the possession limit for Kenai River sockeye salmon from three to six fish	George Matz
103	Amend management plan to drop in river goals from list of escapement goals, prioritize achieving the lower end over exceeding the upper end of an escapement goal, and require the department to utilize all prescriptive elements found in codified plans before going outside of codified plans to achieve established escapement goals.	KRSA

Alaska Board of Fisheries
Board Support Section
907-465-6094

Chairman Johnstone and Board Memebers,

My name is Andy Couch, and I am a 30-year resident Mat-Su Valley sportfishing guide business owner, who primarily guides for king and coho salmon on the Little Susitna River, Deshka River, and formerly the tributaries of the Susitna River between Willow Creek and Sheep Creek. Most of my annual income comes from guiding fishing trips, and I am writing you regarding my concern for greatly reduced numbers of king salmon and coho salmon that have returned to the Mat-Su Valley in the past 3 years.

This extreme shortage of the two most highly sought sport fish in the Mat-Su Valley has caused two years of severe emergency sport fishing restrictions and closures for both king and coho salmon on the Little Susitna River, and also has resulted in two years of severe emergency king salmon fishing harvest restrictions on the entire Susitna River drainage. In 2013 king salmon harvest was entirely prohibited on Susitna River tributaries upstream of Deshka River, and as a result I guided no king salmon fishing trips to locations that had been personal favorites of some or our multi-year guests.

Harvest closures have caused many guest trip cancellations where we refunded reservation down payments received earlier. Such trip cancellations also resulted in lost lodging, fuel, food, and fish processing, parking and camping fees, and license and king salmon stamp sales, and local taxes directly from our guests and from other anglers who went away discouraged about Alaska salmon fishing in the Mat-Su Valley.

Having continued my guiding business through this difficult time caused by shortages in Mat-Su Valley king and coho salmon returns, I would ask Board members to adopt Upper Cook Inlet salmon management changes that help turn around these king and coho salmon shortages. Proposals concepts I would like the Board to consider adopting include a Deshka River king salmon management plan Proposal #296 or 297 that would create a more predictable Deshka River king salmon fishery and might also help rebuild king salmon numbers upstream of Deshka River.

I recognize the importance of fish to commercial fishermen, but would request that Board Members unanimously support some of the concepts found in Drift Fishery Proposals 144, 147, and 139 that would provide more adequate escapements to Mat-Su Valley rivers and may also provide more reasonable salmon harvest opportunities to all users who depend upon Northern District salmon stocks.

I also request unanimous support for proposals that would standardize a one statute mile conservation area around the mouth of significant salmon producing streams throughout Upper Cook Inlet --- please support this concept found in proposals 131, 132, and 79. I know this year both king salmon and coho salmon sport anglers had a larger than standard conservation area where no fishing was allowed below the Little Susitna River weir for most of the salmon season.

After my clients caught only one Little Susitna River sockeye salmon for the entire 2013 season I support my own proposal 314 which would open sport sockeye salmon harvest on this river only after 2500 sockeye salmon could be projected to pass ADF&G's salmon counting weir.

I also ask for Board support of proposals 292, and 293, which would provide consistent conservation sharing amoungst commercial and sport users during times of low king and coho salmon abundance.

Finally, I ask for Board support of proposal 294 which would create more timely inseason management of the Northern District commercial fishery by consistently incorporating use of two already in place ADF&G weirs and the salmon escapement goals those weirs currently measure.

Thank You for your willingness to serve on the Board of Fisheries, and I look forward to you making decisions that provide the greatest good for the greatest number of Alaskans and provide reasonable opportunities for all resource user groups.

Sincerely,

Andrew N. Couch

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Representative Paul Seaton
House District 30

Memorandum

From: Representative Paul Seaton
To: Alaska Board of Fisheries
Date: January 18th, 2014
RE: Supporting documentation for UCI meeting proposals number 47, 48, and 49

Attached to this fax are three separate documents discussing decreased salmon mortality associated with the use of barbless hooks:

A literature review by Bill Bakke entitled "Barbed and Barbless Hooks and their effect on Juvenile and Adult Salmonid Mortality"

Hooking Mortality of Chinook Salmon Released in the Kenai River, Alaska - Terry Bendock and Marianna Alexandersdottir of the Alaska Department of Fish and Game

Mortality of coho salmon caught and released using sport tackle in the Little Susitna River, Alaska – Doug Vincent-Lang, Marianna Alexanderdottir and Doug McBride, ADFG

Please include these documents for the Alaska Board of Fish consideration of proposals dealing with the use of Barbless Hooks (proposals 47, 48, and 49) at the Upper Cook Inlet Board of Fish meeting.

Barbed and Barbless Hooks and their effect on Juvenile and Adult Salmonid Mortality
A Literature Review

By Bill Bakke
April 22, 2008

Introduction

When there is a conservation concern for a wild salmonid population such as one listed as threatened under the Endangered Species Act, each fish is valuable for its potential contribution to recovery of the population. The loss of juvenile steelhead and salmon cannot be provided without negatively affecting adult abundance several years later. It is important to consider all sources of mortality and take appropriate action over those that can be affected by management. Reducing the mortality associated with angling by requiring single barbless hooks is an important policy decision. Doing so can increase survival of juvenile and adult fish by reducing handling time required to take out the hook, and injury from handling as well as exposure to the air.

The following peer-reviewed studies provide a scientific basis for angling regulations to include barbless hooks as a factor important to conservation of native, wild salmonids. While there is ample justification to use barbless hooks on adult fish as required in ocean commercial fisheries to promote easy release with less handling and a goal of reducing mortality, there is also a measurable conservation benefit from using barbless hooks when adult salmonids are captured by angling in freshwater. These studies provide the verification for this conclusion. Using barbless hooks to reduce injury and mortality for juvenile salmon and steelhead is often overlooked when setting angling regulations. Steelhead juveniles rear in freshwater for 2 to 3 years and are exposed to angling mortality in fisheries targeted on trout and adult steelhead and salmon. It only makes sense to include juvenile fish protection as a benefit of barbless hook fisheries.

With a few exceptions such as the Metolius River, the Oregon Department of Fish and Wildlife has adopted a position opposed to the use of barbless hooks as a conservation tool for vulnerable wild salmonid populations. They base this policy on a scientific literature review done by staff in 2001. Oregon stands alone among entities that are concerned about recovery and protection of wild salmon, trout and steelhead. British Columbia requires single barbless hooks province wide, Washington requires single-point barbless hooks in areas designated as "fly fishing only" or "selective gear rules; California requires single barbless hooks on most trout and steelhead fisheries; Idaho says only barbless hooks may be used when fishing for steelhead in the Salmon and Clearwater river drainages and the Snake River below Hells Canyon Dam.

The studies provided below provide the scientific justification for the Oregon Department of Fish and Wildlife and Commission to adopt single barbless hooks as a conservation management tool to protect native, wild salmonids throughout the state. In waters where these fish are threatened, a more precautionary management approach is appropriate to reduce mortality. In waters where wild fish harvest is allowed, a barbless hook regulation would provide a conservation benefit for those that are released. For example, in some rivers a limit of one wild steelhead per day and 5 per year is allowed. In those fisheries a hatchery fish may also be taken. This means that the angler may release one or more wild fish in order to take a legal limit that includes a hatchery fish. There is also evidence that wild steelhead contribute more to the fishery than their numbers would suggest, so single barbless hooks would not only help prevent mortality, they could contribute to more angler satisfaction through multiple hookings.

The point of this paper is to provide the Department and the Commission with information that provides the scientific justification and benefit of using barbless single hooks in Oregon waters for adult and juvenile fish.

Wright, Sam. 1992. Guidelines for selecting regulations to manage open-access fisheries for natural populations of anadromous and resident trout in stream habitats. North American Journal of Fisheries Management 12:517-527.

"Adding restrictions requiring single hooks, barbless hooks, or flies can provide only relatively small incremental improvements in trout survival. However, managers have realized that these can become important in situations where individual fish are hooked many times. The chance of mortality from a single hooking event was examined for various unweighted combinations of terminal gear from our compilation of research results. The categories and single-event losses were as follows:

Barbless hooks with flies	1.76%
All barbless hooks (with flies or lures),	2.16%
Barbless hooks with lures,	3.00%
All hooks with flies,	3.34%
Barbed hooks with flies,	3.88%
All barbed hooks,	5.86%
Barbed hooks with lures,	6.86%

"The most fundamental rule to remember in managing any open-access trout fishery is that effective regulatory control must be applied to every individual fish (Hunt 1970). Fishing seasons and daily bag limits, when used by themselves, are not effective management tools, because they do not apply to each fish that is captured."

Meka, Julie, M. 2004. The influence of hook type, angler experience, and fish size on injury rates and duration of capture in an Alaskan catch-and-release rainbow trout fishery. North American Journal of Fisheries Management 24:1309-1321.

"Recent studies have emphasized a holistic approach to evaluating the effects of catch-and-release angling on fish by evaluating both sublethal and lethal effects. When fish are subjected to angling stress, they are affected by stressors that may not cause immediate mortality; in fact, some may influence ultimate survival. These stressors include physiological disruptions from landing time, handling time, and exposure to air during the hook removal process or when photographed, as well as the potentially confounding effects of nonlethal hooking injuries."

exposure duration and evaluate the consequences on individual fish. Here we evaluated the short-term sublethal effects of exercise (to simulate angling) and air exposure on the swimming performance of hatchery brook trout at 10 degrees C. (50 degrees F.). Nearly half of the fish held out of the water for 120 seconds were unwilling or unable to swim at all. This work suggests that fish possess air exposure thresholds that, once exceeded, result in performance impairments. Fish released after extended air exposure may become easy prey for predators or could be displaced downstream . We conclude that air exposure should be restricted to less than 60 seconds and ideally should be avoided entirely."

(Note: Barbless hooks decrease the amount of time fish are handled and exposed to air while removing hooks in the study by Meka.)

Taylor, Mathew, J., and Karl R. White. 1992. A meta-analysis of hooking mortality of nonanadromous trout. North American Journal of Fisheries Management 12:760-767.

"...fish caught on barbed hooks had higher mortality rates than fish caught on barbless hooks.

"...the mortality rate for fish caught with barbed flies or lures is almost double the mortality rate of fish caught with barbless flies or lures.

""...the effects of handling on hooking mortality have been sparsely investigated. It would be nice to know about variables such as net use, resuscitation techniques, time out of water, and the effect of barbs on handling time. Research on these variables would give a clearer understanding of how to increase survival rates.

"The overall average mortality rate in these 18 studies was just under 12%. Under the best conditions, with barbless flies or lures, the percentage dropped to under 3%.

Reingold, Melvin. 1979. Mortality and catch rates of juvenile steelhead trout caught on single versus treble barbless hooks. Idaho Department of Fish and Game.

"...even at the low level of mortalities observed, losses from treble barbless hooks were 4.5 times that of losses from single barbless hooks. In an intensive catch-and-release fishery, this could be meaningful...anglers hooked and released 75,000 cutthroat trout on the Middle Fork Salmon River in 1978. Applying the percent mortality observed, single barbless hooks would account for 428 deaths versus 1,928 for treble barbless hooks, a difference of 1,500 trout; predominately spawner size individuals. This is 83% of the estimated season trout harvest in that stream in 1969 (1,800) when it was catch and keep."

Pollard, Herbert, A., and Ted C. Bjornn. 1973. The effects of angling and hatchery trout on the abundance of juvenile steelhead trout. Transactions of the Americana Fisheries Society No. 4: 745-752

"...fishing methods and whether J hooks were barbed or barbless significantly influenced new overall injury rates. Fish caught by spin-fishing had similar injury rates as those caught by fly-fishing; thus, significance was from higher injury rates with barbed hooks for both fishing methods as well as higher injury rates for barbed hooks between fishing methods."

"...novice anglers injured proportionally more fish than experienced anglers. The number of new injuries per capture was more significant in small fish. Small fish were hooked in more than one location more frequently than large fish (small fish <440 mm or 17-inches)...small fish were injured more frequently, and bleeding was most significant in fish hooked in sensitive areas and in small fish...small fish had higher bleeding rates. Bleeding was more prevalent in small fish. This presumably was because they were injured in sensitive areas more often as well as injured more often."

"...hook removal time was significantly longer when barbed J hooks were used compared to barbless J hooks. Mortality was also higher for fish caught with treble hooks compared with single hooks, presumably because the increase in hook-point penetrations increased the probability of injury to critical locations and associated bleeding. My results indicate that smaller fish (<17-inches) may be more vulnerable to mortality."

"In this study, barbed J hooks caused significantly more new hooking injuries, took longer to remove, and were more efficient at catching fish than barbless hooks. Higher injury rates and longer handling times for barbed hooks were mostly likely due to difficulty in hook removal and hooks becoming tangled in landing nets, both of which were observed to intensify injuries and bleeding. Barbless hooks have been found to cause a lower incidence of injury and bleeding than barbed hooks and decrease the amount of time fish are handled and exposed to air while removing hooks."

"The results of this study indicate that the use of barbless J hooks may minimize injury and reduce the amount of time fish are handled during hook removal and that angler experience can contribute to hooking injury."

"However, a slight reduction in hooking injuries and less handling time are two important benefits to consider in support of a regulation change or promotion of angler education programs for catch-and-release trout fisheries."

"...focus future research on the prolonged sublethal effects of hooking injury on trout populations, and develop angler education programs and gear restrictions to minimize injury."

Schreer, Jason, F., Dayna M. Resch, and Malachy L. Gately. 2005. Swimming performance of brook trout after simulated catch-and-release angling: looking for air exposure thresholds. North American Journal of Fisheries Management 25:1513-1517.

"Air exposure has been hypothesized as one of the primary stressors present during catch-and-release angling. However, there are few studies that systematically vary air

"A large proportion of juvenile steelhead trout in a stream can be removed with a moderate amount of angling. Age II-plus steelhead are especially susceptible to harvest by angling and 70 to 100% of those present in a 122 m (400 ft) section of stream were removed with 4 angler hours of effort. The normal sport fishery may take as many as half of the catchable size (age II-plus) juvenile steelhead from a stream such as the Crooked Fork each year, and thus may reduce the number of smolts produced."

"Hatchery reared, catchable sized rainbow trout did not act as a buffer to reducing the angling harvest of juvenile steelhead..."

"Removal of the larger pre-smolts by angling could decrease adult returns due to fewer smolts and decreased survival of the remaining, small smolts."

(Note: This study was included to show how vulnerable juvenile steelhead are to a trout fishery and the impact of a fishery on the future abundance of adult returns. Angling with barbed hooks increases tissue damage, handling time, exposure to air, and causes a reduction in smolt numbers and adult returns.)

Cowen, Laura. 2007. Effects of angling on chinook salmon for the Nicola River, British Columbia, 1996-2002. North Americana Journal of Fisheries Management 27:256-267

"Gjernes (1990) found that barbed hooks caused higher hooking mortality rates. Bartholomew and Bohnsack (2005) reported three studies that showed increased mortality when using barbed versus barbless hooks. We did not use barbed hooks in this study."

"The optimal angling gear and techniques used in our study included soft, knotless-mesh landing nets, suitable hook sizes, barbless hooks, short playtime, short handling time, little or no air exposure, angling only at water temperatures less than or equal to 20 degrees C, and leaving deep hooks in or removing them gently with pliers. In addition, Bartholomew and Bohnsack (2005) advocate fishing actively and setting the hook as soon as possible, use of dehooking tools, and avoidance of touching gills and handling the soft underbelly of the fish."

Pelletier, Christine, Kyle C. Hanson, and Steven J. Cooke. 2007. Do Catch-and-release guidelines from state and provincial fisheries agencies in North America conform to scientifically based best practices. Environ Manage 39:760-773

"Barbless hooks were recommended by 34 (or 69%) agencies as an alternative to barbed hooks."

"However, there is compelling evidence that barbless hooks are easier to remove than barbed hooks. Ease of removal results in reduced handling time and tissue damage, thereby decreasing associated mortality."

"The Ontario Ministry of Natural Resources and the Utah Division of Wildlife Resources explained that replacing treble hooks with single hooks will make live release easier.

Because air exposure tends to occur when anglers remove hooks, these agencies have taken a positive approach in stressing the importance of a timely live release."

"Air exposure was the most widely discussed catch-and-release issue among agencies. It was found that 44 of 49 agencies provided advice on the subject. The most common recommendation (64%) was to keep the fish in the water at all times. This is consistent with studies showing that air exposure is extremely harmful in fish that have experienced physiological disturbances associated with angling. Tufts (1992) found that when rainbow trout were exposed to air for either 30 or 60 seconds after exhaustive exercise, mortality increased from 38% to 72%, receptively."

"...removing hooks (in deeply hooked fish) often results in mortality associated with increased handling time and air exposure."

"Considering that water temperature is regarded as the 'master factor' in the biology of fishes, it is surprising that angling at extreme temperatures was not incorporated into all agency guidelines."

"...mortality among Atlantic salmon is minimal when angled at water temperatures between 8 degrees C and 18 degrees C., but as water temperatures increased to greater than 18 degrees C, the risk of angling-induced mortality increases considerably."

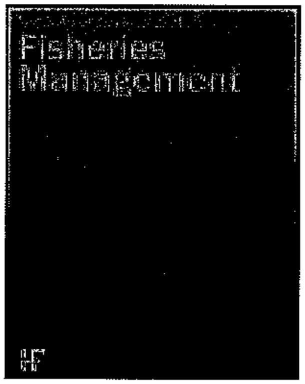
"...we believe that natural resource agencies are the appropriate target of initial attempts to ensure that catch-and-release guidelines are consistent with the best scientific information."

Conclusion

In recent angler surveys by Oregon and Washington fish management agencies, a larger proportion of the respondents practiced catch-and-release fishing. Anglers are embracing live release fishing as a conservation measure. It also does not substantially deplete fish numbers like a kill fishery, and provides at least the expectation that the fish will survive to reproduce or be caught again.

The use of single barbless hooks complements the growing interest in catch-and-release fisheries. As these studies show, their use reduces sublethal and lethal impacts on juvenile and adult fish.

The Oregon Department of Fish and Wildlife and the Commission ought to review their opposition to the use of barbless hooks in selective fisheries. The goal of selective fisheries is to allow angling opportunity while achieving conservation objectives. Barbless hooks advance the conservation objectives of selective fisheries.



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Hooking Mortality of Chinook Salmon Released in the Kenai River, Alaska

Terry Bendock [a] & Marianna Alexandersdottir [b]

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North American Journal of Fisheries Management 13:540–549, 1993

Hooking Mortality of Chinook Salmon Released in the Kenai River, Alaska

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Abstract.—Short-term (5-d) mortality of chinook salmon *Oncorhynchus tshawytscha* caught and released in the Kenai River was assessed with radiotelemetry. From 1989 to 1991, 446 adult chinook salmon were tagged with radio transmitters in four experiments. Overall hooking mortality averaged 7.6% and ranged from 10.6% in 1989 to 4.1% in 1991. Mortality was highest for small males (<750 mm mid-eye length) compared with large males and all females. Wound location and bleeding were the factors principally associated with mortality. Survival of chinook salmon that were hooked in the gills or were bleeding was significantly reduced; however, the frequency of these injuries was small in all experiments. Most mortalities occurred within 72 h of release. These results support the use of hook-and-release regulations in similar freshwater chinook salmon fisheries to reduce sportfishing mortality effectively and achieve spawning escapement goals.

A widespread and successful strategy for managing commercial fisheries for Pacific salmon *Oncorhynchus* spp. is to achieve a desired spawning escapement by manipulating fishing mortality (Minard and Meacham 1987). Implicit in this management strategy is an ability to estimate the in-river abundance of fish. This strategy was recently adopted for the Kenai River, which sustains the largest recreational fishery for chinook salmon *Oncorhynchus tshawytscha* in Alaska. The Kenai River supports two runs of chinook salmon (Burger et al. 1985). Separate escapement goals have been developed for the early run (May–June) and the late run (July–August). Hydroacoustic assessment (sonar) is used to estimate the in-river abundance of chinook salmon, and fishing mortality is estimated from a creel survey. The difference between these two estimates equals the spawning escapement. Management options for the recreational fishery, such as mandatory catch-and-release fishing, restrictions on the use of bait, and total fishery closures, are used to regulate the harvest of chinook salmon to achieve escapement goals for each run.

The Kenai River enjoys a wide reputation for abundant catches of large chinook salmon. As the fishery expanded during the 1980s and bag limits were reduced, voluntary catch-and-release fishing emerged as a popular method to selectively harvest trophy-sized fish. By 1988, the Alaska Department of Fish and Game estimated that the released component of the early-run catch was equivalent to 73% of the spawning escapement. The rapid growth of catch-and-release fishing and the likelihood of using it to achieve spawning escapement goals raised concerns among anglers and fishery managers over the mortality of released fish. Few studies are available on hooking mortality of salmon in freshwater (Wydoski 1980; Mongillo 1984). Estimates of hooking mortality for chinook salmon in marine fisheries vary widely, ranging from 20.5% (Wertheimer 1988) to 71% (Parker and Black 1959). If hooking mortality were high in the Kenai River, the spawning escapement could be seriously underestimated.

The objective of our study was to estimate the short-term (5-d) mortality rate for chinook salmon that were hooked and released in the Kenai River recreational fishery. In this study, we used radiotelemetry to monitor the daily locations of chinook salmon and a matrix of criteria based on telemetry signals and movement behavior to estimate the fates of tagged fish. Associations between mortality and biological and fishery variables were also examined. Based on our results, we discuss the appropriateness of catch-and-release angling as a management option for Kenai River chinook salmon.

Study Site

The Kenai River (Figure 1) is a glacial stream that flows west 136 km across the Kenai Peninsula lowlands before reaching Cook Inlet in south-central Alaska. The river drains an area of approxi-

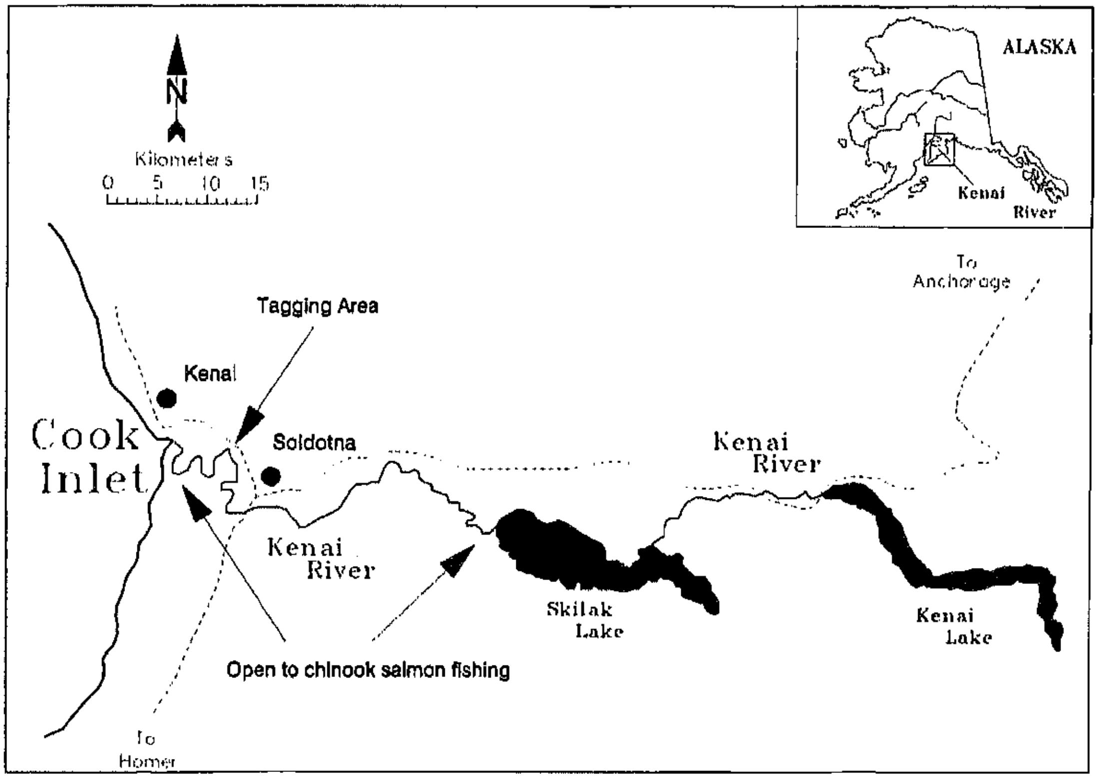

FIGURE 1.—Map of the Kenai River drainage in south-central Alaska.

mately 5,700 km^2 and has a mean annual flow of 160 m^3/s (Scott 1982). Flows are highest in summer due to glacial meltwater; however, peak discharges from glacier-dammed lakes may occur throughout the year. Changes in stream temperature and discharge are moderated by the presence of two large lakes that are intersected by the mainstem Kenai River.

In recent years, up to 26% of the total statewide fishing effort has occurred in the Kenai River drainage. Much of that effort (annual mean, 473,320 angler-hours) is directed at chinook salmon, resulting in a mean annual harvest of 17,223 fish since 1985. Most chinook salmon are caught by anglers fishing from small outboard-powered boats. Fishing takes place throughout the lower 80 km of the main stem; however, 82% of the chinook salmon fishing effort and 88% of the harvest occurs in a 19-km reach of the lower river where our study was conducted.

Methods

Experimental design and assumptions.—The turbidity of the Kenai River prevents direct observation of study animals. The absence of weirs or similar structures and the remoteness of many spawning areas makes the recovery of marked-and-released fish problematic. We used radiotelemetry to identify and locate individual fish, and determine their fates following release. Thus, the mortality we estimate includes effects of handling and tagging. Although radiotelemetry has been used to study chinook salmon spawning and migratory behavior (Liscom et al. 1978; Gray and Haynes 1979; Burger et al. 1985; Eiler 1990), we are not aware of other studies that have used radiotelemetry to estimate hook-and-release mortality.

Radiotelemetry provided a means of estimating the mortality of fish that were released back into the river after hooking, unlike most hooking mortality studies, in which the study population is confined. Daily records of fish locations and status allowed determination of survival of tagged fish, and methods of survival and analysis (Cox and Oates 1984) accounted for removal of animals from the study (tagged fish could be retaken in the fishery or removed from the population of tagged fish if tag failure or emigration occurred). We estimated mortality during the 5 d following hook and release because up to 95% of salmonid hooking mortality has occurred within 48 h of capture in previous studies (Warner 1979; Mongillo 1984).

Attenuation of radio signals is high in salt water (Stasko and Pincock 1977) and there is some evidence that hooking mortality of salmon is higher in salt water than in freshwater (Parker et al. 1959). Consequently, we limited our tagging to a 4.8-km reach of the lower Kenai River that corresponded to the upper limit of tidal influence but was 5–6 km above salt water. We assumed that all fish had a similar opportunity to acclimate to freshwater before entering the study.

Tagging was carried out in four experiments; two replicates for each run of Kenai River chinook salmon provided four separate estimates of survival and an estimate of annual variability. Separate mortality experiments were conducted during the early runs in 1990 and 1991, and the late runs in 1989 and 1990. We attempted to tag 100 fish in each experiment and to deploy the tags in equal weekly proportions throughout each run.

Major assumptions of this study were (1) there was no tagging or natural mortality, (2) fish did not loose their tags, and (3) tags that were detached for reasons other than hook-and-release mortality or that we failed to locate were a random subset of the total sample.

Radiotelemetry.—We used low-frequency transmitters (48–50 MHz; Advanced Telemetry Systems, Inc., Isanti, Minnesota) that had unique radio frequencies separated by 10 kHz. Transmitters measured approximately 20 × 70 mm and had a 350-mm external wire antenna and a battery life of 85 d. Transmitters operated in one of three modes based on pulse rates: (1) normal, indicated by 1 pulse/s and maintained by intermittent movement of the tag; (2) mortality, indicated by 2 pulses/s and triggered when the tag was motionless for 6 h; or (3) active, indicated by the addition of pulses in the normal mode that resulted from exaggerated or rapid movement of the tag (Eiler 1990).

Transmitters were mounted on the right side of each fish beneath the anterior half of the dorsal fin. Nickle pins (7.6 mm), epoxied to each end of the tags, were inserted through the fish's musculature and securely tied against 2.5-cm plastic Petersen discs.

We located tagged fish daily from a Piper Super Cub (PA-18) aircraft that had a directional loop antenna mounted to the left wing jury strut. Aerial tracking was conducted at approximately 105 km/h and 300 m above the water surface. A programmable receiver scanned for frequencies at 2-s intervals, and the location of each fish was estimated to be under the point of maximum acoustic signal strength. Fish activity was recorded as either normal, active, or nil, depending upon transmitter pulse rates. We continued to locate tagged fish for up to 60 d or until a final fate for each fish could be estimated.

Fish acquisition and processing.—Fish used in our study were caught by recreational anglers. We did not attempt to influence the methods or terminal gears used to capture fish; however, a single-hook artificial lure requirement was in place during the 1990 and 1991 early-run fisheries. Our tagging crew, working from a small boat, started a stopwatch when a fish strike was observed. We subsequently inquired if the angler intended to release the fish and, if so, whether we could equip the fish with a radio transmitter. Fish that were obtained in this manner were played to the angler's boat and placed in a landing net. The leader was cut, and the fish and net were passed to the tagging boat without being removed from the water. Our crew started a second stopwatch to record the handling time, removed the fishing tackle, noted the location(s) of hook wound(s), and transferred the fish to a tagging cradle. Fish were not anesthetized, nor were they removed from the water during capture, transfer, or handling. All fish obtained in this manner were tagged and released regardless of the apparent severity of hooking injuries. Biological and fishery variables were recorded for each angling event (Table 1). When tagging and processing were concluded, the cradle was opened and fish were allowed to swim away.

Determining fates of tagged fish.—Each fish was assigned a 5-d and a final fate (Table 2). Tag recoveries from sport, commercial, and subsistence fisheries, interpretations of daily movements, and radio transmission modes were used to estimate fates. Five-day fates could not be established in some cases until later in the experiment due to the tendency of some fish to mill for extended periods in the lower river. The following three classifications defined fates at the end of 5 d.

(1) Survived—fish that sustained upstream movement, transmitted radio signals in either active or normal modes, or were harvested after the 5-d period.

(2) Died—fish that failed to move upstream from the intertidal area at river kilometer (rkm) 19.3, transmitted radio signals in the mortality mode, or were recovered dead (still tagged) within 5 d of release.

(3) Censored—fish removed from the study due

TABLE 1.—Summary of values for biological and fishery variables recorded during each hook-and-release event in the Kenai River, Alaska, 1989–1991.

Variable	1989 Late run (N = 100)	1990 Early run (N = 125)	1990 Late run (N = 120)	1991 Early run (N = 101)	All runs (N = 446)
Sex					
Male	56	69	89	53	267
Female	44	56	31	48	179
Mean mid-eye length (mm)					
Males	854	904	704	836	819
Females	1,003	936	957	911	948
Guided angler					
Yes		96	66	72	234
No		29	54	29	112
Angling method					
Back-troll	8	125	26	101	260
Drift	92	0	91	0	183
Back-bounce	0	0	3	0	3
Terminal gear					
Bait	0	0	0	0	0
Artificial lure	15	125	23	101	264
Bait and lure	85	0	97	0	182
Hook type					
Single	94	122	106	87	409
Treble	6	3	14	14	37
Number of hooks					
One	1	119	9	81	210
Two	99	6	111	20	236
Hooking location					
Gill, eye, tongue	9	8	1	6	24
Jaw, snag	91	117	119	95	422
Hooks removed					
Yes	97	112	112	93	414
No	3	13	8	8	32
Bleeding					
Yes	11	26	15	18	70
No	89	99	105	83	376
Sea lice					
Yes	79	93	101	84	357
No	21	32	19	17	89
Condition					
Vigorous	91	120	116	100	427
Lethargic	9	5	4	1	19
Mean handling time (min)	17.0	14.8	14.8	14.7	15.3

to factors other than hook-and-release mortality, such as harvest in the recreational fishery, commercial fishery, or two in-river gill-net fisheries; fish that returned to salt water and were not subsequently located; and fish that were never located following release.

The most difficult determination of fate was estimating mortality. Because radio transmitters occasionally provided ambiguous evidence of fish death, we developed the following series of decision rules to help determine fate 2.

(2a) If a carcass was recovered within 5 d, the fish was allocated to hook-and-release mortality.

(2b) If a fish consistently moved upstream at any time during and after the first 5 d, it was considered a survivor (regardless of signal mode).

(2c) If a fish remained immobile, transmitted a mortality signal within 5 d, and continued to transmit in the mortality mode thereafter, the fish was considered a hook-and-release casualty regardless of river kilometer of location.

(2d) If a fish remained immobile in the intertidal area below rkm 19.3 within 5 d of release and remained immobile or moved slowly downstream, the fish was considered a hook-and-release casualty regardless of signal mode.

The first two rules (2a and 2b) are unambiguous; tracking a fish farther and farther upstream was

TABLE 2.—Fates of radio-tracked chinook salmon caught and released in the Kenai River, Alaska, 1989–1991. Small males were less than 750 mm (mid-eye length), and large males were 750 mm or longer.

	Late run 1989			Early run 1990			Late run 1990			Early run 1991			
Fate	Small males	Large males	Females	Small males	Large males	Females	Small males	Large males	Females	Small males	Large males	Females	Total
						First 5 d							
Died[a]	4	3	2	3	2	6	6		1	2		2	31
Survived	17	24	22	14	49	49	55	23	28	12	37	45	375
Gill-net harvest	4	2	8		1		2			1	1	1	20
Sport harvest		2	11			1	1	1	1				17
Dropout[b]							1	1					2
Unknown[c]			1										1
Total	25	31	44	17	52	56	65	25	30	15	38	48	446
						End of season							
Died[d]	4	3	2	4	2	9	6		1	3		3	37
Spawner	11	14	15	12	43	39	34	15	22	8	33	36	282
Gill-net harvest	4	4	10		2		7	4	1	2	1	1	36
Sport harvest	2	8	12		3	6	6	3	3	1	3	1	48
Tag failure							1				1	1	3
Dropout[b]	4	1	2	1	1	1	6	3	1			3	23
Upstream, lost[e]		1	2		1	1	5		2	1		3	16
Unknown			1										1
Total	25	31	44	17	52	56	65	25	30	15	38	48	446

[a] Fish that died within 5 d are classified as hook-and-release mortalities.
[b] Fish that returned to salt water and were not subsequently located.
[c] Tagged fish that we never relocated.
[d] Some fish were classified as dead that died after 5 d but prior to spawning.
[e] Fish that moved upstream and subsequently stopped transmitting a signal.

considered proof of survival. Rules 2c and 2d are necessary because transmitter mortality signals did not provide a clear indication of death. We observed mortality signals even in instances when fish were consistently located farther and farther upstream. Transmitters could also transmit several days of mortality signals while the fish remained immobile, then suddenly resume a normal signal while the fish moved upstream. Transmitters on stationary fish could transmit a mixture of mortality and normal signals. Assumptions that we made in rules 2c and 2d were (1) fish that disappeared from the Kenai River were alive, because a dead fish could not float out to sea; (2) because no spawning occurs in the intertidal area below rkm 19.3, fish observed to be stationary or slowly moving downstream in this area were dead regardless of signal; and (3) fish above rkm 19.3 that were immobile but transmitted normal signals were survivors.

Thus, location became crucial in our decision process. The most important assumption was that there was no spawning below rkm 19.3 (Burger et al. 1985), and a fish that did not migrate upstream of this point was dead.

Survival estimation.—Chinook salmon survival was estimated with the nonparametric Kaplan–Meier procedure (Cox and Oates 1984; Pollock et al. 1989). This procedure computed the percentage of fish dying on each day of the experiment from all fish at risk at the beginning of that day, and it allowed for fish that were lost (censored) due to transmitter failure, harvest, or emigration (Pollock et al. 1989). The variance for the survivor function was estimated with Greenwood's formula (Cox and Oates 1984). The Kaplan–Meier estimator was stratified and a chi-square statistic was computed by the log-rank method (Kalbfleisch and Prentice 1980) to test the hypothesis that the survivor functions did not differ among strata. The influence of biological and fishing variables on hook-and-release mortality was estimated with Cox's proportional hazards regression model (Cox and Oates 1984); the Kaplan–Meier estimator was used as a base hazard.

An assumption of survival analysis is that censorship is a random process. We compared the size distributions of tagged fish that were censored with the distribution of the total released sample by using the Kolmogorov–Smirnov statistic (Conover 1980). The hypothesis of no association between the distribution of explanatory variables and censorship was tested with chi-square statistics (Snedecor and Cochran 1967). A chi-square test of independence was also used to compare the distributions of fates by 2-week periods. All statistical tests were conducted at the 95% significance level.

Results

Retention of chinook salmon in the recreational fishery was prohibited during most of the 1990 and 1991 early runs. In order to achieve optimum early-run escapement goals during these runs, the use of bait was prohibited and terminal gear was limited to single-hook artificial lures only. Consequently, a catch-and-release fishery was in place during these periods of the study. Fishery variables recorded during the study (Table 1) reflect these regulatory changes and account for the disparity in fishing methods and gears between the early- and late-run fisheries.

In total, 446 chinook salmon were caught, tagged, and released during 1989–1991 (Table 2). Tagging each fish required from 2 to 10 min and averaged 4.3 min (SD, 1.5 min). Angling times ranged from 20 s to 1 h and averaged 6.5 min (SD, 6.5 min). We tagged 100 fish during the late run in 1989, 125 fish during the early run in 1990, 120 fish during the late run in 1990, and 101 fish during the early run in 1991. Most (375) of these fish survived for 5 d after release, 31 fish died, and 40 were censored (Table 2).

Only 3 chinook salmon defined as hook-and-release casualties were recovered dead within 5 d of release. The remaining 28 casualties were fish that did not move above the intertidal area (rkm 19.3). About half of the tags on these fish transmitted consistently in the mortality mode; the remainder transmitted intermittent mortality signals.

The majority (282 fish; 63%) of our tagged fish were assigned final fates as spawners, and 84 fish (19%) were ultimately harvested. Thirty-nine fish (9%) either returned to salt water or were lost at some point upstream. One fish's (0.2%) final fate was unknown, three fish (0.7%) had tag failures, and an additional six fish (1.3%) died following the 5-d period but before spawning (Table 2).

Mortality of hooked-and-released fish during our four sampling events ranged from 10.6% during the 1989 late run to 4.1% during the 1991 early run. The average mortality for all experiments was 7.6%. The stratified Kaplan–Meier estimates of survival for these four experiments were not significantly different (χ^2 = 4.8, df = 3, P = 0.19). However, the size and sex distributions of fish and censoring patterns differed significantly among the four experiments.

The size distribution of tagged chinook salmon varied among experiments. Females ranged from 590 mm to 1,155 mm (mid-eye length) and averaged 948 mm. Males ranged from 405 mm to 1,210 mm and averaged 819 mm. Few (2%) tagged females were under 750 mm in length because most females mature after spending at least 3 years in the ocean, by which time they are larger than 750 mm. However, the age composition of mature males encompasses younger fish, and 125 (47%) of our tagged males were under 750 mm. The relative proportion of small males varied, constituting up to 54% of the late-run experimental population in 1990.

The rate of censoring was different for the late run in 1989 compared with the other experiments. In 1989, 28 fish (28%) were censored within 5 d of release. Thirteen fish were harvested in the sport fishery and 14 fish were harvested in gill-net fisheries. Most (20) of the censored fish were females, and 11 of these were taken in the sport fishery. This high rate of censoring was not repeated in the 1990 or 1991 experiments, in which only 12 fish were censored (Table 2). To meet the assumption that censoring was random, we stratified our results for the survival analysis by experiment (1989 versus 1990–1991) and by size–sex groups: small males (<750 mm), large males (≥750 mm), and females.

Survival Following Hook-and-Release

Small males had the lowest survival in all experiments. In 1989, females had the highest survival, followed by large males, whereas in 1990–1991, large males consistently had higher survival rates than females. Survival curves (Figure 2) were much steeper for small males, reflecting the higher mortality rates for this group.

The overall survival estimate for 1989 was 0.894 (SE = 0.033). Estimated survival was 0.825 (SE = 0.081) for small males, 0.901 (SE = 0.054) for large males, and 0.935 (SE = 0.044) for females. Survival estimates for the three size–sex groups during 1989 were not significantly different (P = 0.48), but the proportion censored was significantly different among the three groups.

The overall survival estimate for the combined 1990–1991 experiments was 0.936 (SE = 0.013). Estimated survival was 0.885 (SE = 0.033) for small males, 0.982 (SE = 0.013) for large males, and 0.932 (SE = 0.022) for females. These esti-

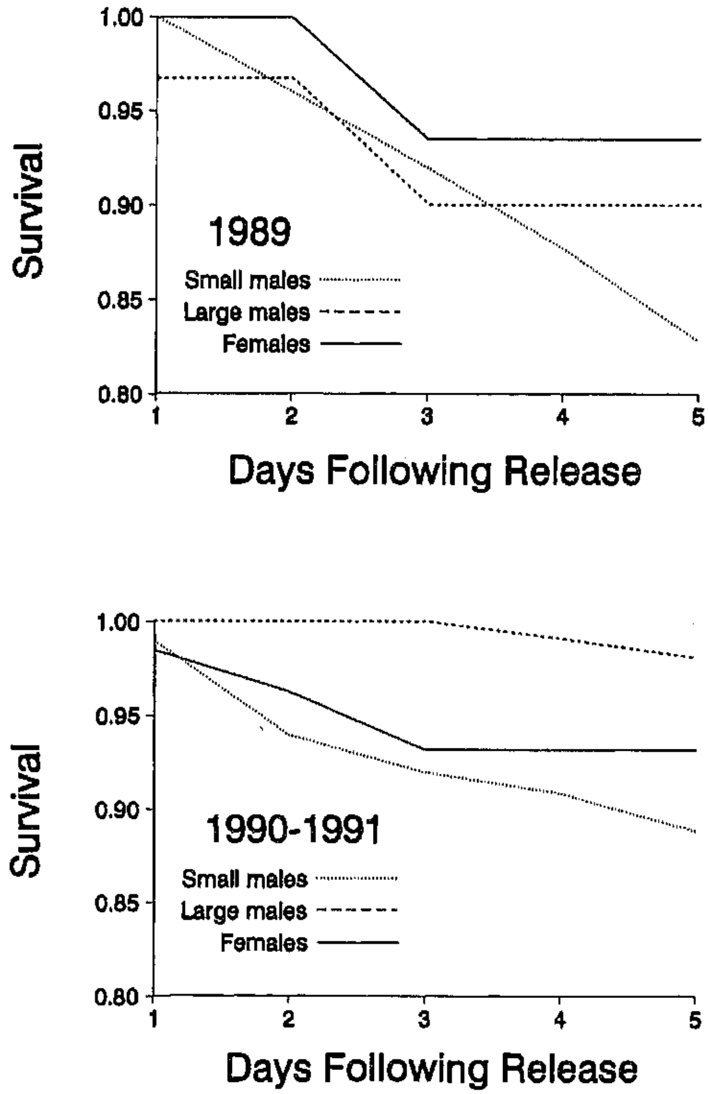

FIGURE 2.—The Kaplan–Meier survival function for chinook salmon by experiment and size–sex group, 1989–1991.

mates of survival by size–sex groups were significantly different. There was little censoring during 1990–1991 and no difference in censoring among size–sex groups.

Thirty-one hook-and-release casualties were detected during the four experiments. Of these, 24 (80%) died on or before the third day following release (Table 3). Hook-and-release mortality was independent of date of release for all of the experiments, and there was no significant association between the rate of censoring and fishery variables. Although two chinook salmon runs enter the Kenai River, and these are managed separately, there was no difference between these runs in their overall rate of hook-and-release mortality.

Variables Affecting Mortality

Hooking location was the most significant factor affecting the survival of released fish. Two proportional hazard models were fit to the data stratified by size–sex groups, one to the 1989 data and the second to the 1990–1991 data. Hooking location was the only explanatory variable that was identified as a significant covariate. Data were stratified by size–sex groups of released fish, and hooking locations were combinated into two

TABLE 3.—Daily numbers of hook-and-release fish at risk[a] and survival estimates for radio-tracked chinook salmon in the Kenai River, Alaska, 1989–1991. Small males were less than 750 mm (mid-eye length), and large males were 750 mm or longer.

Day[b]	Small males		Large males		Females	
	At risk	Survival	At risk	Survival	At risk	Survival
			1989			
1	25	1.000	31	0.968	44	1.000
2	24	0.958	30	0.968	37	1.000
3	23	0.917	29	0.901	31	0.935
4	21	0.873	24	0.901	27	0.935
5	18	0.825	24	0.901	23	0.935
			1990–1991			
1	97	0.990	115	1.000	134	0.985
2	96	0.938	115	1.000	131	0.963
3	90	0.917	112	1.000	128	0.932
4	86	0.907	112	0.991	122	0.932
5	84	0.885	109	0.982	122	0.932

[a] Numbers of fish at risk declined because of both death and data censorship (see Table 2). Fish censored during the first 5 d did not count against survival.
[b] Represents day after release. After day 5, all surviving salmon were censored from the experiment.

groups: vital areas including gills, tongue, or eye; and jaw or snag locations (Table 4). Over the entire 3 years, 24 fish were hooked in vital areas and 11 (46%) of these died (Table 4). The remaining 422 fish were hooked in the jaw or snagged, and of these only 20 (4.7%) died (Table 4). During 1990–1991, bleeding was also found to be significant. In total, 70 fish were bleeding when released and 15 (21.4%) of these died, whereas 16 of 376 fish not bleeding (4.3%) died (Table 4).

The effects of hooking location and bleeding were most pronounced on small males and females (Table 4). The predicted survival for each value of the covariate was estimated, all other covariates being held at their mean values. In the model fit to the 1990–1991 data, a small male hooked in a vital area was predicted to have only a 56.3% chance of survival and a female a 64.2% chance; a large male would still have a 91.6% chance of surviving upon release (Table 5). The predicted values for the model fit to 1989 data were more extreme, but

TABLE 4.—Distribution of explanatory variables by size–sex class and 5-d fates of radio-tracked chinook salmon during 1989–1991. Small males were less than 750 mm (mid-eye length), and large males were 750 mm or longer.

Size–sex group and variable	Numbers of fish (%) by 5-d fate		
	Censored	Died	Survived
Hooking location			
Small males			
Vital area[a]	1 (11)	4 (44)	4 (44)
Jaw or snag	8 (7)	11 (10)	94 (83)
Large males			
Vital area[a]		1 (20)	4 (80)
Jaw or snag	8 (6)	4 (3)	129 (91)
Females			
Vital area[a]		6 (60)	4 (40)
Jaw or snag	23 (14)	5 (3)	140 (83)
Bleeding			
Small males			
Not bleeding	9 (9)	8 (8)	83 (83)
Bleeding		7 (32)	15 (68)
Large males			
Not bleeding	7 (5)	3 (2)	119 (92)
Bleeding	1 (6)	2 (12)	14 (82)
Females			
Not bleeding	23 (16)	5 (3)	119 (81)
Bleeding		6 (19)	25 (81)

[a] Vital area includes gills, tongue, and eye.

TABLE 5.—Comparison of observed 5-d survival probabilities to those predicted with Cox's proportional hazard model (Cox and Oates 1984). Small males were less than 750 mm (mid-eye length), and large males were 750 mm or longer.

Year and fish status	Probability of survival		
	Small males	Large males	Females
Observed			
1989	0.825	0.901	0.935
1990–1991	0.885	0.982	0.932
Predicted			
1989			
Hooked in jaw or snagged	0.876	0.920	0.970
Hooked in gills, eye, or tongue	0.005	0.034	0.316
1990–1991			
Hooked in jaw or snagged	0.931	0.989	0.946
Hooked in gills, eye, or tongue	0.563	0.916	0.642
Not bleeding	0.942	0.991	0.955
Bleeding	0.794	0.966	0.837

sample sizes were much smaller (N = 101) compared with the 1990–1991 combined data set (N = 346).

Discussion

Assumptions of the Study

We assumed that fish did not loose their tags in our study. Only three transmitters were not relocated daily during the first 5 d after release. No fish were found in any fishery with tagging scars, and there were no loose tags reported or turned in. We also assumed that there was no mortality resulting from the tagging procedure. We felt that tagging mortality was unlikely due to the brief handling time and low overall mortality estimates. Our data were stratified in order to satisfy the assumption that censorship was a random process. There were no indications that removal in any fishery or movement out of the river within the first 5 d was associated with any of the variables we measured or the time of tagging.

Estimates of Mortality

Our estimates of mortality for chinook salmon that were caught and released in the Kenai River are low, ranging from 4.1 to 10.6% and averaging 7.6% over four experiments. It is likely that these estimates are conservative, because they include effects from handling and radio-tagging. Also, 66 radio-tagged fish were caught again in the recreational fishery, and some of these fish were released again. Thus it is possible that tagged fish were subject to additional hook-and-release events not reported to us. Our estimates are lower than mortality rates in sport fisheries for many other species caught with bait (Wydoski 1980; Mongillo 1984), and they are considerably lower than estimates for troll-caught chinook salmon in marine fisheries. Parker and Black (1959) estimated a mortality rate of 71% (all sizes of chinook salmon) and Wertheimer (1988) estimated rates of 24.5% for small chinook salmon and 20.5% for large chinook salmon that were caught in marine troll fisheries.

Although our four experiments differed in several aspects, including the size and sex distributions of tagged fish, the rate and pattern of censoring, and the distribution of fishery variables, the final conclusion on the survival of fish that were hooked and released is the same for all experiments. Fish length, hooking locations, and bleeding were the only variables that affected mortality in our study. There were consistent differences in mortality among size–sex groups for all four experiments. Hooking mortality was highest for small males and ranged from 9.2 to 17.6%. For large males, estimates ranged from 0 to 9.7%; for females the range was 3.3–10.7%. The observed relationship between size and mortality was consistent with findings in previous studies of chinook salmon (Wertheimer 1988) and lake trout *Salvelinus namaycush* (Loftus et al. 1988).

Effects of Fishery Variables

Numerous studies have focused on the relationship between anatomical hook locations and subsequent mortality (Wydoski 1980; Mongillo 1984). Bleeding has also been associated with decreased survival of hooked fish (Warner and Johnson 1978; Nuhfer and Alexander 1992). A Kenai River chinook salmon that was hooked in a vital location (gills, eye, or tongue) had a significantly reduced chance of surviving compared with one that was snagged or hooked in the jaw. Fish that were bleeding also suffered increased mortality. However, the frequency of chinook salmon that were hooked in vital areas (5.4%) or bleeding (18.6%) was small in our study. Hence, the overall effect of these factors was minimal. We found no significant difference in mortality rate between fish caught with bait or with artificial lures, even though all of our early-run fish were caught on lures and most (83%) late-run fish were caught on baited hooks. Thus, chinook salmon caught in the Kenai River by backtrolling or drifting in small boats are apparently hooked superficially regardless of the terminal tackle that is used.

Most (80%) of the hooking-related deaths in our study occurred on or before the third day following release, suggesting that mortally wounded chinook salmon succumb quickly. We found no evidence for delayed mortality of our tagged fish. Most of our tagged fish could be accounted for in a fishery or on the spawning grounds up to 45 d following release.

Management Implications

Our findings suggest that fishing mortality for Kenai River chinook salmon can be reduced by over 90% by implementing catch-and-release regulations. However, the findings also suggest that these low mortality rates depend upon the characteristics of the fishery and to some extent on the large size of Kenai River chinook salmon. Nearly all chinook salmon fishing in the Kenai River is conducted from boats, and regulations prohibit an angler from removing a fish from the water if it is intended to be released. These factors must be considered before our results are applied to other stocks of salmon in freshwater fisheries.

Increased pressures on declining stocks have resulted in catch-and-release regulations for selected fisheries in most states and provinces across North America (Barnhart 1989). Catch-and-release regulations for the Kenai River have been successfully used to achieve escapement goals by reducing fishing mortality without restricting angling opportunity. Nevertheless, angler participation on the Kenai River declined precipitously in 1990 and 1991 following the implementation of catch-and-release regulations for the early-run fishery. Strong chinook salmon returns in adjacent Cook Inlet drainages contributed to the decline in Kenai River effort, but it is more likely that anglers who fish for food have been slow to embrace catch-and-release regulations for salmon fisheries.

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Mortality of coho salmon caught and released using sport tackle in the Little Susitna River, Alaska

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ABSTRACT

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Coho salmon (*Oncorhynchus kisutch*) were caught with sport gear in the estuary of the Little Susitna River, southcentral Alaska. Fish were double marked and released. All coho salmon observed migrating through a weir above the estuary and a portion caught in a sport fishery below the weir were examined for marks. A second group of coho salmon were caught using similar sport gear above the estuary. These fish were handled and marked identically as the fish captured in the estuary, except that they were held in a holding pen at the weir with an equal number of coho salmon dip netted at the weir. Coho salmon which were caught and released in the estuary suffered a significantly higher rate of mortality (69%) than did either the coho salmon caught and held above the estuary (12%) or those which were dip netted and held at the weir (1%). Factors that could influence rates of hook-induced mortality were measured at the time of hooking. Hook location, hook removal, and bleeding significantly affected the measured mortality rate.

INTRODUCTION

In many sport fisheries, anglers are asked to release all or a portion of the fish they catch. This management strategy is commonly called 'catch-and-release' (Pettit, 1977). Catch-and-release is a generally accepted and widely applied management tool in sport fisheries across North America (Reingold, 1975; Pettit, 1977; Johnson and Bjorn, 1978; Hunt, 1981; Anderson, 1982; Jones, 1982; Anderson and Nehring, 1984). It is a tool which enables managers to continue maximizing the opportunity to participate in recreational fisheries while reducing mortality to what can be termed 'catch-and-release

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mortality'. In this way, the economic value of recreational fishing is not jeopardized as the opportunity to participate is not reduced (Clawson, 1965; Gordon et al., 1973). The mortality associated with a catch-and-release fishery is a cost that must be considered when developing a management strategy for specific sport fisheries (Cutter, 1974; Anderson, 1975; Wydoski, 1977).

In contrast to resident fish populations (Klein, 1965; Hunsaker et al., 1970; Wydoski et al., 1976; Dotson, 1982; Schill et al., 1986), little quantitative information is available describing catch-and-release mortality in sport fisheries for Pacific salmon (*Oncorhynchus* sp.) (Warner, 1976, 1978; Warner and Johnson, 1978; Warner, 1979). Many salmon sport fisheries are conducted with bait, a practice which has been shown to result in high mortality rates for resident fish (Hunsaker et al., 1970; Wydoski, 1977; Warner and Johnson, 1978).

The Little Susitna River supports the second largest freshwater sport fishery for coho salmon (*Oncorhynchus kisutch*) in Alaska (Mills, 1988). Fishing effort has tripled and harvests of coho salmon have doubled since 1981. Most of the fishing effort and harvest of coho salmon is concentrated in the estuary of the river (Bartlett and Conrad, 1988). Anglers predominantly fish with bait in the estuary (Bentz, 1987) and release about 13% of the coho salmon caught in the estuary (Bentz, 1987; Bartlett and Conrad, 1988). Managers have raised concern that these released fish suffer high mortality rates (Bentz, 1987).

The objectives of this study were to estimate the short-term (5 day) rate of mortality of coho salmon caught and released in and above the estuary of the Little Susitna River and estimate the effects that several hooking factors have on observed rates of hook-induced mortality.

STUDY AREA

The Little Susitna River is a clearwater tributary to Upper Cook Inlet, Alaska (Fig. 1). The river is approximately 180 km in length and has a drainage area of approximately 1000 km^2. The river has an average stream flow of approximately 6 $m^3\ s^{-1}$, with winter flows typically less than 2 $m^3\ s^{-1}$ and peak summer flows near 30 $m^3\ s^{-1}$. During the study, stream flows ranged from 10 to 20 $m^3\ s^{-1}$. In the study area, the river has a channel gradient of approximately 1.0 $m\ km^{-1}$ and channel widths of approximately 25–30 m. Depths in the study area range from less than 1 to 2 m, depending upon stream flow.

METHODS

Three hundred and eighty-four coho salmon were caught in the estuary using sport gear from 20 July through 18 August 1988. All coho salmon were

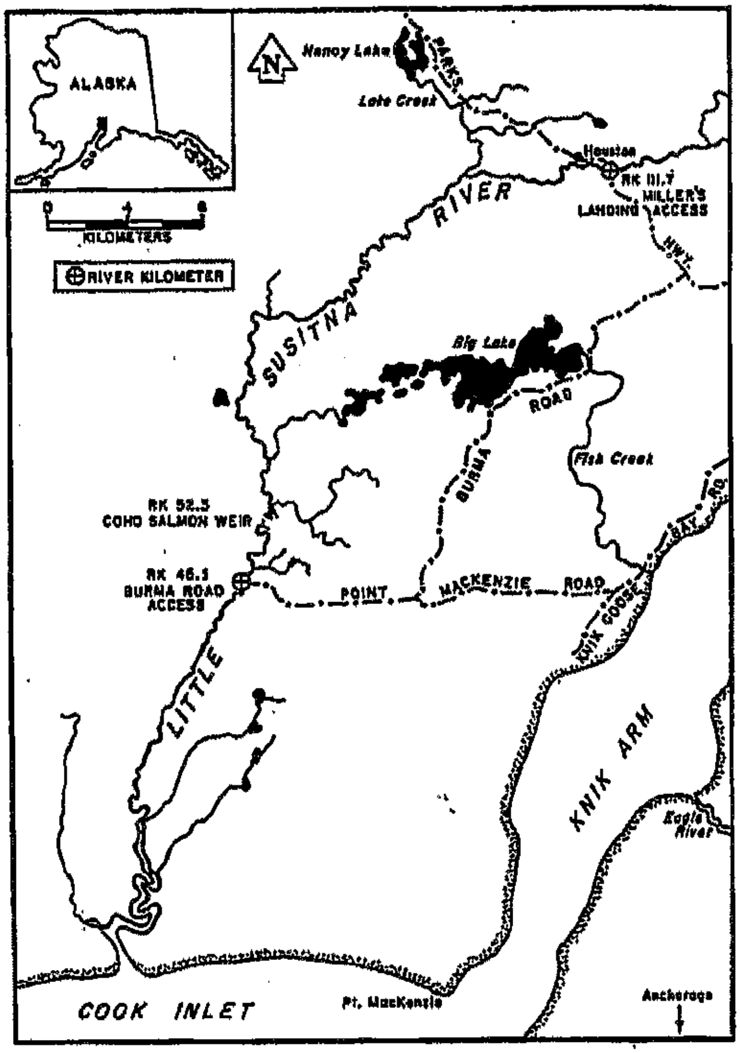

Fig. 1. Study area of the Little Susitna River, Alaska.

captured and released at approximately river kilometer (RK) 32. We were unable to develop a means to capture a control group from this section of the river. Water temperatures during this period ranged from 10 to 13°C. Number 2/0 barbed hooks drifted with clusters of salmon eggs were used to catch fish. This method of fishing was selected over other methods to simulate the typical fishing practices used by anglers fishing the Little Susitna River (Bentz, 1987; Bartlett and Conrad, 1988; Bartlett and Vincent-Lang, 1989). Personnel from the Alaska Department of Fish and Game and volunteers from the public participated in the study.

All coho salmon were hooked, played, and landed in a manner similar to that practiced by most anglers fishing coho salmon in the Little Susitna River, with the exception that all deeply embedded hooks were not removed. An unknown percentage of anglers fishing the Little Susitna River remove deeply embedded hooks. We chose to leave deeply embedded hooks in place as removal has been shown to increase mortality (Mason and Hunt, 1967; Hulbert and Engstrom-Heg, 1980). Each landed fish was marked with an individually numbered Floy FT-4 spaghetti tag. Spaghetti tags were inserted posterior to the dorsal fin using a sharp needle and tied securely using a single overhand knot. In addition, each tagged fish received a punched hole in its caudal fin using a paper punch. After marking, each fish was held in the current, then released.

Several variables that could influence hooking mortality were measured or estimated at the time of capture. The hooking factors or variables recorded for each fish were: time played on hook with two categories (less than 1 min or more than 1 min), time handled out of water with two categories (less than 1 min or more than 1 min), estimated amount of scale loss with three categories (less than 10%, 11–25%, or more than 25%), location of the hook with four categories (mouth, gill, gullet, or head outside of the mouth), whether or not the hook was removed (yes or no), whether or not the fish was bleeding when released (yes or no), and a qualitative assessment of the general condition of the fish when released with two categories (vigorous or lethargic).

All coho salmon observed migrating through a weir upstream of the estuary (at RK 52.3) were examined for tags and punched caudal fins. This weir was a complete barrier to migration of adult salmon and all fish were passed through a trap in the weir where they could be counted and/or examined. The weir was constructed of sealed grey PVC, 2.5 cm schedule 40 electrical conduit pipe (about 3.2 cm o.d.) attached to panels. Spacing between conduits was approximately 3.8 cm. Panels were attached to each other and a 1.0 cm cable secured to a railroad rail substrate. The substrate was attached to the bottom using spikes and sandbags. The buoyancy of the sealed pipes allowed the panels to float. The angle of the panels was adjusted, depending on flow, to vary from 30 to 45°. Over these angles, adult coho salmon were not able to pass through, over, or under the panels.

The number of marked coho salmon removed by the sport fishery below the weir was estimated using a creel survey, with all major access points of the fishery being surveyed. All anglers exiting the fishery at each access point were asked how many coho salmon they had harvested and their harvest of coho salmon was examined during randomly selected time periods for tags and caudal punches. The survey used a stratified (by weekly period), two-stage random sample design with approximately 30% of the total available fishing time being surveyed at each access site. Mean harvest, calculated for the periods sampled, was expanded over all possible periods to estimate total harvest of coho salmon. The harvest and its variance was estimated as described in Sukhatme et al. (1984) and Bartlett and Vincent-Lang (1989), for two-stage designs with unequal numbers of second-stage units (anglers).

The mortality rates for fish caught and released in the estuary were compared with those in a second group of 77 coho salmon which were caught above the estuary, immediately downstream of the weir from 31 July through 11 August 1988. Water temperatures during this period ranged from 10 to 13 °C. These fish were caught using identical capture and marking techniques to those described above, except that these fish were held for 5 days in a 12 m^3 live trap located at the weir. The same hooking variables and mortality rate measured for the fish caught in the estuary were measured or estimated for this group of fish at the end of the 5 days.

In order to separate handling-induced mortality from hooking-induced mortality, a control group consisting of an equal number of coho salmon were dip netted at the weir during the same period and held in the same live trap. Fish that were dip netted at the weir site were handled and marked in the same manner as the angled fish, except that the dip netted fish were not subjected to the effect of being hooked and played by rod and reel. The mortality rate was similarly measured for this group of fish after 5 days.

Mortality rates

The rate of hook-induced mortality ($\hat{M}_e$) for the fish captured and released in the estuary and its variance ($V(\hat{M}_e)$) were estimated. Survivors were assumed to include coho salmon passing the weir (N_w) and those removed in the sport fishery ($\hat{N}_r$). All other coho salmon in the experiment were assumed to be hook-and-release mortalities. Therefore, the proportion surviving (p_s) becomes

$$\hat{p}_s = \hat{N}_r/N_t + N_w/N_t$$

where N_t is the total number of coho salmon marked and released in the estuary.

The number removed in the fishery ($\hat{N}_r$) is estimated, but the number passing the weir and the total sample size are constants, so the variance of the proportion surviving is estimated by

$$V(\hat{p}_s) = V(\hat{N}_r)/N_t^2$$

The mortality or proportion dying, $\hat{M}_e$, is estimated by

$$\hat{M}_e = 1 - \hat{p}_s$$

and the variance is equal to the variance of $\hat{p}_s$. Normal confidence intervals (95%) were calculated for the estimated mortality rate, $\hat{M}_e$.

The number of marked coho salmon removed by the sport fishery between the release location and the weir during each strata of the fishery ($\hat{N}_r$) was estimated by expanding the number of marks observed in the creel during each strata to the total estimated harvest during that strata

$$\hat{N}_r = \hat{H} \times \hat{p}_l$$

where $\hat{p}_l$ is the proportion of coho salmon checked in the creel that were observed to have marks during a specific stratum and $\hat{H}$ is the estimated harvest of coho salmon in the sport fishery during that stratum.

The variance of $\hat{N}_r$ in each stratum was estimated using Goodman's (1960) formula for the variance of a product of two independent variates

$$V(\hat{N}_r) = \hat{H}^2 \, \mathrm{var}(\hat{p}_l) + P_l^2 \, \mathrm{var}(\hat{H})$$

The variance of the proportion, p_l, was calculated using the formula for the variance of a binomial variable (Cochran, 1977). Seasonal totals for $\hat{N}_r$ and its variance were estimated by summing strata estimates as strata estimates were considered to be independent estimates.

The rate of hook-induced mortality ($\hat{M}_{ui}$) for the two groups of fish captured above the estuary and dip netted at the weir (control) was estimated as

$$\hat{M}_{ui} = G_{di} / G_{ti}$$

where G_{di} is the number of fish that died during the holding period in group i and G_{ti} is the number of fish in group i that were placed into the holding pen.

Confidence intervals (95%) for the mortality rate, $\hat{M}_{ui}$, were estimated using the normal approximation to the binomial (Cochran, 1977). This estimate of mortality necessitates the assumption that all hook-induced mortality occurs within the 5 day holding period. The mortality of the control group represents any handling-induced mortality.

Hooking factors

The influence that each of the hooking factors had on observed rates of hook-induced mortality was examined using a series of χ^2 tests. Although all coho salmon that passed through the weir were examined for the presence of tags placed in the estuary, it was not possible to obtain individual numbers for all tags observed during peak migrational periods. Therefore, for fish marked in the estuary, a χ^2 statistic was used to test the null hypothesis that there was no difference ($\alpha = 0.05$) in the distribution of each of the hooking variables for all the fish at the time of tagging and the distribution of these variables for all the fish observed at the weir.

For fish marked and held at the weir, the total sample could be divided into two classes, survivors and mortalities, and a χ^2 statistic was used to test the null hypothesis that the probability of death due to hook-and-release was independent of the hooking variables ($\alpha=0.05$). In several cases, hooking variable categories had to be grouped owing to small sample sizes.

RESULTS

Hook-induced mortality

Ninety-eight of the 384 coho salmon marked in the estuary were passed through the weir. A total of 5589 fish were examined for marks from the sport fishery below the weir, of which a total of nine marked fish were recovered. These nine marked fish were expanded, based on an estimated harvest of 11 616 (SE=392.8), to an estimated 20 (SE=6.7) marked fish recovered by the sport fishery below the weir over the duration of the fishing season (Table 1). An additional 14 marked fish were recovered by anglers fishing below the weir and were voluntarily returned outside of the creel sampling effort. While these 14 recoveries provide for a slightly greater estimate of contribution to the sport fishery (9+14=23 actual tag recoveries as opposed to an estimated 20 tag recoveries), the number of tags returned is well within the confidence limits of the estimate ($7<N_r<33$). For purposes of this anal-

TABLE 1

Data used to estimate the number of marked coho salmon removed by the sport fishery

Strata	Estimated harvest	SE	No. tagged	No. inspected for tags in creel	No. observed with tags in creel	Estimated no. of tags (N_r)	$V(N_r)$
16/7–17/7	88	12.4	0	58	0	0	0.0
18/7–22/7	239	61.9	5	105	0	0	0.0
23/7–24/7	544	52.4	8	390	0	0	0.0
25/7–29/7	2967	273.4	155	1231	1	2	5.8
30/7–31/7	1132	38.2	22	722	2	3	4.9
1/8–5/8	2344	172.4	70	942	4	10	24.7
6/8–7/8	1199	61.5	3	726	1	2	2.7
8/8–12/8	1143	131.2	101	451	0	0	0.0
13/8–14/8	424	29.1	2	294	0	0	0.0
15/8–19/8	787	116.6	18	301	1	3	6.8
20/8–21/8	310	28.0	0	224	0	0	0.0
22/8–26/8	301	61.4	0	76	0	0	0.0
27/8–28/8	106	38.7	0	57	0	0	0.0
29/8–2/9	14	8.4	0	3	0	0	0.0
3/9–5/9	18	7.8	0	9	0	0	0.0
Total	11616	392.8	384	5589	9	20	44.9

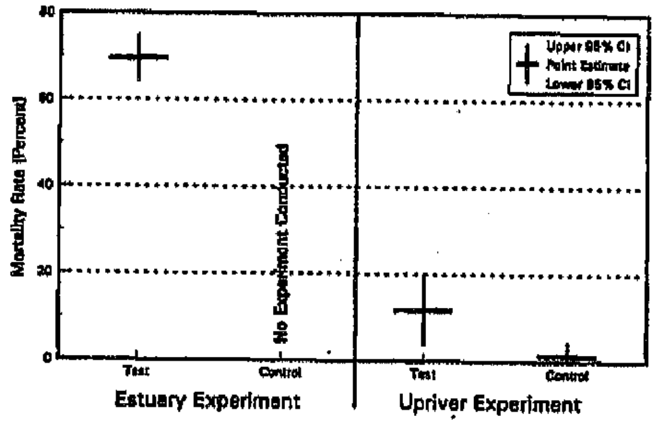

Fig. 2. Estimated rates of mortality for coho salmon in and above the estuary of the Little Susitna River, Alaska.

ysis, we chose to use the unbiased estimate of 20 recoveries in the sport fishery. Therefore, in total, an estimated 118 of the 384 marked coho salmon survived to be recovered either in the sport fishery below the weir (20) or at the weir (98). From this, the estimated rate of hook-induced mortality for the fish captured in the estuary was 69.3 ± 5.3% (Fig. 2).

Of the 77 coho salmon caught above the estuary, nine died during the 5 day holding period, yielding a rate of hook-induced mortality for these fish of 11.7 ± 7.9%. Of the 77 coho salmon dip netted from the weir, only one died during the 5 day holding period, yielding a handling-induced mortality rate of 1.3 ± 3.2%. The mortality rates of the fish captured in and above the estuary significantly (α=0.05) differed from each other as well as from the dip netted fish.

Factors influencing hook-induced mortality

Only 47 of the 98 tag numbers of fish marked in the estuary and passed through the weir were identified. Additionally, there were several fish, both at the point of capture in the estuary and at the point of recovery at the weir, for which not all of the variables were recorded. For example, the bleeding criteria was recorded for only 378 of 384 fish in the estuary and 46 of 47 fish examined at the weir. For this reason, the sample sizes for some of the χ^2 tests vary slightly from the total number tagged and examined.

Variables in the estuary experiment that had significantly (α=0.05) changed in their distribution from the time of tagging to the time observed at the weir were hook location and hook removal (Table 2). Coho salmon which did not have the hook removed represented 67% (257 fish) of the total tagged sample (384 fish) but only 32% (15 fish) of the fish observed upstream at

TABLE 2

Hook-induced variables measured on angled coho salmon for fish tagged in the estuary and observed passing the weir[1]

	Tagged in estuary		Observed at weir		χ^2 statistic
	N	%	*N*	%	
Bleeding					
Not bleeding	262	68	36	77	2.07
Bleeding	116	30	10	21	
Fish condition					
Vigorous	293	76	42	89	4.18**
Lethargic	80	21	5	11	
Hook removal					
Hook not removed	257	67	15	32	27.38**
Hook removed	123	32	32	68	
Scale loss					
1–10%	330	86	45	96	3.32
11–25%	44	11	1	2	
>25%	7	2	1	2	
Time handled					
Handled ≤1 min	323	84	43	92	1.91
Handled >1 min	56	15	4	8	
Time angled					
Played ≤1 min	157	41	24	51	1.45
Played >1 min	224	58	23	49	
Hook location					
Mouth/head	196	51	40	85	20.84**
Gills	77	20	1	2	
Gullet	105	27	6	13	

[1]A total of 384 fish were tagged and 47 seen at the weir; however, some of the above contingency tables total less owing to missing values.

**Significant at $P \leq 0.05$.

the weir (47 total). Of the 182 coho salmon (47%) hooked in the gills or gullet at the time of tagging, only 15% (seven fish) were observed at the weir (Table 2). Hook location and hook removal, however, were not independent variables in the estuary experiment as the hook was not removed from most fish (177 of 184) hooked in the gills or gullet, while of the 197 fish hooked in the head or mouth, 62% (116) had the hook removed (Table 3).

Separate χ^2 tests comparing the observed with the expected frequencies of fish which had the hook removed and with those which did not have the hook removed were carried out for each hook location (Table 3). These tests were only significant ($\alpha = 0.05$) for fish hooked in the head or mouth. Of the 39 fish observed at the weir, only 23% (nine fish) were from the group with the hook not removed, while at the time of release in the estuary this group rep-

TABLE 3

Distribution of hook removal group, by hooking location, for coho salmon caught and released in the estuary and observed passing the weir[1]

		Tagged in estuary		Observed at weir		χ^2 statistic
		N	%	*N*	%	
Mouth/head	Hook removed	116	58.9	30	76.9	5.24**
	Not removed	81	41.1	9	23.1	
Gills/gullet	Hook removed	7	3.8	1	12.5	1.65
	Not removed	177	96.2	7	87.5	

[1]Missing values: hook location, two fish; hook removal, one fish.
**Significant at $P \leq 0.05$.

resented 41% of all fish hooked in the head or mouth areas (Table 3). The same test for fish hooked in the gills or gullet was not significant ($\alpha=0.05$). Few of these fish arrived at the weir and there was not a significant difference in the proportion of these fish at the time of their release and the proportion of these fish that arrived at the weir (Table 3).

In the weir experiment (Table 4), the probability of dying was significantly ($\alpha=0.05$) related to the location of hooking. Of the 77 coho salmon hooked at the weir for the pen experiments, 81% (62) were hooked in the head or mouth but only 22% of the nine fish that died belonged to this hook location group (Table 4). The χ^2 tests were also significant ($\alpha=0.05$) for hook removal and bleeding (Table 4), but as for the estuary experiment there appeared to be interaction with hook location. The hook was not removed from 14 of the penned fish in the weir experiment and of these five (36%) died; however, all of these mortalities had been hooked in the gills or the gullet (Table 5). Of the 62 fish hooked in the head or mouth, only two had the hook left in, too small a sample size to test for an effect of hook removal. Fish that were bleeding represented 34% of the sample and were more likely to die, but again most of the mortalities that were bleeding were also gilled fish (Table 5). In effect, although hook removal and bleeding appeared to significantly contribute to the mortality, the sample sizes were too small to separate these effects from hook location.

A comparison of the two experiments show that the number of coho salmon hooked and released in each group of hooking variables differs between the two experiments (Table 6). For example, a higher percentage of coho salmon were hooked in the gill and gullet in the estuary (48%) compared with fish caught at the weir (20%). Also, few of the fish hooked upstream at the weir that were hooked in the head and mouth area had the hook left in. The higher mortality estimated for the estuary experiment appears to be, at least in part,

TABLE 4

Distribution of hooking variables, by fate, for coho salmon captured and tagged above the estuary and held at the weir

	Fate of tagged fish					χ^2 statistic
	Died		Survived		Total	
	N	%	*N*	%		
Hook location						
Mouth/head	2	22	60	88	62	19.48**
Gill	4	45	1	2	5	
Gullet	3	33	7	10	10	
Bleeding						
Bleeding	7	75	19	28	26	8.83**
Not bleeding	2	25	49	72	51	
Condition at release						
Excellent	6	67	49	72	55	0.17
Good	2	22	18	26	20	
Poor	1	11	1	2	2	
Hook removal						
Hook removed	4	44	59	87	63	9.57**
Hook not removed	5	56	9	13	14	
Scale loss						
1–10%	8	89	66	97	74	1.42
11–25%	1	11	2	3	3	
Time handled						
Handled ≤ min	–	–	7	13	7	<0.01
Handled > 1 min	9	100	61	89	70	

**Significant at $P \leq 0.05$.

TABLE 5

Distribution of hook removal and bleeding group, by hook location, for coho salmon caught and held at the weir

		Survived	Died
Mouth/head	Hook removed	58	2
	Not removed	2	0
Gills	Hook removed	1	2
	Not removed	0	2
Gullet	Hook removed	–	–
	Not removed	7	3
Mouth/head	Bleeding	15	2
	Not bleeding	43	0
Gills	Bleeding	0	4
	Not bleeding	1	0
Gullet	Bleeding	2	1
	Not bleeding	5	2

TABLE 6

Comparison of the number of coho salmon caught and released, by hooking variable, in the estuary and weir experiments[1]

Combination of categories	Estuary exp.				Weir Exp.	
	Total marked		Handled at weir		Total marked	
	N	%	N	%	N	%
Gilled, hook removed, bleed	4	1.1	0		2	2.6
Gilled, hook not removed, bleed	39	10.3	1	2.2	2	2.6
Gilled, hook not removed, not bleed	33	8.7	0		0	
Gilled, hook removed, not bleed	1	0.3	0		1	1.3
Gullet, hook not removed, bleed	31	8.2	1	2.2	3	3.9
Gullet, hook not removed, not bleed	73	19.3	5	10.9	7	9.1
Gullet, hook removed, not bleed	2	0.5	1	2.2		
Eye/mouth, hook removed, bleed	24	6.3	7	15.2	19	24.7
Eye/mouth, hook not removed, bleed	17	4.5	1	2.2	0	
Eye/mouth, hook not removed, not bleed	64	16.9	8	17.4	2	2.6
Eye/mouth, hook removed, bleed	90	23.8	22	42.8	41	53.2

[1]Missing values in total marked in estuary (384): hook removal=1, hook location=2, bleeding=3. Missing values in salmon observed at the weir (47): bleeding=1.

due to the high incidence of fish being hooked in the gills or gullet and to the higher frequency of hook non-removal for fish hooked in the head and mouth area. However, even for the group with the lowest mortality in the estuary (fish hooked in the head/eye or mouth with the hook removed), the estimated mortality is higher than that for the upstream pen experiment. Of the 114 fish released in the estuary group, 29 were seen at the weir and two in the creel. Expanding these as was done for the total sample, a total of 62 fish are estimated to survive in this group, which yields a mortality rate of 46%.

DISCUSSION

Assumptions for the mortality estimates

The validity of estimated mortality rate for coho salmon caught and released in the estuary hinge upon the assumption that a marked fish had only one of three fates: (1) it was removed by the sport fishery below the weir; (2) it migrated through the weir; (3) it died due to hook-induced mortality. There are, however, two additional possible fates that need to be considered: migration out of the estuary to other stream systems or migration to tributaries below the weir. Although not rigorously tested, we have no reason to believe that either of these two alternate fates occurred. We found no evidence that coho salmon marked in the estuary of the Little Susitna River migrated out of the river. Extensive commercial set net fisheries which intercept coho salmon of Little Susitna River origin occur in the marine waters near the Little Susitna River. In addition, extensive sport fisheries occur in various freshwater drainages adjacent to the Little Susitna River. This study was well publicized and industry and the fishing public in Alaska are well aware of tagging studies and the desire of Alaska Department of Fish and Game to have tags returned, yet no tags were returned voluntarily. Conversely, 14 tags were voluntarily returned from the Little Susitna River sport fishery. Additionally, approximately 6000 coho salmon were examined during 1988 in Upper Cook Inlet commercial fisheries, sport fisheries, and spawning escapements in the course of sampling for age, sex, and size data (Vincent-Lang and McBride, 1989). No marked fish were found in this sampling. We therefore conclude that there was little movement of marked fish out of the estuary. We also found no evidence that marked fish, or for that matter any coho salmon, spawned in either the Little Susitna River mainstem or its tributaries below the weir. Historically, there has been no spawning in either the mainstem or tributaries below the weir in the Little Susitna River. Aerial and foot surveys conducted from 1977 to 1979 and during 1988, failed to document any spawning downstream of the weir site in either the mainstem or tributaries (L. Engel, Alaska Department of Fish and Game, personal communication, 1989). Based on this information, we conclude that the fate of a marked fish in the estuary was limited to one of the three fates described above.

Several additional assumptions are necessary in assessing the validity of these estimates: (1) there was no handling-induced mortality; (2) there was no tag loss; (3) all hook-induced mortality occurred before marked fish reached the weir and a marked fish which was recaptured in the sport fishery below the weir was considered a survivor. The observed rate of handling mortality after 5 days for dip netted fish at the weir was 1%. Given the magnitude of the mortality rates in this study for sport-caught fish, this level of handling-induced mortality can be considered insignificant. No untagged coho salmon examined in the sport fishery or at the weir had a caudal fin punch. Thus, no tag loss was observed. The last assumption states that all hook-induced mortality occurred before the fish reached the weir or before they could be recaptured in the sport fishery. Previous studies indicate that 90–95% of hook-induced mortalities occur in the first 48 h (Stringer, 1967; Hunsaker et al., 1970; Falk et al., 1974; Warner and Johnson, 1978). The average travelling time of our tagged fish to the weir was 18.8 days, with the first tag observed 5 days after tagging and the last tag observed 32 days after tagging. Short-term mortality occurred within 5 days of tagging, well before any of the fish reached the weir. Of the 23 tagged fish actually recovered from the sport fishery, only 5 (21%) were taken within 5 days of being tagged. Therefore, a small percentage of the fish that were sport-caught might otherwise have died owing to hook-induced mortality. However, if true, then our estimate of hook-induced mortality from the estuary fishery is conservative, as recoveries from the sport fishery are assumed to be survivors in this analysis.

Mortality rates

The measured rate of hook-induced mortality for coho salmon caught by anglers using bait in the estuary of the Little Susitna River (69%) is higher than mortality rates reported in the literature for bait-caught fish while the measured mortality rate for coho salmon caught above the estuary of the Little Susitna River (12%) was lower than rates reported in the literature. Warner and Johnson (1978) found that landlocked Atlantic salmon *Salmo salar* caught with bait suffered a mortality rate of 35%. Wertheimer (1988) estimated hooking mortality for troll-caught chinook salmon *Oncorhynchus tshawytscha* to be 20.5–24.5%. Bendock and Alexandersdoitter (1991) found that the mortality of chinook salmon caught in the estuary of the Kenai River using baited sport tackle was less than 10%. Rates of hook-induced mortality for brown *Salmo trutta* and brook *Salvelinus fontinalis* trout (Shetter and Allision, 1958), cutthroat trout *Salmo clarki* (Hunsaker et al., 1970), and rainbow trout *Oncorhynchus mykiss* (Shetter and Allision, 1958; Stringer, 1967; Klein, unpublished data, 1974) caught with bait ranged from 20 to 48%. In combination, these data suggest that release mortality of coho salmon caught with bait in estuarine waters is higher than for other species of salmon and trout.

Factors influencing hook-induced mortality

The factors which influenced observed rates of hook-induced mortality during this study were hook location, hook removal, and bleeding. Hook location has been reported in the literature to influence hook-induced mortality. Rainbow trout (Stringer, 1967), brook trout (Shetter and Allision, 1958), and landlocked Atlantic salmon (Warner, 1979) hooked in the gullet or gills suffered higher rates of mortality than when hooked in other locations. Wertheimer (1988) reported that wound location was associated with mortality in troll-caught chinook salmon. Wertheimer (1988) also reported that wound severity was related to mortality. Warner and Johnson (1978) observed that 86% percent of the landlocked Atlantic salmon that were bleeding later died, and that there was a probable relationship between hooking location and bleeding. Mason and Hunt (1967) and Hulbert and Engstrom-Heg (1980) showed that removal of hooks from deeply hooked rainbow and brown trout resulted in higher mortality than when the hook was left in place. Nearly 95% of the rainbow trout and 60% of the brown trout died when the hook was removed in comparison with just over 30% and 20%, respectively, when the hook was not removed. Although increased play and handling time (Marnell and Hunsaker, 1970; Wedemeyer, 1972; Hattingh and van Pletzen, 1974); and scale loss (Black, 1957, 1958) have all resulted in increased rates of mortality, these factors did not significantly influence rates of hook-induced mortality in our study.

The degree of mortality suffered by coho salmon in the Little Susitna River appeared to be related to the location of catch in the river. Fish that were caught and released in the estuary suffered significantly higher rates of mortality (69%) than did fish caught and released above the estuary (12%). This appears in part to be due to the higher incidence of gill or gullet hookings in the estuary than above the estuary. Identical gear was used to catch fish in both areas, suggesting that coho salmon are more likely to become hooked in a lethal location in the estuary than above the estuary. We could not find any explanations for this in the literature. One possible explanation, however, may be that coho salmon in the estuary are still actively feeding and as a result, strike more aggressively at the bait, than do fish which are above the estuary and are off the feed. Although not specifically measured in this study, participants reported an increased aggressive behavior of salmon in the estuary compared with those above the estuary.

Other hooking factors also appeared to contribute to the high rate of hook-induced mortality for coho salmon caught in the estuary of the Little Susitna River. For instance, our data showed that estuary-caught fish hooked in a non-lethal location were more likely to survive and reach the weir if their hook was removed. Because we did not remove deeply embedded hooks from the coho salmon we caught in the estuary, this practice likely contributed to the high measured mortality for estuary-caught fish. We also observed that a large number of coho salmon handled in the estuary easily lost their scales, while those at the weir did not lose their scales as readily when handled. In the estuarine experiment, scale loss was not significant, but high scale loss has been observed to be a contributing factor to increased mortality in other studies. Black (1957, 1958) found that scale loss and abrasion of the mucus coat were major factors contributing to observed rates of mortality.

Various environmental factors can influence rates of hook and release mortality of sport-caught fish, one of which is temperature. Increased temperature at time of hooking and play has been shown to increase the mortality rate of sport-released fish (Dotson, 1982). In this study, water temperatures were relatively constant (only a 3 °C variation) between areas of the river sampled. Given this, we believe that temperature probably did not influence the differences in mortality rates of coho salmon hooked and released in different areas of the river during this study. Also, the observed temperatures recorded during this study were relatively cool (10–13 °C) in comparison with other studies, suggesting that the mortality rates observed in this study may be minimum rather than maximum rates.

MANAGEMENT IMPLICATIONS

The rates of hook-induced mortality observed in this study for coho salmon show that the mortality of released coho salmon in intertidal sport fisheries is high. This is especially important in intertidal fisheries which have a large catch-and-release component. In such fisheries, catch-and-release may not be a viable management option.

ACKNOWLEDGEMENTS

The authors wish to thank Larry Bartlett for his overview of the field data collection aspects of this project. The authors also wish to thank Bob Conrad for his help in designing the study. Lastly, the authors wish to thank Kelly Helper and Andrew Hoffmann for their help with data analysis.

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ALASKA SPORT FISHING ASSOCIATION

1-17-2014

Statement from Alaska Sport Fishing Association

The Alaska Sport Fishing Association represents the fishing community in Alaska that does not sell or trade their catch for anything other than subsistence foodstuffs. To elaborate a bit, ASFA represents subsistence users whether you call them sport fishermen, dip netters, village fishermen trying to feed their families fish, or any other group of personal use fishermen who are the consumptive users of the resource the Constitution of Alaska reserved for the people of Alaska..

This might seem to put this group at odds with those who catch fish to sell: commonly referred to as "commercial" fishermen. In reality it does not – these people, too, fish for subsistence via another economic system. ASFA is all for the commercial fishing industry catching every single fish that is not needed for personal use and reproduction. Commercial fishermen feed a lot of others in addition to themselves with the Mother Nature's bounty! Ultimately, both groups will benefit if we can increase the numbers of fish.

The problem we are all dealing with here in Upper Cook Inlet is that there are not enough fish to meet the demands of all the users. The population of Alaska has grown by seven times since WW II and a major part of that population growth is centered in this area. Demand has greatly increased but the supply of fish has not.

I personally have great sympathy, as do we all, for those who have "traditionally" commercially fished for a living, or a part of their living, sometimes for more than one generation, but commercial fishing in Upper Cook cannot continue. The fact is that there is not, nor has there been an excess fish bounty in Upper Cook Inlet for quite a number of years but commercial fishing still occurs here. It should not. Yes, some commercial fishermen who will not adapt will be "hurt" if they are forced to stop fishing but when there is no excess bounty, the economic needs of the commercial fisherman must be met in other ways. Since the average annual fishing income (gross) in Upper Cook Inlet is only about $25,000 with a net income much less than that, that lost income can be readily replaced. There are many ways to support oneself, particularly here in the economic center of the State, but the fish cannot be readily replaced.

Fish & Game has done a heroic job of managing the resource, all things considered, but they cannot effectively deal with this situation because their hands are tied. Today this Board can untie those hands.

Change is the only Universal Truth. If humanity did not change, we would not exist today. Permanent change has occurred – there are more people and fewer fish! If we don't change our rules today, the fish won't exist tomorrow! If we cannot deal with reality, all will suffer. If the Board acts now the multitudes that subsistence fish need not be totally deprived of this constitutionally guaranteed resource. The intent of the State Constitution was to reserve the fish for all Alaskans. When someone (particularly a non-resident) deprives those who fish for subsistence, they are violating the intent of our constitution.

According to the Bureau of Economic Analysis, Per Capita Real GDP in Alaska was $[illegible] in 2010. The population of the Kenai Borough was 55,400 as of the 2010 census. This means the greatly exaggerated economic and human impact of the loss of this fishery amounts to less than 3 tenths of 1 % (.03%) of the economy of the area and affects less than 1% (.8%) of the population! The economic and human cost of the permanent closure of the set gillnet Fishery pales into insignificance when compared to the loss of the Kings in the Kenai and the rest of Upper Cook Inlet!
http://bea.gov/scb/pdf/2011/07%20July/0711_gdp-state.pdf

ASFA, with great sorrow and empathy for those who will suffer, respectfully recommends to this Board that all commercial fishing in Upper Cook Inlet and in those areas that would substantially diminish the flow of fish to this area be terminated. There is no other rational option.

Alaska Sport Fishing Association
Phil Cutler, President,
Martin Meigs, V.P.

attachments:

1.Commercial salmon fishermen income analysis Summary

P.O. Box 221614, Anchorage, AK 99522 Phone: 907-240-4568
Website: www.aksportfishingassociation.com E-Mail: contact@alaskasportfishingassociation.info
ASFA is a 501(c)(3) non-profit corporation

20 year Permits, Harvest and Income, Cook Inlet

Fishery	COOK INLET	Year	Resident	Nonres	Total	Total Fished	Total lbs	Avg lbs	Total Earnings	Avg Earnings
S 03H	DRIFT GILLNET	1993	400	183	583	580	16,815,486	28,992	$16,537,133	$28,512
S 03H	DRIFT GILLNET	1994	394	189	583	569	16,289,701	28,629	$18,766,136	$32,981
S 03H	DRIFT GILLNET	1995	393	189	582	577	15,485,598	26,838	$13,912,083	$24,111
S 03H	DRIFT GILLNET	1996	396	187	583	560	16,874,926	30,134	$17,736,374	$31,672
S 03H	DRIFT GILLNET	1997	395	187	582	572	16,021,059	28,009	$17,448,194	$30,504
S 03H	DRIFT GILLNET	1998	395	186	581	528	5,406,367	10,239	$4,303,378	$8,150
S 03H	DRIFT GILLNET	1999	391	185	576	487	10,395,737	21,346	$12,134,809	$24,917
S 03H	DRIFT GILLNET	2000	391	186	577	513	6,414,163	12,503	$4,438,593	$8,652
S 03H	DRIFT GILLNET	2001	395	179	574	467	6,256,255	13,397	$3,711,269	$7,947
S 03H	DRIFT GILLNET	2002	394	178	572	409	12,635,440	30,893	$5,686,049	$13,902
S 03H	DRIFT GILLNET	2003	396	176	572	418	10,891,761	26,057	$6,329,162	$15,142
S 03H	DRIFT GILLNET	2004	400	171	571	440	19,336,476	43,947	$11,798,178	$26,814
S 03H	DRIFT GILLNET	2005	405	166	571	471	17,142,608	36,396	$15,251,702	$32,382
S 03H	DRIFT GILLNET	2006	400	170	570	396	6,125,229	15,468	$5,159,160	$13,028
S 03H	DRIFT GILLNET	2007	401	170	571	417	13,409,028	32,156	$12,759,634	$30,599
S 03H	DRIFT GILLNET	2008	409	162	571	426	7,577,541	17,788	$7,823,008	$18,364
S 03H	DRIFT GILLNET	2009	404	166	570	404	7,758,421	19,204	$8,202,181	$20,302
S 03H	DRIFT GILLNET	2010	406	163	569	378	12,896,974	34,119	$19,300,530	$51,060
S 03H	DRIFT GILLNET	2011	409	160	569	462	21,982,454	47,581	$30,378,044	$65,753
S 03H	DRIFT GILLNET	2012	413	156	569	496	23,684,009	47,750	$30,546,478	$61,586
										$546,378
									Avg Gross	**$27,319**

Average Net Income is considerably less than the Gross due to high fuel prices.

Fishery	COOK INLET	Year	Resident	Nonres	Total	Total Fished	Total lbs	Avg lbs	Total Earnings	Avg Earnings
S 04H	SET GILLNET	1993	638	107	745	641	14,671,119	22,888	$14,317,093	$22,336
S 04H	SET GILLNET	1994	628	117	745	617	13,162,797	21,334	$15,272,678	$24,753
S 04H	SET GILLNET	1995	626	119	745	625	9,131,234	14,610	$8,936,995	$14,299
S 04H	SET GILLNET	1996	620	125	745	604	12,716,723	21,054	$13,570,507	$22,468
S 04H	SET GILLNET	1997	622	123	745	603	14,316,576	23,742	$15,637,913	$25,934
S 04H	SET GILLNET	1998	620	125	745	559	5,670,497	10,144	$4,351,636	$7,785
S 04H	SET GILLNET	1999	618	127	745	556	7,809,505	14,046	$9,993,704	$17,974
S 04H	SET GILLNET	2000	622	123	745	533	5,490,871	10,302	$4,319,800	$8,105
S 04H	SET GILLNET	2001	623	121	744	505	6,608,371	13,086	$4,081,429	$8,082
S 04H	SET GILLNET	2002	620	123	743	496	10,987,787	22,153	$5,547,596	$11,185
S 04H	SET GILLNET	2003	618	124	742	472	12,119,220	25,676	$8,086,607	$17,133
S 04H	SET GILLNET	2004	621	118	739	481	15,504,196	32,233	$11,120,261	$23,119
S 04H	SET GILLNET	2005	615	122	737	499	16,625,895	33,318	$15,406,920	$30,876
S 04H	SET GILLNET	2006	616	122	738	482	8,935,533	18,538	$8,591,257	$17,824
S 04H	SET GILLNET	2007	618	120	738	483	10,258,292	21,239	$10,181,085	$21,079
S 04H	SET GILLNET	2008	613	125	738	484	9,242,351	19,096	$11,368,513	$23,489
S 04H	SET GILLNET	2009	608	130	738	472	7,382,198	15,640	$8,963,165	$18,990
S 04H	SET GILLNET	2010	608	128	736	488	9,000,915	18,444	$14,160,033	$29,016
S 04H	SET GILLNET	2011	606	130	736	543	14,089,410	25,947	$20,116,813	$37,048
S 04H	SET GILLNET	2012	619	117	736	456	2,335,327	5,121	$2,536,346	$5,562
										$387,057
									Avg Gross	**$19,353**

Average Net Income is considerably less than the Gross due to high fuel prices.

10 years Upper Cook Inlet Set Gillnet Earnings (Adjusted Gross $)

http://www.adfg.alaska.gov/static/regulations/regprocess/fisheriesboard/pdfs/2013-2014/uci/cfec_uci_report.pdf

Year	Permits Fished	Earnings		
2003	448	$6,948,416		
2004	463	$13,362,511		
2005	484	$17,975,564		
2006	460	$9,558,285		
2007	470	$11,008,434		
2008	470	$11,659,302		
2009	454	$9,236,506		
2010	468	$14,749,895		
2011	491	$20,222,655		
2012	408	$2,428,818		
Avg	**461.6**	**$11,715,038**	**$25,379**	**Avg / Permit**

According to the BEA, http://bea.gov/scb/pdf/2011/07%20July/0711_gdp-state.pdf, Per Capita Real Gross Domestic Product was $63,424.00 in 2010. The population of the Borough was 55,400 as of the 2010 census. This means the greatly exaggerated economic and human impact of the loss of this fishery amounts to less than 3 tenths of 1 % of the economy of the area and affects less than 1% (.8%) of the population! The economic and human cost of the permanent closure of the set gillnet Fishery pales into insignificance when compared to the loss of the Kings in the Kenai and the rest of Upper Cook Inlet!

THE STATE of ALASKA
GOVERNOR SEAN PARNELL

Department Natu

Division of Parks & Outdoor Recreation
Kenai/Prince William Sound Area

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January 13, 2014

Alaska Department of Fish & Game
Board of Fisheries
333 Raspberry Road
Anchorage, AK 99518-1565

Re: Board of Fisheries Proposal #233

To Whom It May Concern:

The City of Soldotna has submitted a proposal to the Board of Fisheries that would close fishing on the Kenai River near the Centennial Boat Launch. Proposal 233 was submitted by the City of Soldotna to help promote an orderly fishery and will prohibit fishing in the lagoon from July 1 – August 30 of each year. Historically, there have been conflicts with bank anglers and power boaters in this area and the City of Soldotna has submitted this proposal to address this issue.

The Alaska Division of Parks & Outdoor Recreation is tasked with managing recreational uses within the Kenai River Special Management Area. DPOR supports this proposal and believes it will promote an orderly fishery, reduce conflicts with bank anglers and power boats, and improve public safety.

Thank you for the opportunity to comment on this proposal.

Sincerely,

Jack Blackwell
Area Superintendent

To whom it may concern,

I live and recreate in the MatSu Valley and am becoming increasingly concerned with the decreasing salmon stocks in the Big Su and Deshka Rivers, all of the northern district for that matter. Please take measures to protect my families and future generations fishing rights by allowing more fish to return to our rivers.

It is my belief that priority should be given to protect the fisheries for all not just the commercial industry.

RECEIVED
JAN 17 2014
BOARDS
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Jay Gunny (907) 841-5417
1271 Vermillon
Palmer AK 99645

1/17/14

My name is Ralph Renzi. I am wondering where all the fish have gone in the Matsu Valley. I am a disabled veteran and truly enjoy being able to relax with a day of fishing but the fish are nonexistent. Please do something to help me get back to nature and revive my hobby.

Respectfully,

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Ralph Renzi
2640 N. Hematite Dr.
Wasilla, AK 99654
(907) 357-7153

PC 461
1 of 1

Fishing

From: DanaLyn Dalrymple
Sent: Fri, Jan 17, 2014 at 6:04 pm
To: jehnifer.ehmann@excel-pt.com

image001.png (38.8 KB)

Jehnifer:

Thank you for bringing this issue to us during the Board meeting this morning. As the wife and mother of sport fishermen/boys, this is an important topic in our household. I was raised in Idaho with a freezer full of beef but now we rely on a freezer full of fish to feed our growing boys each year.

We have seen the impact in the last few years on the reduction of local resources. My boys have had to travel to Kenai to fill our freezer rather than fishing local streams and rivers. As a local business woman, this concerns me for economic reasons. Given the rich heritage of our Valley, we need to have more fish in our waterways to meet the needs of families and to drive the local economy.

Please submit this email to the Board of Fisheries on my behalf.

Thank you,

DanaLyn Dalrymple
Attorney

Dalrymple Law, P.C.
danalyn@matsulaw.com
907-745-6332 • Fax: 907-745-6331
927 S. Cobb St. • Palmer, AK 99645
Visit our website at www.matsulaw.com

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- Business
- Real Estate
- Wills & Probate

1/17/14

To Whom it May Concern,

My name is Pete Christopher and I am the General Manager of the Mat-Su Miners, a summer collegiate baseball team. One of my responsibilities is to recruit players from the lower 48 for the team. I'm competing with hundreds of other teams for players. One of the points I try to sell is the great fishing up here in the Mat-Su Borough. My first seven years as GM the fishing was great in the area but over the last four years, not so good. We try to create a fun experience for the players the two months they are up here and fishing is a big part of that. I support the commission's efforts in returning fish to the northern area.

Pete Christopher, General Manager
Mat-Su Miners Baseball - Alaska Baseball League
P.O. Box 2690, Palmer AK 99645
Tel. 907-745-6401
Fax 907-746-5068
Home 907-746-4914
Cell 907-373-8730

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1/17/14

I am very concerned about the decline in the number of salmon we are seeing in the Mat-Su Valley. I live near Jim Creek and have seen substantial declines over the past few years. When visitors from out-of-state come, they too are disappointed that they spent thousands of dollars on their dream vacation and go home with no fish. Word of that travels like wildfire. Protecting our natural resources in the Mat-Su Valley is critical to our economic future. It not only impacts local sports fishing businesses, but our restaurants, hotels and retail establishments. PLEASE support the initiative to protect the salmon and the future of the Mat-Su Valley.

Respectfully,

Kelley Barker
4030 S. Aurora View Circle
Palmer, AK 99645

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1/17/14

As a business owner and resident of the Mat-Su Valley, I'm very concerned with the decline of salmon that are making it to our rivers each year. The decline negatively impacts several corners of our economy and the livelihood of many small business owners; including those NOT directly involved in the fishing industry.

On a personal level, it's disappointing to have to tell our family members who travel to Alaska each summer that they will likely be limited in their fishing if they choose to stay in the Mat-Su Valley. For the last few years, they're making the decision NOT to stay in the Mat-Su Valley.

I encourage the Fish Board to work together on a viable solution to this problem.

Thank you,

Jeanette Gardiner
Gardiner Business Support Services
907.745.6127

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1/17/14

My complaint is they restrict the Sport Fisherman. Shouldn't restrictions to the same degree be put on the commercial fisherman?

You can't catch them if they are not in the rivers and if you commercial fish them at sea or in the mouth of the river they will never build back up the runs. Maybe if everybody had to fish with a pole for about 10 years the population would make a come back.

-Lenard Gardiner

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Committee A

Personal Use (PU) Fisheries

Chair – Huntington, Morisky, Jeffrey

Proposals 269-280, 172, 281-291, 318

Supporting Documents:

Proposals:

269 – Oppose – PU fisheries should be linked to abundance (run size) - prefer proposal 159 or 283

270 – Support – This definition will be useful, brings clarity as to when the public has to clip the tail fins, helps with compliance issues

271 – Support – Having thousands and thousands of personal use permits not returned is unacceptable, support better reporting of PU harvests that are both timely and accurate

272 –Support – Anything that can be done to achieve higher compliance rates will be useful

273 – ? – Support the creation of a PU permit that is separate from a sport fishing license, compliance issues and limiting future participation in PU

274 – Support – Support an interactive on-line system for all fishing activities, support PU limits, prefer proposal 159 or 283

275 – Oppose – Administrative and compliance costs will be very high

276 – Originally PU harvests were only allowed after the top of an escapement goal was going to be exceeded, does ensure adequate escapements at low-run strengths, prefer proposal 159 or 283

277 – Does ensure adequate escapements at low-run strengths, prefer proposal 159 or 283

278 – Oppose – Prefer proposal 159 or 283

279 – Oppose – Prefer proposal 159 or 283

280 – Oppose – Prefer proposal 159 or 283

172 – Support – Links PU fishery to lower end of the escapement goal

281 – Support – Modify no retention of large Chinook greater than 30 inches, keep small jack (male) Chinook

282 – Oppose – Allocative, creates congestion on river banks, impacts on Kenai/Kasilof Rivers unacceptable, prefer proposal 159 or 283

283 – Support

- Revise (1) – 2,000,000 to 2,300,000
- Revise (2) – 2,000,000 to 2,300,000
  4,000,000 to 4,600,000
  Change 15 salmon to 10 salmon
- (d) – Delete "not"
- Links PU fishery to Kenai Sockeye run strength
- Bag limits lowered below 2,300,000 on Kenai Sockeye returns
- Lowers bag and possession limits at middle tier
- Disperses use to other fisheries, rivers and opportunities
- Creates reasonable expectations on harvests
- Average family still can harvest salmon

284 – Support

- Links PU harvests to abundance like all other fisheries
- Utilizes the three tiers for all fisheries and harvesters

285 – Support

- The amount of vessel traffic up and down the Kenai River is just crazy
- Somehow would be nice to lower the Kenai River water turbidity levels due to PU vessel traffic
- Limit boat traffic above the Warren Ames Bridge
- One round trip per day – all vessels

286 – Support – Need to address safety issues in this portion of the river, should extend up to river mile 8

287 – ?

- Each summer there are tens of thousands of salmon caught in a dipnet and kicked or tossed back into the water

- Should PU fishermen be allowed to toss back (other than kings) salmon that are good food just because they want a different salmon?

288 – Support – Should PU fishermen be allowed to toss back (other than kings) salmon that are good food just because they want a different salmon, cannot identify the various species of salmon or are just recreationally harvesting and tossing back fish?

289 – Oppose – Many State and Federal agencies have adequate rule, regulations and laws to achieve this result

290 – Oppose – The dates create conflicts with the East Side Set Net Commercial Fishery

291 – Oppose – Could support if both PU and commercial fisheries were operated at the same time

318 – Oppose – Could support as long as this PU fishery will not result in loss of fishing time or fishing area for commercial harvesters

Committee B

Cook Inlet Commercial Fishing, West Side, Northern Pike

Chair – Kluberton, Jensen, Johnson

Fishing Seasons, Periods, Gear, Gillnet Specifications, Registration, Closed Waters, Reporting Requirements

Supporting Documents: NOAA Weather Forecast for PKZ139-111500

Cook Inlet Commercial Fishing

Proposals 121 thru 125, 81, 128-133:

121 – Support

- This is an historic fishery, two 12-hour periods per week will not harm the resources
- All current regulations and restrictions were developed during the time when the Northern bound (Yentna) stocks were not counted correctly
- Run reconstructions have shown that the Yentna counter, for 25 years, underestimated these sockeye returns
- All current area restrictions should be eliminated or revised to reflect current salmon issues in the Mat-Su

122 – Support – Safety issue. Modify – NOAA has revised weather forecast areas. PKE139-111500 Cook Inlet Kalgin Island to Point Bede, winds above 25 knots, storm or gale warning.

123 – Oppose – ? – Would like to hear public testimony.

124 – Support – Housekeeping

125 – Oppose – Establishes a new gear type with unknown exploitation or harvest rate. Unknown survival rate of released Chinook

81 – Oppose

- Chinook abundances are fluctuating in a different time series than crab numbers
- Crab population numbers declined long ago, 30+ years
- Chinook numbers have declined in the past 5+ years; hard to show cause & effect

- Which is cause: crab or chinook?
- Which is effect: crab or chinook?

128 – Support – If this makes registration and getting permits easier, then good. All fish & Game licenses, permits or registration have an electronic system.

129 – Support – These types of registrations are out of date, misinformation can be collected by other means.

130 – Support – This type of registration is no longer needed.

133 – Support – All users should report on size and length of King Salmon harvested in Upper Cook Inlet

West Side

Proposals 134, 79

134 – Oppose – East side of Kalgin Island harvests are on similar stocks as the Drift Fleet. Recent genetic studies indicate a slightly higher harvest of Northern bound sockeye occur in this area.

79 – Oppose

- The tidal flats along the east side of the mainland on the western edge of the Inlet extend 2-3 miles out into the Inlet
- Extensive areas go dry at low tide exposing large mud flats containing rocks, tree roots and numerous snags
- This proposal is just mean spirited

Northern Pike

Proposals 181, 182

181 – Support in Concept

- Could be limited to where there are only pike
- Could be limited to lakes that are going to be rehabilitated, restocked or where the goal is to reduce or hold pike populations to some level.

182 – ? – Do not know where funds would come from? What will be provided as evidence of harvesting a pike?

Committee C

Kenai River Resident Species, Guides, Boundaries and Habitat

Chair – Johnson, Jeffrey, Huntington

Supporting Documents:

Sport – Kenai River Resident Species

Proposals 252-258:

252 – Support – Appears reasonable. How will fishing for Chinook be handled when the public says "I am fishing for rainbows" when in fact they are attempting to catch & release a Chinook?

253 – No Action – Take no action on proposal based on the passing of proposal 252.

254 – Support – There are some interesting aspects of this proposal. Concerned about the "bait" issues, unintended consequences unknown

255 – Support – Seems reasonable

256 – Support – Seems reasonable

257 – Support – Seems reasonable

258 – Support – Seems reasonable

Guides – Kenai and Kasilof Rivers

Proposals 259-262, 266-268

259 – Oppose

- Provides for a variety of restrictions/liberalizations and gear modifications – all subject to political pressure and lobbying efforts
- Allocative aspects of changes suggested are unknown and unquantifiable.

260 – Oppose

- Subjects the fishing public to guide competition for seven days per week

- The fish enforceability is questionable
- Does away with drift only days.

261 – Oppose – Changing from 4 to 5 active fishermen in guide vessels is questionable, safety and boat wake issues.

262 – ? – Would like to hear proponent's comments about this proposal

266 – Support

- Understand that 91 guides currently fish both the Kenai and Kasilof Rivers
- The Kasilof is a very small river compared to the Kenai; crowding issues
- Can the Kasilof Chinook populations actually withstand this fishing pressure?
- If their proposal were to pass, will the private angler be forced off of the Kasilof River?

267 – ? – Don't know how to do this?

268 - ? – Don't know what the outcomes are of any proposed discussions, would like to hear proponent's comments at public testimony.

Sport Kenai River Boundaries and Habitat

Proposals 229-236

229 – Support in Concept

- Would like to see the proposal on a map
- How does this proposed area relate to set net sites?
- Will this alter the USCG codified "Rules of the Road" and how vessels interact?

230 – Support in Concept – Seems reasonable; would like to see map of marker locations referenced in this proposal.

231 – Oppose – Prefer proposal 219. This proposal does not conserve Early Run Kings.

232 – OK – Prefer proposal 219; seems reasonable to deal with the Moose River – Kenai River confluence area.

233 – Support – Will help reduce vessel congestion and improve safety for all involved. Reasonable regulation.

234 – Support – Seems Reasonable. Conservation measure, bank erosion, improves Kenai River habitat.

235 – Support – Absolutely necessary to conserve riparian habitats along the Kenai River.

236 – Support

- Absolutely necessary to conserve riparian habitats along the Kenai River
- Can involve NGO's (Non-Governmental Organizations)
- Provides basis for grant/funding application
- Provides basis for raising NGO funding.

PC 469

Committee D

Northern Cook Inlet Escapement Goals and Commercial, Sport & Subsistence

Northern District Commercial Salmon

Chair – Jensen, Morisky, Kluberton

Supporting Documents:

- Little Susitna River Salmon History from 1886 to 2012
- Assessing Climate Change Impacts in Cook Inlet Salmon Streams: Landscape Controls on Stream Temperature and Thermal Sensitivity
- Water Quality in the Lower Little Susitna River, 8/1/2013

Northern Cook Inlet Escapement Goals

Proposals 300, 301, 309, 313, 315, 321

300 – Oppose – Too vague, do not know what "If at times the goals are not being made, Actions to protect the resource would need to be placed" indicates.

- No data presented with proposal for review
- No data presented on run timing
- Five year base is inadequate, why not full 10 years of data?
- No discussion as to Actions, when placed, on whom? In River? Saltwater?
- No discussion, as to below the weir, how the in-river fishery is to be managed
- No discussion as to methods & means or bag & possession limits.
- No in-river step down plans
- Unknown allocation aspects.

301 – Oppose – Proposal is vague.

"<u>Proposal 300</u> – **5AAC 61.112. Special provisions and localized additions and exceptions to the seasons, bag, possession, and size limits, and methods and means for Unit 1 of the Susitna River Drainage Area.** Establish an Optimal Escapement Goal (OEG) for Deshka River coho salmon, as follows:

Establish an OEG (Optimal Escapement Goal) on the Deshka River for coho salmon. Currently the Deshka River has a weir that counts coho and has 10 plus years of complete data. Base the lower end of the OEG on the five year average of complete coho returns at 13,000 coho and have the upper end of the OEG based on the 10 year average of complete counts at 25,000 coho. Or direct the ADF&G to establish an SEG (Sustainable Escapement Goal) for coho on the Deshka River."

- Measured: How? Sonar? Weir? ?....?....? BOF cannot direct ADF&G funding.

309 – Serves one person's allocation desires. The current subsistence allocation has not been utilized. Sufficient fish are available.

313 – Oppose – Don't know what "Late-Run" sockeye is referencing.

- This stock has had a 30+ year history of hatchery introductions (exotic stocks)
- During the 1986-1995 era, extra-large hatchery stocks were released into the Little Susitna
- Inappropriate time period – 1986-1995. See Fishery Related Aspects of Faulty Sonar Data, Over-Escapement and Impaired Habitat for Susitna Sockeye and Mark/Recapture sockeye run reconstructions
- Benefit statement in proposal is misleading – "former abundance" yield levels

315 – Oppose – Little Susitna is not an index for chums.

- Would like to see the data – but no data was presented
- No management plan presented
- Allocative aspects not presented
- How to address past, present and future allocations

321 – Oppose – Inaccurate data set referenced – allocative consequences not discussed "Harvest restrictions or closures" not clear what proponent has in mind

Northern District Commercial Salmon

Proposals 292-295

292 – ? – Due to run timing in Cook Inlet versus the Deshka Weir, it is very difficult "to practice in-season adaptive management." Not comfortable with the proposed "paired" restrictions

293 – Oppose – This proposal virtually closes the Northern District Commercial Fisheries. Paired restrictions not equitable, don't like this policy pattern. If followed by the BOF, most commercial fisheries will be closed.

294 – Oppose – Fish Creek and the Little Susitna have had high levels of urbanization, hatchery manipulations, habitat, pike and culvert problems. The Little Susitna River is a poor index or indicator stream for any salmon populations at present time.

295 – Support – Adds clarity to management and fulfills the original intent of the management plan.

Susitna River Sport Fisheries

Proposals 296-299, 302-306

296 – Oppose

- Does not discuss below the Deshka weir management decisions
- Harvests below the weir can trigger these step down plans
- Allocative aspects of proposal need discussion
- Suggest above and below the weir harvests, what should trigger these step down plans?

297 – Oppose

- How will ADF&G project a shortage of up-river Susitna River Tributary Kings?
- Even if ADF&G could do this (see above) how will ADF&G know which river or creek has adequate escapements or needs additional escapements?
- Even if ADF&G know the answers to the two issues above, how would ADF&G be able to affect a management solution in the Susitna River?

298 – Oppose – Bait issue, use of poisonous, cured baits. Securing bait (eggs) requires targeting of female Chinook and Coho.

299 – Oppose – Tries to direct ADG&G use of funds.

302 – Support

- Larson Lake sockeye escapements are the main sockeye index location on the main stem of the Susitna River
- Close this area to all salmon fishing
- Sockeye salmon school in this confluence area (Larson Creek and Talkeetna River) prior to ascending up Larson Creek (approx. 1 mile) prior to entering Larson Lake.
- The recreational harvesters and harvests in this area are a direct 1:1 reduction in the Larson Lake escapement goal.

- In this confluence area, recreational harvests have increased from 1500-2000 to over 6000 sockeye in recent years.

303 – Support

- Sport harvests directly come out of the possible escapements
- Larson Lake sockeye escapements are one of the three monitored locations in the Mat Valley
- Larson Lake sockeye escapements are the main sockeye index location on the main stem of the Susitna River

304 – Support – Prefer proposal 302

305 – Support – In addition to proposal 302

306 – Support – Anything to control pike depredations on salmon stocks

Subsistence – Susitna Salmon

Proposals 307, 308

307 – Oppose – Affects individuals that live part-time along the Upper Yentna that also live and work in the Willow-Palmer area. Should explore other "gear" – other alternative fisheries area available

308 – Oppose

- Oppose the location of this dipnet fishery
- Huge allocative consequences
- No bag & possession limits
- Location is in a mixed stock location
- How this proposal relates to achieving escapement goals is not discussed
- Dipnets are not subsistence fisheries
- Which escapement goals will be used to monitor or to be used for EO announcements?

Sport Fisheries – Knik River Area

Proposals 310-312, 314, 316, 317, 322, 376, 325

310 – Support

- The Little Susitna River flows through a highly urbanized area
- Little Susitna – very accessible for over 60 miles
- Habitat Impacts
- Bag & possession limits need some addressing due to habitat and exploitation rates
- Should be managed as other roadside rivers and streams in highly accessible urban areas:
    - Ship Creek, Campbell and Chester Creeks in Anchorage
    - Deep Creek, Ninilchik and Anchor Rivers on the Kenai Peninsula
    - Eklutna, Peters, Cottonwood and Jim's Creek in the Chugiak & Palmer areas

311 – Support – Good idea

- Funding
- Several streams in the Mat Valley could use a stocking program
- Could be part of an Action Plan, if a Stock of Yield Concern (habitat) were to continue for the Susitna River sockeye

312 – Support – Good idea

- Funding
- Several streams in the Mat Valley could use a stocking program
- Could be part of an Action Plan, if a Stock of Yield Concern (habitat) were to continue for the Susitna River sockeye

314 – ? – The Little Susitna is a highly urbanized accessible river

- Is the Little Susitna River already beyond repair, rehabilitation or remediation?
- Waters are Class 5 Impaired
- Why worry about the Little Susitna?
- Waters are very warm in summer time during the time sockeyes are migrating

316 – Support

- Little Susitna has high hydrocarbon concentrations from 2-stroke engines, 4-stroke would help
- Recent report indicates even 4-stroke engines will exceed hydrocarbon limits – this is due to the intense level of public use and being readily accessible

317 – Support – Public use and harvest of salmon is intense and needs to be reduced. This proposal will help the Little Susitna. Need proposals 310 and 312

322 – Support – Seems Reasonable

323 – ? – Need to resolve area description in this proposal and proposal 322

376 – ? – No proposal 376

325 – Support – Seems reasonable

Little Susitna River

Salmon History from 1886 to 2012

Little Susitna River, Mark Meyer Photography

United Cook Inlet Drift Association

2013

Little Susitna River

Salmon History from 1886 to 2012

Abstract

The Little Susitna River and salmon history can be characterized by three distinct eras: First, from the late 1880 up until the 1960's; Second, from the 1960's thru 1996; and Third, from 1996 until the present. The first era is the mining era from the 1880's until 1964 (Good Friday earthquake). Lode gold mining with cyanide leaching for gold recovery eventually eliminated native salmon populations from the Little Susitna River. The second era is characterized by development of the Fort Richardson, Fire Lake and Big Lake Hatcheries. All three hatcheries mixed local King and Coho stocks with at least six King and Coho stocks imported from Washington and Oregon, as well as Kodiak, Seward and Petersburg, Alaska. During the second era, 1964-1996, 10-20 million Coho fry/smolt, as recorded, were stocked into the Little Susitna River. Additionally, millions of unreported/undocumented stockings also occurred. The third era, 1996 until present, all reported stockings ceased. Since then, the King and Coho returns to the Little Susitna River have declined, most notably in the last 2 to 3 years. Since the late 1970's, the sport fishing exploitation, 50%, has occurred, even during the last three years of small Coho returns. These smaller, less than 25,000 returns, are the result of public access, Coho availability, hook and release mortality, parasites, diseases, invasive northern pike, warm water temperatures (13°C), blocked culverts, beaver dam blockage, urbanization and impaired water quality. These are all issues occurring in the Little Susitna River today.

Prepared by:

- Roland Maw, PhD, UCIDA Executive Director
- Audrey Salmon, UCIDA Office Manager

United Cook Inlet Drift Association

Soldotna, Alaska

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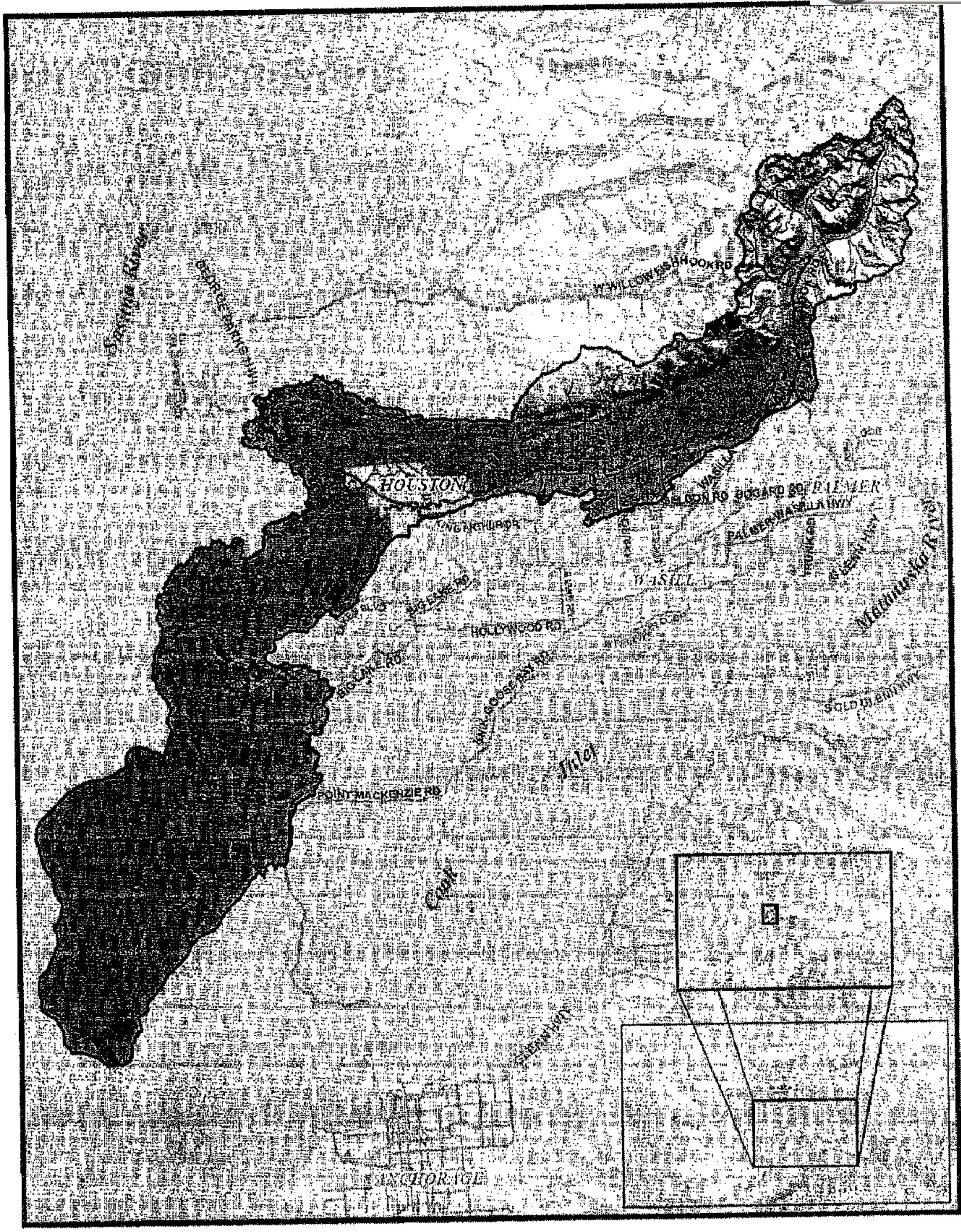


Map of the Little Susitna River Drainage

Little Susitna River
Salmon History from 1886 to 2012

1. Location

The Little Susitna River rises in the Talkeetna Mountains about 60 miles northwest of Anchorage, Alaska. The main stream has its source in Mint Glacier, a small ice field of less than 400 acres area, with its terminus at approximately 4,500 foot elevation. The river flows in a generally southwesterly direction through a typical "U" shaped glacial valley for about 17 miles to the south edge of the Talkeetna Mountains. For the last mile before leaving the mountains, the valley becomes quite confined with two narrow constrictions. Archangel Creek, now named Hatcher Pass, draining an area to the north and west, empties into the river about 10 miles down from Mint Glacier. Fishhook Creek, draining an area to the west, enters the river about three miles further downstream. These two streams are the only tributaries of any size. After leaving the mountains, the river turns southwest to the valley of the Susitna River. It then turns south, parallel to the Susitna River, and flows into Knik Arm, reaching tidewater eight or ten miles east of the mouth of the Susitna River. The area of the entire basin is 416 square miles.

The Little Susitna is 110 miles long, of which seventy miles is readily accessible by road, 4x4 trails and water craft. The river passes through numerous subdivisions, communities and municipal areas in the Matanuska-Susitna Borough.

Placer gold was discovered in the Willow Creek Mining District, which includes the Upper Little Susitna River basin, in 1897 and the first gold quartz lode was located in 1906. Gold lode mining has since completely over-shadowed placer mining in this area.

Hatcher Pass still has active recreational gold mining and is also open to the public for recreational mining.

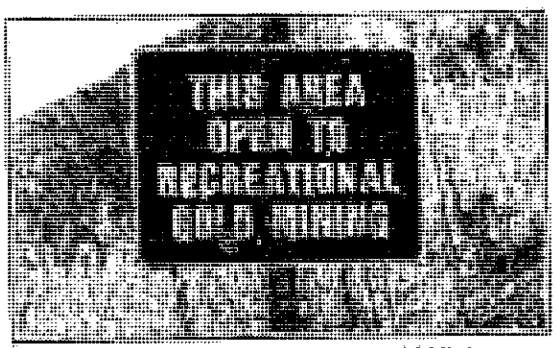


Figure 1. Area Open to Recreational Gold Mining

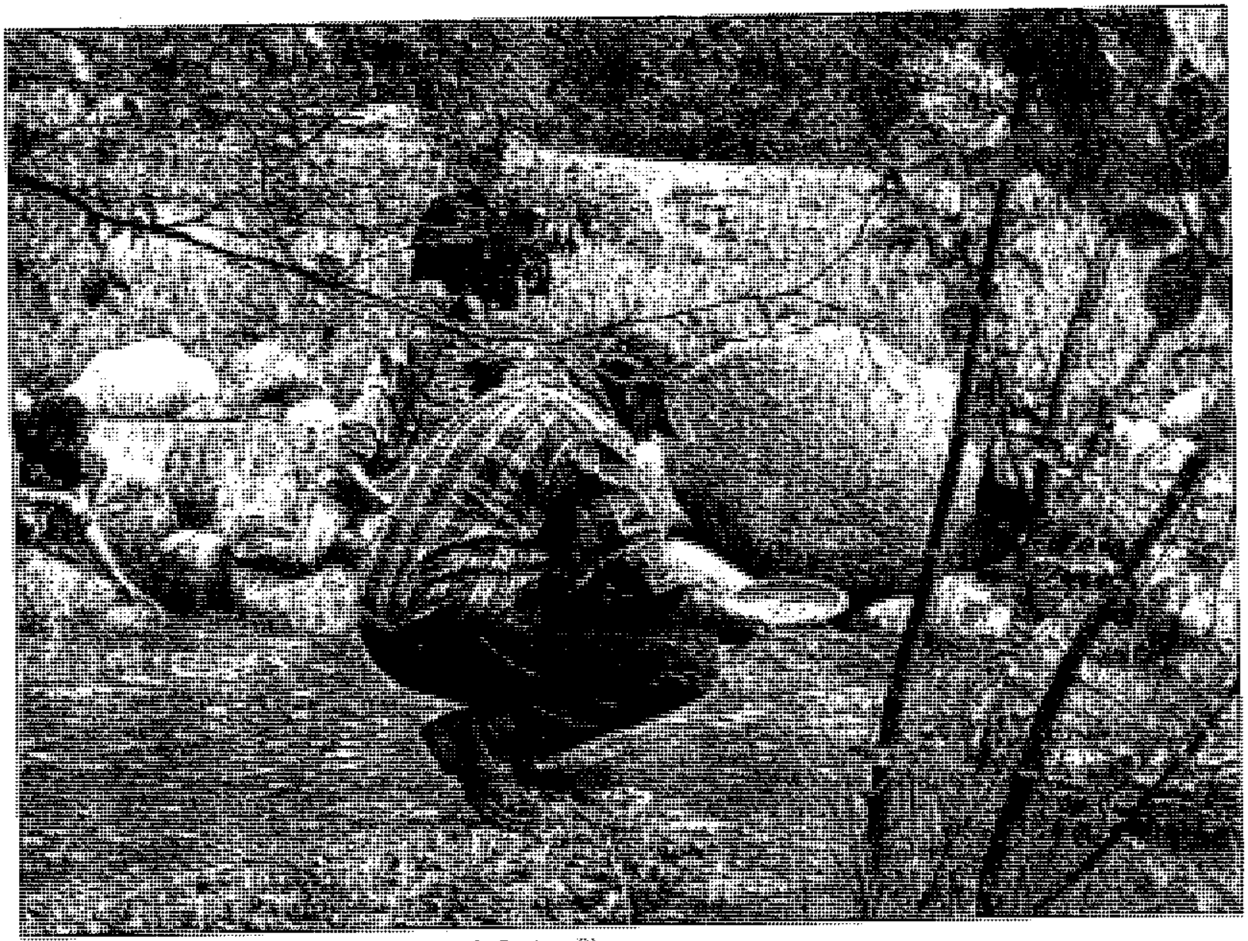


Figure 2. Recreational Gold Mining in the Little Susitna River

Water Quality (Lawrence, 1949):
"During the summer months, the water of the Little Susitna River is slightly turbid, probably from the rock flour from the Mint Glacier at its headwaters. During the winter the water is clear.

Cottonwood Creek receives most of its flow from ground water and is unpolluted except for animal waste from a few farms. Salmon run up the stream and fingerlings are plentiful in Cottonwood and Wasilla Lakes in the spring."

2. Significant Historical and Salmon-Related Events

1886 – Gold, a magical word, was discovered southeast of present-day Anchorage attracting thousands of gold seekers to this region.

1886-1890 – A quarter of a million gold seekers begin a stampede into Southcentral Alaska, including the Susitna River Basin, finding both placer and lode gold deposits.

1906 – Robert Lee Hatcher discovered and staked the first gold claim in what was called the Willow Creek Valley, later called Willow Creek Mining District.

1906-1910 – The Independence Lode Gold Mine on Granite Mountain is staked and mining started. (Hatcher Pass) **Cyanide** leaching of the gold-bearing ore started.

– Alaska Free Gold Lode mine on Skyscraper Mountain is staked and gold mining operations started. (Hatcher Pass) **Cyanide** leaching started.

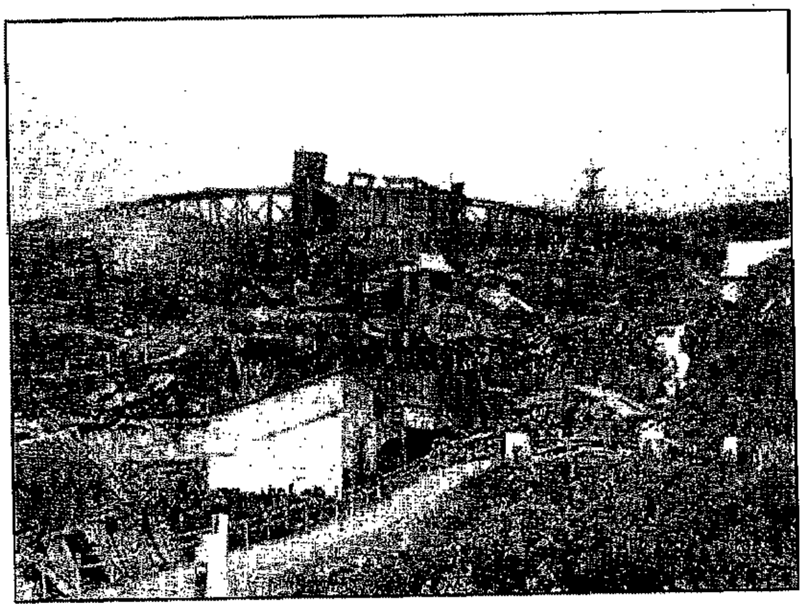


Figure 3. Independence Mine, Hatcher Pass, Alaska

1938 – Both mines consolidated into the Alaska-Pacific Mining Company. **Cyanide** leaching process used to recover gold at both mines until mine closure in 1951.

1941 – World War II – Most gold mining in Alaska and the lower 48 is nearly shut down due to the war – the Alaska-Pacific Mine at Hatcher Pass continues operations due to the mining of gold and tungsten. The mined tungsten was needed for making steel and light bulbs.

1943 – The Independence Mine was ordered to close by the owners.

1946 – Independence Mine reopens and resumes **cyanide** leaching.

<u>**1949**</u> – Fred F. Lawrence, USGS, reports the following on pages 14 and 15:

> "It was reported that all fish life in the stream had been killed in years past by mine waste, possibly **cyanide** from concentrating processes. The mines have not been operating since before the war and small native trout are now plentiful. However, if a favorable change in the price of gold should occur, the mines would resume operation and this type of pollution would again become a problem, particularly for any irrigation development. <u>**Salmon do not run in this stream**</u>."

<u>**1951**</u> – Independence Mine Closes. No **cyanide** clean-up or remediation occurs at that time or during the last 60 years.

<u>**1958**</u> – Fort Richardson State Fish Hatchery was built

> "Hatchery Background: The Fort Richardson State Fish Hatchery is located on Fort Richardson, a U.S. Army post near Anchorage, Alaska. The hatchery sits on the banks of Ship Creek, just downstream of the Glenn Highway. The facility was built in 1958 by the U.S. Army to provide fish for post lakes. [Note: "post" refers to Fort Richardson Army Post lakes, also included Elmendorf Air Force Base lakes.]
>
> The Department of Fish and Game became involved with this hatchery in the early 1960's, and assumed full operation by the late 1960s. In 1981, a state bond was approved to rebuild and expand the hatchery, and construction ended in 1984."

<u>**1961-63**</u> – Fire Lake Hatchery construction is started, and reconstructed after the 1964 Good Friday Earthquake.

<u>**1962-63**</u> – Sport Fish Investigators of Alaska; ADF&G, Progress Report F-5-R-4

> "Exceptionally good runs of silver salmon ascended two Matanuska Valley salmon streams. Angling success at Wasilla Creek reached two fish per hour of effort in mid-August. Reports were received of high angling success on the lower part of Little Susitna River which is accessible by airplane. One trip was made to the area. Although the peak of the run had passed, large numbers of fish were present and angling success exceeded one fish per hour."

1964-65 – Kubik S.; ADF&G, Progress Report F-5-R-6 has the following recorded:

"The King salmon fishery in Cook Inlet had been so seriously depleted in recent years that in 1963 the Alaska Board of Fish and Game declared a closure of King salmon fishing to both commercial and sport fishing in an effort to increase escapement and rebuild the salmon runs."

Table 4 in Kubik's 1964 report records only 3 **King salmon in the Little Susitna River** during the 1964 foot survey.

1964-65 – Jones, D.; ADF&G Progress Report F-5-R-6 has the following recorded:

"The March 27 earthquake severely damaged the upstream-downstream control structure on Lower Fire Lake."

"During July, Fire Creek was surveyed below Lower Fire Lake and two beaver dam barriers were removed. Salmon were present in the stream at this time."

"The source of both rainbow trout and silver salmon in Lower Fire Lake is no doubt largely due to inadvertent escapement from the hatchery."

"Two adult male silver salmon were captured on September 25. A survey of Fire Creek, below Lower Fire Lake, in October revealed about 50 spawning silver salmon."

In Kubik's 1970-71 report, the 1965, 1966 and 1967 kings came from the Green River Hatchery in Washington. The 1968 and 1969 cohos came from Big Creek and Eagle Creek in Oregon (See Table 1).

1965 – Kubik, S.; ADF&G, Progress Report F-5-R-7 has the following recorded:

"Table 4 records only 3 **King salmon in the Little Susitna River** during the 1965 foot survey."

1965-66 – Sport Fish Investigators of Alaska; ADF&G, Progress Report F-5-R-7

"Silver salmon eggs totaling 345,900 were obtained from Fish Creek in the Palmer area. During the spring of 1962, 1,202,600 rainbow trout eggs were received from **McLeary's Trout Lodge Springs in Washington and 118,000 from Fall River Hatchery in Oregon.**

The 1962 fish stocking program was completely fulfilled. A total of 86,200 silver salmon and 682,000 rainbow trout were stocked in 48 lakes and rivers during the summer. Most of the lakes planted are located in the Matanuska Valley. An additional 10,000 silver salmon and 165,400 rainbow trout were transferred to other hatcheries.

Silver salmon eggs taken at the egg take sites located at **Swanson River near Sterling and from Bear and Dairy Creeks near Seward**, during October and November totaled 1,464,000 eggs. The eggs were broug[h]t to the "eyed" stage without difficulty. Treatments with malachite green prevented the formation of fungus. Initial mortality due to handling and non-fertilized eggs was 19 per cent. The silver salmon eggs received on October 5, 1962, began hatching on January 23, 1963, giving a total of 111 days at an average water temperature of 38.6° F. After the initial handling mortality, egg and fry mortalities tapered off to less than one per cent per month."

<u>1970-71</u> - Kubik, S.; ADF&G, Project Report F-9-3, G-II report contains the following:

- Ship Creek Kings were used as an egg source for the Fort Richardson Hatchery. [Remember these Coho and Kings came from Fire Lake Hatchery that was damaged in the 1964 Good Friday Earthquake.]

- "King salmon eggs (approx. 260,000) were taken from 32 females trapped at the Chugach Dam fish ladder and Ship Creek weir during July. Fry from these eggs are currently being reared at the Fort Richardson Cooling Pond and the resultant smolts are scheduled for release into Ship Creek during May, 1971.

- A total of 177,000 silver salmon, <u>O. kisutch</u>, and 45,700 King salmon reared to smolt size at the Fort Richardson Cooling Pond were marked with an adipose fin clip and released into Ship Creek during May, 1970.

- A total of 105 marked adult King salmon returned to Ship Creek during 1970. All these fish represented four consecutive annual releases (1966-69). A total of 247 returning King salmon were captured at the Chugach [dam] ladder, of which 16.6% were "jacks".

- Five hundred forty-three silver salmon marked and released during the spring, 1970 were captured at the Chugach Dam facility, returning as "jacks" during the fall 1970. In addition to the "jacks" 204 adult silver salmon were enumerated."

- "King salmon, Oncorhynchus tshawytscha, have been reared at the Fort Richardson Cooling Pond, marked and released into Ship Creek since 1963 in an effort to enhance the anadromous stocks in that creek. The silver salmon, O. kisutch, program, with the same objective, began in 1968."

- These **Green River Washington Hatchery Kings** were hybridized with the Fire Lake Kings and possibly native Ship Creek stocks.

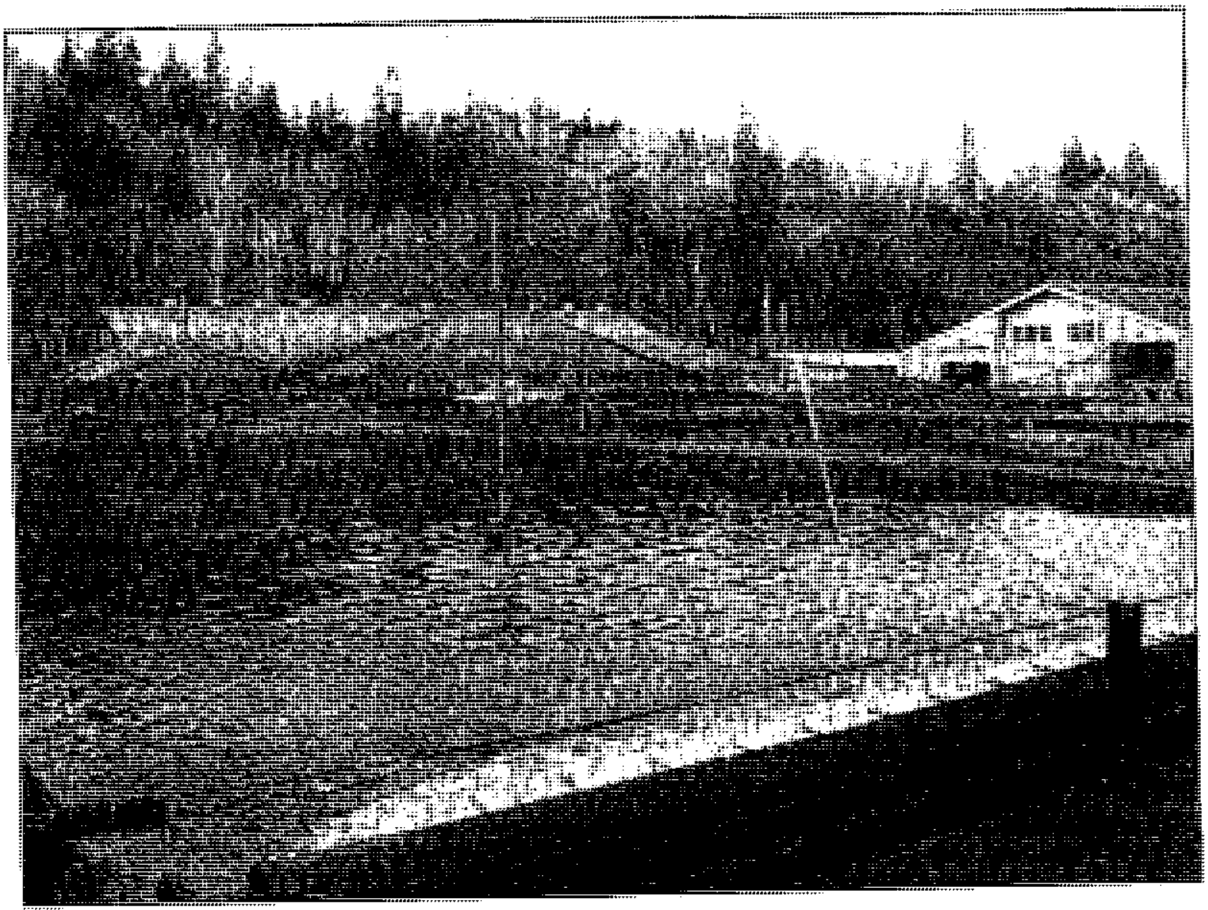


Figure 4. Green River Hatchery, Washington State

- These 8,432 King salmon smolt that occurred in 1964 were from an egg transplant from the **Green River/Coos River Hatcheries from Washington.**

– **Bear River (Seward) Coho** were also brought to Fort Richardson Hatchery, raised, released and allowed to hybridize with Fire Lake Hatchery Coho.

Table 1 is reproduced from Kubik, ADF&G, 1970-71, Table 1 page 58

Table 1 King and Silver Salmon Smolt Releases - Ship Creek - 1964 – 1970						
Year	**# Kings**	**# Silvers**	**Origin**	**Dates Released**	**Size**	**Mark**
1964	428		Ship Creek	6/3	76mm	Right Pelvic & Adipose
1965	352		Ship Creek	3/18	76mm	Adipose
1965	8,432		**Green River ****	8/6	99mm	Left Pectoral
1966	166,870		**Green River ****	July	98/lb	Half-Dorsal
1967	63,852		Ship Creek	5/8 thru 5/12	18.6/lb	Adipose
1967	474,516		**Green River ****	5/22 thru 6/21	58.4/lb	Adipose
1968		129,318	**Big Creek***	4/15 thru 4/22	19.9/lb	Adipose
1968	81,316		Ship Creek	5/23 thru 5/24	28.5/lb	Adipose
1969		101,300	**Eagle Creek***	5/5 to 5/16	13.7/lb	Adipose
1969	95,900		Ship Creek	5/5 to 5/16	16.6/lb	Adipose
1970		177,240	Bear Creek	5/18 thru 5/27	10 to 11/lb	Adipose
1970	45,690		Ship Creek	5/18 thru 5/27	29/lb	Adipose

*Oregon
**Washington

<u>1973-74</u> – Kalb, C.; ADF&G, Performance Report F-9-6, G-III-D

"Recommendation – Determine survival, growth and total yield of fry and fingerling plants of **Winthrop, Washington and Ennis, Montana strains of rainbow trout** in Long, Seymour, and Short Pines Lakes, and of **Kodiak, Alaska and Green River, Washington strains of Coho** in Loon Lake.

A sixth lake was selected to conduct a similar evaluation of two Coho stocks. Equal numbers of **salmon from Kodiak, Alaska, and Green River, Washington,** measuring 143 and 133 per lb., respectively, were planted in Loon Lake at a density of 300 per acre. Stocks are identified by left and right ventral fin clips. This comparison will hopefully provide information on the growth and survival of Coho in a landlocked lake and the sustainability of out-of-state stocks in Alaskan waters.

Short Pine Lake, located on the Kenai Peninsula, was **stocked with Ennis[, Montana] and Winthrop[, Washington] strains** of approximately equal size. By isolating a group of **Winthrop[, Washington] fry** early in the summer and promoting accelerated growth, it was possible to approximate the size of **Ennis[, Montana] fingerling**, allowing comparison of both stocks under similar conditions. Each stock composed half of the total plant of 15,600 fish at a combined density of 300 per acre. At the time of planting **Winthrop[, Washington] fish** measured 125 per lb and the **Ennis[, Montana] group** were 112 per lb. To make identification possible, both groups received opposing fin clips."

In addition to Kings and Coho salmon, **rainbow trout from Ennis, Montana and Winthrop, Washington** were all brought to the Fort Richardson Hatchery for rearing, stocking, hybridization and brood stock development.

Table 2 is reproduced from Kalb, ADF&G, 1973-74, Table 1 page 7

Table 2 Rainbow Trout Stock Origins, 1973

Lake	Date Stocked	Strain	Fish per lb	Number of Fish
Long	July 6, 1973	Winthrop, WA	1,178	41,700
		Ennis, MT	107	11,100
Christiansen	Lake remained toxic - stocking postponed			
Seymore	July 6, 1973	Winthrop, WA	1,178	257,600
Marion	Lake remained toxic - stocking postponed			
Short Pine	July 26, 1973	Winthrop, WA	125	7,800
		Ennis, MT	112	7,800
		Coho Salmon - origin unknown		
Loon	August 8, 1973	Kodiak, AK	143	16,270
		Green Lake, WA	133	16,135

<u>1973-74</u> – McHenry et al.; ADF&G, Project Report F-9-6-, G-II-H

– Fish Creek Weir constructed and operational (Big Lake, Mat-Su Valley)

– Helicopter Survey of the Little Susitna River records:
  – 374 King salmon
  – 0 Coho salmon

"As previously noted, precipitation during the year 1950 was the lowest recorded during the 1943-1972 period in the Palmer area, and was also one of the lowest precipitation years in Talkeetna. Coho escapements into Fish Creek were 277 and 71 in 1952 and 1953, respectively. Prior to 1973 these were the two lowest escapements recorded in Fish Creek. It appears that the lowest precipitation in 1950 may have had an adverse effect on the two-year classes residing in the system during 1950."

"The Cook Inlet commercial Coho harvest also declined substantially during the 1971-1973 period (Table 3). The commercial Coho catch in 1972 was the lowest since 1951, the first year complete records were available, yet the harvest in 1968, the parent year of the 1972 population, was the highest on record. Commercial harvests, although a useful index of run strength, cannot be directly compared from year to year because of unmeasured fluctuations in fishing time and effort."

Table 3 is reproduced from McHenry, 1974, Table 4 page 54

Table 3* **Numbers of Coho Escapement Index Areas (Foot Counts), Upper Cook Inlet, 1968 - 1973**

Creek	1968	1969	1970	1971	1972	1973	Average 1968-1973
Wasilla Creek	---	---	101	104	19	28	63
Cottonwood Creek	22	9	5	29	21	10	16
Birch Creek	125	142	206	138	69	106	131
Fish Creek	35**	852	176	141***	118	75	233
Meadow Creek	54	109	49	9	27	14	44
Question Creek	---	---	---	---	---	59	---
Total	236	1,112	537	421	254	292	

* Averages recalculated
** Count made after peak of spawning
*** Due to high water a boat count was necessary

Comment: Little Susitna River is not included in above Coho escapement counts.

1976-77 – Kramer, M.; ADF&G, Project Report F-9-6, G-III-J, Concerning Silver Salmon Stocking in interior Alaska, in Harding and Birch Lakes [near Fairbanks].

Table 4 is reproduced from Kramer; ADF&G, 1976-77, Table 1 page 109

Table 4	Summary of Silver Salmon Stocking Into and Recovery From Nursery Lakes						
Lake	Date	Origin of Stock	No. Stocked	Fish/lb (kg)	Date Recovered	No. Recovered	Fish/lb (kg)
Little Harding Lake	8/29/72	Delta Clearwater, AK	78,400	253 (536)	5/22/73	20,207	36.3 (80)
	7/13/73	Green River, WA	40,000	440 (970)	---	0	---
	8/28/74	Seward, AK	40,570	120 (265)	5/28/75	2,301	14.0 (31)
	8/26/76 - 8/31/76	Blind Slough, Petersburg, AK	48,400	75 (165)	---	---	---
Lost Lake	7/11/73 - 7/13/73	Green River, WA	200,820	440 (970)	5/31/74	18,567	49.3 (109)
					5/28/75	5,907	26.0 (57)

1976 – Big Lake Hatchery is constructed on Fish creek, tributary to the Little Susitna River.

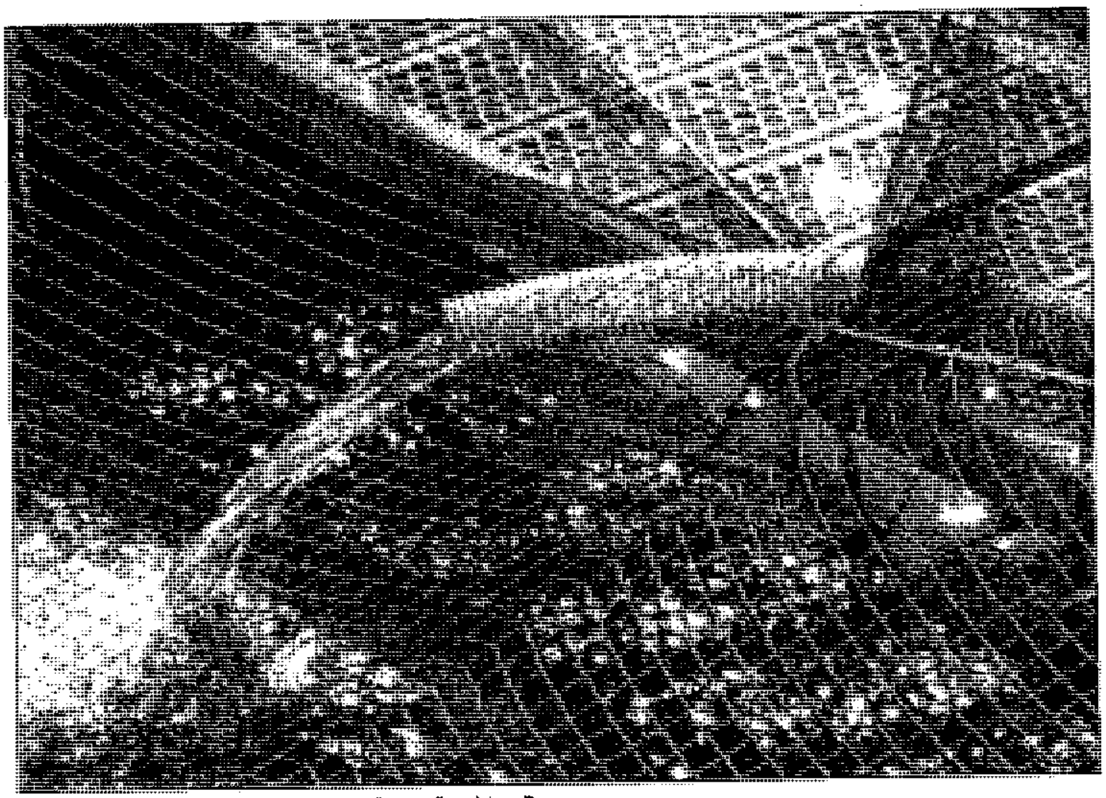


Figure 5. 2012 Resurrection Bay Salmon Stocking Program

1981-82 – Bentz, R.; ADF&G, Project Report F-9-14, G-I-D

"This was the first year Chinook salmon were stocked in landlocked lakes in this area.

A Coho salmon creel census was initiated on Cottonwood Creek and the Little Susitna River. An estimated 5,222 Coho salmon were harvested in 4,380 man-days of effort at the Little Susitna River, with a catch rate of 0.31 fish per hour. At Cottonwood Creek, a weekend-only fishery, 1,396 Coho and 1,945 sockeye salmon, Oncorhynchus nerka (Walbaum), were harvested in 3,344 man-days of effort, with catch rates of 0.136 and 0.189 fish per hour, respectively. Age determination of 189 Coho salmon scales identified 92 percent as Age 2.1 fish. Little Susitna River Coho salmon averaged 10.4 centimeters and 2.9 pounds larger in length and weight respectively than Cottonwood Creek Coho salmon.

The importance of this system as a high quality, productive sport fishery is reflected in that a Coho salmon stock enhancement program on the Little Susitna River is the number one priority in the Plan for Supplemental Production of Salmon and Steelhead for Cook Inlet Recreational fisheries, 1981.

An [Coho] enhancement program developed by the Fisheries Rehabilitation Enhancement and Development (FRED) Division was initiated in 1977 to augment natural production in the Cottonwood system. Eggs were taken from Fish Creek Coho salmon and incubated at the Alaska Department of Fish and Game (ADF&G), Big Lake Hatchery complex. The resulting fry were released throughout the system in favorable lentic rearing areas. **The fry releases have continued on an annual basis since 1977 to the present, with an average number of 320,000 fry released each year."**

Both the Fort Richardson and Big Lake Hatcheries are rearing and stocking Kings and Coho. The initial King and Coho stocks for Big Lake Hatchery were from the Fort Richardson/Ship Creek/Fire Lake stocks that included:

- **Green River, Washington Hatchery Kings**
- Ship Creek Kings, Alaska
- **Green River, Washington Hatchery Coho**
- **West Side Kodiak Island Coho (Ayakulik or Karluk), Alaska**

- Ship Creek Coho, Alaska
- **Fort Richardson Hybrid Coho (Washington, Oregon)**
- Bear Creek Coho, Seward, Alaska
- Blind Slough, Petersburg, Alaska
- Delta Clearwater, Alaska
- **Eagle Creek, Oregon**
- **Big Creek, Oregon**

1985-86 – Bentz, R.; ADF&G, Project Report S-32-6 Reports:

> "...the Little Susitna River...angling effort at the lower river fishery has increased 666 percent, from 933 angler-days in 1981 to 7,142 in 1985, making it the fastest growing segment of the Coho sport fishery. This rapid growth is a direct result of improvements over the past 3 years to the road that accesses this portion of river. Fishing effort is expected to continue to increase substantially as additional improvements are completed. Coho spawning escapement was estimated by helicopter and foot surveys at 4,500 fish. The total in-river return was estimated at 9,086 Coho.
>
> The value placed on this system as a high quality productive sport fishery is reflected by Alaska Department of Fish and Game (1981a); this publication lists a Coho salmon stock enhancement program on the Little Susitna as the number one priority. In response to this priority, the Fisheries Rehabilitation, Enhancement, and Development (F.R.E.D.) Division began a brood stock enhancement and egg-take program in 1981. Over 4.1 million eggs have been collected from Little Susitna River Coho from 1981 through 1985. Coho fingerlings resulting from these egg-takes have been released into five connecting lake systems since 1982. Coho smolts have also been released since 1985. The first significant adult returns from this stocking program are anticipated in 1986, when over 2,100 hatchery-reared adult Coho salmon are expected to enter the Little Susitna River."

These Coho average 2 rm of upstream migration. It takes 30-40 days for these Coho to move from salt water to spawning areas. During these 30-40 days, these Coho are readily accessible to the sportfishing public.

1990 – Original Little Susitna Escapement Goal established at 7,500 Coho past the weir **based on hybrid Washington/Oregon/Kodiak stocks.**

1991 – Bartlett, L.; ADF&G, Fisheries Data Series No. 91-46

"The Little Susitna River has had the highest sport fishery effort in the Matanuska-Susitna Valley since 1981 and currently supports the second largest freshwater Coho salmon *Oncorhynchus kisutch* fishery in the state (Mills 1979-1990). The harvest of Coho salmon in the Little Susitna River has increased 450% since 1977. In response to the large increases in effort and harvest, the Little Susitna River has been stocked annually with Coho since 1982 (ADF&G 1981, Chlupach 1989). **Eventually, 11,838,251 Coho fry or smolt were stocked in the Little Susitna River from 1982-1993.**

A weir was constructed across the Little Susitna River at rkm 52. Daily and cumulative counts of five salmon species *Oncorhynchus* were recorded from 18 July through 9 September as the salmon passed through the weir...

Escapement

From 18 July through 9 September 15,511 Coho salmon; 3,224 chum salmon; *O. keta*; and 7,604 pink salmon *O. gorbuscha* were passed through the weir at rkm 52 [rm32.6]. Forty-five Chinook salmon *O. tshawytscha* and 1,045 sockeye salmon *O. nerka* were also passed but the counts for these species are incomplete because high spring runoff prevented the weir from being installed until after the majority of the fish of these species were upstream of the weir site."

All five species of salmon are present; however, the record is silent as to stocking rates and origin of these salmon. It is reported that local area ADF&G staff regularly planted salmon fry/smolt at numerous road/bridge crossings in the Susitna Valley. ADF&G stocked an additional **11,000,000** more Coho fry/smolt than the record indicates.

"A total of 22,311 Coho salmon were accounted for in the Little Susitna River during 1990. The actual inriver return is somewhat greater than this due to fishing effort by anglers who access the sport fishery through the Port of Anchorage and were not surveyed during 1990. This estimate is based on an estimated escapement of 14,310 Coho salmon above the weir, and the estimated sport harvest of 1,201 Coho salmon above the weir, and an estimated sport harvest of 6,800 Coho salmon below the weir. Based on a total estimated sport harvest of 8,001, this represents a minimum inriver exploitation rate by the sport fishery of about 36%.

Hooking mortality and a small number of salmon that pass upstream after the weir is removed also add to the uncounted number of Coho salmon in the return. Studies by Vincent-Lang et al. *(Unpublished)* show that the mortality of hooked and released Coho salmon in the intertidal waters of the Little Susitna River is as high as 69%. A 69% mortality of the released fish would comprise about 6% (395 fish) of the total catch of Coho salmon by anglers fishing downstream of the Burma Road access."

Figure 6. Excessive limit of coho salmon

<u>1996</u> – Bartlett, L.; ADF&G, Fisheries Data Series No. 96-16, 1986-1994 Data Analysis

"The resultant estimated proportional contribution of both [Fort Richardson and Big Lake Hatchery] releases of fish was about 25% of the total harvest."

Table 5 is adapted from Bartlett, ADF&G, 1996, Table 8 page 18

Table 5 Escapement Index Counts of Coho Salmon in the Little Susitna River, 1981-1994

Year	Hatchery	Non-Hatchery	Total
1981			6,750
1982			6,800
1983			2,666
1984			20,991
1985			3,540
1986			7,511*
1987			4,865
1988	4,428	16,063	20,491
1989	6,862	8,370	15,232
1990	3,370	10,940	14,310
1991	8,322	29,279	37,601
1992	2,690	19,492	22,182
1993	9,189	25,633	34,822
1994	4,162	24,786	28,948

* Weir washed out in flood from 21 July - 29 July 1986

"September and October of 1994 were characterized by low stream flows. These low flows allowed the construction and maintenance of new dams by beavers *Castor Canadensis.* Beaver dams inhibited the upstream migration of sockeye and Coho salmon on two (and possibly more) Coho salmon index streams."

<u>1996</u> – Recommendations (Bartlett, ADF&G, 1996)

The following points relative to this study are suggested:

1. "**Suspend enhancement of the Little Susitna River with hatchery fish** until it is demonstrated that the non hatchery stock can not sustain the sport fishery (and use the freed hatchery space to establish a Coho salmon fishery in Moose Creek, a tributary to the Matanuska River, or in the Knik River ponds). If recent levels of nonhatchery escapement

continue, the inriver return from a release of 126,000 smolt will not provide enough fish to the sport fishery to make a noticeable difference.

5. Investigate anecdotal **reports of northern pike in the Little Susitna River** drainage. Set a gillnet at the outlet of Nancy Lake in the early spring of 1996 to test for the presence of pike during their spring spawning migration. If pike are present in small numbers, develop a program to attempt extermination."

<u>1996</u> – Bartlett, L.; ADF&G, Fisheries Data Series No. 96-39, 1995 Data Analysis summarizes Coho stocking into the Little Susitna River.

– 6,809,092 Coho salmon fry were released 46 times into lakes in the Mat-Su Valley from 1982 to 1990.

– 5,029,159 Coho salmon smolt were released 17 times into the Little Susitna drainage from 1983 to 1993.

"Data collected during this project also aid in assessing the stocking program. The stocking program has contributed up to 75% (an estimated 10,660 fish) of the sport harvest (1989) and has added an inestimable number of angler-days to the sport fishery."

"The estimated proportional relative contribution from tag code 32-23-01 to the 1995 harvest of Little Susitna River Coho salmon by boat anglers exiting the Burma Landing sport fishery was 20.1%."

– The Little Susitna River stocking programs from 1964-65 thru 1993 were discontinued.

– All these multiple millions of stocked Coho and Kings were introduced as hybrid stocks **from Washington, Oregon, Kodiak, Bear Lake and Blind Slough.**

<u>1999</u> – The Little Susitna River Coho escapement goal was raised to 9,600 – 19,200 from the original escapement goal of 7,500. Included stocked Coho run components.

<u>2001</u> – The Little Susitna River Coho escapement goal was raised again to an SEG of 10,100 – 17,700 from 9,600 – 19,200. Included stocked Coho run components.

Table 6 outlines the yearly inriver run / angler-days and in-river exploitation rates from 1977 thru 2011. It is clear that the 2007-2011 averaged are significantly below the 1977-2011 or the 2000-2010 averages in all parameters, except for the inriver exploitation rate. Even though 2007-2011 the inriver run averages had decreased by 40%, the inriver exploitation rate only decreased by 3-4%. There was not a corresponding decrease between inriver runs and inriver sportfishing exploitation. Had there been an equal reduction in the inriver sportfish exploitations, escapement goals would have been achieved. In 2009, the inriver run was down 48.9% (from the 2000-2010 average), while the inriver exploitation rate was up 4%. The result was a Coho escapement of 9,523, which was 577 Coho below the 10,100 escapement goal minimum. Had the inriver exploitation rate just remained at the 2000-2010 average, .502 or 50.2%, the spawning Coho escapement would have been within the 10,100 escapement goal.

It is very clear that if the inriver exploitation rate had been lowered by 48.9%, equal to the smaller Coho return, an overall lowered exploitation rate of .250 or 25% would occur. The 2009 inriver run of 19,925 Coho at the 25% parity exploitation rate would yield a Coho escapement of about 14,900, which is within the 10,100 - 17,700 escapement goal range for the Little Susitna River.

In years of smaller, less than 15,000 total inriver runs, the escapement goal would have been achieved if the total inriver exploitation rates had been lowered.

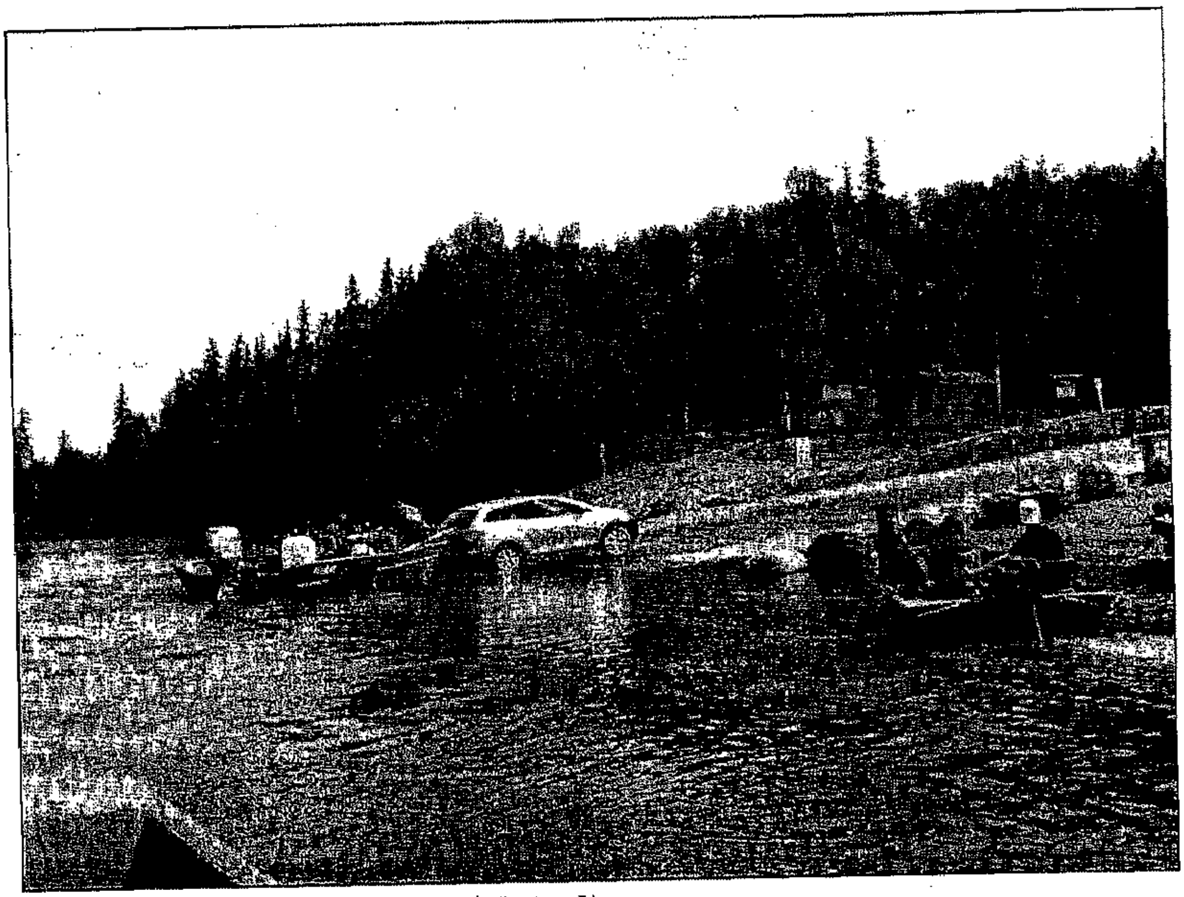


Figure 7. Public Use Facility Boat Launch, Little Susitna River

In 2011, as shown in Table 6, even though the angler-days were reduced to about 1/3 of the 1977-2011 average angler days, the exploitation rate remained high, 48.5%.

Table 6 Little Susitna River Sport Harvest by Year, 1977-2011
Not including Nancy Lake (Approximate Numbers)

Year	Angler Days	Coho Escapement	Coho Harvest	70 Percent Release	Total Mortality	In-River Run	In-River Exploitation
1986	45,770	7,511	6,039		6,039	13,550	0.446
1987	35,659		13,003		13,003	13,003	
1988	49,731	21,437	19,009		19,009	40,446	0.470
1989	54,798	15,855	14,129		14,129	29,984	0.471
1990	40,159	15,511	7,497	3,434	10,931	26,442	0.413
1991	50,838	39,241	16,450	3,284	19,734	58,975	0.335
1992	49,304	21,182	20,033	5,572	25,605	46,787	0.547
1993	42,249	34,822	27,610	7,412	35,022	69,844	0.501
1994	45,149	28,948	17,665	3,203	20,868	49,816	0.419
1995	41,119	12,266	14,451	3,781	18,232	30,498	0.598
1996	24,575	15,803	16,753	4,370	21,123	36,926	0.572
1997	27,883	9,894	7,756	2,663	10,419	20,313	0.513
1998	22,108	15,159	14,469	2,906	17,375	32,534	0.534
1999	20,437	3,017	8,864	2,125	10,989	14,006	0.785
2000	39,556	15,437	20,357	7,812	28,169	43,606	0.646
2001	33,521	30,587	17,071	5,296	22,367	52,954	0.422
2002	40,346	47,938	19,278	7,913	27,191	75,129	0.362
2003	31,993	10,877	13,672	5,584	19,256	30,133	0.639
2004	33,819	40,199	15,307	6,772	22,079	62,278	0.355
2005	27,490	16,839	10,203	2,271	12,474	29,313	0.426
2006	28,547	8,786	12,399	5,711	18,110	26,896	0.673
2007	35,636	17,573	11,089	2,664	13,753	31,326	0.437
2008	31,989	18,485	13,498	3,584	17,082	35,567	0.480
2009	28,151	9,523	8,346	2,056	10,402	19,925	0.522
2010	24,846	9,214	10,662	1,504	12,166	21,380	0.569
2011	12,779	4,826	2,452	968	3,420	8,246	0.415
Ave. 1977-2011	**35,710**	**18,837**	**13,722**	**4,131**	**17,267**	**35,380**	**0.502**
Ave. 2000-2010	**32,354**	**20,496**	**13,807**	**4,652**	**18,459**	**38,955**	**0.503**
Ave. 2007-2011	**21,850**	**11,924**	**9,209**	**2,155**	**11,364**	**23,288**	**.485**

The apparent failure to meet the bottom end of the 10,100 – 17,700 Coho escapement goal is directly attributable to a lack of parity reductions between the inriver exploitation rates and harvests. The Coho were in the river. The Central and Northern District commercial fishermen provided Coho for adequate spawning only to be overharvested by the inriver removals.

Of the 35 ADF&G inventoried culverts on Little Susitna tributaries, 66% (23) were categorized as "red", or culverts that are inadequate for juvenile fish passage, and 29% (10) as "gray", culverts that require additional data and analysis to categorize fish passage. "Green" culverts are assumed to allow juvenile fish passage.

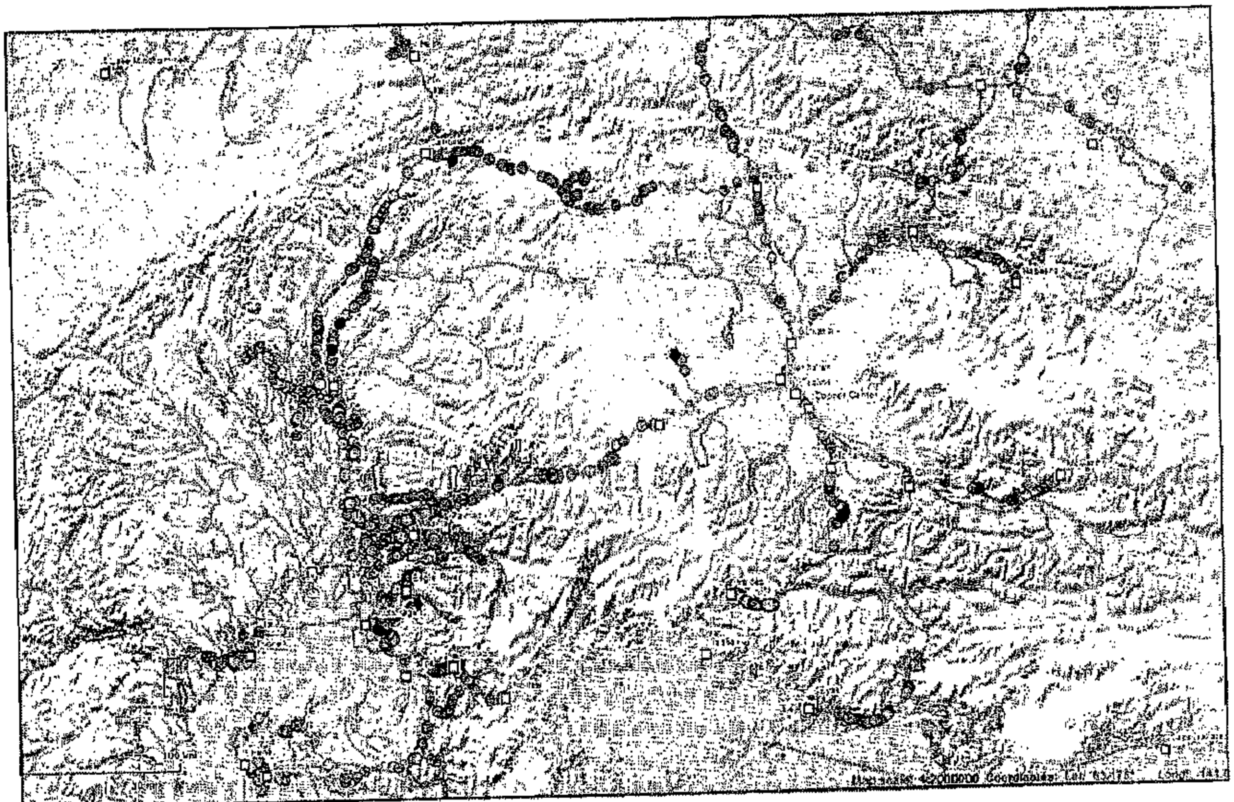
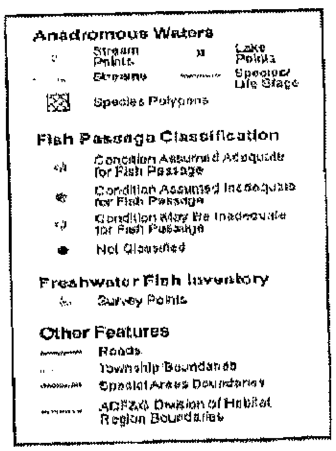


Figure 8. Alaska Department of Fish & Game Interactive Map



3. <u>Summary of Little Susitna Coho Stock</u>

A. Original native salmon stocks were probably destroyed by mining activities that used **cyanide** leaching processes from around 1900 thru the early 1960's.

B. **Kodiak, Alaska, Green River, Washington Coho and Kings, Oregon Coho, Bear Lake Coho and Blind Slough Coho** were selected and brought to Fire Lake and Fort Richardson and later to Big Lake Hatcheries. All these stocks were hybridized together in various combinations.

C. **The Kodiak and Green River Coho stocks and the Seward/Bear Lake Coho** were hybridized and developed as brood stocks at Fort Richardson and Big Lake Hatcheries.

D. These hybrid Coho stocks were introduced into the Little Susitna River many times. Numerous other streams, rivers and lakes in Southcentral Alaska were also stocked from 1972-1993. These hybrid Coho displayed hybrid vigor and exotic introduced vigor and reproduced quickly.

E. In addition to these hybrid Coho stocked in the Little Susitna River, there were 10-15 million additional hatchery fry and smolt releases that added to the system's production. Harvesting of these hybrid Coho occurred in both the commercial and sport fisheries. Hatchery stockings slowed and were discontinued in 1993.

F. The original BEG of 7,500 in 1990 was based on weir counts and harvest data that included both **hybrid spawners** and millions of additional hybrid fry and smolt hatchery contributions.

G. The 1999 BEG of 9,600 – 19,200 was based on the years including these maximum returns returning from these maximum hybrid hatchery fry and smolt releases.

H. The 2001 SEG of 10,100 – 17,700 was based on the same data set that included maximum hybrid hatchery fry and smolt releases.

I. A new SEG needs to be determined using the post-stocking (1996) Coho data.

J. Establish a new OEG of 3,000 – 12,000 for the Little Susitna Coho stocks.

K. Establish a new Coho indicator system isolated from the effects of urbanization.

L. Resume the Little Susitna Coho and King stocking programs.

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Water Quality in the Lower Little Susitna River

Cumulative Report: July 2007 through August 2012

FINAL

8/1/2013

Prepared for

Alaska Department of Environmental Conservation

By

ARRI
Aquatic Restoration & Research Institute

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Summary

This report summarizes Little Susitna River water quality studies conducted from 2007 to 2012. The water quality studies monitored petroleum hydrocarbons and turbidity to determine if increases in concentrations were caused by motorized boating and if values were in excess of Alaska Water Quality Standards (WQS). Concerns about Little Susitna River water quality were raised due to the increasing number of boats during the sport fisheries and documentation of hydrocarbon concentrations above WQS due to similar boating activities for fisheries in the Kenai River. In response to these concerns, the Alaska Department of Environmental Conservation (DEC) initiated a water quality monitoring study in 2007 for the lower part of the Little Susitna River (Lower Little Susitna River). Initial study objectives were to determine if total aromatic hydrocarbons (TAH) from gasoline adjacent to the Public Use Facility (PUF) boat launch were present at detectible concentrations and if so, whether concentrations were measured above WQS. Additional studies were conducted from 2008 through 2012 during part or all of the summer season (May – August) to determine the relationship between boat use and hydrocarbon concentrations, the length of stream and duration of time (annual, seasonal, daily) hydrocarbons were present, and exceedances of WQS. Initial study results also detected increases in stream water turbidity. Therefore, study objectives were expanded to include measures of turbidity along with measures of TAH. Biological monitoring was conducted to determine if water quality could be negatively affecting the aquatic community.

TAH Results

The 3-day average concentrations of TAH exceeded the WQS in 2009 and 2010 (Table 8). In 2013, DEC drafted a listing methodology for TAH which recommends that a 4-day average be used to evaluate chronic effects on aquatic life. The concentrations of TAH needed to exceed WQS if a fourth day of sampling had been conducted are estimated to be 11 µg/L in 2009 and 5 µg/L in 2010.

The PUF entrance booth boat count data allowed for estimates of TAH concentrations in the river from the boat launch on week days and weekends when data collection and boat observations were not conducted at the PUF boat launch. Using these regression equations and total boats, TAH concentrations would exceed 10 µg/L on days when 39 or more boats passed the PUF entrance booth, with a 95% confidence interval of 26 to 72 boats. The number of consecutive days when more than 39 boats passed the entrance booth was 5 in 2008, 4 in 2009, and 3 in 2010. Therefore, in both 2008 and 2009 the 4-day average would have likely exceeded the water quality standard.

Using the cumulative dataset, maximum TAH concentrations exceeded WQS[1] during every year except August 2012 (Table 6). Of the 362 samples taken primarily on weekend days (i.e. high boat activity) collected from 2007-2012, 66 samples, or 18.2%, were above WQS. Broken down by day, of the 62 sample days from 2007-2012, 26 of these days (42%) had at least one or more of the sample sites with TAH concentrations greater than 10 µg/L. Maximum and minimum values are shown in Figure 3 for all sample dates and a summary of TAH samples for each site is provided in Table 7.

[1] The WQS for Petroleum Hydrocarbons to protect aquatic life is 10 µg/L (18 AAC 70, see Table 5).

TAH concentrations were highest in June and August, on weekends and were highly variable throughout a day ranging from below method detection limits to well over WQS during the day. Average daily TAH values exceed WQS on the busiest use days; however, study results show that TAH concentrations do not remain above WQS throughout an entire 24 hour day. TAH concentrations were highest downstream from the PUF boat launch. TAH concentrations greater than 10 μg/L were recorded at sites located from 4 km (2.5 miles) upstream from the PUF boat launch to 12 km (7.5 miles) downstream.

Turbidity Results

Data collected from 2008-2011 showed turbidity levels exceeded the WQS for all three designated uses: water supply, recreation, and growth and propagation of fish, shellfish, other aquatic life, and wildlife. However, the aquatic life criterion was exceeded less than 10% of the time.

Stream water turbidity was higher downstream from the PUF in comparison to the un-impacted upstream site. The statistically defined "natural conditions" turbidity value at the reference site is 14.9 NTU (90% of the values are lower than this value). Turbidity values downstream from the PUF were above the natural condition and exceeded water quality criteria (WQC) for water supply and recreation and, at times, the aquatic life criterion. Turbidity 4 km (2.5 miles) downstream from the boat launch exceeds this natural condition value by 5 NTU 30% of the time, and by 10 NTU 15% of the time. Increases in turbidity are greater when analyses are limited to times of increased boat activity, June and August and even more so if limited to days of the week with most boating activity (Saturday and Sunday).

The combination of boat activity and presence of fine substrate resulted in turbidity values that exceed WQS. A significant relationship between the number of boats and increases in turbidity exists. In addition, turbidity changes throughout a day, starting with a sharp increase beginning early in the morning at the start of boating activity. Turbidity increases throughout the day by 15 to 20 NTU until around 11:00 PM, and then declines gradually through the night. This pattern is strongest during peak boat activity and is absent when boats are absent. This daily pattern was not observed at the upstream reference site and cannot be explained by any natural processes.

Biological Monitoring

Ecosystem production, invertebrate drift, and juvenile salmon abundance were lower downstream from the PUF compared to the upstream sample site. Declines in primary production were linked to changes in turbidity. This study cannot confirm that differences in macroinvertebrates and juvenile salmon abundance are the result of decreased water quality; however, changes in water quality, and reduced ecosystem production have the potential to negatively affect rearing salmon and invertebrates and could be at least part of the cause of the observed differences. Further biological studies would be needed to identify the exact cause of the biotic differences.

In conclusion, the operation of motor boats in the Lower Little Susitna River causes an increase in TAH concentrations and turbidity. TAH concentrations at the boat launch are closely related to the number of 2-cycle motors but average downstream concentrations are more closely related to the total number of boats, regardless of motor type. TAH concentrations often exceed 10 μg/L, but do not remain above this concentration on all sampling dates. Turbidity downstream from the boat launch exceeds WQC. The abundance of juvenile salmon and aquatic insects is lower downstream from the PUF boat launch compared to upstream which may be due to changes in water quality and the physical environment from motorized boat traffic; or other factors unrelated to human activity.

Water Quality in the Lower Little Susitna River

August 1, 2013

1.0 Introduction

The Little Susitna River, located in Southcentral Alaska, supports five species of Pacific salmon. The river is accessible from the urban centers of Anchorage and Wasilla resulting in large numbers of anglers during the Chinook and coho salmon fisheries. There are two primary boat access points to the Lower Little Susitna River, private and unimproved boat launches near the City of Houston approximately 100.5 km (62.8 miles) upstream from Cook Inlet, and at the PUF boat launch located approximately 40 km (25 miles) upstream from Cook Inlet. Use of the river is concentrated near the PUF. The number of boats and anglers has been increasing over time along with concerns about water quality.

Outboard motors can discharge burned and unburned hydrocarbons (Butcher 1982, Jüttner et al. 1982, Lerner et al. 2009). The use of outboard motors has been found to result in the discharge of petroleum hydrocarbons to lakes and rivers (Lico 2004, ADEC 2009). Hydrocarbons consist of volatile organic compounds (VOC) (benzene, toluene, ethyl-benzene, and xylene) and the heavier polycyclic aromatic hydrocarbons (PAHs). VOC is synonymous with state hydrocarbon TAH standards. Lico (2004) measured VOCs and PAHs in high boat use areas of Lake Tahoe and the adjacent Donner Lake, California. PAHs have been detected in surface waters and sediments of Crater Lake, Oregon (Oros et al. 2007). Seasonal patterns of PAH concentrations in Auke Lake, Alaska were correlated with the operation of 2-cycle motors (Rice et al. 2008). Using similar methods, Moles et al. (2006) detected PAHs in the Kenai River, Alaska in portions of the river subject to intensive boat use during the salmon fisheries. VOCs have also been detected within the Kenai River and Big Lake, Alaska (DEC 2007, 2009) at concentrations that exceed Alaska Water Quality Standards (DEC 2011) in high boat use areas.

Two-cycle motors have been shown to discharge 10 to 30% unburned fuel, up to 10 times greater than discharge from 4-cycle motors (Jüttner et al. 1982). The discharge from 2-cycle motors is greatest at idle or low operating speeds (Butcher 1982). The partial ban on 2-cycle motors in the Kenai River reduced TAH concentrations (DEC 2010). Concentrations of VOCs in Lake Tahoe also decreased in response to a ban on 2-cycle motors, but did not result in significant declines in PAHs (Lico 2004).

Petroleum hydrocarbons can have lethal and sub-lethal effects to aquatic organisms. Sculpin (*Cottus asper*) condition, number of parasites and the abundance of lesions has been shown to be related to differences in PAH concentrations (Moles and Marty 2005). PAH is hypothesized to be the cause of the loss of mussels (*Anodonta* sp.) and sticklebacks (*Gasterosterus* sp.), and reduced sockeye salmon abundance in Auke Lake (Moles and Marty 2005). Rainbow trout (*Onchorhynchus mykis*) exposed to exhaust from 2-cycle motors exhibited DNA damage and reduced carbohydrate metabolism (Tjarlund et al. 1996). Chinook salmon smolt and juveniles exposed to PAHs can cause reduced biomass and fat content which could affect overwinter survival (Meader et al. 2006). The exposure of pink salmon embryos to 1 μg/L PAH can result in reduced survival and growth (Heintz et al. 1999, 2000 in Rice et al. 2008). Alaska WQC for the protection of aquatic life based on tolerance limits for salmon species are 10 μg/L for VOCs and 15μg/L for the sum of VOCs and PAHs (DEC 2006).

Concentrated boat and shore traffic can result in increased rates of bank erosion, increases in suspended sediments and increases in petroleum hydrocarbon concentrations. Foot traffic along riverbanks can remove vegetation and reduce the sheer strength provided by plant roots leading to bank failure (Beesen and Doyle 1995, Davies-Colley 1997, Anderson and Bledsoe 2001). Bank failures can be exacerbated by boat waves that increase near-shore tractive forces increasing erosion and steepening banks (Nanson et al. 1994). Boat induced changes in streambed tractive forces can elevate concentrations of suspended sediment (Yousef 1974, Hilton and Philips 1982, Garrard and Hey 1987, Osborne and Boak 1999).

The influence of boats on suspended sediment and turbidity is variable. Yousef (1974) showed that in shallow lakes, boats could increase turbidity, depending on water depth, motor size, and bed sediments. Garrard and Hey (1987) demonstrated an increase in turbidity in rivers caused by a single boat passage, and the time in suspension increased with boat speed. By modeling suspended sediments as a function of boat passage in rivers, Hilton and Philips (1982) showed that turbidity can continue to increase if the frequency of boats does not allow for the resettlement of particles. Suspension of bed sediments is a function of tractive forces which are related to vessel wave heights (Nanson et al. 1994, Osborne and Boak 1999) that vary with vessel speed (Garrard and Hey 1987), and hull design or displacement (Garrard and Hey 1987, Maynard 2001). Particles can remain in suspension due to boat-induced turbulence and the passage of additional waves (Garrard and Hey 1987, Osborne and Boak 1999).

Considerable work has been conducted evaluating the effect of turbidity and suspended sediment on stream primary productivity, and macroinvertebrate and fish communities (Oregon DEQ 2007). Suspended sediment reduces primary production by reducing the amount of light reaching the streambed (Laperrier et al. 1989; Davies-Colley 1992) and can remove periphyton through abrasion (Davies-Colley 1992). Small changes in turbidity can cause rapid decreases in primary productivity (Davies-Colley 1992, Lloyd et al. 1987). Loss of periphyton biomass from reduced primary production and abrasion can reduce the abundance of grazing aquatic insects (Fairchild and Lowe 1984, Lamberti et al. 1989). Suspended sediment can reduce the quality of food captured by filter feeders (Lemly 1982, Love and Baily 1992). The reduction of benthic invertebrates can result in lower levels of invertebrate drift (Minshall and Petersen 1985). Reduced visibility due to suspended sediment and lower concentrations of invertebrates can limit the ability of rearing juvenile salmon to capture prey (reviewed in Newcombe and McDonald 1991). Sediment particles also can directly damage fish gills (Lake and Hinch 1999). Therefore, turbidity and suspended sediment can directly affect rearing salmon and indirectly through reductions in the abundance and ability to capture prey.

Concentrated boat use on the Lower Little Susitna River during the Chinook and coho salmon fisheries has raised public concern over potential changes in water quality and affects to salmon populations. In response to these concerns and documentation of hydrocarbon concentrations in the Kenai River above WQC, DEC initiated Little Susitna water quality studies in 2007.

Beginning in 2007, limited water quality sampling was conducted to determine if hydrocarbon concentrations in the Little Susitna River were present at concentrations above detection limits and if so, if results were in compliance with WQC. Sampling sites were located upstream and downstream from boat launches near the city of Houston, and upstream and downstream from the PUF in the lower river (Table 1). These two locations, along with launches at campgrounds within the city of Houston, are the only sites that provide motor-boat access. Sampling was conducted weekly from the middle of July through the middle of September 2007, and from the middle of May through the middle of June 2008. Stream water turbidity was measured concurrent with hydrocarbon sampling and boat use was estimated by counting the number of boat trailers. Initial screening results showed that TAH exceeded WQS on some dates upstream and downstream from the PUF concurrent with high boat use and that stream water turbidity was elevated relative to upstream reference values.

Due to initial findings, water quality in the Lower Little Susitna River became an Alaska Clean Water Action (ACWA) priority (see Table 2 for study summaries). Sampling continued in July of 2008 concentrating on locations extending from 1 km (0.6 miles) upstream to 4 km (2.5 miles) downstream of the PUF boat launch. Sampling was conducted weekly (on Saturday or Sunday) through the Chinook (late May and June) and coho (August) sport fisheries. TAH sampling at these locations continued through 2009 and the spring of 2010. To investigate daily variability in TAH concentrations, more intensive sampling (from 06:00 to 21:00 Saturday through Monday) was conducted at the PUF boat launch. To determine how far along the river corridor concentrations exceeding WQC were distributed, sampling locations were extended in the fall of 2010 to 8 km (5 miles) upstream and 12 km (7.5 miles) downstream from the PUF. In the spring of 2011 TAH monitoring was conducted throughout the day at the PUF boat launch to measure daily variability. In August 2012, sampling was extended to obtain a 4-day average TAH concentration. Boat use was recorded during each sampling event by counting the boats by motor type (2-cycle or 4-cycle) and size (horse power) operating at the PUF, and from counts at the state operated entrance booth.

Turbidity and basic water physical and chemical characteristics (pH, specific conductance, and dissolved oxygen) were measured from grab samples collected concurrent with TAH sampling. Turbidity from grab samples was augmented with data collected by water quality sondes (Hydrolab MS-5) that recorded values hourly beginning in 2008. One sonde was initially placed at a reference site located 8 km upstream from the PUF (LS 8 km up); however, due to frequent boat use at this location, the sonde was moved to a site downstream from the city of Houston (LS 60 km up) in 2009 and 2010. Sondes were also located at potentially impacted sites located 4 km (LS-4 km dn) and later at 8 km (LS-8 km dn) downstream from the PUF.

Biological monitoring was initiated in the fall of 2008 and continued into spring and fall of 2009 and 2010. Biotic monitoring was conducted as a screening tool to test for differences in the abundance of invertebrates and rearing salmon upstream and downstream from the boat launch. Biotic monitoring included measures of macroinvertebrate drift and juvenile salmon abundance at a reference reach 12 km (7.5 miles) upstream of the PUF and a sampling reach located 4 km (2.5 miles) downstream of the PUF. Consistent differences in the biotic community prompted measures of stream channel physical characteristics at these two locations in June of 2012. In 2008, an independent project was conducted to measure ecosystem productivity using the change in dissolved oxygen, and to evaluate these changes relative to differences in stream flow and turbidity.

All sampling, except for measures of ecosystem productivity, followed Alaska Department of Environmental Conservation (DEC) approved Quality Assurance Project Plans (QAPPs). Annual reports

Committee E

Upper Cook Inlet/Kenai/Kasilof Sport Fish

Chair – Morisky, Kluberton, Jeffrey

Supporting Documents:

- The Fates and Impact on Spawning Salmon as a Result of Catch/Hook and Release Practices
- Effect of commercially available egg cures on the survival of juvenile salmonids

Cook Inlet – Area-wide Sport Fisheries

Proposals 47-54, 183, 55, 56, 184, 185, 57

47 – Support

- Would like the BOF and ADF&G address the negative effects on spawning salmon populations
- Using barbless hooks would be one of many solutions
- Prohibit the use of bait in freshwaters, especially poisonous substances

48 – Support

- Support single, unbaited, barbless hooks in the freshwaters of Cook Inlet:
  - When baits are used
  - When Catch & Release is the management option
  - Limit line strength to provide a weak link to facilitate breaking line to possibly avoid extensive "playing time"

49 – Support – Introduces the use of circle hooks, which actually work well in hooking fish in the mouth

50 – Support – Coho salmon have high scale losses when hooked as they attempt to free themselves. Catch & keep is a poor management option.

51 – Support

- Coho "brought to hand" become part of bag & possession limits, even if the fish is released
- When bag & possession limits are reached, then fisherperson is "done for the day"
- Close all the lower reaches of freshwater systems to coho fishing

52 – Support

- Catch & keep cohos, where appropriate.
- Where managers are trying to achieve the lower limit of an escapement goal, establish a catch and release limit 1, 2, 3 or 4. Currently, there is no limit on the number of fish that can be caught and released.
- The BOF has had testimony that an individual caught and released 200-300 steelheads per year.

53 – Support

- ADF&G's "best practices" are just not effective.
- If they were effective, then why are anglers catching and releasing hundreds of salmon per year?
- Limit the number of Catch & Release events daily. Once this limit is reached, then fisherperson is "done for the day."

54 – Support

- These areas can be identified by local ADF&G managers and implemented by EOs
- BOF might state an intent and implement via EOs
- It just does not make a whole lot of sense to fish on spawning beds when escapement goals are not being met or barely being met.

183 – ? – Support in Concept

- Prefer proposals 48-54
- Could be implemented by regulation
- Could be implemented by "best practices" as a last resort

55 – Support – As long as Chinook are at low abundance levels, this is a reasonable proposal.

56- Support

- Chinook are in low numbers and this proposal will result in a few more fish being available for other harvesters and escapements
- Put a sunset date on this new regulation, 3-6-9 years from now.

184 – Support – UCIDA has requested a real-time (as possible) reporting system. With the technology that is available, the development of a reporting system is easy.

185 – Support – UCIDA has requested a real-time (as possible) reporting system. With the technology that is available, the development of a reporting system is easy.

57 – Support

- Most coastal states put limits on fish, game and aquatic plants that can be removed form a state's jurisdiction
- Numbers of fish would be better than poundage
- We already limit the number of moose, caribou, etc. that can be shipped out of State
- Legal to export from Alaska, with fish/salmon that are legally caught under an Alaskan license, the equivalent of two daily possession limits – not 10 days' worth of possession limits, i.e. – not 5 caribou

Kenai River Vessel Restrictions

Proposals 237-243

237 – Support

- This proposal was publically discussed, debated and supported by many Kenai residents
- The City of Kenai original charter predates Alaska Statehood
- The City of Kenai owns the lands, shores, and beds of the Kenai River and portions of Cook Inlet north and south of the Kenai River. As the land owner, the City of Kenai is asking from this regulatory change in order to conserve and maintain public order and to conserve public property
- Encourage the BOF to adopt this proposal

238 – Support – This is a habitat issue affecting the ecological health of the Kenai River

239 – Support in Concept – Prefer proposal 237

240 – Support in Concept – agree with both issue and problem statement

241 – Support

- Seems reasonable during times of low Chinook abundance.
- Shares the conservation burden
- Compliance issues are straight forward
- Can be changed by departmental EO if Chinook abundance occurs

242 – Support

- Many rivers in the lower 48 have limited the use of outboard motors as a means of reducing use on lakes and rivers.

- Seems to be a reasonable approach
- Equally applies to all fishermen on the Kenai River

243 – ? – Prefer proposal 242

Sport – Kenai/Kasilof River Salmon

Proposals 244-247, 249-251

244 – Support – Housekeeping – Corrects a regulatory oversight.

245 – ? – Would like to see a map(s) associated with this proposal

246 – Support – Support any proposal that will reduce the immediate hook and release mortality and the extended negative effects on the salmon's spawning success.

247 – ? – Needs clarity:

- "All salmon hooked" must retained
- How might this proposal, if adopted by the BOF, relate to bag & possession limits by species?
- Does this apply only to sockeye?

249 – Support

- Cured eggs that were prepared using substances that are poisonous to small fish, aquatic insects and organisms, birds and humans – should be avoided
- Support the concept that in times of low Chinook abundance
- Prohibit the use of eggs as bait is reasonable
- This proposal would reduce the targeting of female Chinook in order to secure the eggs that are used for bait

250 – ?

251 – Support – This is a precautionary approach. The Kasilof River King population is much smaller that the Kenai River King population

Group 1

Committee of the Whole

Public Testimony & Deliberation Materials

Stocks of Concern and Action Plans

Proposals 103, 104, 105 and 106

Supporting Documents – Attached or Referenced:

1. Fishery Related Aspects of Faulty Sonar Data, Over-Escapement and Impaired Habitat for Susitna Sockeye
2. Looking at Salmon Production in the Susitna River Watershed – CIAA submission (PC#?)
3. Euphotic Volume Model Estimates of Sockeye Salmon Production
4. A Comprehensive Inventory of Impaired Anadromous Fish Habitats in the Matanuska-Susitna Basin, with Recommendations for Restoration, 2013 – ADF&G Report
5. Assessing Climate Change Impacts in Cook Inlet Salmon Streams: Landscape Controls on Stream Temperature and Thermal Sensitivity
6. Alaska's Final 2010 Integrated Water Quality Monitoring and Assessment Report
7. A Watershed Prospective on Salmon Production in the Mat-Su Basin, June, 2013

Proposals:

103 – Oppose – Proposal is vague as to application in a geographic area or related stocks

- Does not provide direction or assistance in mixed-stock fisheries
- Every year there might be a few stocks that are near the minimum of an escapement goal. At which point does the Department exceed the upper end of a goal? Can always wait for more fish, much harder to remove fish.
- No direction as to application, 10 fish or 10,000 fish under a goal, what then?
- There is no balancing of the harm.

104 – Support – Move 5AAC 21.363(e) to another appropriate area of the regulations

105 – Oppose – Creates another layer of regulations to an already complicated regulatory framework in the management of Cook Inlet fisheries.

106 – Support – Where possible, all these UCI management plans could be simplified and better coordinated.

Fishery Related Aspects of Faulty Sonar Data, Over-Escapement and Impaired Habitat for Susitna Sockeye

Prepared for UCIDA by Catherine Cassidy and Erik Huebsch, January, 2014

Summary

ADF&G is recommending to the BOF that Susitna River sockeye salmon remain classified as a stock of yield concern (RC 8). A stock of yield concern is defined as "a concern arising from a chronic inability, despite the use of specific management measures, to maintain specific yields, or harvestable surpluses, above a stock's escapement needs." Susitna River sockeye do not meet that definition. The "specific management measures" that have been used were based on faulty data or no data at all and they have had the opposite effect from their intent. If the Bendix sonar counter had been properly counting the actual number of returning salmon there would not be a stock of yield concern designation for Susitna sockeye.

For 30 years there was a perception that the sockeye returning to the Susitna River were not meeting the escapement goals. This was driven by the premise that the Bendix sonar counter and the fishwheel apportionment were accurately counting the sockeye escapements. The perception led to restrictions on the Central District drift fleet and Northern District setnets. The effectiveness of the restrictions was never examined. The 2006-2008 ADF&G escapement goal study revealed that the escapement counting methodology was grossly underestimating sockeye escapement into the Susitna River. From 1981 through 2008 escapement goals were being exceeded by an average of more than 100 percent, some years the goals were exceeded by 300-400 percent or more.

These chronic over-escapements have led to instability in the sockeye runs and have masked the growing in-river habitat problems. The restrictions placed unnecessarily on commercial fisheries had no demonstrated effectiveness, severely limited the department's ability to manage the Cook Inlet salmon fishery and cost the industry many millions of dollars in lost harvest opportunity on Susitna and other sockeye stocks.

At this time the department cannot scientifically justify designating Susitna sockeye salmon as a stock of yield concern. Restrictions on commercial fisheries for sockeye conservation also have no legitimate justification. The Board should remove the stock of yield concern designation for Susitna sockeye. In addition, the Board should eliminate restrictions on Central District drift gillnetting during the July 9 through July 31 time period. The department should continue collecting data through the test boat fisheries in Cook Inlet and use genetic testing to scientifically inform future decisions.

Background

The purpose of an escapement goal is to ensure sustainability and maximize yield. State policy requires that escapements goals must be scientifically defensible. "Over-escapement, in general, is not sustainable…." Quote from ADF&G *2007 Biological and Fishery-Related*

Aspects of Overescapement in Alaskan Sockeye Salmon, by Robert Clark, M Willette, S Fleischman and D Eggers.

An escapement goal for Susitna sockeye was established in 1979 based on non-system specific characteristics. The Bendix sonar counter was placed into service at that time to measure the escapement. (The counter was placed in a Susitna tributary, the Yentna River, and the SEG for that location was used to manage sockeye salmon throughout the Susitna River watershed.) In the late 1980's the goal was revised using system specific information on salmon production based on a euphotic volume study of 24 salmon producing lakes in the Susitna drainage and a 4:1 return per spawner ratio.

The escapement counts were periodically called into question, particularly after the 1989 season when the Exxon Valdez oil spill caused drift gillnetting to be closed in Cook Inlet - with no apparent effect on the Susitna escapement sonar count. Increasing uncertainty with the escapement assessment prompted ADF&G to initiate a 3-year study in 2006. The study utilized a DIDSON system, weir counts and a mark-recapture program to compare with the Bendix sonar counts.

In 2008, before the study was completed, the BOF designated Susitna sockeye a stock of yield concern due to a chronic inability to meet the Yentna SEG (range 90-160,000) as measured by sonar. In 2009 ADFG released a special report outside of the normal three year cycle of escapement goal review because the errors with the sonar enumeration were so significant. The results of the study suggested that both the Bendix and DIDSON were grossly underestimating the number of sockeye salmon spawning in the Yentna River. (*Fair, L. F., T. M. Willette, and J. Erickson. 2009. Escapement goal review for Susitna River sockeye salmon, 2009. Alaska Department of Fish and Game, Fishery Manuscript Series No. 09-01, Anchorage.)*

Data from pages 18 and 21 of the report indicate that the Bendix sonar count (dating back to 1981) was biased low by more than 100 percent. While it is not possible to go back and re-count the escapements, it is evident the escapement goals were being met and in all years, except for 2005, the upper end of the goal range was significantly exceeded (see Table 2).

The report recommended eliminating the Yentna SEG and replacing it with SEGs for 3 individual lakes (Chelatna, Judd and Larson) in the Susitna watershed. The new escapement goals became effective for the 2009 salmon runs.

During the decades that area restrictions were placed on the drift fleet to conserve northern sockeye stocks, no studies were ever done and no evidence or data was ever generated to show that the restrictions had any effect on escapements. The latest research incorporating genetic testing with Off-shore Test Fishing in the Central District has demonstrated that sockeye stocks are intermingled and dispersed, both spatially and temporally, throughout Cook Inlet as they migrate.

Genetic testing of commercially caught sockeye has also shown that the percentage of northern-bound sockeye caught by drift fishermen in restricted corridors is not significantly different than the percentage caught when the fishermen are dispersed throughout Cook Inlet. In

2011, drift fishermen caught 781,146 sockeye while restricted to the Corridor. Of these, 6.8% were genetically identified as Susitna fish. While not restricted to the Corridor in 2011, drift fishermen caught 2,261,582 sockeye of which 5.7% were identified as Susitna fish.

The department also reported in RC 8 that Susitna median yield (harvest) estimates in 2008–2013 were 26% larger than those from 2003–2007. This increase in yield occurred even though the drift fleet had additional area restrictions during that time period that were intended to reduce the yield.

What we have learned from the use of mandatory restrictions is that they prevent fishery managers from reacting to real-time information during the season and interfere with their ability to manage the whole fishery. Harvest opportunity has been lost due to the restrictions; not only the millions of sockeye that exceeded escapement goals in the Susitna, but also millions of sockeye that exceeded escapement goals in other Cook Inlet systems due to mandatory restrictions that were based on faulty sonar data and flawed assumptions.

Susitna Sockeye – Not a stock of yield concern

In their memorandum (RC 8) to the BOF dated October 3, 2013, the ADF&G recommended that Susitna River sockeye salmon remain classified as a stock of yield concern because:

1) Five of the escapements in 3 different lakes (out of 15 total) have been below the minimum goal, and

2) Harvests in Central and Northern districts from 2008 through 2013 were generally less than the long-term averages.

Their justification was that in the Central District drift fishery, Susitna median yield (harvest) estimates in 2008–2013 were 26% larger than those from 2003–2007, and about 75% of those from 1983–2002 and 1993–2002, the two time periods to which recent (2003–2007) yields (harvest) were compared when determining the stock of yield-concern in February 2008.

The first glaring error with this justification is that the Department has no reliable data for run size, escapement or yield from 1981-2013 as the sonar counters used until 2008 were so inaccurate. There is still no reliable method for counting all the salmon that return to Mat-Su streams. Without some reasonably accurate method for enumerating salmon escapement they have no way to determine the yield (harvest) as a percentage of run size.

The attempt to use reduced median yield (harvest) estimates as a justification for maintaining a stock of concern classification also fails as it does not recognize that there were new management regulations for the Central District drift fishery from 2008-2013 that were intended to reduce the yield (harvest). This application of circular logic has no business masquerading as science.

What does it mean? If the median yield (harvest) estimates from 2008-2013 were 26% larger than the 2003-2007 time period as the Department stated, then either the restrictions on the drift fishery are not effective at conserving particular stocks, or, these stocks are much more robust than were assumed.

The methodology of using combined escapement counts from three different lakes does not fit the criteria for a Stock of Yield Concern. The escapement goals for these 3 lakes (Chelatna, Judd and Larson) do need to be re-evaluated as the returns to Chelatna and Judd are showing oscillating patterns in their sockeye populations from year to year, which can be an indicator of over-escapement. These escapement goals were based on returns to those lakes during years that we know the Susitna river goal was exceeded, so these goals are likely too high. In Judd Lake the fry size and weight suggest they are exceeding the rearing capacity of the lake and are near starvation (see Table 1). The Chelatna Lake escapement goal has been met four of the past five years, Judd Lake two of the past five years, and Larson Lake four of the past five years.

Again, a stock of yield concern is defined as "a concern arising from a chronic inability, despite the use of specific management measures, to maintain specific yields, or harvestable surpluses, **above a stock's escapement needs**". The department has a poor grasp of what the current sockeye escapement is or should be in the Susitna.

At least 14 of the original 24 sockeye producing lakes studied in 1989 now contain invasive northern pike. Six of those lakes with pike no longer produce salmon, five more lakes with pike have severely reduced production. Shell Lake, one of the largest producers, had nearly 70,000 spawners in 2006 and now it has none due to pike and disease.

The October 3, 2013 memo (RC 8) from ADF&G to the BOF also failed to factor the increasing sport fish harvest into the yield (harvest). During the same time period, 2008-2013, while restrictions were placed on the commercial fisheries (both Central and Northern District) for conservation purposes, the sport fishery yield (harvest) had no similar restrictions and continued to increase. Quote from ADF&G *2011 Fisheries Management Report 10-50:* "The action plan states sport harvest will not be used to determine escapements or in developing escapement goals. Further, the Susitna sport fisheries will remain open with a three fish bag limit unless otherwise directed by the BOF and any harvest restrictions will be realized in the commercial fisheries..."

Conclusion - Stock of Habitat Concern

ADF&G has not assessed and updated escapement goals for the Susitna river system. Sockeye production capacity has been significantly reduced by invasive northern pike and migration impedances. Maintaining escapement levels without accounting for the decreases in production capacity will inevitably cause adverse density-dependent effects in the systems that are still productive. As mentioned in the previous section, Judd Lake is showing effects symptomatic of over-escapement – oscillating returns and dangerously low fry size and weight.

Decades of escapements that routinely exceeded the goals by an average of 200% flooded the system with spawners. This masked and obscured the habitat issues that were gradually reducing production during this time.

Restrictions placed on commercial fisheries over the past 30 years were not necessary and were never supported by any assessment of effectiveness. The negative consequences of the mandatory restrictions include preventing fishery managers from doing their jobs and lost harvest opportunity for the commercial industry on the scale of tens of millions of dollars. Intensive management of saltwater fisheries cannot solve habitat-related production problems.

The Sustainable Salmon Fisheries Policy defines three levels to the stock of concern - yield, management and conservation - with yield being the lowest level of concern and conservation the highest level of concern. All three levels use the measurement of returning salmon, or escapement, as a threshold or trigger to determine the status of a stock. In the case of Susitna salmon stocks these levels of concern address the wrong end of the equation. The habitat for spawning and rearing salmon in the Susitna watershed is so affected by invasive northern pike, beaver dams, disease, culverts and the effects of urbanization that salmon production is the overriding problem, not the number of returning salmon.

ADF&G's 2012 *Upper Cook Inlet Management Report 2012* clearly stated that: "...unless the impacts from pike predation, disease and beaver dams can be significantly reduced, the total sockeye salmon production in the Susitna River drainage will continue to suffer, regardless of the amount of restrictions placed on commercial fisheries."

In 2013 ADF&G published *A Comprehensive Inventory of Impaired Anadromous Fish Habitats in the Matanuska-Susitna Basin, with Recommendations for Restoration* wherein the Habitat Research and Restoration Staff described habitat problems affecting salmon production and recommended restoration and research projects totaling over $8.5 million. Many of these projects are only assessing damage or will require annual funding so the actual cost of restoration is yet to be determined.

Within the Sustainable Salmon Fisheries Policy, a new level of concern needs to be added - "a stock of habitat concern" - defined as "a concern arising from the inability of salmon to successfully spawn and rear in their freshwater habitats as a result of invasive species, parasites, pollution, migration impedances or other habitat disturbances." This would enable the Board of Fisheries and ADF&G to focus their efforts on the cause of declining salmon runs, not just the effects. A new action plan should be developed that will help stabilize salmon production in systems that are still functioning, work towards eliminating pike from other systems, set goals for removal of migration impedances and develop a restocking program.

At this time the department cannot scientifically justify designating Susitna sockeye salmon as a stock of yield concern. Restrictions on commercial fisheries for sockeye conservation also have no legitimate justification. Therefore the Board should eliminate restrictions on Central District drift gillnetting during the July 9 through July 31 time period. The department should continue collecting data through the test boat fisheries in Cook Inlet and use genetic testing to scientifically inform future decisions.

- Sonar counts from 1981-2008 were inaccurate and biased low by more than 100%
- Stock of Yield Concern for Susitna sockeye was based on this faulty data.
- Restrictions placed on the Drift Fleet and Northern District set nets for over 20 years were based on this faulty data.
- Restrictions placed on commercial fisheries under the guise of conservation were not paired with restrictions on the sport fishery.
- Problems with Susitna salmon production have been identified and are the result of freshwater habitat issues.
- Intensive management of saltwater fisheries will never solve the problems found in the freshwater habitats of spawning and rearing salmon.

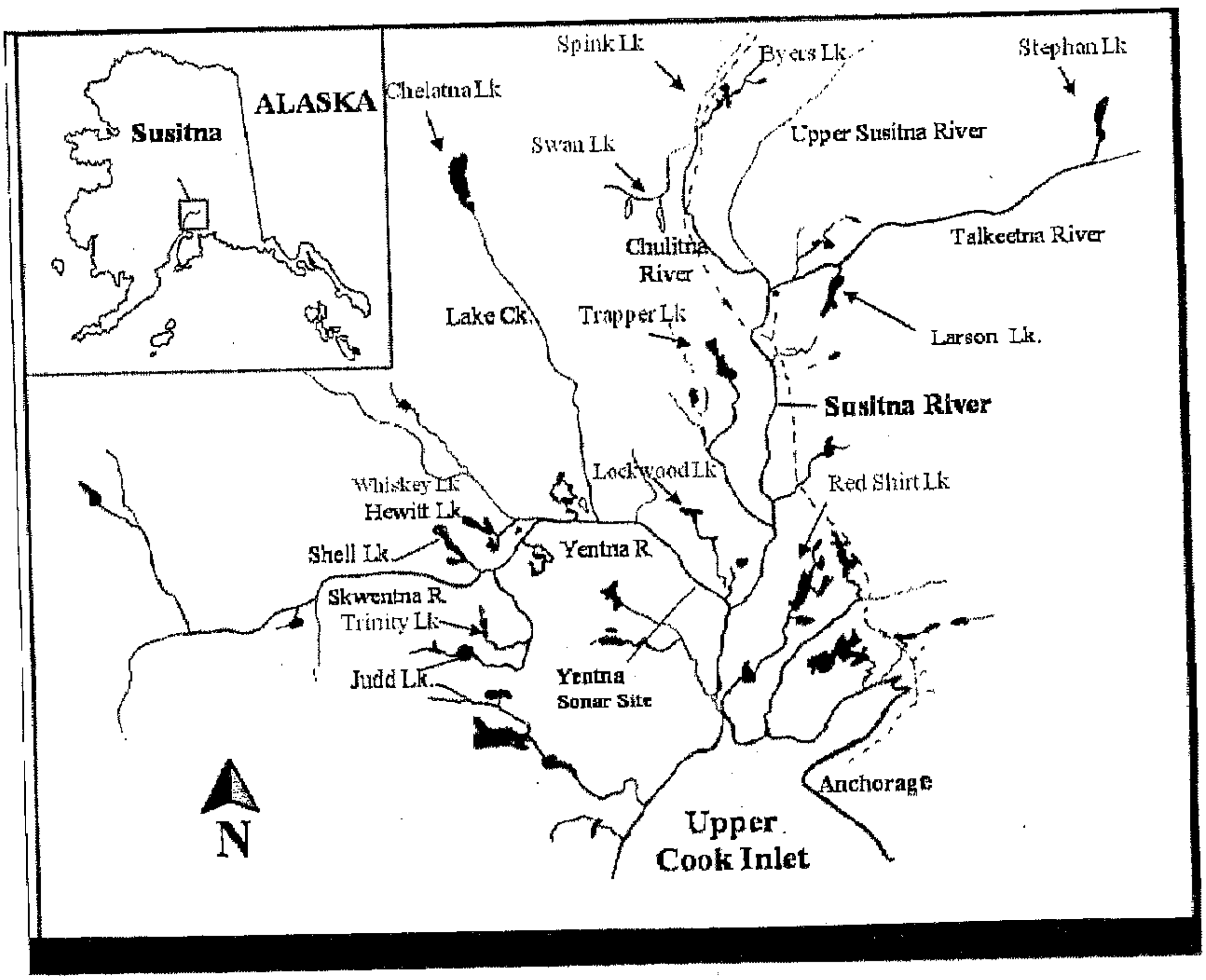


Table 1
Susitna Sockeye Fry Size Relative to Escapement

Chelatna Lake	SEG range 20-65		
Year	Escapement*	Age 0 Fry Length (mm)	Age 0 Fry Weight (g)
2005		57.5	2.7
2006		50.8	1.7
2007	18,433*	68.1	4.0
2008	41,290*	45.6	1.3
2009	73,469*	60.6	2.8
2010	17,865*	48.2	1.7
2011	37,784*	52.2	2.0
2012	70,353*	46.9	1.3
2013	36,577*		
2014	70,555*		
*Weir count from previous year			

Judd Lake	SEG range 25-55		
Year	Escapement*	Age 0 Fry Length (mm)	Age 0 Fry Weight (g)
2005		43.8	1.0
2006		53.8	2.1
2007	40,633*	47.6	1.3
2008	58,134*	37.6	0.7
2009	54,304*	41.2	0.8
2010	43,153*	38.0	0.7
2011	18,361*	50.3	1.4
2012	39,997*	39.0	0.6
2013	18,303*		
2014	14,021*		
*Weir count from previous year			

Larson Lake	SEG range 15-50		
Year	Escapement*	Age 0 Fry Length (mm)	Age 0 Fry Weight (g)
2005		58.9	2.5
2006	9,751*	62.4	2.9
2007	57,411*	61.5	3.0
2008	47,736*		
2009	35,040*	64.2	3.1
2010	41,929*	59.9	2.9
2011	20,324*	71.9	4.4
2012	12,413*	61.7	2.9
2013	16,708*		
2014	21,813*		
*Weir count from previous year			

Judd Lake average fry weight in 4 of the last 5 years indicates they were near starvation. Salmon fry at .6 grams or less in weight do not have enough body mass and/or fat reserves to survive the winter. Fry with decreasing weights of less than 1 gram have increasing higher mortality rates when compared to healthy fry.

Description of information in Table 2
Historic Yentna Escapement Data

Column

1. Year 1982 through 2008 (27 years).

2. Original Bendix sonar escapement number. ADFG reports.

3. DIDSON equivalent escapement number, based on a three year comparison with Bendix and DIDSON systems running concurrently in the Yentna River. ADFG reports.

4. Upper end of Yentna escapement goal. ADF&G reports.

5. DIDSON adjusted for fish wheel selectivity. Calculated using fish wheel selectivity coefficients and adjusted to provide the lowest possible Mean Absolute - Percentage Error (MAPE) compared with mark-recapture abundance estimates. ADF&G data.

6. Escapement goal exceeded, percentages are calculated by first subtracting the number in column 4 from the number in column 5, then dividing the remainder by the number in column 4. The number is this column is the percentage that is over and above the upper end of the escapement goal.

7. DIDSON adjusted for mark-recapture based on a 5 year average ratio. ADF&G data

8. Escapement goal exceeded, percentages are calculated by first subtracting the number in column 4 from the number in column 7, then dividing the remainder by the number in column 4. The number in this column is the percentage that is over and above the upper end of the escapement goal.

9. Average goal exceeded number, calculated by subtracting the number in column 4 from the average of column 5 and column 7. The number in this column is the average number of salmon over and above the upper end of the escapement goal. Total number at the bottom, multiplied by a 6 pound average for total weight.

The escapement numbers listed in columns 5 and 7 are intended to represent the approximate escapement. These numbers are mathematically derived and not actual fish counts.

Table 2 Historic Yentna Escapement Data from ADF&G data and reports

1	2	3	4	5	6	7	8	9
Year	Original Bendix Escapement Number	DIDSON Equivalent*	Upper End of Escapement Goal	DIDSON Adjusted for Fish Wheel Selectivity	Escapement Goal Exceeded Percentage	DIDSON Adjusted for Mark/Recapture	Escapement Goal Exceeded Percentage	Average Goal Exceeded Number
1982	113,847	253,982	100,000	667,733	568%	523,203	423%	495,468
1983	104,414	210,105	100,000	323,461	223%	432,816	333%	278,139
1984	149,375	298,383	100,000	773,450	673%	614,669	515%	594,059
1985	107,124	211,806	100,000	417,147	317%	436,320	336%	326,734
1986	92,076	169,048	150,000	974,513	550%	348,239	132%	511,376
1987	66,054	130,040	150,000	291,897	95%	267,882	79%	129,890
1988	52,330	101,854	150,000	286,421	91%	209,819	40%	98,120
1989	96,269	189,554	150,000	491,489	228%	390,481	160%	290,985
1990	140,290	259,729	150,000	682,631	355%	535,042	257%	458,836
1991	109,632	217,158	150,000	347,900	132%	447,345	198%	247,623
1992	66,074	130,966	150,000	463,272	209%	269,790	80%	216,531
1993	141,694	282,837	150,000	593,576	296%	582,644	288%	438,110
1994	128,032	251,856	150,000	413,317	176%	518,823	246%	316,070
1995	121,220	232,856	150,000	416,842	178%	479,683	220%	298,263
1996	90,660	172,882	150,000	308,169	105%	356,137	137%	182,153
1997	157,822	308,949	150,000	379,445	153%	636,435	324%	357,940
1998	119,623	211,500	150,000	445,538	197%	435,690	190%	290,614
1999	99,029	186,981	150,000	280,900	87%	385,181	157%	183,040
2000	133,094	291,848	150,000	409,266	173%	601,207	301%	355,236
2001	83,532	153,847	150,000	376,228	151%	316,925	111%	196,576
2002	78,591	158,564	160,000	479,228	200%	326,642	104%	242,935
2003	180,813	344,224	160,000	609,591	281%	709,101	343%	499,346
2004	71,281	142,187	160,000	347,900	117%	292,905	83%	160,403
2005	36,921	71,264	160,000	131,541	-18%	146,804	-8%	
2006	92,051	166,697	160,000	390,567	144%	343,396	115%	206,981
2007	79,901	125,146	160,000	206,146	29%	257,801	61%	71,973
2008	90,146	131,772	160,000	252,804	58%	271,450	70%	102,127
Average	103,774	200,224		435,592	214%	412,460	196%	
							Total fish over goal	7,549,5
* Actual DIDSON counts used for 2006-2008							Total weight	45,297,1
							Loss of direct revenue	$45-$90 millio

Table 3. Susitna River sockeye salmon studies, 2006-2012.

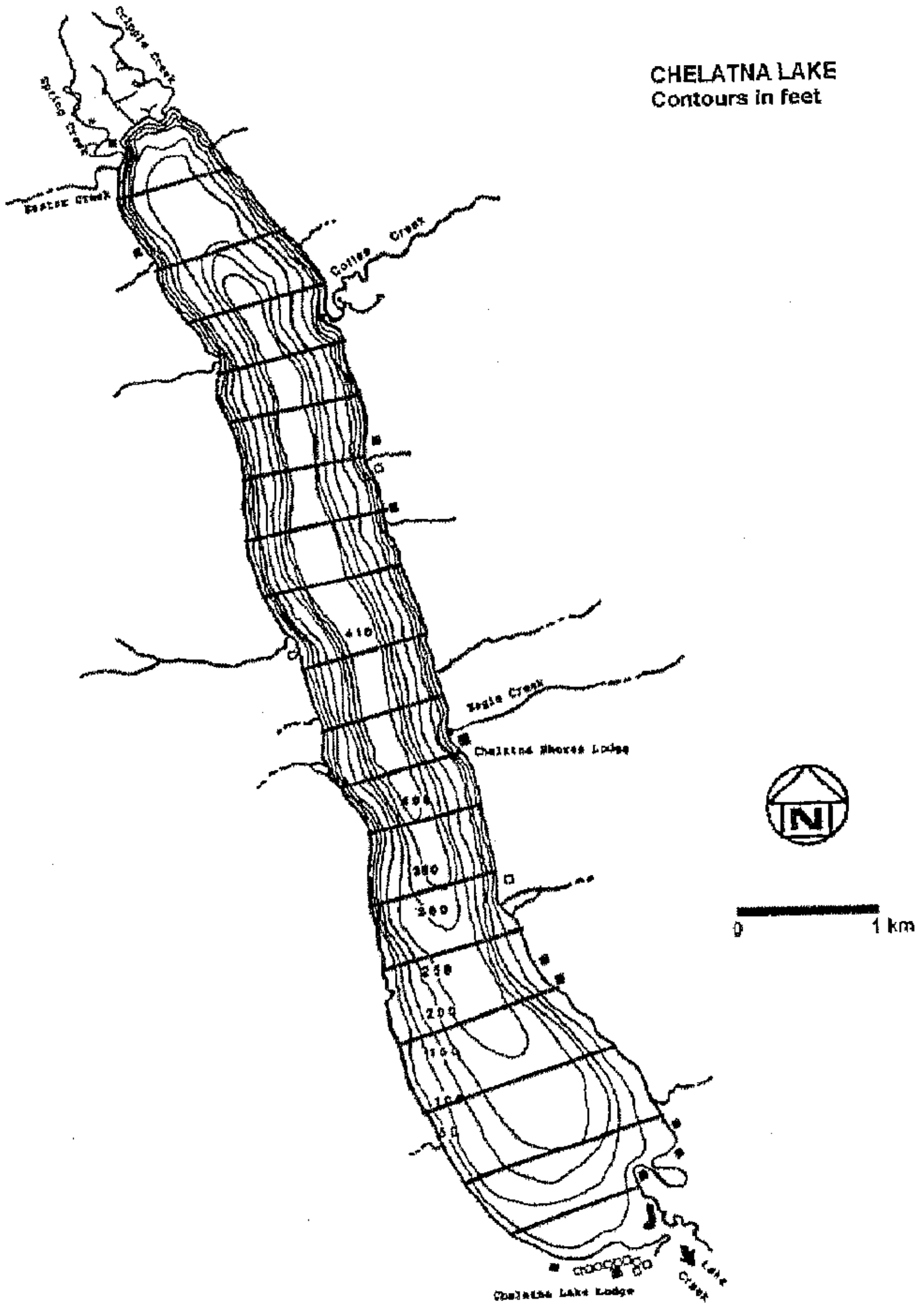
Yentna River Passage	2006	2007	2008	2009	2010	2011	2012
Bendix	92,051	79,901	90,146	28,428			
DIDSON-adjusted	166,697	125,146	131,772	43,972–153,910	53,399–144,949	62,231–140,445	30,462–89,957

Weir Data	2006	2007	2008	2009	2010	2011	2012
Chelatna	18,433	41,290	73,469	17,865	37,784	70,353	36,577
Judd	40,633	58,134	54,304	43,153	18,361	39,997	18,303
Larson	57,411	47,736	35,040	41,929	20,324	12,413	16,708
Weir Totals	116,477	147,160	162,813	102,947	76,469	122,763	71,588

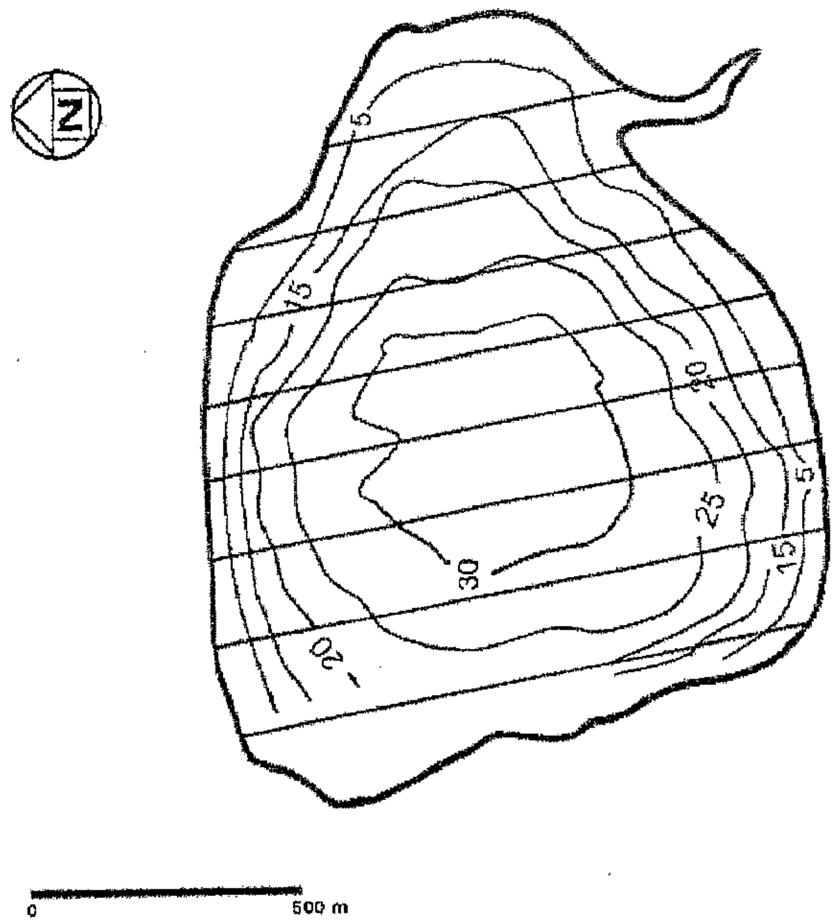
Susitna Population Estimates	2006	2007	2008	2009	2010	2011	2012[b]
Mark Recapture	418,197	327,732	359,760	219,041	190,460	314,447	141,804
MR : Weirs ratio	3.6	2.2	2.2	2.1	2.5	2.6	2.0
MR : Bendix ratio	4.5	4.1	4.0	9.7	ND	ND	ND

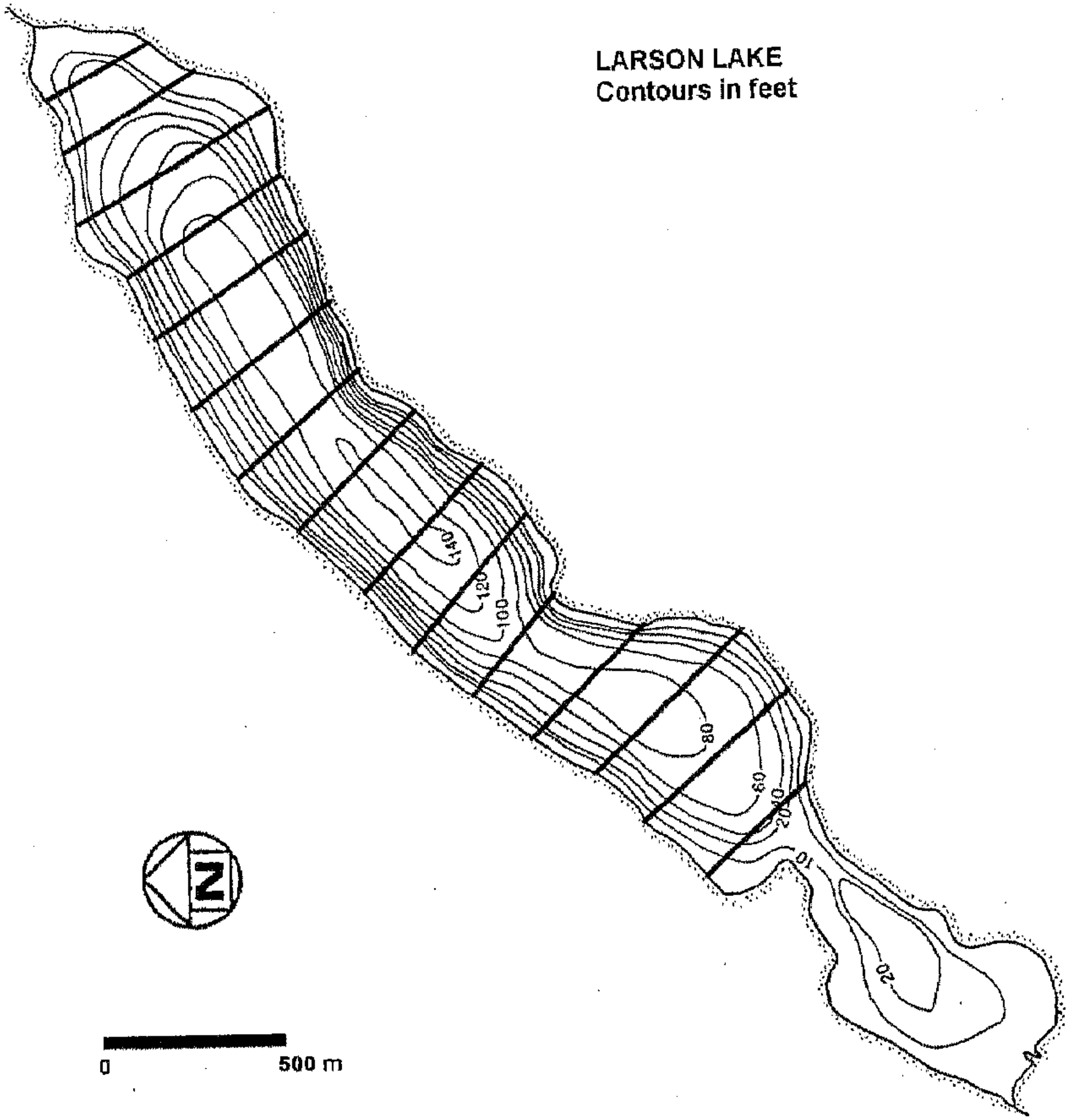
[a] Mark recapture estimates from 2009 to 2011 are preliminary values

This table shows the escapement estimate data from 2006 - 2012. The bottom line showing the Mark-Recapture to Bendix ratio clearly correlates with the historic escapement data in Table 2. ADFG Annual Management Report 2012.


CHELATNA LAKE
Contours in feet
Coffee Creek
Chelatna Shores Lodge
Chelatna Lake Lodge
Lake Creek
0
1 km

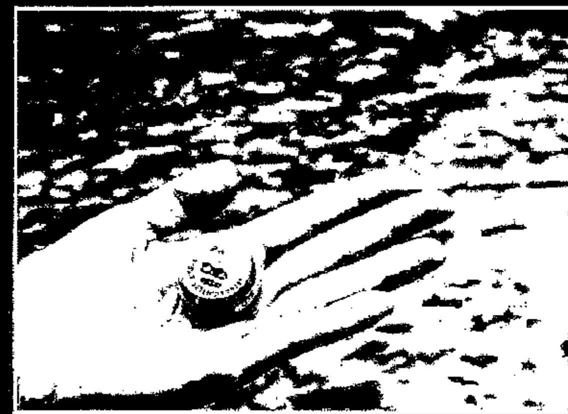
JUDD LAKE
Contours in meters




LARSON LAKE
Contours in feet
140
120
100
80
60
40
20
10
20
N
0
500 m

Euphotic Volume Model Estimates of Sockeye Salmon Production (Lakes with northern pike are shaded in green)

Drainage	Lake	Lake Area (acres)	Adult Production	Percent
Chulitna	Byers	368	37,200	3.80%
	Swan	385	11,000	1.10%
	Spink	252	23,500	2.40%
	Bunco	106	1,600	0.20%
	Total	1,111	73,300	7.60%
Mainstem	Caswell	159	13,700	1.40%
	Trapper	1,188	16,800	1.70%
	Fish	132	10,600	1.10%
	Sucker	273	8,300	0.90%
	Red Shirt	1,272	69,500	7.20%
	Neil	115	7,600	0.80%
	Total	3,139	126,500	13.00%
Talkeetna	Larson	437	45,100	4.60%
	Stephan	899	63,700	6.60%
	Total	1,336	108,800	11.20%
Yentna	Chelatna	3,906	363,574	37.50%
	Trinity	308	19,300	2.00%
	Whiskey	271	23,600	2.40%
	Fish Creek	111	9,000	0.90%
	Shell	1,293	90,265	9.30%
	Puntilla	90	8,800	0.90%
	Eightmile	115	5,600	0.60%
	Movie	110	6,700	0.70%
	Lockwood	233	11,000	1.10%
	Judd	316	59,500	6.10%
	Hewitt	697	60,600	6.20%
	Red Salmon	113	3,400	0.40%
	Total	7,563	661,339	68.20%
	Grand Total	13,149	969,939	100%



Assessing climate change impacts in Cook Inlet salmon streams:

Landscape controls on stream temperature and thermal sensitivity

Sue Mauger, Cook Inletkeeper
Daniel Rinella, UAA Alaska Natural Heritage Program
Rebecca Shaftel, UAA Alaska Natural Heritage Program
Jason Leppi, The Wilderness Society

CLEAN WATER · HEALTHY SALMON
INLETKEEPER®

Regional stream temperature patterns

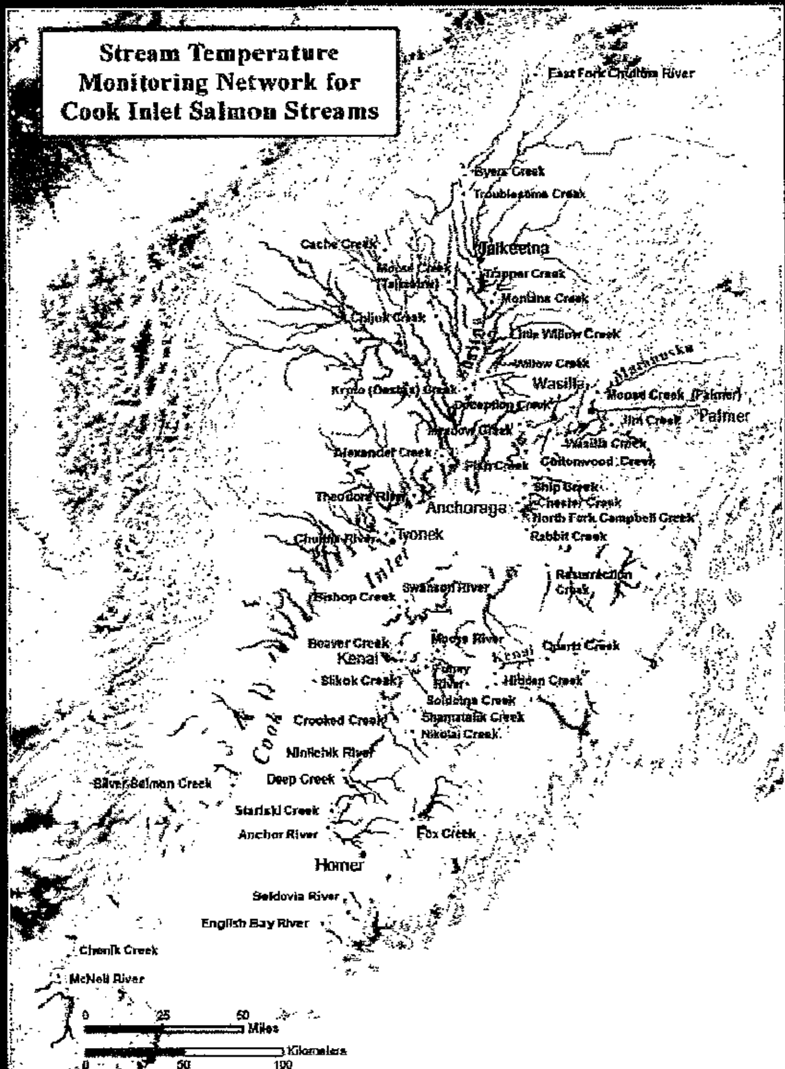
Landscape controls

Relationship to air temperature

Climate change vulnerability

Relevance for other regions

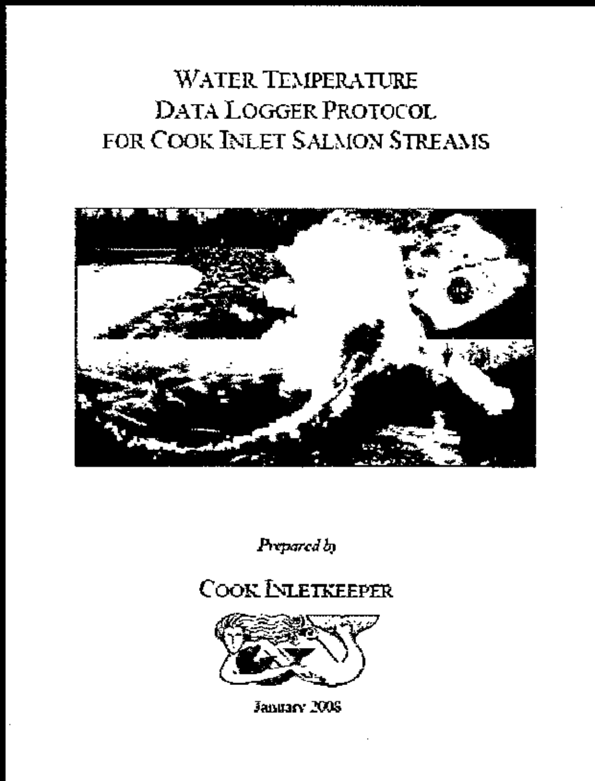
Regional Patterns



48 Salmon Streams

- no/minimal glacial influence
- broad geographic distribution
- large and small watersheds
- range in landcover types
- reasonable access to lower reach
- QA partner options

Regional Patterns


WATER TEMPERATURE
DATA LOGGER PROTOCOL
FOR COOK INLET SALMON STREAMS

Prepared by

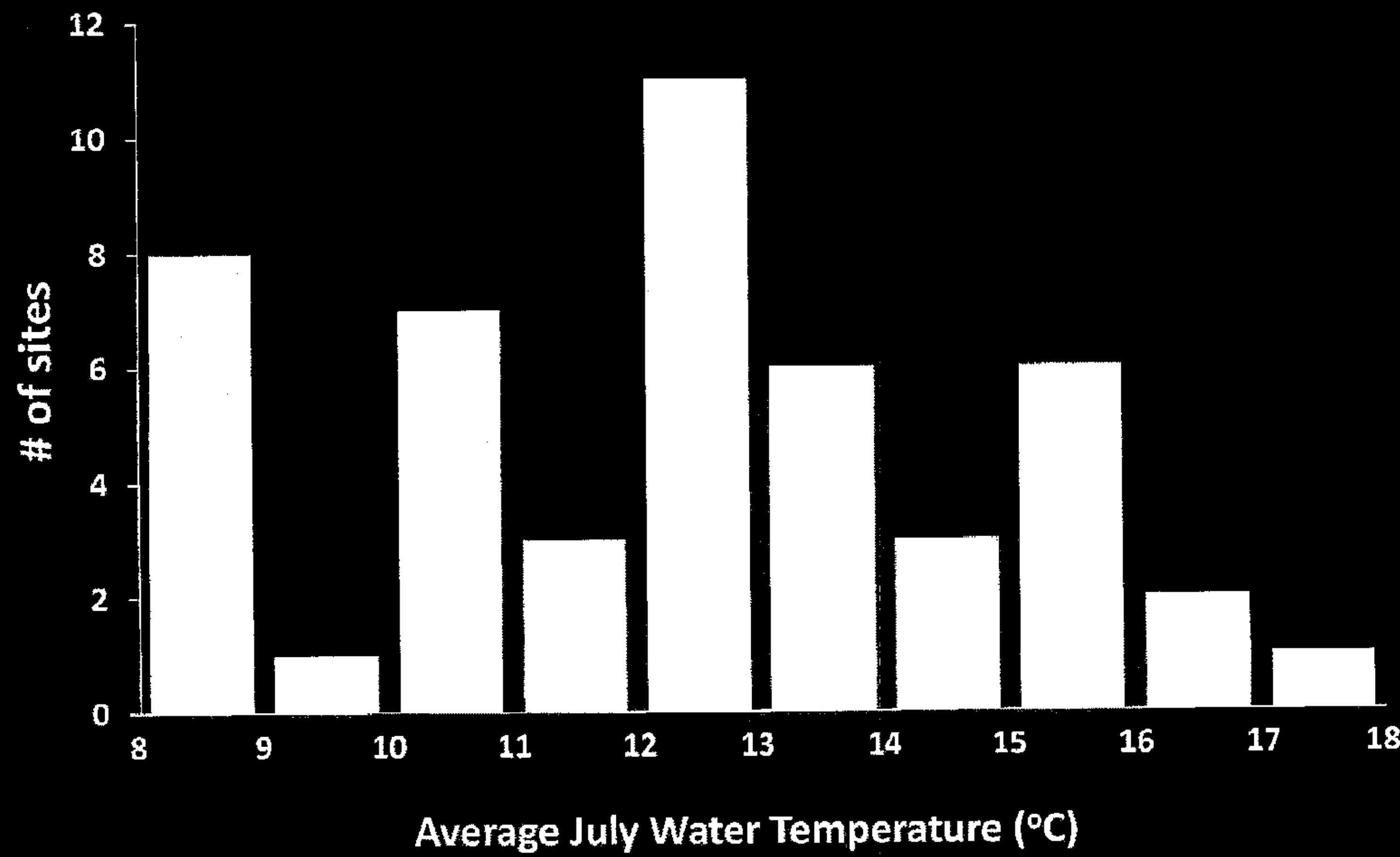
COOK INLETKEEPER

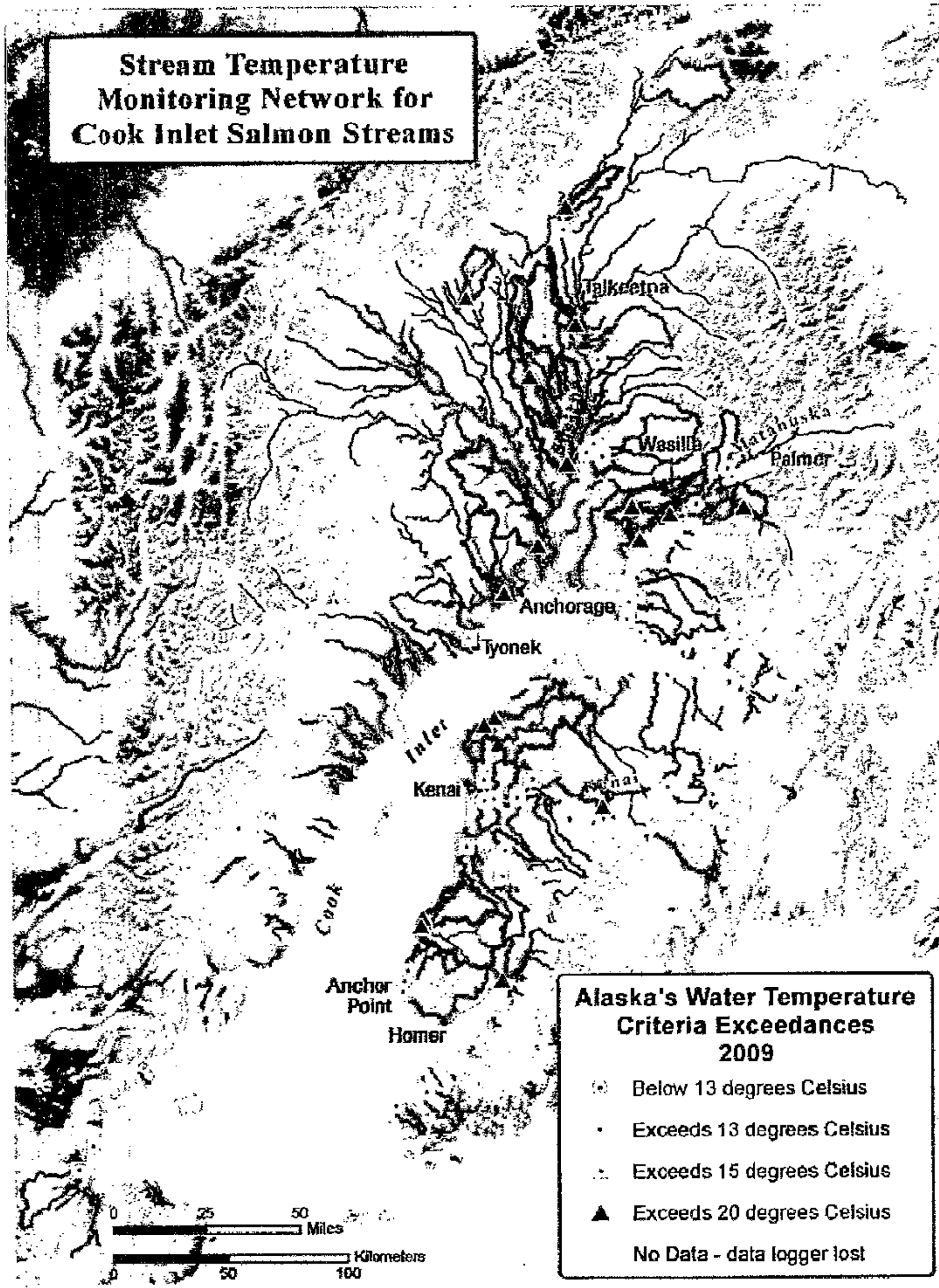
January 2008

- June 1 – October 1
- 5 years (2008-2012)
- 15 minute intervals
- Water and air temperature

INLETKEEPER — CLEAN WATER · HEALTHY SALMON

Regional Patterns

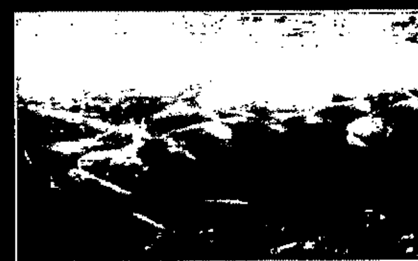


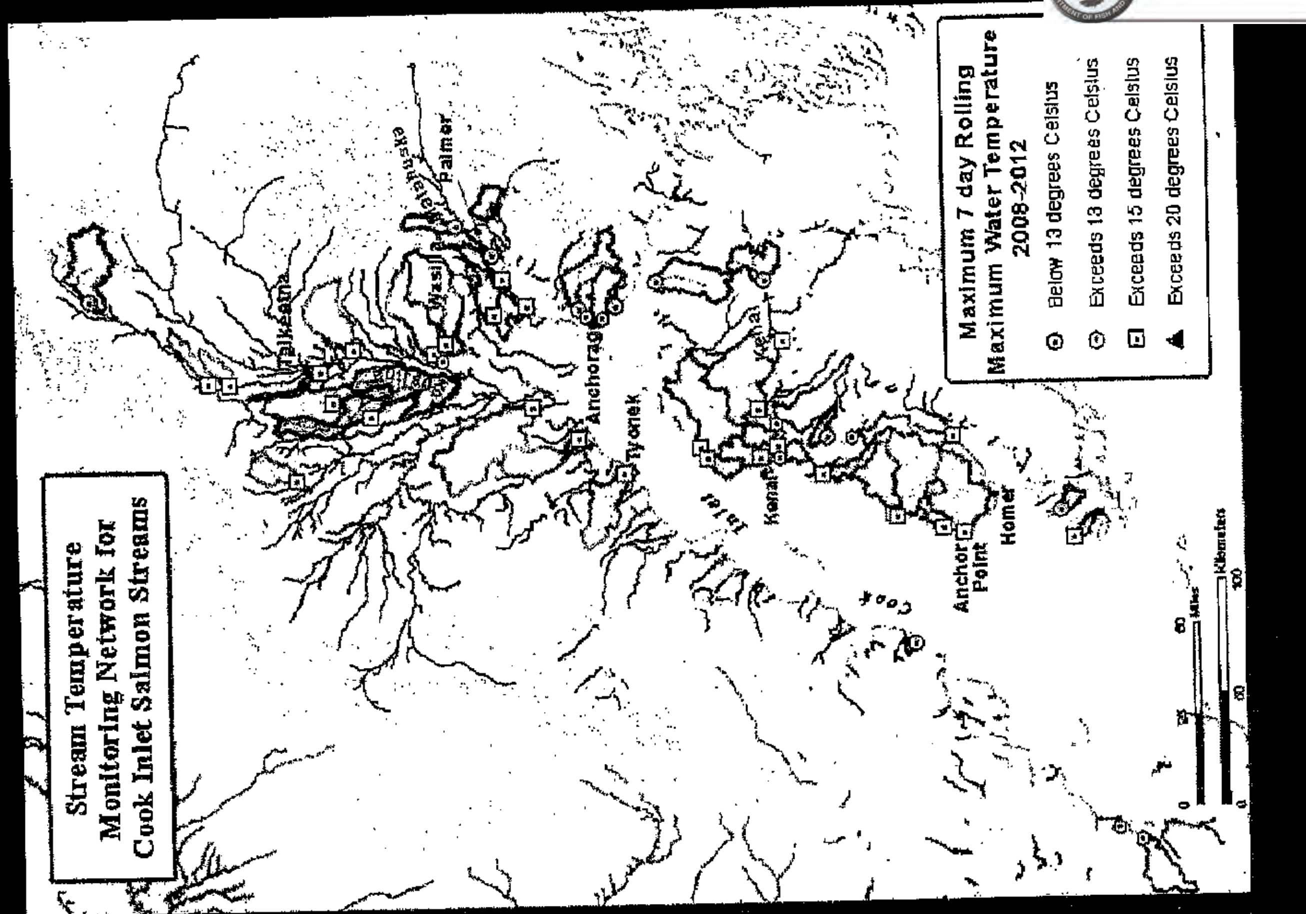


2009 Results
Maximum Temperatures

13°C
(55.5°F)

15°C
(59°F)




Stream Temperature Monitoring Network for Cook Inlet Salmon Streams
Maximum 7 day Rolling Maximum Water Temperature 2008-2012
Below 13 degrees Celsius
Exceeds 13 degrees Celsius
Exceeds 15 degrees Celsius
Exceeds 20 degrees Celsius
Talkeetna
Wasilla
Palmer
Matanuska
Anchorage
Tyonek
Kenai
Cook Inlet
Anchor Point
Homer
Miles
Kilometers


Stream Temperature Monitoring Network for Cook Inlet Salmon Streams
Maximum 7 day Rolling Average Water Temperature 2008-2012
Below 13 degrees Celsius
Exceeds 13 degrees Celsius
Exceeds 15 degrees Celsius
Talkeetna
Wasilla
Palmer
Matanuska
Anchorage
Tyonek
Kenai
Cook Inlet
Anchor Point
Homer
Miles
Kilometers

Landscape Controls

24 ⟶ 8 predictor variables

Watershed Size
Watershed slope
Average elevation
South aspect percentage
Wetland percentage
Developed percentage
Lake influence
Air temperature

Multiple linear regression models used to explain differences in temperature profiles

'Best' models included only geomorphic variables

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Landscape Controls

Cold water

Small → watershed size →

High ← percent slope ←

High ← ave. elevation ←

Landscape Controls

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Cold water

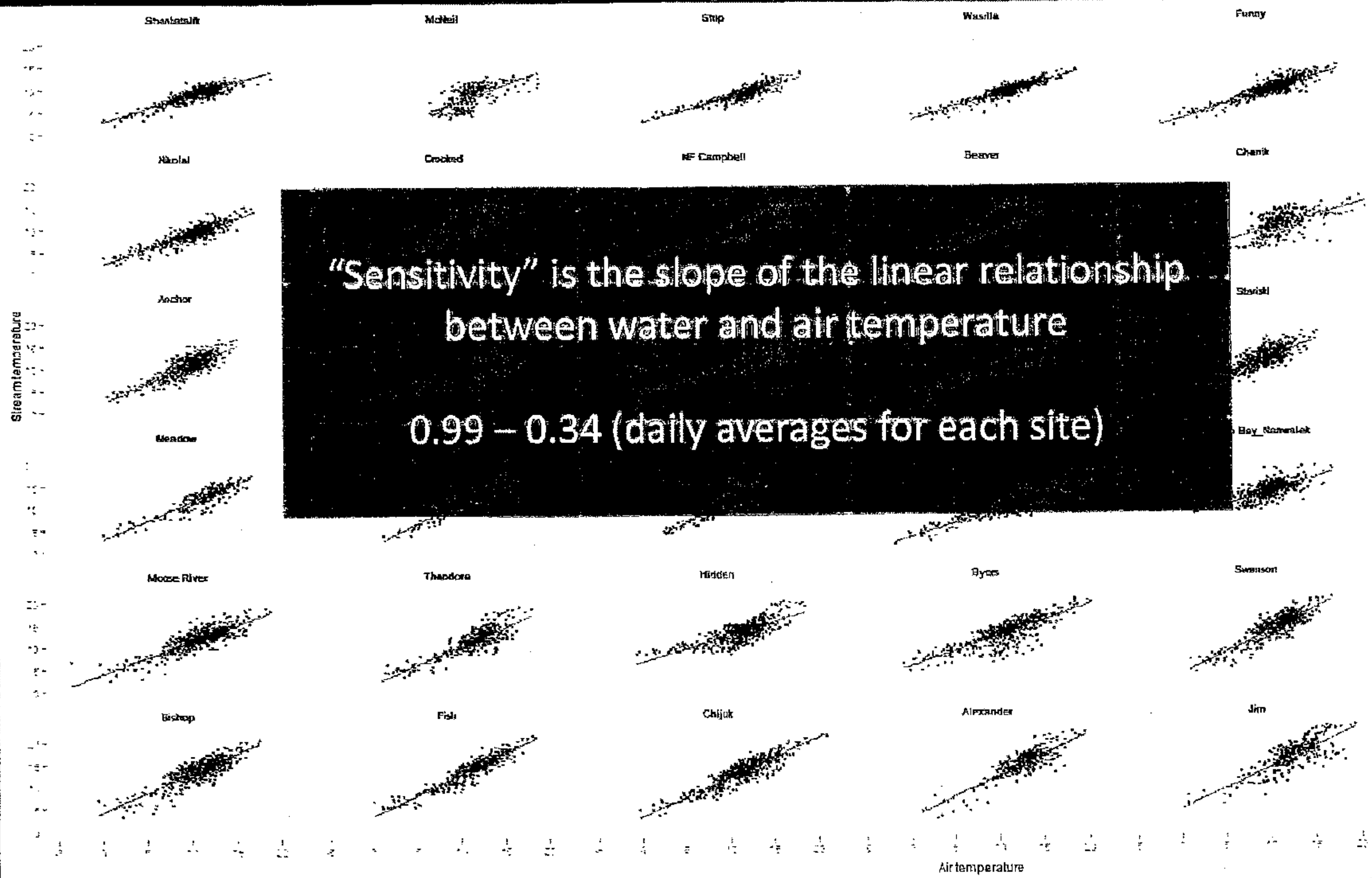
Small ⟶ 100K acres, watershed size ⟶ +0.85 C

-0.24 C High ⟵ 1% percent slope

-0.30 C High ⟵ 100 m ave. elevation

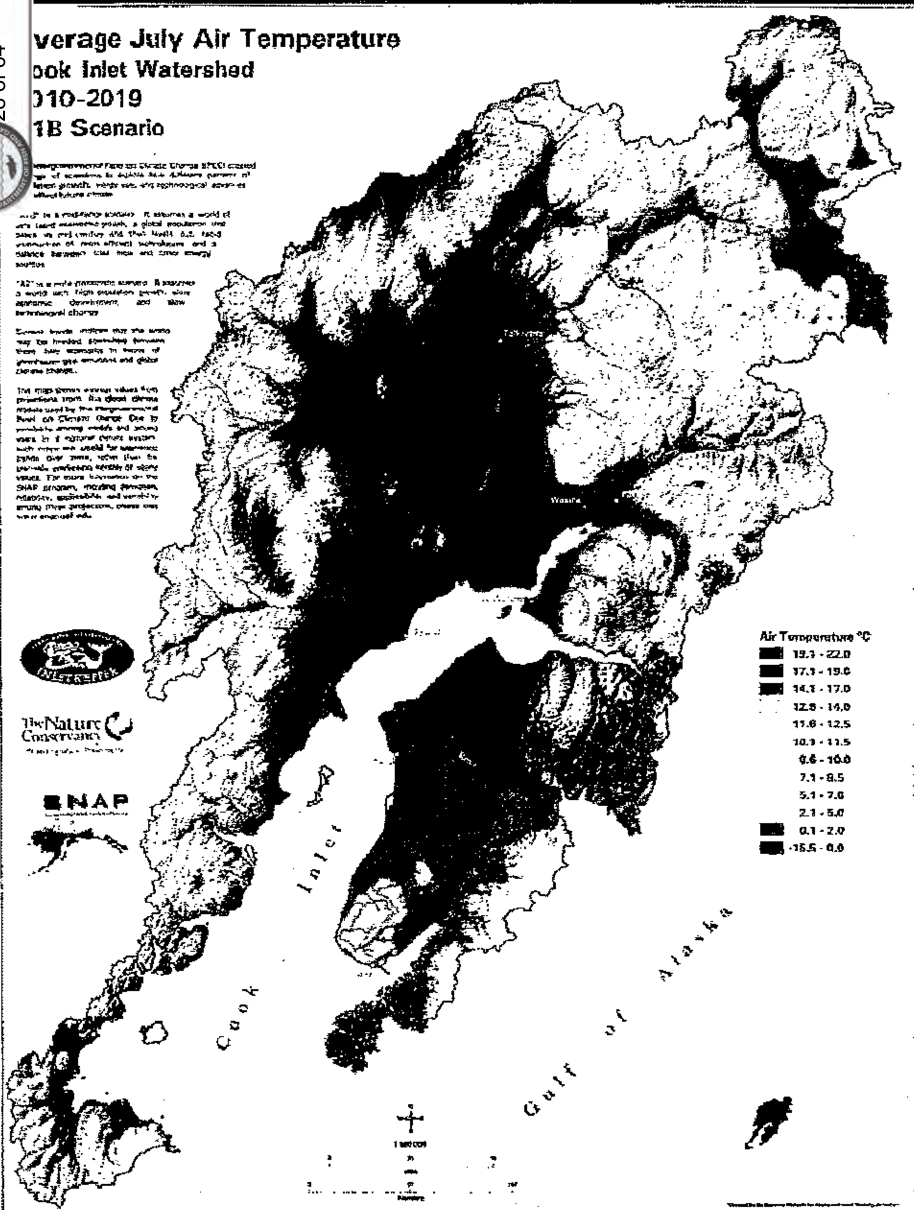
Average July water temperature

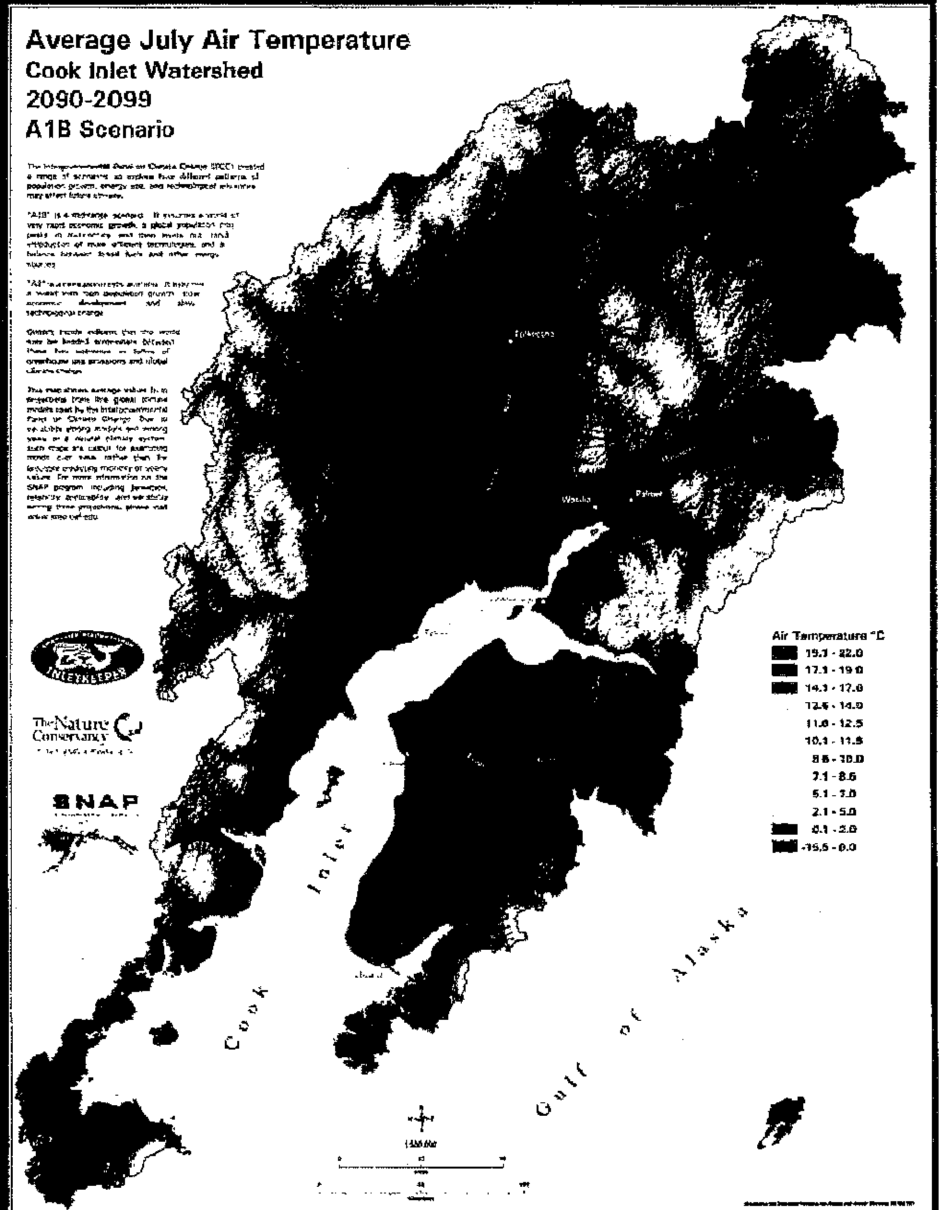
Sensitivity



"Sensitivity" is the slope of the linear relationship between water and air temperature

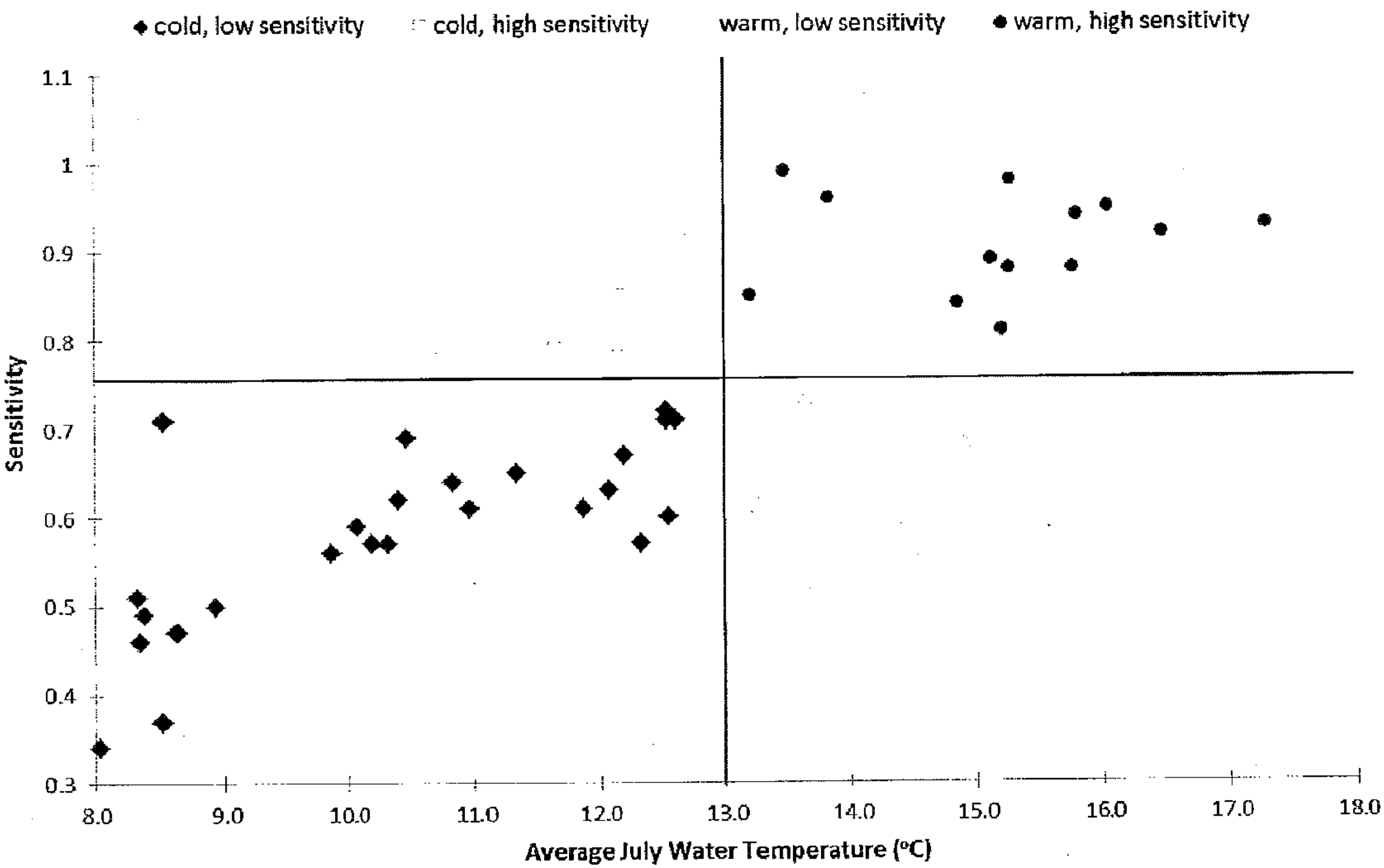
0.99 – 0.34 (daily averages for each site)





July air temperature will increase by 2.6 – 2.9°C at all sites by 2099

Climate Change Vulnerability



Vulnerability Framework

Cold, low sensitivity	Cold, high sensitivity	Warm, low sensitivity	Warm, high sensitivity
Silver Salmon Creek	Crooked Creek	English Bay River	Theodore River
Rabbit Creek	Stariski Creek	Moose Creek (Talkeetna)	Fox Creek
Seldovia River	Anchor River	Moose River	Chuitna River
Resurrection Creek	Ninilchik River	Hidden Creek	Meadow Creek
Quartz Creek	Deep Creek	Byers Creek	Chijuk Creek
McNeil River			Trapper Creek
East Fork Chulitna River			Cottonwood Creek
Moose Creek (Palmer)			Swanson River
Ship Creek			Bishop Creek
Shantatalik Creek			Alexander Creek
Chenik Creek			Fish Creek
Wasilla Creek			Kroto (Deshka) Creek
Funny River			Jim Creek
Nikolai Creek			
Slikok Creek			
Cache Creek			
NF Campbell Creek			
Willow Creek			
Little Willow Creek			
Deception Creek			
Montana Creek			
Soldotna Creek			
Troublesome Creek			
Chester Creek			
Beaver Creek			

Relevance for Fish Habitat Partnerships

Thermal vulnerability framework can be a useful tool to prioritize future research, protection and restoration activities:

"warm, high sensitivity" streams

- research at the reach-level to identify critical cool water refugia that might be important to help salmon move up and down an otherwise warm channel.
- restoring degraded riparian areas might improve temperature profiles by increasing stream shade.

"cold, low sensitivity" streams

- resolving fish passage issues important
- protecting key habitats through conservation easements could help maintain fish populations for both the short and long term.

Relevance for other regions

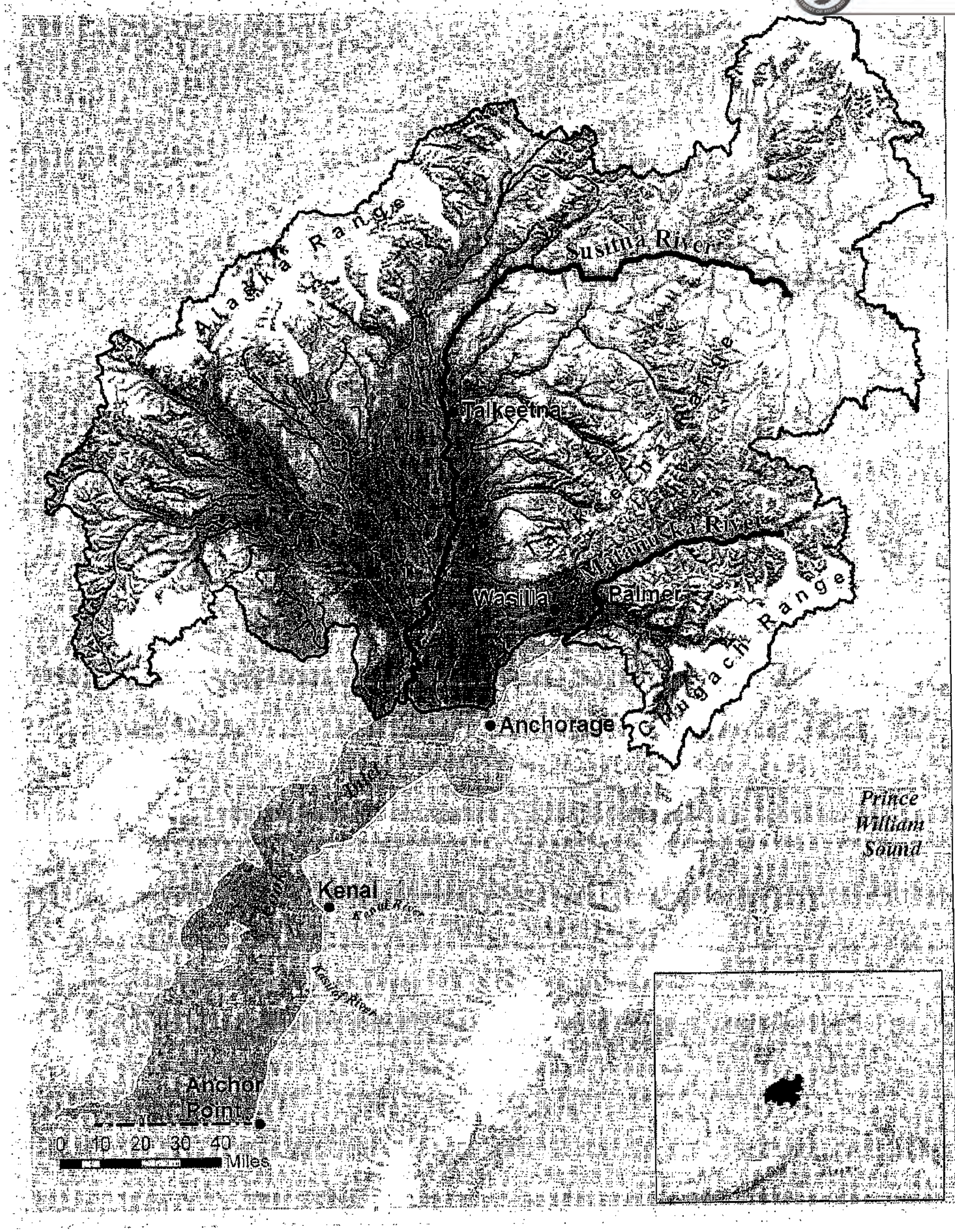
- NHD Plus and better resolution GIS layers will improve our understanding of landscape controls.
- Capturing gradients of these landscape controls is important when designing regional monitoring programs.
- Long term programs (>5 years) will be needed to assess and track climate change vulnerability.
- Collaborative, multi-partner networks can be effective for collecting and managing temperature data at a regional scale.

Acknowledgements

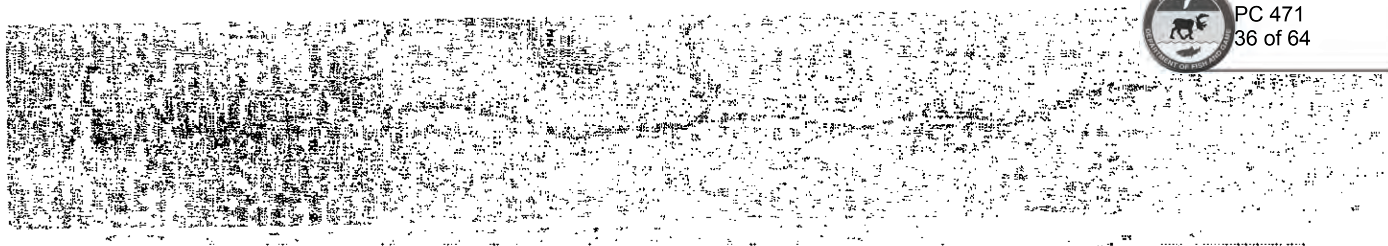
Alaska Department of Environmental Conservation
Alaska Department of Fish and Game
The Nature Conservancy of Alaska
Kenai Watershed Forum
Wasilla Soil and Water Conservation District
Upper Su Soil and Water Conservation District
Anchorage Waterways Council
Aquatic Restoration and Research Institute
U.S. Fish and Wildlife Service
National Park Service
U.S. Forest Service
Native Village of Tyonek
Seldovia Village Tribe
Nanwalek Traditional Council
The Wildlifers
Denali Trekking Company
and numerous community volunteers!

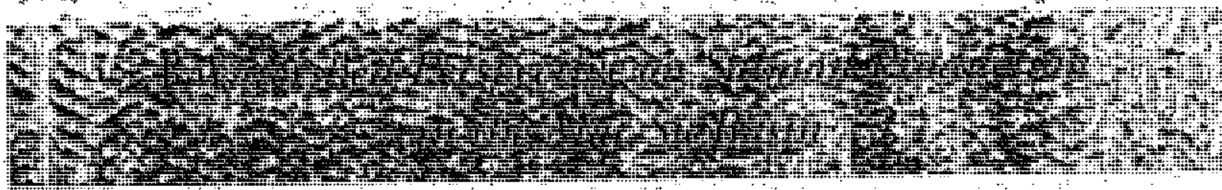
Support provided in part by Alaska Clean Water Action grants from Alaska Department of Environmental Conservation, U.S. Fish and Wildlife Service's Coastal Program, Mat-Su Salmon Partnership, Kenai Peninsula Fish Habitat Partnership, Bullitt Foundation, Marisla Foundation, Lawrence Foundation, Wolfensohn Foundation, Skaggs Foundation, Collins Alaska Charitable Trust, and Alaska Conservation Foundation.

A Watershed Perspective on Salmon Production in the Mat-Su Basin



The Matanuska and Susitna Watersheds



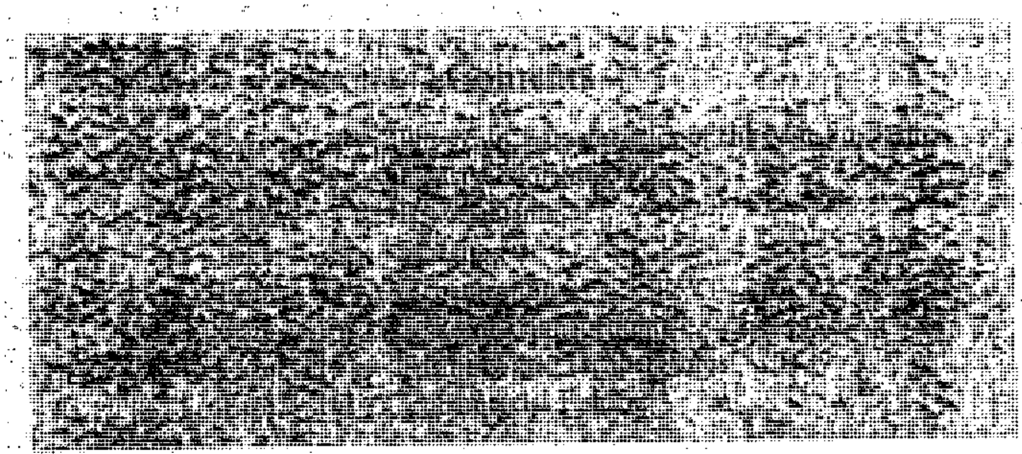


Southcentral Alaska's Cook Inlet is a stunning exemplar of natural beauty and natural bounty. For thousands of years the salmon returning to the Inlet's rivers, lakes and streams have nourished people, wildlife and the land itself. Inhabitants of this region have always had the benefit and pleasure of consuming salmon. Five species of salmon return to spawn in the diverse landscapes of Cook Inlet's watersheds. The particular habitat required by sockeye salmon is abundant enough to generate Alaska's second largest sockeye runs. Today there are many natural resources that contribute to the economy of Southcentral Alaska but salmon continue to support traditional subsistence lifestyles, sportfishing enthusiasts and businesses, tourism, commercial fishermen, seafood processors, retailers and supporting industries.

While natural wild salmon runs are typically variable and cyclical, some salmon returns to rivers in the Matanuska-Susitna Basin have been in a recent decline. The primary response has been to restrict commercial fisheries in central Cook Inlet with the intent of allowing more salmon to reach the Mat-Su rivers to the north.

Unfortunately, the cause of declining salmon numbers in the Mat-Su Basin is linked to the decreasing ability of the salmon to successfully reproduce in its freshwater systems. It doesn't matter how many fish return to the Mat-Su rivers if they can't spawn or the young salmon can't survive there long enough to migrate out to sea. **Invasive northern pike, beaver dams, deadly parasites, pollution, improperly constructed culverts and other unmitigated effects of urbanization, over-escapement and rising water temperatures are slowly but surely chipping away at the future of salmon in the valley.**

The purpose of this publication is to bring together all of the issues facing salmon production in the Mat-Su Basin. Policy makers and concerned citizens need to change their focus toward prioritizing efforts and directing resources to solving the problems at the source. Harvestable surpluses of sockeye, king and coho salmon populations in the Mat-Su Basin cannot be sustained without addressing the serious problems within the river systems.



This report was compiled and produced for the United Cook Inlet Drift Association, Soldotna, Alaska, June, 2013.

Physical Characteristics of the Mat-Su Basin

The Matanuska-Susitna watersheds cover about 24,500 square miles. Dense networks of small streams and braided river channels fill the lowlands of the basin. The countless miles of waterways provide abundant fish habitat but some of the system's natural characteristics are counter-productive to the consistent and reliable generation of large numbers of salmon, particularly sockeye salmon.

There are many lakes in the watersheds but the lakes are small and generally shallow. The largest lake in the Mat-Su Basin, Chelatna Lake, has a surface area of only 4,181 acres. The basin's 24 largest lakes have a combined surface area of less than 15,000 acres. For comparison, the Kenai River watershed contains Kenai Lake and Skilak Lake with a combined lake surface area of almost 38,000 acres. The Kasilof River connects to Tustumena Lake with a surface area of over 73,000 acres. Large lakes within a watershed provide benefits like buffering flood waters and stabilizing water temperatures. They also provide enormous capacity for rearing and over-wintering juvenile fish, especially sockeye salmon.

Susitna River

The extensive complex of braided rivers and tributaries, side channels and sloughs found in the Mat-Su basin spread the water out. **Shallow river systems like these are more susceptible to a variety of risks.** Spawning beds and riparian areas are easily scoured out by flood waters. Warm sunny weather can quickly raise the water temperatures to levels unhealthy or lethal for salmon. Hatching and rearing salmon are utterly dependent on adequate ground water flow during the winter; minor changes in water tables and flows can have major impacts in streams. The natural characteristics of the Mat-Su watersheds, the small lakes and shallow, relatively slow moving waters, create a delicate balance that is easily disrupted.

The importance of the topography and hydrology of a system can be clearly observed by comparing salmon runs in different Upper Cook Inlet rivers. **The Susitna River watershed is over eight times the size of the Kenai River watershed but on average produces less than twenty percent of the amount of sockeye salmon.**

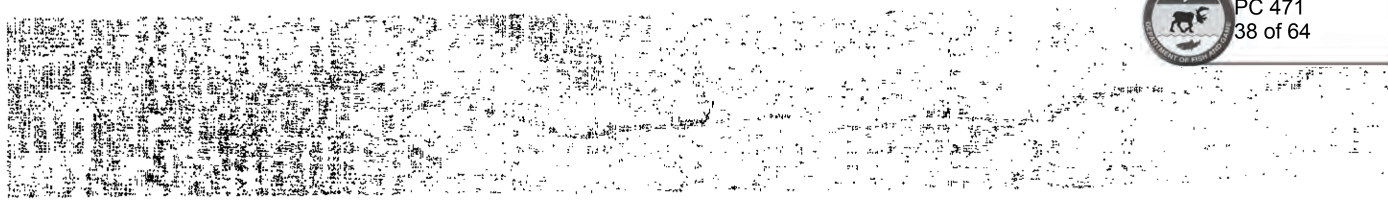
The natural capacity for sockeye production in the Mat-Su basin is on a different, much smaller scale due to the absence of large lakes. Other species of salmon are better adapted to the physical characteristics of the basin but their numbers still don't reflect the inherent size advantage of the larger watershed.

Relative Sockeye Salmon Productivity of Susitna River

	Size of Watershed	Average Annual Sockeye Return
Susitna River	18,919 square miles	437,000 (2006-2012)*
Kenai River	2,200 square miles	3,792,000 (1986-2012)
Kasilof River	860 square miles	962,000 (1986-2012)

Return numbers from ADF&G Upper Cook Inlet Annual Management Reports

* The Susitna return average is for the period 2006-2012 because earlier count numbers are inaccurate. Research conducted from 2005 through 2008 determined that the sonar counting systems used in the Susitna for almost 30 years were under-counting the actual sockeye escapements by 50 to 100 percent.



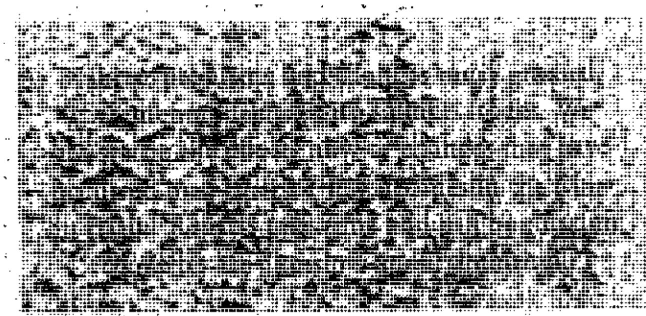
The physical characteristics of these river systems have also made it difficult for fisheries managers to reliably count salmon returns, escapements and out-migrations of smolt. Even without definitive measures, the various methods used to estimate run sizes have indicated recent downturns in sockeye, coho and king stocks.

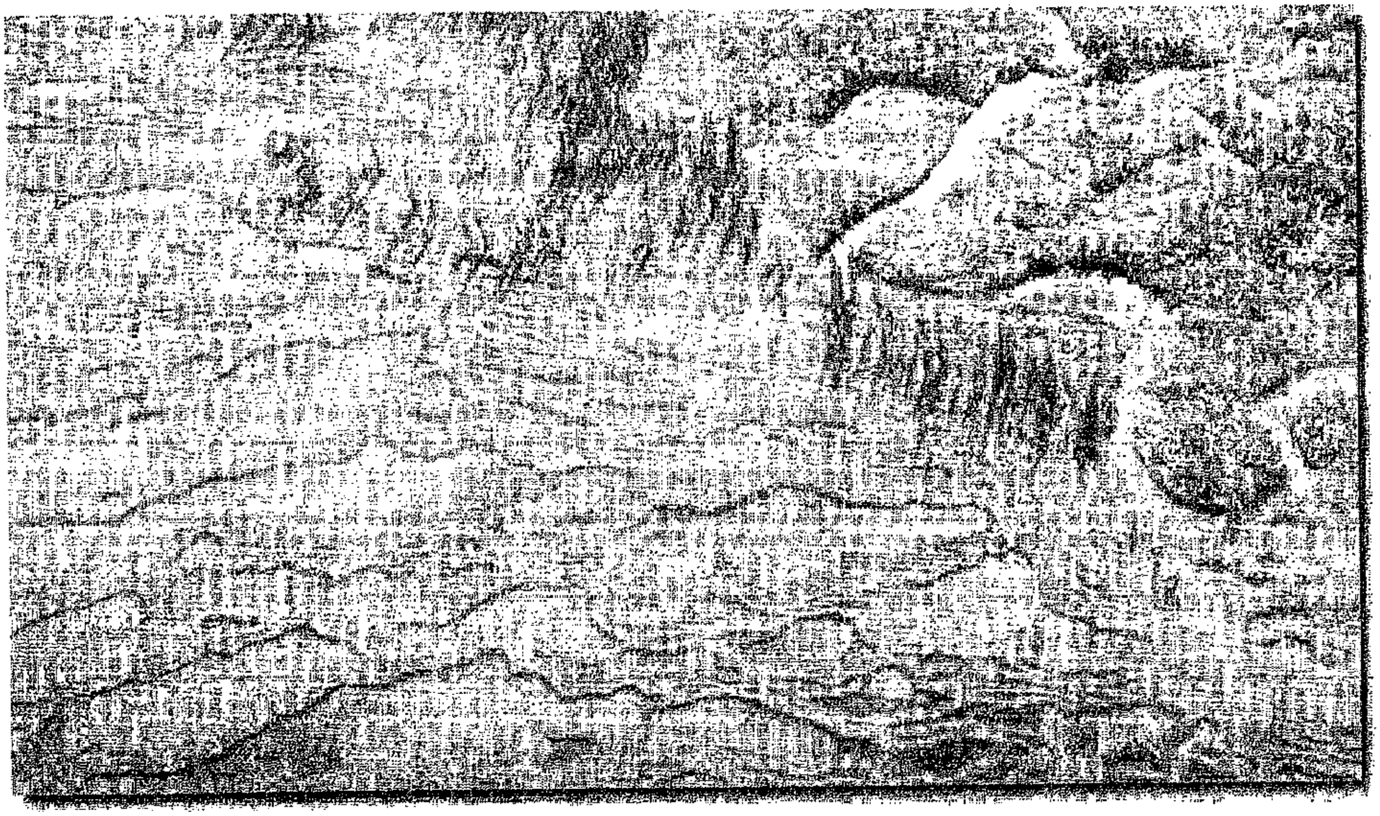
The reasons for decreasing salmon production in the valley can be found in the valley. Multiple factors are affecting salmon's ability to spawn and rear in the Mat-Su Basin. These include -

- **invasive northern pike predation on juvenile salmon**
- **beaver dam proliferation**
- **salmon fatalities due to parasites**
- **urbanization - including -**
  - **water pollution (hydrocarbons, turbidity, fecal coliform bacteria/sewage)**
  - **the presence of hundreds of improperly constructed road culverts blocking fish access to hundreds of miles of spawning and rearing areas**
  - **loss of riparian and wetland habitats**
  - **water table disruption**
- **rising water temperatures**

These factors threaten the very existence of the salmon resources that we all enjoy. Without a comprehensive and long-term plan, and an equally long-term commitment to solving or mitigating the issues affecting salmon production, the continued decline of salmon returns to the valley streams can be expected. Extinction and endangered species listings may not be far away.

The large stocks of pink and chum salmon that spawn in the Mat-Su basin are not monitored. These species are also impacted by the same threats but the effects are not measured at this time.





Invasive Northern Pike

Pike were illegally introduced into waters in the Susitna Basin beginning in the 1950s. The slow, shallow waters there provide ideal pike habitat. Fisheries research has long documented the danger of northern pike predation on native stocks of fish and pike's voracious predation on juvenile salmon in particular. Over the decades the pike spread throughout the Mat-Su basin while additional research evidence was accumulating of the hazard of non-native pike to salmon stocks. ADF&G did very little about the threat until after pike had nearly wiped out the king salmon run in Alexander Creek, a tributary of the Susitna River, previously one of the most productive king salmon systems in northern Cook Inlet (Yanusv & Rutz, 2009). Pike in some systems were even protected under trophy fish regulations passed by the Board of Fisheries in the early 1990s. Other systems in the Mat-Su Basin had seasons, bag and possession limits on pike.

During the 1980s and 1990s Alexander Creek supported a multimillion dollar king salmon sportfishing industry that included nine lodges, float plane charter and guide operations and cabin and boat rentals. In 2007 king salmon escapements had dropped to 480, from a previous average of 3,500. Annual angler days in the system had dropped to 2,666 from a previous high of 26,000. In 2008 ADF&G had to close Alexander Creek to king salmon fishing. In 2009 ADF&G published the Alexander Creek/ Lake White Paper attributing the king salmon decline and subsequent closure to pike predation on juvenile king salmon (Yanusz & Rutz, 2009). In the report the authors stated that other salmon species and resident fish stocks were also affected but they couldn't say to what extent because only the king salmon had been monitored. By 2010 the king escapement count had dropped to 177.

The threat was understood well before Alexander Creek's closure. ADF&G's Division of Sport Fish conducted a study in 1996 and 1997 in four Susitna River tributaries on pike movement and stomach contents. The report, published in 1999, stated:

> **"Given the immense size of the Susitna River drainage and the vast range of northern pike expansion, it is probable that northern pike predation may result in a severe, yet unquantifiable, loss of salmonid production within individual tributaries. However, if we focus our effort on major problems areas identified below, we believe a successful northern pike removal program will be effective in reducing predation on selected salmonid populations…. Eradication efforts have been inadequate given the magnitude and the consequences of the proliferation of pike" (Rutz, 1999).**

In spite of this clear recommendation, pike suppression or eradication programs were not begun in the Mat-Su until more than ten years later. The devastating consequences of the pike invasion are occurring all over the drainage but have only been measured in the few areas where salmon numbers have been under close observation by fisheries managers.

Sockeye, coho and king salmon are very vulnerable to pike in the lakes and waterways where they spend their first year of life. A recent study on pike diets in two Susitna River tributaries, the Deshka River and Alexander Creek, found that salmonids were the pike's dominant prey during the summer (Sepulveda et al, 2013). The researchers discovered up to 47 salmonids per pike stomach. Juvenile sockeye salmon have a better chance of escaping predation in lakes with deep water but those are rare in the Mat-Su watersheds.

In 1989 ADF&G studied 24 of the sockeye producing lakes in the Susitna River drainage to measure their biological capacity for rearing sockeye salmon (Tarbox, 1989). The results from the study indicated a potential capacity for a sockeye return to the Susitna of around one million fish. Actual returns are now about half of that.

Data collection in the Mat-Su basin has been very irregular over the years and methodologies have been inconsistent. Since 2006, ADF&G and the Cook Inlet Aquaculture Association have been counting sockeye spawners and smolts in some of the lakes that were in the 1989 sockeye rearing capacity study. This recent data shows:

- At least 14 of the original 24 lakes studied are known to contain pike.
- Six of the lakes with pike (Chelatna, Fish, Fish Creeks, Hewitt, Shell and Whiskey) had a combined potential production capacity of 596,800 adult sockeye but now have a combined average of less than 62,000 adult spawners per year.
- Five of the lakes with pike, (Caswell, Neil, Red Shirt, Sucker and Trapper) had a combined potential capacity of 116,000 sockeye but now have zero adult spawners returning.
- Chelatna Lake, the largest in the system, has pike but also has deep water which increases the chances of salmon fry survival. Chelatna Lake's potential capacity was measured at 389,200 sockeye. Adult sockeye escapement into the lake averaged 41,444 from 2008 through 2012.
- Judd and Larson Lakes do not have pike. Their combined potential capacity was measured at 104,600 sockeye. The actual escapement of adult reds averaged 77,900 from 2006 through 2011. If you add the number of fish harvested in the commercial and sport fisheries (combined average rate of 39-42%) to the average escapement, then the average return has been 108,000-110,600 sockeye in these lakes.

Judd and Larson Lakes' average escapement and return numbers are over the maximum level for their production capacity. Since we are using average escapement numbers then obviously in some years the goal was significantly exceeded. Escapements over and above the lakes' capacity for production cause compounding cyclical fluctuations in the returns. Over-escapement is a serious risk when escapement goals are based on a functioning multi-lake system in which, now, many lakes have few or no returning salmon. Efforts to maintain or increase system-wide escapement levels will inevitably cause over-escapement into the functioning parts of the system.

As of 2010, ADF&G had identified 135 lakes, rivers and streams in the Mat-Su Basin as pike infested. Many additional tributaries and lakes are still at risk in those watersheds and around Cook Inlet. This is the consequence of ADF&G management treating Mat-Su pike like a sport fish instead of an invasive species for decades - against the advice of their own biologists.

ADF&G has recently begun some pike suppression efforts in northern Cook Inlet at Alexander Creek. Without a multi-year, multi-million dollar plan for suppressing and eradicating pike, the affected salmon populations will not recover.

The Mat-Su Borough has been slow to acknowledge the threat of invasive northern pike. In the Matanuska-Susitna Borough Mayor's Blue Ribbon Sportsmen's Committee's publication "Upper Cook Inlet 2011 Fishery Issues & Recommendations," more than five pages are devoted to their concern about sockeye returns and escapements to Susitna River lakes but pike are not mentioned once. Beaver dams rated one brief mention.

Pike caught in Chelatna Lake by Cook Inlet Aquaculture staff.

Beaver Dams

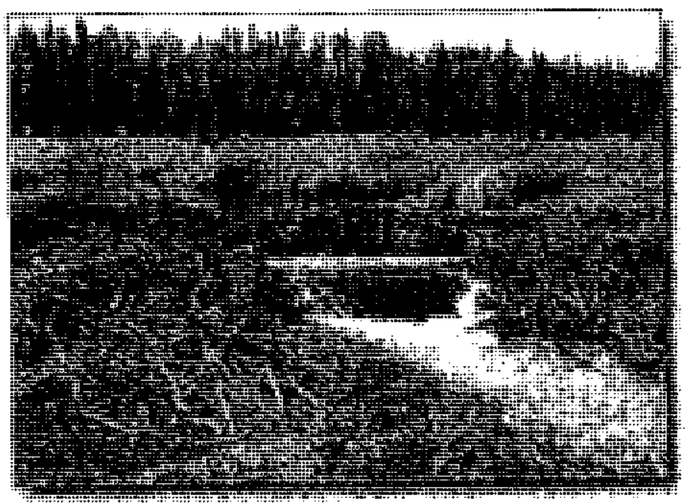
In many circumstances the presence of beaver dams improves fish habitat. Dams can help maintain stream flows and provide habitat for rearing salmon. Unfortunately, a large, well-constructed beaver dam can also stop adult salmon from migrating upstream to spawning areas and block juvenile salmon from migrating downstream to the sea. Records show that beaver dams have been a recognized problem in Cook Inlet for at least the past eighty years (ADFG, 1960). During the 1930s, 40s and 50s one or two teams of men were sent out every summer to blow up beaver dams in the Knik, Susitna, Kenai, Kasilof and other drainages around Cook Inlet. The work was paid for by the Territory, salmon canning companies and the U.S. Fish and Wildlife Service. In 1948 fifty-three dams were blown downstream of Red Shirt Lake in the Susitna River watershed; the report mentioned that salmon were able to reach spawning areas around that lake for the first time in three years.

In the 1970s ADF&G stopped monitoring and managing beaver dams in the Mat-Su Basin, apparently for budgetary reasons. Beaver trapping was a small help in reducing the number of dams but trapping has declined and dams have proliferated. Staff in the Commercial Fisheries Division of ADF&G tried at various times to develop beaver dam management plans for the Mat-Su but never received departmental support.

The problem has not gone away. Trapper Creek, a 20 mile long tributary of the Susitna River, contained 20 beaver dams in 2009, twelve of them large enough to block salmon (CIAA, 2012). During the summer of 2012 there were six dams across Shell Creek below Shell Lake. Three of the dams were large enough to block fish passage. The Cook Inlet Aquaculture Association (CIAA) is the only entity that has been systematically mitigating beaver dam impediments to salmon migration. In recognition of the benefits that beaver dams can provide, CIAA "notches" dams by manually opening up a section to allow fish passage. Limited funding has limited the scope of CIAA's ability to cope with the growing problem. Managing beaver dams requires regular effort with consistent funding.

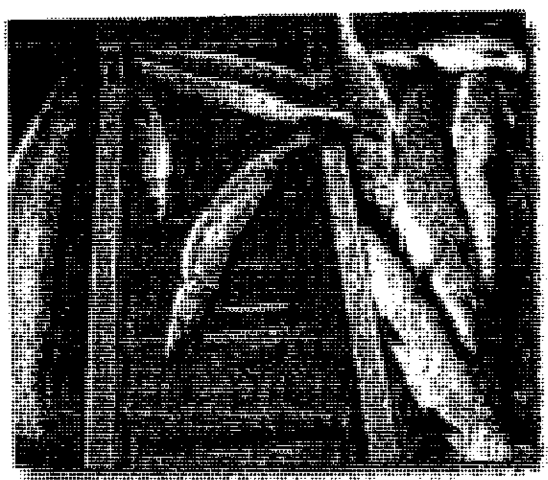
Cook Inlet Aquaculture Association staff "notching" a beaver dam.

Fish passage is once again allowed.

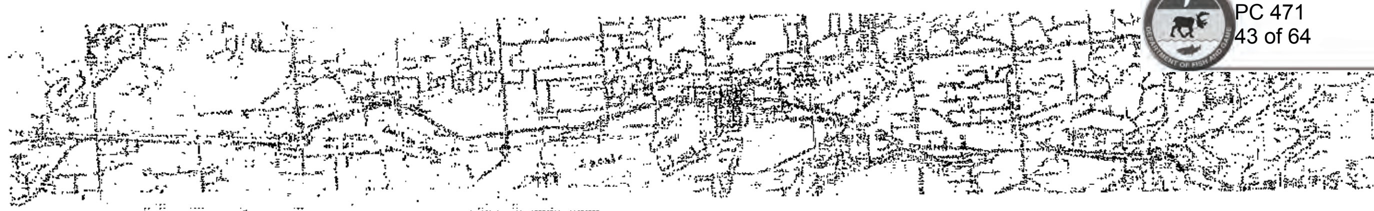


Loma Parasite

In 2012 a new threat to Mat-Su salmon stocks was discovered. While Cook Inlet Aquaculture Association staff members were working on a sockeye rehabilitation and enhancement project at Shell Lake in the Susitna drainage they noticed that a number of adult sockeye salmon were dying before spawning. Tissue samples were collected and sent to the ADF&G Pathology Laboratory in Anchorage. Analysis determined that the gills of the dead fish were infested with a parasite, Loma salmonidae. The Loma parasite causes the gill tissues to swell and impedes the transfer of oxygen. In other words, the fish suffocate. An investigation into the parasite's presence in the Susitna is beginning.



Pike captured in Shell Lake by Cook Inlet Aquaculture Association staff in 2010.



Urbanization

Our scientific understanding of what salmon need in their freshwater environment has increased tremendously in the past few decades. It is not enough just to get adult salmon back to the mouths of rivers and streams where they came from. To successfully reproduce they require all the moving and living parts of their complex habitat to function just the right way. From the trees shading the banks of a stream all the way down to the tiniest microorganisms digesting organic matter in wetlands, a multitude of factors contribute to salmon reproduction.

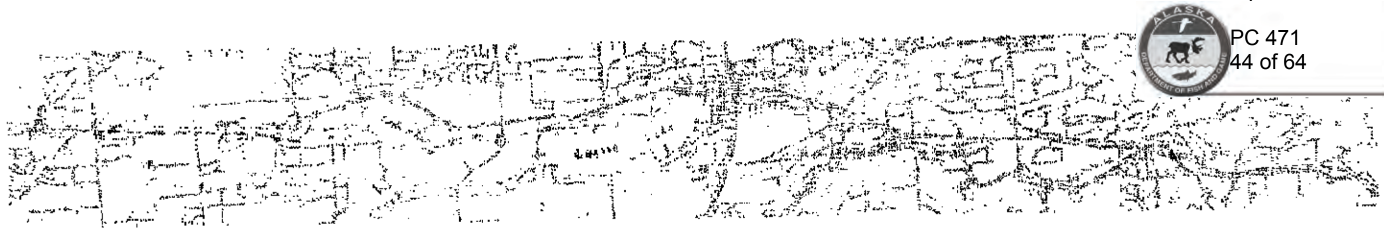
Urbanization can alter and damage salmon habitat in a variety of very significant ways when development is allowed without any consideration or mitigation for fish. The alterations happen incrementally, so it is hard to convince people that their individual actions can threaten salmon stocks, but the cumulative effect is devastating. In the Pacific Northwest, the Columbia River now has less than 3% of the enormous salmon runs that it once had. This not only can happen in Alaska, it is happening in Alaska. The human population of the Mat-Su Basin has doubled in the past 20 years to almost 90,000. It is expected to continue to be one of the fastest growing areas in the United States. Much damage has already been done.

Improperly Constructed Culverts

ADF&G has identified over 430 improperly constructed culverts in the Mat-Su Basin that act as barriers to fish (ADF&G Fish Passage Inventory Database as of 5/13). Of the 668 culverts that have been evaluated to date, 65% block the passage of juvenile and/or adult salmon. These "migration impediments" effectively cut off hundreds of miles of spawning and rearing habitat for salmon, particularly cohos. Coho salmon can spawn in seemingly inconsequential little creeks and streams. The juveniles spend a year or two moving around through these small waterways, sloughs and wetlands to find food and unfrozen over-wintering areas. Research supporting the problem and impacts of improperly constructed culverts has been meticulously documented in the Matanuska-Susitna Basin Salmon Habitat Partnership Fish Passage Working Group's report published in 2011 (www.matsusalmon.org/resources/).

The Mat-Su Borough has estimated the cost of restoring one improperly constructed waterbody crossing (culvert) at $200,000 to $500,000. In the past ten years the Borough and the U. S. Fish and Wildlife service have spent millions of dollars repairing 80 improperly sized and constructed crossings over salmon streams. At some point it should become apparent that prevention, i.e. building the structures correctly in the first place, would be far less costly than repair. The Kenai Peninsula Borough made that calculation and changed their standards for culverts in road construction in 2008. In 2013 the Mat-Su Borough Assembly is considering a resolution that would incorporate modern standards for fish passage culverts into their Subdivision Construction Manual. That manual has not been amended since 1991.

In April of 2012, the Mat-Su Borough passed a "Title 43" that relaxed their subdivision platting regulations (not to be confused with the Construction Manual.) Changes in the new regulations included allowing waivers for "pioneer road standards" to replace "residential road standards" within Road Service Areas (Mat-Su Borough, 2012).



Pollution

The Clean Water Act works to ensure that Alaska's waters remain swimable and fishable. When those standards are violated, the water is considered polluted.

Big Lake in Wasilla has been polluted by sewage since at least the early 1970s. It is currently also polluted with hydrocarbons from motorized watercraft (ADEC, 2012). Lake Lucille in Wasilla is polluted with urban runoff. Cottonwood Creek in Wasilla is polluted with urban runoff and "unspecified septic sources". The Matanuska River in Palmer is polluted with all kinds of residues and debris from an active open dump located beside and in the river. In 1949 the Little Susitna River no longer had salmon in it due to cyanide leaching from gold mining operations (Lawrence, 1949). Mining sites were never cleaned up or remediated and no one knows if cyanide is still present in the watershed. Currently the Little Susitna River is known to be polluted with hydrocarbons and excessive turbidity from motorized watercraft (Davis, 2011). That research project, published in 2011, showed that juvenile salmon and macroinvertebrates (food source for the salmon) decreased in abundance in areas of the river where hydrocarbon and turbidity levels increased. The published study also fully documented the research base for understanding how elevated turbidity harms salmon.

There are additional water quality problems in the valley that don't show up on the Department of Environmental Conservation's Impaired Water Bodies list. For example, in 2011 the owner of a Mat-Su septic pumping business was caught, and later convicted of, dumping raw sewage into a tributary of the Little Susitna River. A downstream neighbor had been trying to get authorities to do something about the illegal dumping for some time (ADN, 8/29/2012).

The Mat-Su Borough has a volunteer program for water-quality monitoring of its lakes. That's a good first step but the program does not measure or monitor many of the potential pollutants that harm salmon such as hydrocarbons or bacteria (sewage) (MSB Volunteer Lake Monitoring Program, http://www.matsugov.us/planning/divisions/environmental-division/wq/vlmp).

There are over 21,000 septic systems and outhouses in the Mat-Su and more being added all the time as new development spreads out further and further into the valley. The 2006 Update to the "Mat-Su Comprehensive Economic Development Strategy" contained the following statement: **"Since most of the Borough relies on on-site septic systems and wells, the proper installation and maintenance of these systems is a concern. In some areas, inadequate systems are leaching into lakes and streams. This impacts both water quality and natural aquatic systems and needs to be addressed."** It has not been addressed and in fact the Mat-Su Borough's new Title 43 removed the requirement of an engineer's report stating the suitability of some subdivided lots to contain an on-site septic system (Mat-Su Borough, 2012).

The proliferation of impervious surfaces - roads, parking lots and rooftops - associated with urbanization causes pollution. Run-off from rain and snow-melt collects contaminants and flows unfiltered into waterways. The rapid flow of water off impervious surfaces also contributes to flooding and reduces the amount of water that percolates down into the soil to replenish the ground water supply. When the ground water supply is diminished, salmon habitat in shallow streams and wetlands disappears. Wells and drinking water supplies can also suffer from the deleterious effects of impervious surface run-off and contamination. Research, including studies conducted in Anchorage, have defined ways that the negative impacts can be mitigated but it requires dedicated land-use planning (Ourso, 2003).

The 2006 Mat-Su Comprehensive Economic Development Strategy also contains the following language: "Rapid development has also replaced vegetation with paved or impervious surfaces. As development occurs, traditional drainage patterns are disturbed, rerouted, confined or eliminated. Frequent high flows and unimpeded run-off can directly impact lakes and streams by causing excessive erosion and destroying habitat for fish and aquatic life. The pollutants carried with such runoff (gasoline, oil, sediment, heavy metals, and herbicides) can potentially contaminate water supplies for those who depend on wells." The Borough acknowledges the problems but asks its citizens only for "voluntary practices" for conservation.

Riparian and Wetland Damage

Cutting vegetation, excavating and building near the edges of lakes, rivers and streams used by salmon harms the fish in various ways. Riparian zone vegetation provides shelter to juvenile salmon and helps keep water temperatures cooler. Debris from shore-side vegetation adds nutrients to the water and shelter for adult and juvenile fish. Clearing, excavation and building in riparian zones causes siltation and pollution. Siltation can make gravel spawning beds unusable for salmon or suffocate eggs already laid. Polluted run-off into lakes and streams can kill juveniles and returning adult salmon before they have a chance to spawn.

The Mat-Su Borough has regulated setbacks from waterbodies for buildings and septic systems but has not codified any other protections for riparian zones. The Kenai Peninsula Borough enacted riparian zone protection on the Kenai River in 1996 to preserve and restore essential fish habitat along the banks of the Kenai River and its tributaries. Other salmon streams were subsequently added and the Kenai Peninsula Borough is currently working to extend riparian zone protection to all of the waterways used by salmon in the borough. It is not easy, popular or inexpensive but these types of regulations are essential for sustaining salmon.

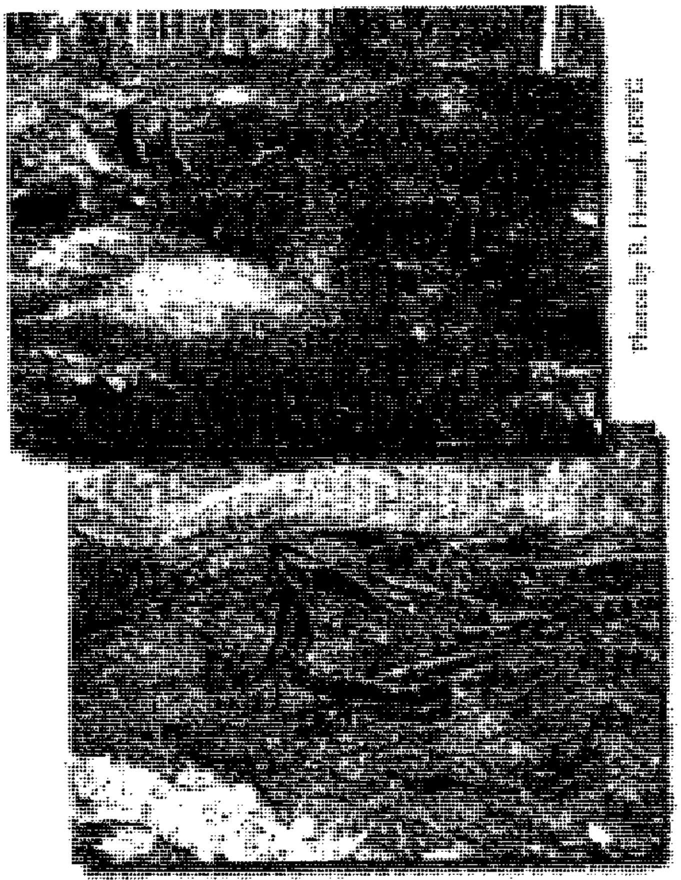
Wetlands are another critical component of salmon habitat, and much more. The Matanuska-Susitna Borough Wetlands Management Plan Executive Summary contains the following language:

> "Wetlands link land and water, and in doing so, afford the residents of Mat-Su with many lifestyle, environmental, and economic benefits. These benefits often include:
> - Lifestyle Benefits: open space, clean water, and recreation opportunities
> - Economic Benefits: tourism, hunting , fishing, skiing, snow machining, and other outdoor recreation activities; stormwater management; flood control; and clean water
> - Environmental Benefits: clean water; flood reduction; erosion control; habitat for moose, salmon, and waterfowl; and groundwater recharge and purification."

Again, the Mat-Su Borough appears to recognize the function and importance of the natural system but is unwilling to commit to any pro-active management.

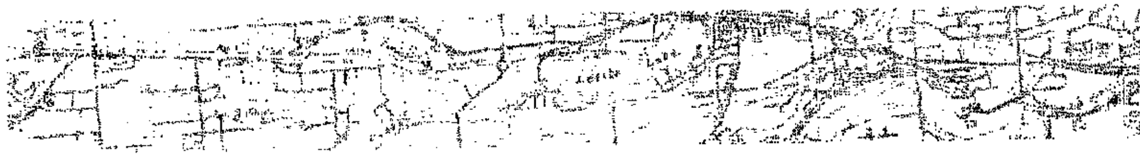
An additional source of damage in the Mat-Su Basin is the use of ATVs near and in waterbodies, including wetlands. Swiftwater Creek, a tributary of the Little Susitna River with valuable coho habitat, has long had an ATV trail running along, and through, the stream. ATV use along McRoberts Creek in the Jim Creek watershed eroded the bank of the creek to the point where the water was diverted out of the stream channel and into the trail. These are just two examples of human-caused damage to salmon streams. There are hundreds of miles of ATV trails throughout the valley and likely hundreds of other examples of stream damage that individually may seem innocuous but collectively have a large, unmonitored impact on salmon migration, spawning and rearing.

Illegal ATV trails crossing Upper Jim Creek in the Knik River Public Use Area. Bottom photo shows coho spawners in precisely the same location.



The Mat-Su Borough's Title 43 relaxed access standards for subdivisions outside of Road Service Areas: road access is not required; trail access is sufficient; and the access trails don't have to be designed or built for to subdivision approval. Trail standards were also eased and allow wetland crossings and open-water stream and river crossings. The plat approval requirements for drainage management, erosion control and flood hazard indications were reduced by Title 43. The requirement for a plat note concerning setbacks from shorelines was eliminated (Mat-Su Borough, 2012). All of these changes, enacted in 2012, will increase the amount of damage done to salmon habitat by development in the borough.

The State of Alaska Department of Natural Resources is not taking responsibility to protect salmon habitat from motorized vehicles in the Knik River Public Use Area and on other state-owned lands.



Hydroelectric Dam

The habitat problems resulting from urbanization described in the preceding sections have been contributing to recent salmon declines. A future hazard is currently in the planning stages and should be of great concern to people and entities who want to maintain salmon stocks in the Susitna River.

The Alaska Energy Authority is proposing to construct a hydroelectric power facility in the upper Susitna River, 184 miles from Cook Inlet and 87 river miles above Talkeetna. The facility would include a 735-foot dam creating a 24,000 acre reservoir stretching 42 miles in length above the dam.

The project is the early stages of a permitting process with the Federal Energy Regulatory Commission (FERC). This is the preliminary study period of the project. The Alaska Energy Authority has identified 58 research studies to be conducted over two years covering 186,000 acres along the Susitna River. Information about all of the studies is available at the project's website (www.susitna-watanahydro.org).

Many of the planned studies are focused on salmon. Project planners have already identified many ways in which the dam will affect salmon and salmon habitat. Much of the research is oriented toward determining how to reduce and mitigate negative impacts to fish.

Generating hydroelectric power requires changing the natural flow of the river. Less water would flow below the dam in the spring because water would be stockpiled during the snowmelt season. River water levels would be higher in the winter, and river water would be warmer, as water is released to meet demand for electricity. The planners also expect to release water on a daily basis according to demand, so water levels would change significantly during the course of each day in the 184 miles of river downstream of the dam.

Among other things, researchers will be trying to determine exactly how these altered water levels will affect stream temperatures, stream ice processes, water levels and fish passage between the main river and tributaries, side channels and sloughs, and water levels and siltation in spawning beds. Another study focus is the risk of mercury contamination of fish in the Susitna. Newly created reservoirs have a well-studied natural tendency to concentrate highly toxic methylmercury in the food chain leading to fish and fish-eating wildlife.

The Alaska Energy Authority's Study Plan makes it clear that there would be inevitable negative impacts on salmon from a hydroelectric dam. Most effects would happen slowly through subtle changes to the system. For example, the dam reservoir will trap much of the larger particulate-sized sediments. The consequences for salmon spawning beds downstream is poorly understood. Winter ice cover on the river is known to create hydrostatic pressure that maintains the upwelling of groundwater into the system essential to providing winter habitat for juvenile salmon. The release of warm water and the fluctuating flows from the reservoir during winter months will reduce the ice cover. These are just two examples demonstrating the complexity and vulnerability of fish habitat. It is not possible to dam the Susitna River without ultimately and inevitably harming the salmon production. Opponents of the dam argue that the dam and its footprint in the Susitna watershed is likely in legal conflict with Alaska's Sustainable Fisheries Policy as set forth in 5AAC 39.222 (Coalition for Susitna Dam Alternatives, 2013).

The Susitna-Watana hydroelectric project would provide flood control and infrastructure that would accelerate residential and other development in the valley. That development, in the absence of any regulatory protections for fish habitat, would also accelerate the decline of salmon.

Urbanization is just one piece of the matrix of problems causing the decline of some salmon stocks in the Mat-Su Basin. Growth and development aren't bad things. Unlimited, unregulated, unmitigated development, however, is simply incompatible with the conservation of natural systems required for salmon production. It is not possible to have both. The story of salmon extinction in the Pacific Northwest is the story of short-term economic gains inevitably prevailing over long-term resource planning and conservation.

Fisheries Management

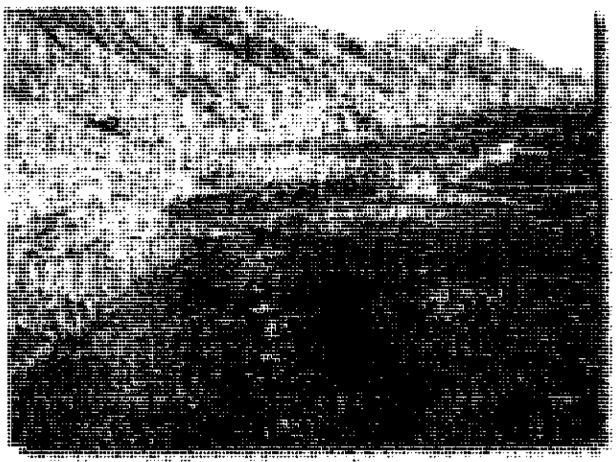
Invasive northern pike and beaver dams are not the only problems that haven't been handled adequately by ADF&G management. Coho salmon stocks are being harmed by poor management decisions as well as habitat losses.

Returns of coho salmon to the Mat-Su Basin are measured against escapement goals at only three places in northern Cook Inlet - the Little Susitna River, Fish Creek, and Jim Creek, a tributary of the Knik River. Escapement counts from these three systems are used by Fish and Game to make decisions regarding coho stocks in the entire Mat-Su drainage and Upper Cook Inlet. **These three waterbodies should not be used at all for counting returns because they are among the dirtiest, most urbanized and most exploited streams in Southcentral Alaska.** It is wrong to make coho management decisions based on these systems. It is unacceptable to allow coho returns to these rivers to influence the management decisions for the central district sockeye fishery during the peak of the sockeye runs.

The Little Susitna River is not only polluted, but the coho stocks there now aren't even native to the river. A 1949 study by the U. S. Geological Survey determined there were no longer any salmon in the river due to toxic run-off from mining (Lawrence, 1949). From the 1960s through 1993 the Little Su was stocked regularly with hatchery coho and kings that originated from stocks in northern Cook Inlet, the Kenai Peninsula, Resurrection Bay, Kodiak, Washington and Oregon. A total of 11,838,251 juvenile coho were stocked in the Little Susitna River between 1982 and 1993. The coho stocking was suspended in 1993 with the purpose of determining if the non-hatchery stock could sustain the sport fishery. It cannot sustain the sport-fishing pressure but stocking has not been resumed. Escapement goals for the river are still based on data from the years during which there was significant stocking of hatchery fry and smolt. Pike are present in the watershed. The escapement in this river should not be used as an indicator of coho returns in Upper Cook Inlet.

Fish Creek also has pike in its drainage. Fish Creek flows out of Big Lake. This lake has been intensively developed for residential use in the past four decades and its water currently exceeds state standards for hydrocarbon pollution. From 1977 through 1993 a total of 13.4 million juvenile cohos were stocked in Fish Creek. A hatchery was operated in the watershed from 1977 through 1993. Hatchery activities changed seasonal water flows and introduced infectious hematopoietic necrosis virus (IHNV). A weir blocking all fish passage was used above the hatchery for some time to prevent the spread of the IHNV (Litchfield, 2002). Juvenile salmon survival rates in Big Lake have been abnormally low since the 1970s for both wild and hatchery stocks. Sockeye stocking was discontinued in 2008 due to poor smolt survival (ADF&G, 2011). Fish Creek is not representative of coho or sockeye systems in the Mat-Su Basin and should not be used to make management decisions affecting the entire Upper Cook Inlet.

Jim Creek doesn't have as unlikely a history as the Little Su or Fish Creek but it is very questionable as a return indicator for coho stocks. Jim Creek, a.k.a. "Circus Creek" is heavily accessed not only by sport fishermen but also by ATVs, dirtbikes and off-road trucks. In fact, the Mat-Su Borough Assembly voted in February, 2013 to turn their 471 acres of land around the mouth of this heavily fished salmon creek into an ATV motor park. McRoberts Creek is a major tributary of Jim Creek and is the same creek mentioned previously for having had the water from its channel diverted down a trail as a result of ATV traffic.



This photo shows damage by airboats in Leaf Lake and Swan Wetlands in the Jim Creek drainage. This is a coho salmon rearing area. (Photo by T. Cox)

Using these three waterbodies for counting coho escapements to the entire Upper Cook Inlet is also inappropriate because of their extremely high rates of in-river exploitation. For the past 30 years the Little Susitna has had an average in-river harvest rate of 50% on returning coho salmon. An escapement count there is clearly not comparable to a stream system that is not so accessible or intensively fished. Using these heavily exploited rivers as return indicators for the whole valley

does not provide an accurate picture and almost guarantees over-escapement into the less accessible areas. Over-escapement leads to major population fluctuations. Coho escapement counts should be conducted on multiple streams that are not heavily exploited or in urbanized areas. This would generate a realistic picture of overall escapement into the Mat-Su drainage and Upper Cook Inlet.

The Mat-Su's increasing population (and proximity to Anchorage) results in intensive concentration of fishing effort on any accessible sites. Streams with good access get inundated with fishermen and effort. If more salmon are allocated, then some additional fish may be caught in those streams; but inaccessible streams, without much sport harvest, get too many fish, which leads to the large fluctuations, or "cycling", in returns.

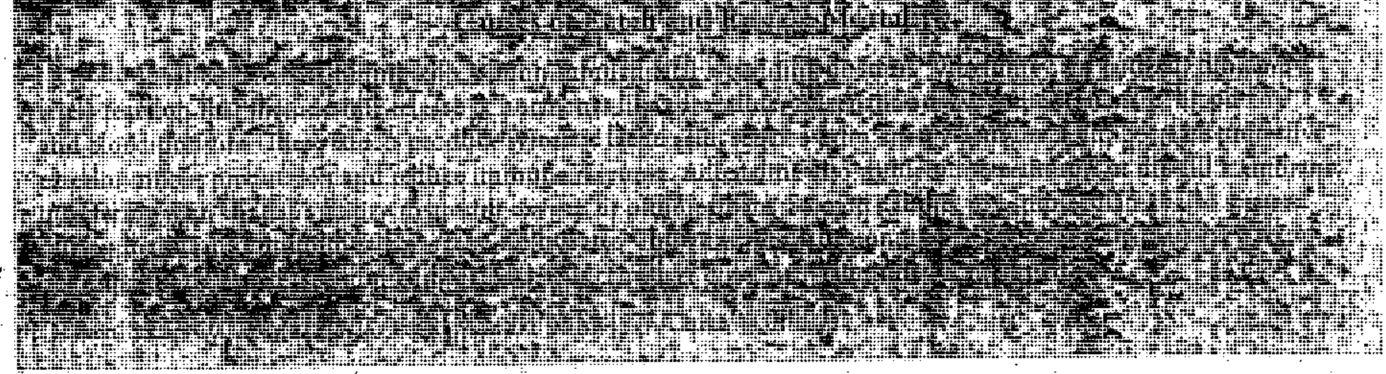
ADF&G Sportfish Division management has demonstrated an irresponsible unwillingness to manage in-river sportfishing exploitation of stocks in the Mat-Su. The most egregious example is their management of catch and release fishing. In 1993 ADF&G biologists published the results of their study on the mortality of caught and released coho salmon in the Little Susitna River (Vincent-Lang, 1993). **The research showed that coho salmon hooked and released in the lower Little Susitna River suffered a 69% mortality rate.** The mortality rate for cohos hooked and released in the river above the estuary was 12%. These were the rates for coho salmon caught and released a single time. The study did not examine the effect of multiple hooking of a fish nor whether the salmon that survived were able to spawn after being caught and released.

Fish and Game's escapement goals for the Little Susitna were not met in 2009, 2010 or 2011. The escapement goal may have been artificially high, as it was still based on data from the years during which the river was heavily stocked, but nonetheless, the escapement goal was not met in those years. If ADF&G was concerned about the coho returns in the Little Su it seems reasonable that they would have, at the very least, curtailed catch and release fishing in the lower river knowing that particular activity would result in a large number of dead, discarded coho. ADF&G did not restrict catch and release fishing. Based on the sportfish survey data for the Little Susitna, the 69% mortality rate for hooked and released coho resulted in over 2,000 dead and discarded coho salmon in 2009, over 1,500 in 2010 and over 950 in 2011.

In 2009 and 2010 the escapements were close to the goals; minor adjustments to in-river exploitation would have achieved the goals. In 2011 the coho escapement in the Little Susitna was 5,000 fish short of the goal. Still, ADF&G made no changes in 2012 until the season was almost over. When you have a highly accessible stream that is not reaching escapement goals and ADF&G does nothing to reduce in-river exploitation rates, there appears to be a management deficit.

ADF&G estimates that an average of 68,650 coho were caught and released annually in northern Cook Inlet between 1996 and 2009. At the most conservative measure of a 12% mortality rate we are looking at over 8,200 cohos killed and discarded every year. That adds up to 82,000 every ten years - at the minimum estimated mortality rate. The actual number of dead and discarded coho could easily be as high as 30,000 fish per year. A completely unmonitored effect is the impact on salmon's ability to spawn after having been hooked and released one or more times.

ADF&G has encouraged, not discouraged, catch and release fishing. Restricting catch and release fishing is a management tool that could be utilized with relative precision to conserve thousands, and even tens of thousands, of spawning salmon in northern Cook Inlet. Instead, ADF&G has tried to manage northern Cook Inlet salmon using only the inefficient and ineffective tools of restricting the commercial fisheries in central Cook Inlet.



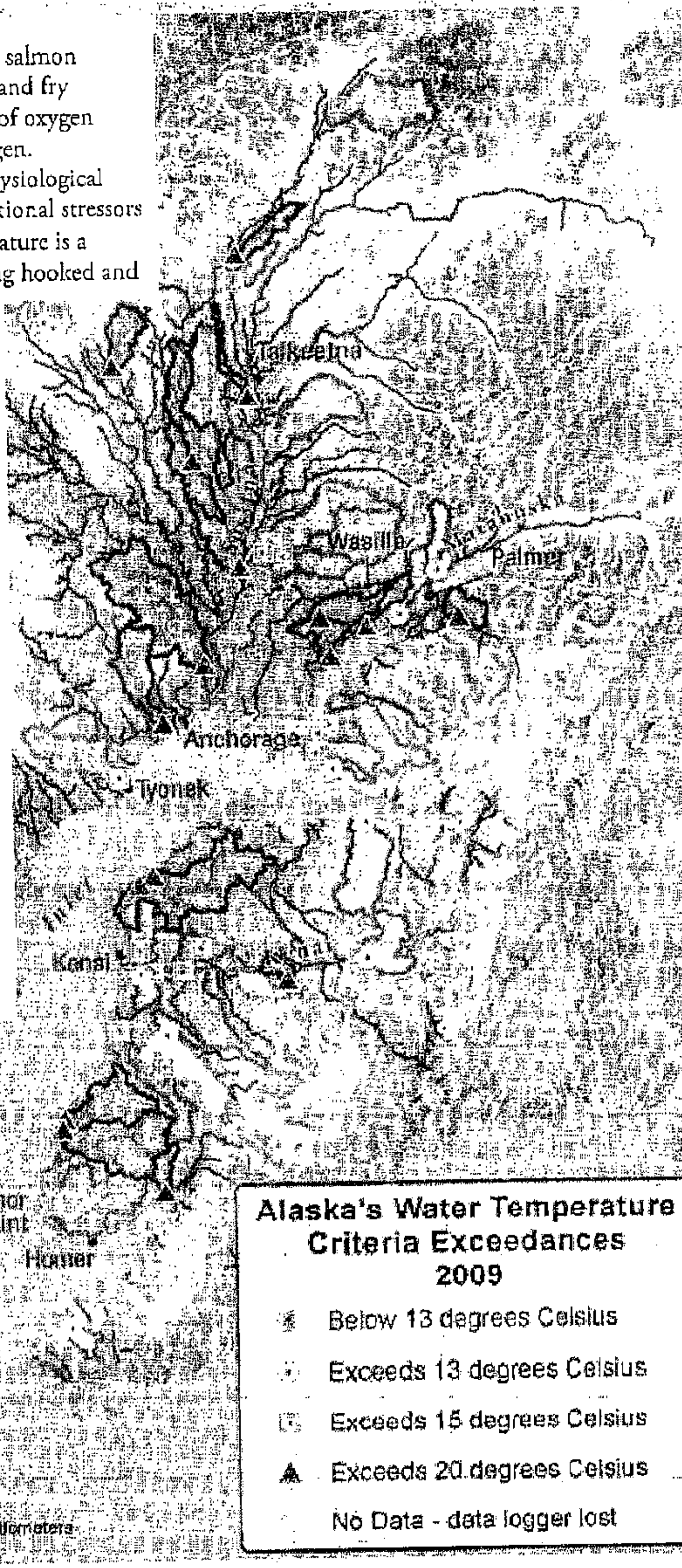
Salmon in Hot Water

Water temperature is critically important for salmon production. Stream and lake temperatures affect egg and fry survival, food supply, migration timing, the amount of oxygen available in the water and salmon's ability to use oxygen. Excessively high water temperatures cause salmon physiological stress. The fish then become more vulnerable to additional stressors like predators, parasites and pollution. Water temperature is a factor affecting a salmon's ability to survive after being hooked and released in a sport fishery.

Extensive research has delineated temperature parameters and limits for salmon health and survival. When stream temperatures reach 17°C (63°F) there is not enough dissolved oxygen in the water to allow salmon to swim upstream. The shallow, meandering character of much of the waterways in the Mat-Su Basin increase the systems' vulnerability to rising temperatures.

This map shows one year of data from a multi-year program conducted by Cook Inletkeeper to collect consistent, long-term temperature data for salmon streams around Cook Inlet. Beginning in 2008, continuous water and air temperatures were taken in 48 non-glacial salmon streams during open water periods. The information collected will help resource managers prioritize efforts to study impacts on salmon, buffer effects and restore habitat where appropriate.

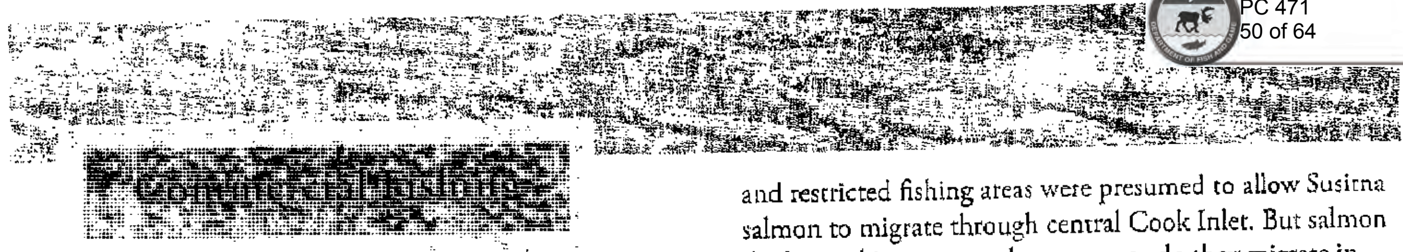
The effects on salmon migration, spawning and rearing in a "warm" summer like 2009 will show up in decreased returns two to five years later.



Alaska Water Quality Standards
(18AAC 70)
The following maximum temperatures shall not be exceeded, where applicable:

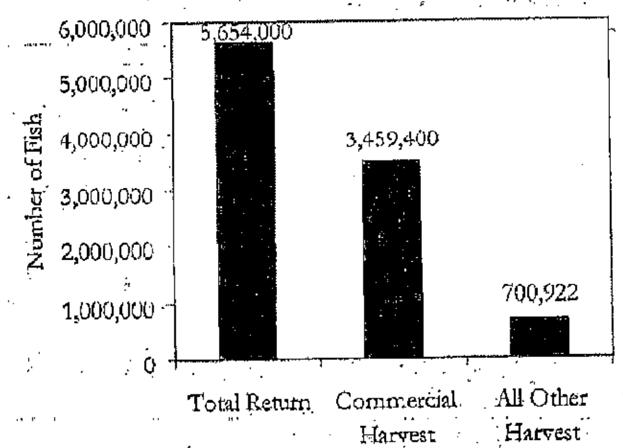
egg & fry incubation = 13°C (55°F)
spawning areas = 13°C (55°F)
migration routes = 15°C (59°F)
rearing areas = 15°C (59°F)

Mauger, S. 2011. Stream Temperature Monitoring Network for Cook Inlet Salmon Streams 2008-2010. Alaska Clean Water Action Grant 11-01, FY2011 Final Report. Cook Inletkeeper, Homer, Alaska.



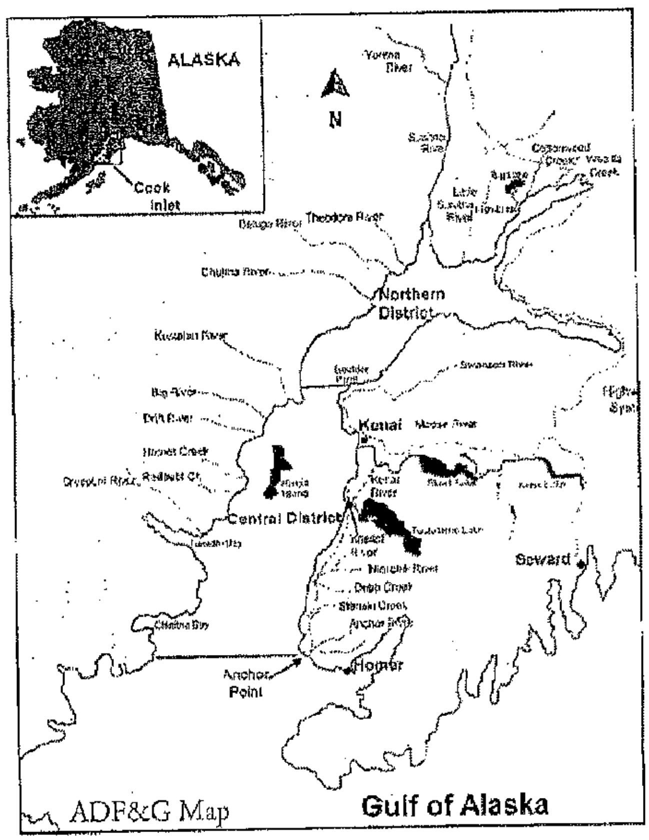
The commercial fishing industry has been sustainably harvesting salmon in Cook Inlet for over 130 years. Upper Cook Inlet has produced the second largest runs of sockeye in Alaska and contributes at least 5% of the world's supply of sockeye salmon (Ruggerone, 2010 and Pinsky, 2009). The commercial harvest of sockeye in Cook Inlet averaged almost 3.5 million fish per year between 2002 and 2011. Total other harvests, including sportfishing and personal use, averaged over 700,000 sockeye salmon per year. The abundant harvestable surplus of high-value sockeye in upper Cook Inlet is what makes the commercial fishery such an important contributor to the region's economy and provides more fish for recreational users than any other species.

Upper Cook Inlet Average Annual Sockeye Harvests 2002-2011
(Source: ADF&G Annual Mgt Reports)



Over twenty years ago ADF&G began restricting commercial fisheries with the aim of increasing sockeye escapements into the Susitna River. Unfortunately, the escapement numbers they were using were from the inaccurate sonar counters that were underestimating actual sockeye escapements by 50 to 100%. While it is not possible to go back and re-calculate exact figures, we now know that escapement goals were being exceeded and the restrictions on the commercial fisheries were, in all likelihood, not necessary. When the extreme level of inaccuracy was determined in 2008, the restrictions on the commercial fisheries were not changed accordingly.

In addition, recent research has refuted much of the theory behind the commercial fishing restrictions. Closures and restricted fishing areas were presumed to allow Susitna salmon to migrate through central Cook Inlet. But salmon don't travel in segregated groups, nor do they migrate in straight lines to their destinations. The latest research **incorporating genetic testing with Off-shore Test Fishing in the central district has demonstrated that sockeye stocks are intermingled and dispersed throughout the inlet as they migrate.** Studies have shown that Kasilof and Kenai sockeye salmon often account for more than half of the catch in Northern District setnets - far to the north of their destinations. Susitna sockeye catches vary between 14% and 26% of the sockeye harvest in the Northern District (Barclay, 2010).

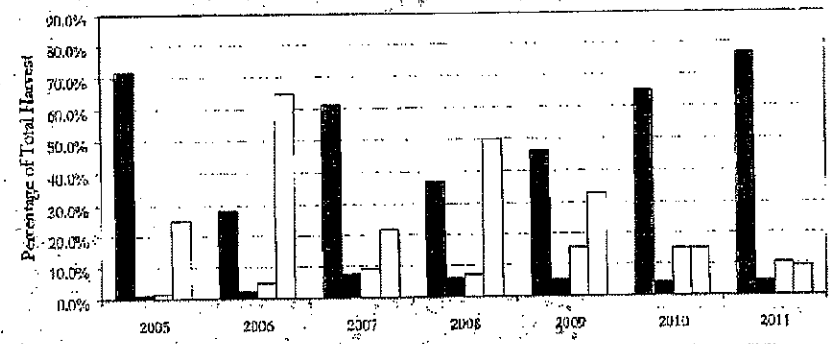


Genetic testing of sockeye caught commercially has also indicated that the percentage of northern-bound sockeye caught by drift fishermen in restricted corridors is not significantly different than the percentage caughr during a district wide opening.

In 2011 drift fishermen caught 781,146 sockeye while restricted to the Corridor. Of these, 6.8% were genetically identified as Susitna salmon. While not restricted to the Corridor during the same season, drift fishermen caught 2,261,582 sockeye of which 5.7% were identified as Susitna salmon (ADF&G, 2012).

An average of 35% - 38% of the returning Mat-Su sockeye stocks are commercially harvested each season (P. Shields, Pers. Comm. 2013). This is a relatively low rate, well below what is considered a sustainable rate of exploitation. Commercial fisheries harvest 55-70% of the sockeye runs in the Kenai and Kasilof Rivers. The difference in the exploitation rates is related to geography. The northern limit of the central district commercial fishing area is nearly 50 miles away from the mouth of the Susitna River. The majority of fishing effort takes place well south of that northern limit.

Stock Composition of Upper Cook Inlet Commercial Sockeye Harvest 2005-2011
(Source: ADF&G, 2012)



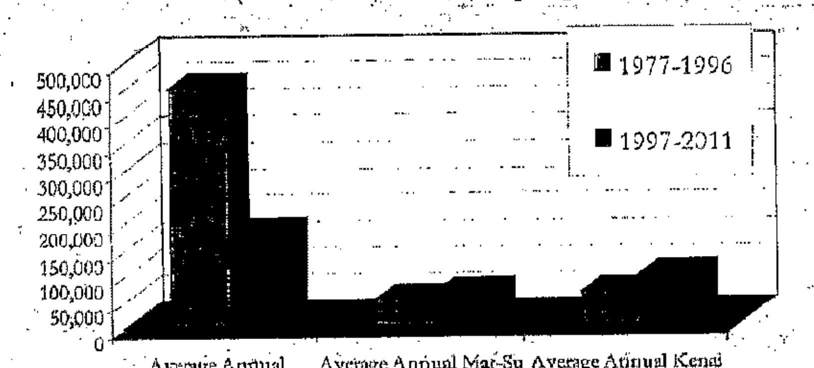
All of the in-river problems facing spawning and rearing salmon in the Mat-Su Basin should make it obvious that simply putting more fish in the streams is not a solution. The ADF&G 2011 Upper Cook Inlet Management Report states it very clearly: "...**unless the impacts from pike predation and beaver dams can be significantly reduced, the total sockeye salmon production in the Susitna River drainage will continue to suffer, regardless of the amount of restrictions placed on commercial fisheries.**" In fact, current Susitna escapement goals need to be re-evaluated in light of the decreasing production capacity.

Mandatory restictions placed on the commercial fisheries since 1990 related to Susitna sockeye were based on bad science and flawed assumptions. Susitna River sockeye salmon make up an average of only four percent of the total commercial sockeye harvest. Trying to base fishery management decisions on a stock that makes up only 4% of the total can have exponential effects on the larger components of the harvest.

Besides being ineffective, attempts to manage Susitna sockeye by manipulating commercial fisheries has caused other problems. Fisheries managers require the flexibility to respond to salmon returns in real time. None of the salmon run on timetables or in discrete areas. Decisions need to be made day-to-day based on data received within 24 hours. Pre-determined rigid schedules of closures, corridors and other restrictions has resulted in over-escapements and lost harvest opportunities, all of which cost the industry and local communities millions of dollars.

Tens of millions of dollars in ex-vessel revenue have been lost since 2002 due to unharvested, surplus over-escapements of sockeye into the Kenai River. This does not include the loss of the direct, indirect and induced revenues to the processors, supporting businesses, local and state economy or the loss of the value of the future diminished return.

Coho Harvests Before and After August Commercial Closures
(Source: ADF&G Annual Mgt Reports)



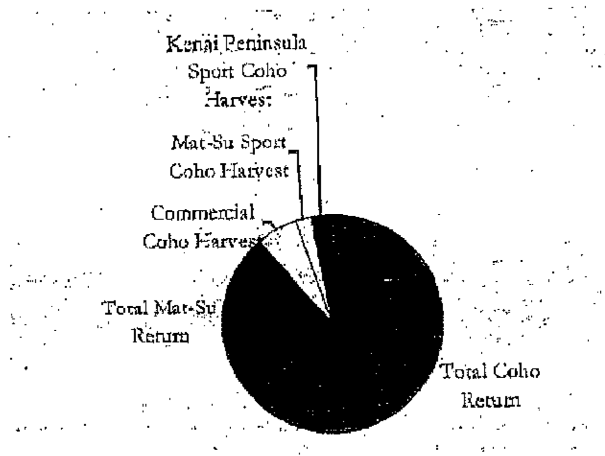
Similar effects have resulted from efforts to manage coho runs. In the past the Upper Cook Inlet commercial fishery was open from early May through October. The beginning of the commercial season was changed to late June to prevent the commercial harvest of early run king salmon. The season has been progressively shortened in an effort to prevent the commercial harvest of coho salmon.

Beginning in 1997 the commercial fisheries lost most of their normal fishing time after early August. The consequences for the commercial industry were dramatic.

The annual average commercial harvest of coho salmon from 1977 through 1996 was 451,000. After the restrictions began, from 1997 through 2011, the average annual coho harvest dropped to 177,000; a decrease of 274,000 fish. Average annual sport harvest of coho after 1996 in the Mat-Su Basin increased by 13,000 fish. The Kenai Peninsula annual average sport coho harvest increased by 30,600 fish.

There is very little return on the sacrifice. The increase to the Mat-Su's average coho harvest was less than 5% of the harvest lost to commercial fisheries.

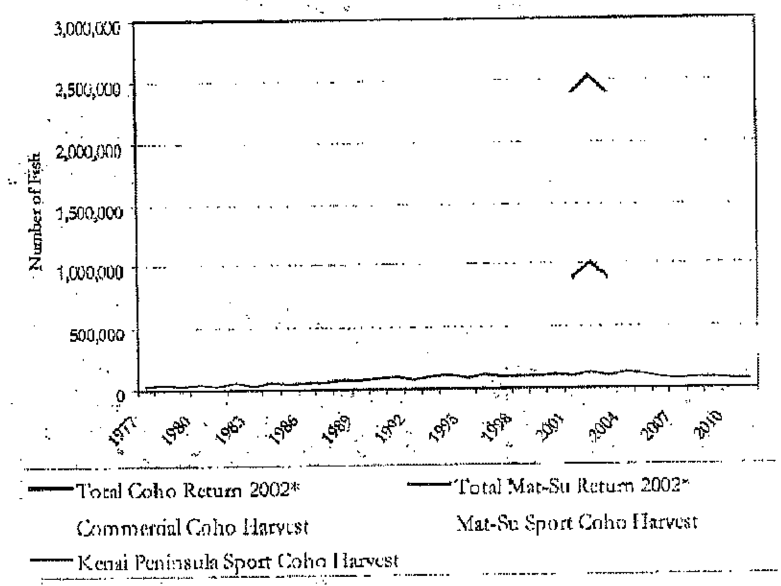
Harvest numbers are the data used because total coho escapements into Upper Cook Inlet are not normally counted, nor total returns calculated, with the exception of the returns in 2002.*

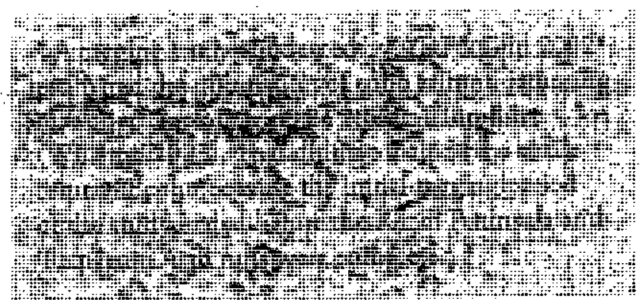


2002 Upper Cook Inlet Coho Returns and Harvests
(Source: ADF&G Annual Mgt Reports; Willette, 2003)

- **Commercial fisheries harvest 10% or less of the entire coho return to Upper Cook Inlet, and 7% or less of the coho returns to the Mat-Su Basin (Willette, 2003).**
- The average annual sport harvest of coho salmon in Cook Inlet from 1996 through 2011 was 180,175 fish. This figure does not include any catch and release mortality data.
- The average annual commercial harvest of coho salmon from 1996 through 2011 was 186,086 fish. This figure includes harvest of coho stocks by all gear types, including drift and setnet in the Central District, Northern District setnet and the late season openings on the West side of Cook Inlet including Chinitna Bay.

Upper Cook Inlet Coho Harvests and Return
(Source: ADF&G Annual Mgt Reports; Willette, 2003)

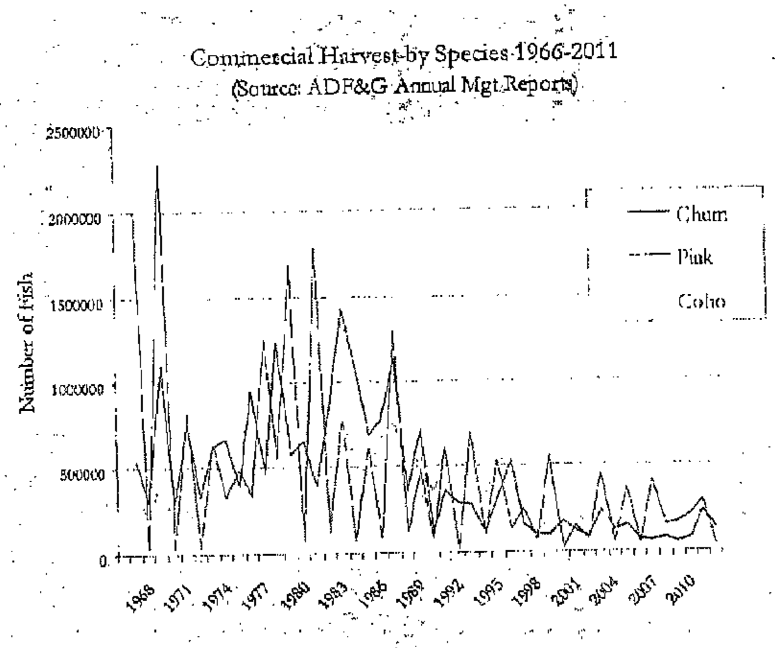




The significant reduction in commercial harvest of coho salmon has not prevented the recent coho return declines in the systems under observation.

Efforts to manage coho runs by restricting commercial fishing has very limited effectiveness and excessive economic consequences for the commercial fishing industry. Restricting commercial fishing, particularly in August when the bulk of the northern-bound coho have already passed through the central inlet, has almost no measurable effect on those coho runs (Willette, 2003). Analysis has shown that commercial harvests of Kenai River coho are also quite low (ADFG, 2011). But August closures and restrictions on commercial fishing during July and August significantly decrease the harvest of robust stocks of upper Cook Inlet chum and pink salmon. Commercial exploitation rates for pink salmon are less than 12% and rates for chum salmon are only around 6% (Willette, 2003).

If the commercial harvest on the 2001-2011 pink and chum runs in Cook Inlet had an average exploitation rate of 40% the ex-vessel value could have been, on average, an additional 4 million dollars per season. Including direct, indirect and induced economic effects, the pink and chum harvest could have realized in excess of 14 million dollars to the local and state economy per year.



In 2011 the Mat-Su Borough petitioned the Board of Fish to completely close the Upper Cook Inlet commercial fishing season on August 5 and discourage expansion of the commercial fishery targeting chum and pink salmon in order to (possibly) allow a slightly higher number of coho to reach northern drainages. Salmon population declines in northern Cook Inlet have not been caused by commercial fishing but efforts to solve the problems by restricting commercial fishing are costing the industry and the local communities many millions of dollars. The Mat-Su Borough and the ADF&G Sportfish Division have expected the commercial fishing industry to bear destructive costs while they have taken very little responsibility and made few effective changes.

It is in everyone's interest to conserve and sustain wild salmon in all of Cook Inlet's drainages. Commercial fishermen have been putting millions of dollars into habitat restoration and stocking programs in the Mat-Su Basin through the Cook Inlet Aquaculture Association.

This non-profit association was started by commercial fishermen in 1976 and funded with a self-imposed 2% tax on the gross value of salmon harvested. The purpose was to use commercial fishing money to create an organization that could provide a science-based infrastructure to protect, rehabilitate and enhance salmon stocks and habitat for all users.

Since 1980 Cook Inlet commercial fishermen have contributed an annual average of $775,000 to the Cook Inlet Aquaculture Association. This money has been leveraged with state grants and other income sources to fund many monitoring, rehabilitation and stocking programs in the Mat-Su Basin that have benefited everyone. In the past ten years the Cook Inlet Aquaculture Association has expended $4.2 million dollars on Mat-Su basin projects directly related to improving salmon production including: pike management and suppression; beaver dam management; sockeye spawner and smolt enumerations; and sockeye enhancement.

The commercial fishing industry will continue to support science-based problem solving and promote sustainability of the salmon resources in the Cook Inlet watersheds.

Conclusion

Many groups, governmental and non-governmental, are concerned about and studying various aspects of salmon production and the general health of the ecosystem in the Mat-Su Basin.* The threats are clear, the lessons have been learned during the experience of losing thousands of wild salmon stocks in the Pacific Northwest over the past 100 years (NRC, 1996). The Mat-Su Basin Salmon Habitat Partnership has begun a process of bringing everyone together to develop goals, plans and priorities. What is needed is the public and political will to choose pro-active prevention over expediency.

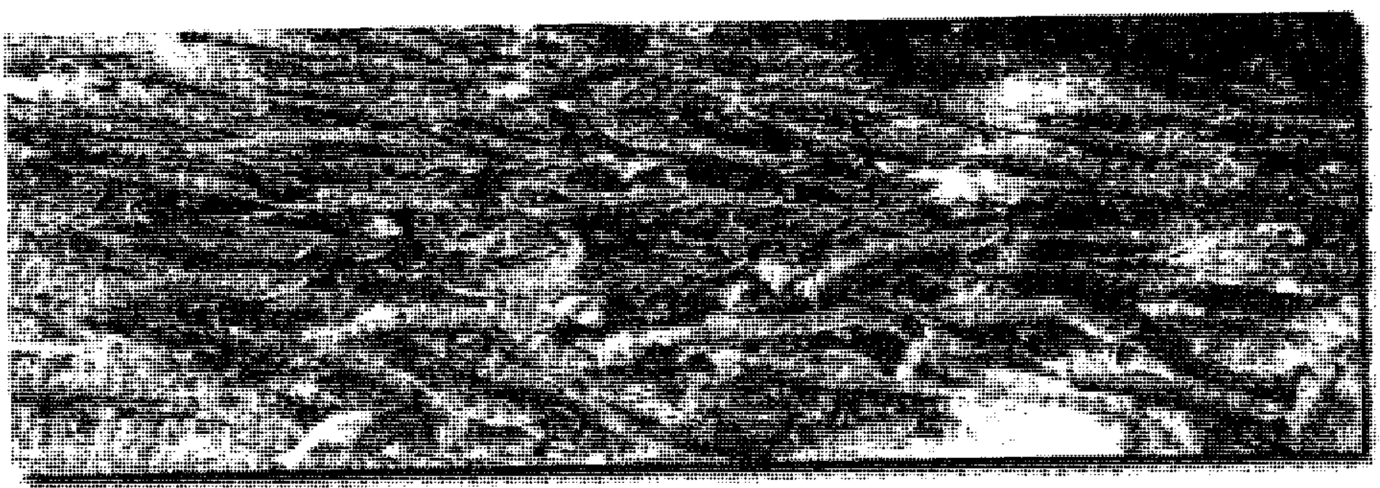
For over twenty years ADF&G restricted commercial fishing in the central district of Cook Inlet in various ways to try to increase escapement into the Susitna River. The problem they were attempting to solve turned out to be inaccurate counters, not over-exploitation. Those decades of experience with many permutations of commercial fishing restrictions in the central district did demonstrate that restrictive lines and corridors only reduce the efficiency of the fleet and are ineffective at conserving or targeting any specific stock.

Now that problems with Mat-Su salmon production have been found to be in freshwater, ADF&G and policy makers are still attempting to fix the situation with restrictions on saltwater fisheries in spite of the fact that there is no scientific basis for that tactic and plenty of evidence to the contrary. It appears that the department has lost sight of its mission and is more interested in managing public perception than in managing fishery resources.

Only the willfully uninformed can maintain the opinion that the problem with Mat-Su salmon production is not enough adult fish making it back to northern Cook Inlet streams. Continued denial of the facts will effectively prevent necessary steps from being taken to conserve salmon in their endangered habitats in the Mat-Su Basin. This would not only eliminate the economic and cultural benefits of salmon in the Mat-Su but would also undermine, if not destroy, an entire sustainable commercial salmon fishery that is a critical part of the economy of the Kenai Peninsula Borough and Southcentral Alaska.

The state legislature recently granted over seven million dollars to ADF&G and the Mat-Su Borough for Mat-Su Basin salmon research, restoration, protection and enhancement. This is an opportunity to implement some major projects for suppressing pike and improving fish passage through culverts and beaver dams. If the funds are spent judiciously, and additional money is allocated in the future, salmon population numbers could begin showing improvements within a decade.

Alaska's Fish and Game Act requires the Department of Fish and Game to "...manage, protect, maintain, improve, and extend the fish, game and aquatic plant resources of the state in the interest of the economy and general well-being of the state." (AS 16.05.020) In the best interest of the state, the salmon resources and all the user groups, ADF&G needs to carry out its mission.



(* USGS, USFWS, ADF&G, Cook Inletkeeper, Chickaloon Native Villlage, Wasilla Soil & Water District, Palmer Soil & Water District, AKDNR Divisions of Agriculture and Parks and Recreation, US Army Corps of Engineers, UAA, Mat-Su Borough, The Nature Conservancy, Cook Inlet Aquaculture Association, National Marine Fisheries Service, Alaska Salmon Alliance.)

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Alaska's
Final
2010 Integrated Water Quality Monitoring and Assessment Report

July 15, 2010

Alaska
Department of Environmental Conservation

1 Introduction

The Purpose of the 2010 Integrated Water Quality Assessment Report

The Clean Water Act (CWA) mandates that each state develop a program to monitor and report on the quality of its surface and groundwaters and prepare a report describing the status of its water quality. The U.S. Environmental Protection Agency (EPA) then compiles and summarizes the information and sends this information in a report to Congress. The process for developing information on the quality of the nation's water resources is contained in several sections of the CWA. Most prominent are Section 305(b), which requires that the quality of all waterbodies be characterized, and Section 303(d) which requires that states list any waterbodies that do not meet water quality standards (WQS). The Alaska WQS are documented in Title 18, Chapter 70, of the *Alaska Administrative Code* (18 AAC 70). EPA has recommended that the Section 305(b) reports and the Section 303(d) list of impaired waters be integrated into a single, comprehensive monitoring and assessment report, the Integrated Water Quality Monitoring and Assessment Report (Integrated Report).

This integrated approach allows each state to identify any water quality problems, develop remediation plans, and ultimately, achieve WQS in all of its waters. The Alaska Department of Environmental Conservation (DEC) considers the Integrated Report an important tool for understanding the health of Alaska's waters and identifying actions that can be taken to improve water quality in Alaska. Water quality information is one component that contributes to the efforts and priorities under the Alaska Clean Water Actions (ACWA) initiative, a much broader and more comprehensive assessment that includes water quality, water quantity, and aquatic habitat. More detailed descriptions of the ACWA initiative and its process for assessing information and establishing waterbody priorities are available in Section 2 and Appendix F.

The 2010 Integrated Report is a statewide water quality assessment. It describes whether the existing condition of each Alaska waterbody is sufficient to maintain multiple designated uses of that waterbody. Alaska WQS designate seven uses for fresh waters (drinking water; agriculture; aquaculture; industrial; contact recreation; non-contact recreation; and growth and propagation of fish, shellfish, other aquatic life, and wildlife) and seven uses for marine waters (aquaculture; seafood processing; industrial; contact recreation; non-contact recreation; growth and propagation of fish, shellfish, other aquatic life, and wildlife; and harvesting raw mollusks or other raw aquatic life for human consumption). Sources of information used by DEC to develop the biannual water quality assessment include monitoring data (e.g., water testing), professional knowledge, and evaluations such as those provided by water resource managers, fish and wildlife biologists, and aquatic biologists.

This Integrated Report fulfills the CWA Section 305(b) requirement that each state provide a comprehensive report of water quality to EPA. The report documents a comprehensive evaluation of the status and health of each waterbody in the State of Alaska and describes state programs for maintaining or improving the quality of Alaska's waters.

In addition, this report describes the process for evaluating whether waterbodies attain WQS or are impaired (polluted). This process includes classifying each waterbody according to five categories, depending on their health; determining which waterbodies need further action; scheduling when each impaired waterbody will be addressed; involving the public in determining how water quality will be addressed; and determining how waterbodies are removed from the impaired waterbody list.

DEC water quality programs are described in Appendix F.

Assessment Results

Alaska is rich in water quantity, water quality, and aquatic resources; almost half of the total surface waters of the United States are located within the state. Because of the size, sparse population, and remote character of Alaska, the vast majority of its water resources are in pristine condition. More than 99.9% of Alaska's waters are considered unimpaired. Among the state's vast water resources are more than 3 million lakes, 714,000 miles of streams and rivers, 44,000 miles of coastline, and approximately 174,683,900 acres of wetlands. Less than 0.1% of these water resources have been identified as impaired. Historically, Alaska's water quality individual assessments have focused on areas with known or suspected water quality impairments. Appendix A provides detailed information about the individual assessments and Appendix F provides information about the probalistic assessment program. The table below provides information about Alaska.

Table 1: Alaska Quick Facts

Atlas – Topic	Value	Value
State population		686,000 [a]
State surface area (square miles)		656,425
Total miles of rivers and streams		714,004
Number of lakes/reservoirs/ponds		3,000,000+
Acres of lakes/reservoirs/ponds		12,787,200
Miles of coastal shoreline		44,000
Wetland Acreages [b]		
Palustrine –non-tidal: muskegs, bogs, forested wetlands, tundra, open water	172,503,400	
Estuarine—bays, salt marshes, beaches	2,131,900	
Marine intertidal—ocean shoreline	48,600	
Total wetland acres		174,683,900

Notes:
a. US Census Bureau National and State Population Estimates, September 2009 http://www.census.gov/popest/states/NST-ann-est.html
b. U.S. Fish and Wildlife Service, Cowardin Classification of Wetlands and Deepwater Habitat, 1979

In Alaska, surface fresh water supplies three-fourths of water needed for industry, agriculture, mining, fish processing, and public water use and is used for about half of the domestic water supply. Alaska's surface waters include more than 15,000 salmon streams, an important resource for Alaskans and the world. Alaska also has the largest groundwater resources of any state.

Alaska is sparsely populated, having approximately 686,000 residents (approximately one resident per square mile). Urban development is concentrated in a few main population centers, and the majority of people live in Southcentral Alaska. The 2007-2008 U.S. Census showed population increased since the previous census in most areas of the state. Almost 50% of the state's population lives in the Municipality of Anchorage in Southcentral Alaska. The other major population centers are Juneau, the state capital, in Southeast Alaska, and Fairbanks in Interior Alaska. Communities outside these major population centers tend to be small and generally not connected by roads.

As population grows and the natural resource-based economy expands in Alaska, an increasing number of state waters, especially in urban areas, face the threat of degradation. In specific localized parts of Alaska, surface water quality has been impaired. Waters in urban settings (cities, towns, and villages) are predominantly impaired from sediment, turbidity, and fecal coliform (FC) bacteria contamination caused by urban and stormwater runoff. Other sources of impairment are sediment and turbidity from mining activities in Interior Alaska, residues from seafood processing facilities in coastal zones, contaminated military sites in Southcentral and Southwest Alaska, and bark and wood residues from timber processing and transfer facilities in coastal Southeast Alaska. Petroleum products, such as oil spills or fuel leaks, are also sources of impairment within the state.

Waterbody Categories

Generally, waterbodies are assigned to categories by the degree to which water quality goals are attained. The five categories and three subcategories are described below:

- **Category 1.** All WQS for all designated uses are attained.
- **Category 2.** Some WQS for the designated uses are attained, but data and information to determine whether the WQS for the remaining uses are attained are insufficient or absent.
- **Category 3.** Data or information is insufficient to determine whether the WQS for any designated uses are attained.
- **Category 4.** The waterbody is determined to be impaired but does not need a total maximum daily load (TMDL).
    - **Category 4a.** An established and EPA-approved TMDL exists for the impaired water.
    - **Category 4b.** Requirements from other pollution controls have been identified to meet WQS for the impaired water.
    - **Category 4c.** Failure to meet a water quality standard for the impaired water is not caused by a pollutant; instead, the impairment is caused by a source of pollution such as nuisance aquatic plants, degraded habitat, or a dam that affects flow.
- **Category 5.** WQS for one or more designated uses are not attained and the waterbody requires a TMDL or recovery plan. Category 5 waters are those waters identified on the Section 303(d) list of impaired waters.

The following table summarizes the number of waterbodies in each category as determined by the evaluation of existing and readily available water quality data and information reviewed for this draft 2010 Integrated Report.

Table 2: Number of Waterbodies

Category	Number of Waterbodies
1	Majority of Alaskan waters
2	44
3	304
4a	33
4b	4
4c	0
5	28

Alaska's Approach to Impaired Waterbodies

Alaska's process for listing an individual waterbody for failure to meet WQS, as required in the CWA Section 303(d), begins with an internal review of existing and new information to determine (1) the presence of pollutants, (2) whether persistent exceedances of WQS are occurring, (3) whether impacts on the designated uses are occurring, and (4) the degree to which WQS and the other criteria are attained. The specific criteria used for evaluation and listing of waterbodies associated with residue discharges from log transfer or seafood processing facilities are found in Appendixes G and I.

When a waterbody is placed on the Section 303(d) list, a TMDL or recovery plan is developed, unless data obtained after the listing indicate that the waterbody is no longer impaired or other measures are undertaken to restore the waterbody. State of Alaska waterbodies on the Section 303(d) list are scheduled for development of a TMDL (see Appendix C) or waterbody recovery plan between now and 2014. Specific criteria apply for delisting of impaired waterbodies in Section 2, and Appendices G and I.

When a TMDL or waterbody recovery plan is developed, a public process is initiated. As part of the process, the public is notified of the document and can comment on it.

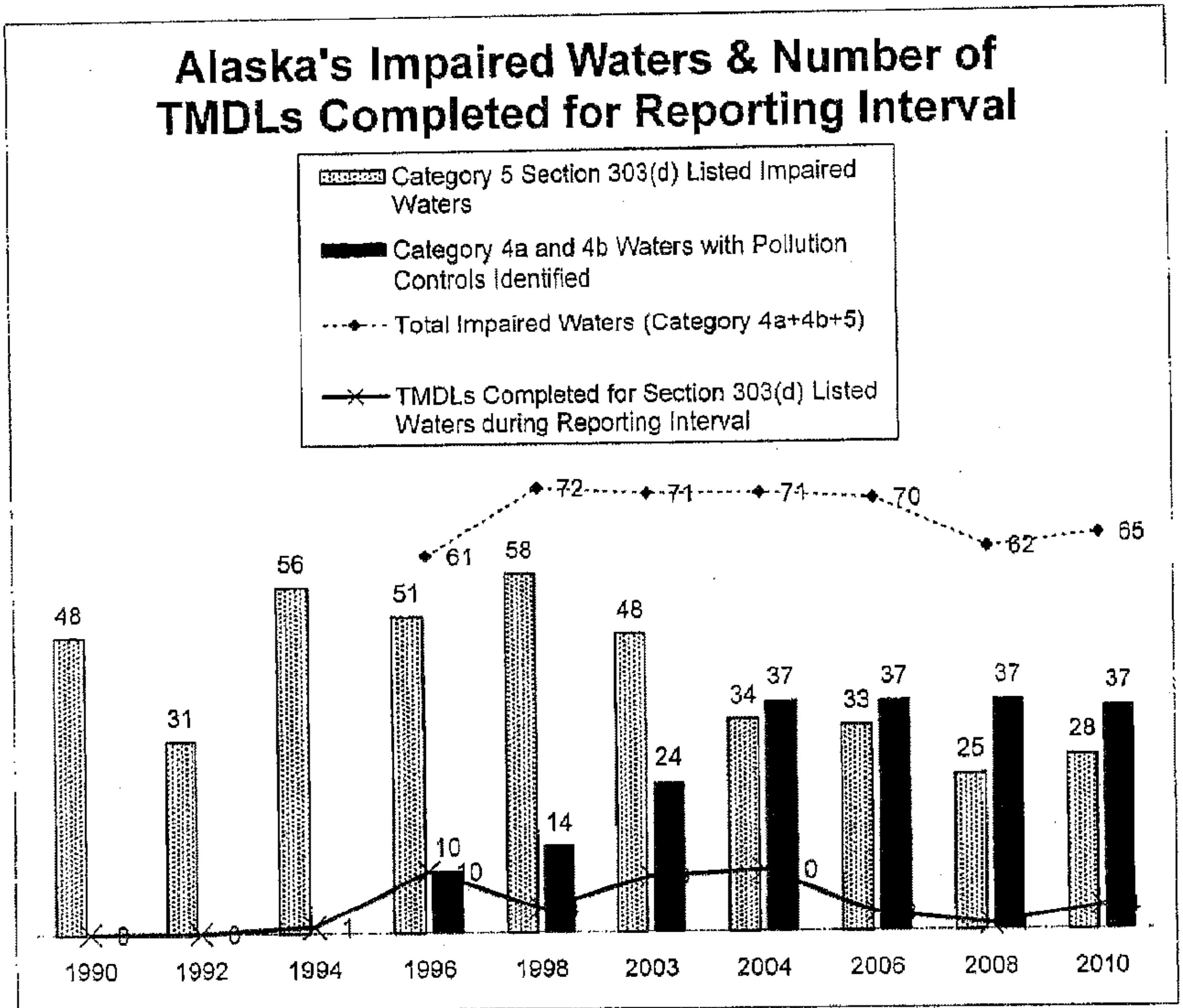

Figure 1 **Alaska's Impaired Waters & Number of TMDLs Completed for Reporting Interval**

Significant Changes from Alaska's 2008 Integrated Water Quality Assessment Report

This 2010 Integrated Report documents the following water quality impairment changes from the 2008 Integrated Report:

- Addition of nine new impairments to the Section 303(d) list of impaired waters (Category 5):
  - Coffman Cove Creeks – consisting of five creeks, impaired from cadmium, copper, iron, manganese, nickel, and zinc.
  - Cottonwood Creek –7 miles of the creek impaired from FC bacteria.
  - Kuskokwim River – 1000 feet of the river near confluence with Red Devil Creek impaired from antimony, arsenic, and mercury.
  - Red Devil Creek – 0.5 miles of the creek impaired from antimony, arsenic, and mercury.
  - Salt Chuck Bay – impaired from copper

- Five waters now attaining WQS:
  - Caribou Creek – The water is meeting the turbidity standard.
  - Iliuliuk Bay – The water is meeting the petroleum hydrocarbons standard.
  - Jewel Lake – The water is meeting the FC bacteria standard.
  - Kenai River – The water is meeting the petroleum hydrocarbons standard.
  - Nakwasina River – The water is meeting the turbidity and sediment standards.
- Four impaired waters now under a plan:
  - Jordan Creek – A TMDL has been developed for sediment and dissolved oxygen (DO).
  - Klag Bay – A TMDL has been developed for metals.
  - Noyes Slough – A TMDL has been developed for residues; the waterbody remains impaired from sediment and petroleum hydrocarbons.
  - Pullen Creek – A TMDL has been developed for metals.
- Six modifications of waters with impairments:
  - Cottonwood Creek – This water is no longer impaired from residues; however, 7 miles of the creek are being listed for FC bacteria.
  - Chena River – This water is no longer impaired from petroleum hydrocarbons; it remains listed for sediment.
  - Chena Slough – This water is no longer impaired from petroleum hydrocarbons; it remains listed for sediment
  - Dutch Harbor – Most of the water has been found to be meeting WQS, but areas of impairment still exist.
  - Hood/Spenard Lakes – This water is no longer impaired from FC bacteria; it remains impaired from low DO.
  - Ward Cove – This water is no longer impaired from sediment toxicity; it remains impaired for residues.

New listing and assessment methodology has been proposed for pathogens. No impairment determinations based on this new methodology were made in this 2010 report. The new listing and assessment methodology proposed for pathogens does not change the FC bacteria standard within Alaska's WQS (in 18 AAC 70); however, it does provide direction for implementing the standard when making water quality attainment or impairment determinations.

Other broader changes reflected in the 2010 report include the following:

- Six new waterbodies are reported in Category 3 because waters were added to the DEC water quality assessment database, which now identifies 303 Category 3 waterbodies.
- Narratives were updated based on existing and readily available information. Updates to Category 4a waterbody narratives were completed to describe development of TMDLs.
- ACWA waterbody priority rankings are included in Appendix H.
- Some descriptions of water quality management programs were updated in Appendix F.

Public Process Overview

DEC has an open, ongoing solicitation for water quality data and information. To solicit ACWA waterbody nominations, DEC coordinates a continuous effort among state resource agencies. During the preparation and development of Alaska's 2010 Integrated Report, DEC actively solicited readily available and existing water quality data and information for use in preparing the report.

DEC posted a public notice solicitation for existing and readily available water quality data and information from August 3 to September 18, 2009. A 30-day public review and comment of the draft 2010 Integrated Report was provided from February 26, 2010, to March 30, 2010.

DEC considered public comments on the public notice draft of the report and made necessary changes to the final report. DEC prepared a responsiveness summary on the public comments received on the draft report and information received during the solicitation.

PC 472

Group 3

Committee of the Whole

Kenai River Early Run King Salmon Management Plan

Proposals 190, 186-189, 191-194, 196

Supporting Documents:

Proposals:

190 – Oppose – Many of the "so-called" Early Run Kings are actually "Late Run" main stem spawners that belong to the Late Run. Early run escapement numbers are inflated due to counting Late Run as Early Run Kings.

- The Early Run is much smaller (1,000) than reported due to Late Run Kings being counted as Early Run Kings
- This proposal will overharvest Early Run Kings
- Any harvest areas, if at all, might occur below Slikok Creek

186 – Oppose

- Targets large females
- Catch & Release effects on spawning needs to be realistic
- Cured eggs issue resolved

187 – ?

188 – Support

189 – ?

191 – ?

192 –

193 –

194 – Support – Amend to only one King above 28 inches can be retained until the middle of the escapement goal is reached

196 – Oppose – Amend to "thru July 15^{th}"

Group 4

Committee of the Whole

Kenai River Early and Late Run King Salmon Sport Fishery

Proposals 195, 197-206, 219-228

Supporting Documents:

- Consequences of acute stress and cortisol manipulation on the physiology, behavior, and reproductive outcome of female Pacific salmon on spawning grounds
- A King Without a Crown: Chinook Vulnerable to Ocean Forces – Morris Communications
- Effect of Commercially Available Egg Cures on the Survival of Juvenile Salmonids (RC)
- The Fates and Impact on Spawning Salmon as a Result of Catch/Hook and Release Practices (RC)

Three Issues:

1. Skewed Sex Rations
2. Late-Run Kings being counted as Early Run Kings in the Kenai River
3. Catch & Release effects on Spawning

Early Run & Late Run Sport Fishery

Proposals 195, 197 thru 206

195 – Support – No retention of female Chinook greater than 30 inches until sex ratio are appropriate

197 – Oppose – Currently, there is a skewed sex ratio in Chinook greater than 30 inches. This proposal will target large, greater than 30 inch, females.

198 – Oppose – Doesn't address skewed sex ratios

199 – Oppose – Below escapement levels, skewed sex ratios

200 – ? – Doesn't address skewed sex ratios

201 – Oppose – Bait must be non-poisonous, doesn't include Early run spawning, Early Run peak spawn is July 17th

202 – Support

203 – ? –

204 – ? – No action needed if Kenai River above Slikok Creek is closed to King fishing

205 – ? – Attractive. Need to prevent targeting of large females while catching less than 30 inch male Chinook

206 – Support in Concept – However, closed areas may not be adequate to protect Early Run Kings. Doesn't address skewed sex ratios

Kenai River Late Run King Salmon Sport Fishery

Proposals 219-228

219 – Support in Concept

220 – Support in Concept – Questionable management strategies? Is it enforceable? Or does it need modification?

221 – Support in Concept – Concerned about being able to identify Chinook spawning areas year to year. Modify or Amend

222 – Support in Concept – Establish in regulation what constitutes "legal cured eggs." It may be easier to describe "air" and "sea salt" egg cures instead of trying to list all the "poisonous substances" that cannot be used to cure eggs. Commercial preparations and home recipes are a nightmare of poisons (WD-40, oil, all types of salt). The poisoning of small fish birds and aquatic organisms occurs. "Best Practices" is insufficient. Prohibiting the use of poisonous baits is one of many right steps that can and should occur.

223 – Support in Concept – If this proposal is to use hooks that facilitate the easy and quick release of a fish, then this also is a step in the right direction.

224 – ? – Prefer no bait. However, this may reduce the catch and release effect on spawning and doesn't address "playing or hooking" time. Salmon have poorly developed circulatory systems and when playing or hooking time exceeds a few minutes, lactic acids develop in the tissues. When released, this lactic acid leaves

muscles entering eggs (reproductive gametes) resulting in egg mortality to some degree.

225 – Oppose – More of the less than 28-30 inch Kings need to be harvested. Kings above 30 inches, especially large females, need total conservation for a few (3-6) years, especially the Early Run, main stem spawners.

226 – Support – There are just not enough Chinook to accommodate this practice. Modify to harvest small males less than 30 inches?

227 – Support – This is a good idea. Apply this to sockeye and coho fisheries in UCI

228 – ? – Stocking and enhancement are possible management tools. We are concerned that stocking and enhancement could be utilized while forgetting about habitat and other management or regulatory actions.

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Consequences of acute stress and cortisol manipulation on the physiology, behavior, and reproductive outcome of female Pacific salmon on spawning grounds

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ABSTRACT

Life-history theory predicts that stress responses should be muted to maximize reproductive fitness. Yet, the relationship between stress and reproduction for semelparous salmon is unusual because successfully spawning individuals have elevated plasma cortisol levels. To tease apart the effects of high baseline cortisol levels and stress-induced elevation of cortisol titers, we determined how varying degrees of cortisol elevation (i.e., acute and chronic) affected behavior, reproductive physiology, and reproductive success of adult female pink salmon (*Oncorhynchus gorbuscha*) relative to different states of ovulation (i.e., ripe and unripe). Exhaustive exercise and air exposure were applied as acute stressors to manipulate plasma cortisol in salmon either confined to a behavioral arena or free-swimming in a spawning channel. Cortisol (eliciting a cortisol elevation to levels similar to those in post-spawn female salmon) and metyrapone (a corticosteroid synthesis inhibitor) implants were also used to chemically manipulate plasma cortisol. Cortisol implants elevated plasma cortisol, and impaired reproductive success; cortisol-treated fish released fewer eggs and died sooner than fish in other treatment groups. In contrast, acute stressors elevated plasma cortisol and the metyrapone implant suppressed plasma cortisol, but neither treatment significantly altered reproductive success, behavior, or physiology. Our results suggest that acute stressors do not influence behavior or reproductive outcome when experienced upon arrival at spawning grounds. Thus, certain critical aspects of salmonid reproduction can become refractory to various stressful conditions on spawning grounds. However, there is a limit to the ability of these fish to tolerate elevated cortisol levels as revealed by experimental elevation of cortisol.

Introduction

Considerable evidence supports the notion that stress can impair the reproductive outcome of a wide range of vertebrates, including birds (Silverin, 1997; Wingfield, 1988), reptiles (DeNardo and Sinervo, 1994a, 1994b), mammals (Negro-Vilar, 1993; Boonstra et al., 1998), and fish (Pickering et al., 1987; Schreck et al., 2001). The acute stress response and associated elevation of glucocorticoids is believed to be adaptive, while chronic elevation of glucocorticoids can have various negative tertiary effects, including impaired immune function and fitness whenever resources are directed towards an emergency response (Barton and Iwama, 1991; Wingfield et al., 1998; Barton, 2002; Wingfield, 2003) and animals attempt to regain allostasis (Wingfield, 2003; Schreck, 2010). Yet, much of the existing work on chronic stress/glucocorticoid elevation is focused on the long-term consequences for animals during non-reproductive periods rather than immediately before or during reproduction. For example, many toxicological studies demonstrate direct long-term reproductive impairments (e.g., suppression of reproductive hormones) associated with emergency resource reallocation to maintenance and survival (e.g., reviewed in Van Der Kraak et al., 1998; see also Jardine et al., 1996; Janz et al., 1997; Bowron et al., 2009). Furthermore, most of these studies consider iteroparous species (i.e. repeat breeders), which have the life-history option of delaying a reproductive event when challenged.

In contrast, semelparous species usually cannot delay the reproductive event because they invest in reproduction only once in a lifetime. For semelparous fishes such as Pacific salmonids (*Oncorhynchus*

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spp.), some argue that the spawning date is genetically fixed, which implies that it cannot be altered by external stressors (Quinn et al., 2000). Curiously, virtually nothing is known about whether exposing semelparous Pacific salmonids to stress on spawning grounds influences their behavior and reproductive success. Yet, these fish routinely encounter many stressors that trigger a cortisol response as they approach their spawning date, suggesting that the acute stress response remains active during the reproductive period. For example, plasma cortisol rises when fish encounter hydraulic challenges and elevated water temperature during the spawning migration (Hinch et al., 2006; Mathes et al., 2010). Furthermore, a progressive increase in baseline plasma cortisol levels of unknown etiology occurs as salmon swim to the spawning grounds (Robertson and Wexler, 1959; McBride et al., 1986; Tierney et al., 2009; Hruska et al., 2010). Plasma cortisol concentrations rise from ~25 ng ml^{-1} in pink salmon (*O. gorbuscha*) at river entry (McBride et al., 1986), to ~350 ng ml^{-1} on arrival at the spawning ground (female sockeye salmon [*O. nerka*]; Hruska et al., 2010), and ~1287 ng ml^{-1} when the fish become moribund (female sockeye salmon; Hruska et al., 2010). Thus, an acute stressor can elevate plasma cortisol against a background of progressively increasing plasma cortisol levels during the spawning migration.

A stressed state should generally be incompatible with reproduction and, based on life-history theory, one could postulate that the cortisol stress response of semelparous salmon should be muted, or physiologically irrelevant, during this period (Wingfield and Sapolsky, 2003) to mitigate any potential negative effects of cortisol elevation above the (high) baseline levels on spawning grounds. Thus, we postulate that reproductive drive in a semelparous salmon species will outweigh any cortisol-mediated mating inhibition. Acute, stress-related increases in plasma cortisol suppress the normal increases in plasma sex hormone concentrations for Pacific salmon during early phases of upriver migration (Dye et al., 1986). However, increases in plasma cortisol during migration are regarded as adaptive and necessary for salmon to be able to return to their natal streams and spawn (Carruth et al., 2002). Complicating matters is the fact that spawning Pacific salmon also undergo senescence, which alters many physiological processes, including hormone regulation (Morbey et al., 2005; Hruska et al., 2007, 2010). To address these issues, we experimentally determined how short-term changes in and experimental manipulation of plasma cortisol influenced the reproductive physiology, behavior, and spawning outcome of wild female pink salmon (*O. gorbuscha*). We administered cortisol implants and predicted that plasma cortisol elevation, lasting between 2 and 5 days, would negatively affect reproductive behavior (e.g., less time spent guarding eggs or fighting for a mate), physiology (i.e., suppression of reproductive hormones), and outcome (i.e., number of eggs released). We also predicted that the response to acute stressors (i.e., exhaustive exercise or air exposure) would be muted in semelparous salmon and would not alter these same responses. Conversely, an intraperitoneal (IP) implant of metyrapone, which blocks the last step of glucocorticoid synthesis, was expected to lower plasma cortisol levels (Doyon et al., 2006) and retard reproduction and senescence. To our knowledge, hormone manipulations of this type had not before been performed on senescing Pacific salmon.

Materials and methods

Metyrapone validation

All fish were handled in accordance with the guidelines of the Canadian Council on Animal Care (Carleton University, B09-12; University of Ottawa, BL-228). A pilot laboratory experiment was carried out to determine the effectiveness of metyrapone (2-methyl-1, 2-di-3-pyridyl-1-propanone; Sigma 85625, Sigma-Aldrich) at blocking cortisol synthesis when delivered in a cocoa butter implant. Metyrapone successfully blocks cortisol synthesis in fish in the short-term (<24 h: e.g., Hopkins et al., 1995; Milligan, 2003; Rodela et al., 2009), but has rarely been used with a cocoa butter carrier (but see Doyon et al., 2006). Rainbow trout (*O. mykiss*), a congeneric of pink salmon, weighing approximately 150 g were anesthetized with benzocaine (0.05 mg ml^{-1} water; p-aminobenzoic acid ethyl ester; Sigma E1501, Sigma-Aldrich) and given an IP injection of metyrapone mixed in heated liquid cocoa butter (200 mg kg^{-1} fish in 1 ml cocoa butter kg^{-1} fish); upon injection into the fish, the cocoa butter rapidly cools to a thick paste, providing a slow-release metyrapone implant. After 1 and 5 days, fish were subjected to 1 min of air exposure as an acute stressor, and a blood sample was withdrawn by caudal puncture 30 min later for assessment of plasma cortisol levels. The expectation was that this 30-min delay would be sufficient for the maximum or near maximum rise in plasma cortisol level to be manifested (Gilmour et al., 2005).

Weaver Creek spawning channel

All field experiments were conducted at the Weaver Creek spawning channel located in British Columbia, Canada (see Hruska et al., 2010 for detailed information). Each experiment involved groups of naive fish (i.e., fish were not reused among experiments). The artificial channel, 2.93 km long and 6.1 m wide, is composed of a cobble (1.2–7.6 cm) substrate and has a consistent water depth of 25–30 cm. Fish densities and flow conditions were monitored throughout the spawning period and manually operated gates were used to regulate fish movements into the spawning channel (Hruska et al., 2010). Experiments were timed to coincide with peak pink salmon spawning activity in early October 2009.

Reproductive physiology on arrival

On arrival at the spawning channel in early October, female pink salmon were individually removed from the raceway via dip net and immediately placed in a trough supplied with flow-through water from the raceway. Fish were categorized as either "unripe" (N = 52, unovulated, where eggs are still confined to intact ovaries) or "ripe" (N = 60, ovulated, where eggs have been released into the body cavity and gentle abdominal pressure near the vent easily expels eggs) and a blood sample was collected via caudal puncture (2 ml blood sample; collected using 3 ml vacutainer and 1.5 in., 18 ga needle, lithium heparin; Becton Dickson, NJ) within 30 s (Cooke et al., 2006). Within 3 min the fish were released back into the spawning channel. Blood samples were stored in an ice-water slurry and centrifuged (5 min at 10,000 g) within 45 min, after which the plasma was frozen in liquid nitrogen immediately. Samples were subsequently stored at −80 °C until further analysis.

In addition, subsets of ripe (N = 6) and unripe (N = 12) salmon were given an intraperitoneal (IP) injection of either cortisol (hydrocortisone 21-hemisuccinate; Sigma H4881, Sigma-Aldrich; 110 mg kg^{-1} fish in 50 ml melted cocoa butter kg^{-1} fish; Dibattista et al., 2005) to elevate cortisol levels for a short period (i.e., 2 to 5 days), or metyrapone (200 mg kg^{-1} fish; 1 ml cocoa butter kg^{-1} fish) to block glucocorticoid synthesis (Mommsen et al., 1999), before being placed in individual, opaque, experimental chambers (~50 l) situated on the bank of the channel and equipped with flow-through water. Fish were left undisturbed for approximately 24 h, after which they were individually removed and blood was sampled immediately via caudal puncture.

Longevity and reproductive status study

On October 6th and 7th 2009, 120 unripe pink salmon that had voluntarily entered the raceway were marked with unique individual Peterson disk tags placed in the dorsal musculature. The tags could be read on free-swimming fish with binoculars, which allowed the fish to be observed without any disturbances. Fish were randomly assigned to one of six treatment groups (N = 20 per treatment group): a) control fish (only tagged); b) sham injection-controls (tagged and given an IP injection of 50 ml kg^{-1} melted cocoa butter); c) cortisol-treated (as described above); d) metyrapone-treated (as described above); e) chased (acutely stressed by 3-min of being "chased" by hand around a circular tank supplied with flow-through channel water); and f) air-exposed (as in (e), followed by 1 min of air exposure to increase the severity of the acute stressor). Afterwards, fish were immediately released into the spawning channel and closely monitored during daylight hours so that moribund or dead fish could be collected daily.

Longevity in the spawning channel following release (i.e. time until death after arrival) was calculated using the methods outlined in Hruska et al. (2010). Fork length, total mass, gonad mass, epidermal coverage by fungus, and general condition also were documented. Reproductive status was reported as the percentage (%) of eggs released by each individual. The relationship between percentage of eggs remaining relative to percentage of eggs initially expected was determined following the methods of Hruska et al. (2010). Briefly, the anticipated initial gonad mass was determined from a known relationship between body mass and gonad mass established for a separate group of mature, unripe pink salmon sampled from the spawning channel (N = 21; gonad mass = 10.1 · body mass − 297.9, R^2 = 0.80, P = 0.005). Eggs were weighed and counted in whole ovaries and a linear body mass to fork length relationship, together with a linear fork length to gonad mass relationship, was used to interpolate the expected egg mass before ovulation for the experimental fish. Many fish had spawned all of their eggs (100% success), but any eggs remaining were weighed first as five groups of 10 eggs, with any eggs remaining thereafter being weighed collectively. Individual egg mass is known to be uniform within an individual (D. Patterson, personal communication), and so this method provided an accurate estimate of the number of eggs retained by each fish without having to count every egg.

Spawning behavior in enclosures

Behaviors were studied in unripe and ripe salmon held in enclosures that had been constructed within the spawning channel. A blood sample (as described above) was withdrawn from 30 salmon (6 treatment groups as above; N = 5 for each treatment group) in the raceway before placing them in a holding tank for transfer to a section of the spawning channel that housed a net-pen (2 m wide by 15 m long; constructed out of Vexar rigid mesh fencing; Masternet, Mississauga, Ontario). Fish were treated according to their experimental group before being placed into the enclosure. Twenty "ripe" male pink salmon (i.e. males that released sperm when squeezed gently near the vent) had been placed into the net-pen 12 h earlier. Fewer males were placed in the pen than females to facilitate competition among females. Two trials were completed for unripe salmon in early October 2009, and two trials were completed for ripe fish in late October 2009.

Behavioral observations were carried out for 10 min daily on four consecutive days. The order of observing each fish was randomized daily. Reproductive behaviors of pink salmon are well known, and are similar to behaviors displayed by other semelparous Pacific salmon (Heard, 1991; Mehranvar et al., 2004). Females prepare their nesting area, fend off intruders from their territory through aggressive action, and spend time with males to ensure fertilization occurs. We recorded on what day fish established a territory, how much time the fish spent holding that territory (represented as a percent, averaged over days on territory), what percentage of their time females spent with males (averaged across days on an established territory), the number of nest construction digging behaviors that occurred (averaged across days spent on a territory), how many times a fish made an aggressive display towards a conspecific, and how many times that fish was on the receiving end of an aggressive act (both were summed and divided by total observation minutes, and aggression received was subtracted from aggression given to yield an overall aggression score). The daily duration of behavioral observations on each fish (i.e., 10 min) was consistent with other studies (Cook et al., 2011) and is believed to be representative of longer time periods given the reasonable predictability and stability of behavioral repertoires for this species. After 4 days, the fish were collectively culled in a process lasting < 10 min; fish were killed by cerebral percussion. After immediate blood sampling, the percentage of eggs released was estimated (as described above).

Plasma analysis

Plasma glucose and cortisol concentrations were measured as indicators of stress (Farrell et al., 2001a, 2001b). Briefly, plasma glucose values were determined using a YSI 2300 STAT Plus glucose analyzer (YSI Inc., Yellow Springs, Ohio). Plasma cortisol levels were measured using a commercial ELISA kit (Neogen Corporation # 402710, Lexington KY). For cortisol, the assay has 47% cross-reactivity with the drug prednisolone, which would not be present in the samples.

The assay also has ~15% cross-reactivity with cortisone and 11-deoxycortisol. The analytical sensitivity (B/B_0, 80%) for the cortisol assay was at 0.04 ng ml^{-1}. Testosterone and 17β-estradiol are both major reproductive hormones and plasma concentrations of these hormones also were measured by ELISA kits (Neogen Corporation, www.neogen.com, catalog numbers: 402110, 402510). Testosterone and 17β-estradiol were extracted from plasma samples using ethyl ether according to the kit manufacturer's protocols. The assay manufacturer states that the estradiol assay does not cross-react with any other estrogens. Analytical sensitivity (B/B_0, 80%) was at 0.03 ng ml^{-1}. According to the manufacturer, the testosterone assay is 100% cross-reactive with dihydrotestosterone and the analytical sensitivity (B/B_0, 80%) was at 0.006 ng ml^{-1}. Cortisol, glucose, testosterone, and 17β-estradiol were assayed in duplicate at appropriate dilutions. Inter- and intra-assay variability was < 10% for all assays. More detailed descriptions of the analytical techniques can be found in Farrell et al. (2001a, 2001b).

Statistical analysis

Results from the metyrapone pilot study were analyzed using a two-way analysis of variance (ANOVA) to determine whether cortisol values varied by treatment and time. Results from the cortisol and metyrapone validation study before and after 24 h were compared using two-way repeated measures ANOVA models with time and treatment as effects. For the channel experiment, longevity among treatment groups was compared using a log-rank survival analysis to 50% mortality. The percentage of eggs released by each fish was averaged within groups and compared using a one-way ANOVA. For the enclosure experiments, all hormone and blood physiology values and behavioral metrics were compared before and after 4 days using two-way repeated measures ANOVA models with time and treatment being the independent variables. Time until territory establishment was determined using log-rank survival analyses. The percentage of eggs released by each fish was averaged for each treatment group and compared using a one-way ANOVA. Tukey's post-hoc tests were employed following significant one-way ANOVAs to determine differences among groups (where $p < 0.05$). The assumptions of equality of variances and normal distribution were tested for all analyses and relevant transformations applied where assumptions could not be met. Percentage data were arcsine transformed prior to analysis. Where transformation of the data was not possible or effective, non-parametric analyses were performed. All analyses were conducted using JMP, version 8.0.2 (SAS Institute Inc., Cary, NC). The level of significance (α) for all tests was assessed at 0.05. All data are presented as mean ± standard error unless otherwise noted.

Results

Effectiveness of metyrapone

Metyrapone-treated rainbow trout subjected to an acute stressor exhibited significantly lower plasma cortisol concentrations than sham-treated fish 1 day following treatment (two-way ANOVA Time effect: $F = 7.8$, $df = 1$, $p = 0.02$; Fig. 1), but not after 5 days (Treatment effect: $F = 3.1$, $df = 1$, $p = 0.1$; Interaction: $F = 4.7$, $df = 3$, $p = 0.03$; Fig. 1). Therefore, we assumed that pink salmon would experience a short-term depression of plasma cortisol during acute stress (i.e., for at least 24 h but not as long as 5 days) and used cocoa butter as a vehicle for metyrapone delivery.

Raceway blood physiology and hormone validations

Reproductive hormone titers were indicative of whether pink salmon in the spawning channel were ripe or unripe (Dye et al., 1986; Table 1). Plasma estradiol and testosterone were both significantly lower in ripe fish (estradiol: $F = 70$, $df = 1$, $p < 0.001$; testosterone: $F = 25$, $df = 1$, $p < 0.001$; Table 1). However, plasma cortisol concentrations were similar (one-way ANOVA, $F = 0.31$, $df = 1$, $p = 0.6$; Table 1) and plasma glucose concentrations were higher in ripe fish (one-way ANOVA, $F = 13$, $df = 1$, $p < 0.001$; Table 1) for arriving pink salmon.

For unripe fish held in isolation chambers, cortisol implants significantly elevated plasma cortisol by 10-fold, but metyrapone implants had no effect on circulating cortisol levels after 24 h (two-way repeated-measures ANOVA: Treatment effect: $F = 55$, $df = 1$, $p < 0.001$; Time: $F = 70$, $df = 1$, $p < 0.001$; Interaction: $F = 15$, $df = 3$, $p < 0.001$; Fig. 2A). Plasma glucose was unchanged 24 h after either treatment (Treatment effect: $F = 0.69$, $df = 1$, $p = 0.4$; Time: $F = 0.90$, $df = 1$, $p = 0.4$; Interaction: $F = 0.39$, $df = 3$, $p = 0.9$; Fig. 2B). Plasma concentrations of both estradiol (Treatment effect: $F = 0.8$, $df = 1$, $p = 0.8$; Time: $F = 8.5$, $df = 1$, $p = 0.02$; Interaction: $F = 1.5$, $df = 3$, $p = 0.3$; Fig. 2C) and testosterone (Treatment effect: $F = 0.13$, $df = 1$, $p = 0.7$; Time: $F = 5.7$, $df = 1$, $p = 0.04$; Interaction: $F = 1.7$, $df = 3$, $p = 0.2$; Fig. 2D) decreased 24 h after either treatment.

For ripe fish held in isolation chambers, the cortisol implant again increased plasma cortisol values, but the response was attenuated compared with that of unripe fish (Fig. 2E). Plasma cortisol concentration was not affected by the metyrapone implant (two-way repeated-measures ANOVA: Treatment effect: $F = 1.0$, $df = 1$, $p < 0.001$; Time: $F = 34$, $df = 1$, $p < 0.001$; Interaction: $F = 5.4$, $df = 3$, $p < 0.001$; Fig. 2E). Plasma glucose values increased 24 h after either treatment (Treatment effect: $F = 5.1$, $df = 1$, $p = 0.3$; Time: $F = 6.8$, $df = 1$, $p = 0.02$; Interaction: $F = 2.2$, $df = 3$, $p = 0.03$; Fig. 2F). Estradiol was unaffected by either treatment (Treatment effect: $F = 0.69$, $df = 1$, $p = 0.4$; Time: $F = 0.90$, $df = 1$,

Table 1
Initial blood hormone and glucose values of ripe and unripe pink salmon (*Oncorhynchus gorbuscha*) removed from the Weaver Creek raceway in October, 2009, presented as mean (±SE). $N = 52$ for unripe fish and $N = 60$ for ripe fish. All data were analyzed using the Wilcoxon Rank-Sum Test, except for cortisol (*), which was analyzed using log-transformed data in a one-way ANOVA.

Variable	Unripe	Ripe	Statistics	
			Statistic	P-value
Glucose (mmol l^{-1})	$4.6^B \pm 0.18$	$5.7^A \pm 0.17$	13.0	<0.001
Cortisol (ng ml^{-1})*	338 ± 21	297 ± 21	0.310	0.579
Estradiol (ng ml^{-1})	$4.5^A \pm 0.3$	$0.28^B \pm 0.3$	70.4	<0.001
Testosterone (ng ml^{-1})	$150^A \pm 13$	$63^B \pm 12$	24.8	<0.001

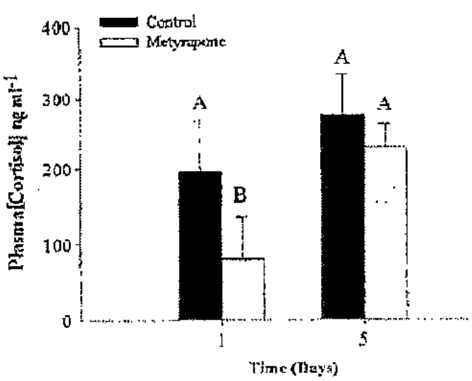

Fig. 1. Mean (±SE) cortisol values for control and metyrapone-treated rainbow trout (*Oncorhynchus mykiss*) subjected to an air-exposure stressor either 1 or 5 days after treatment with metyrapone. Data were log-transformed and analyzed using a two-way ANOVA. Dissimilar letters denote a significant difference between treatment groups and/or time periods (Tukey–Kramer HSD test, $p < 0.05$). Sample sizes are as follows: 1 day: control = 2, metyrapone = 5. 5 days: control = 4, metyrapone = 4.

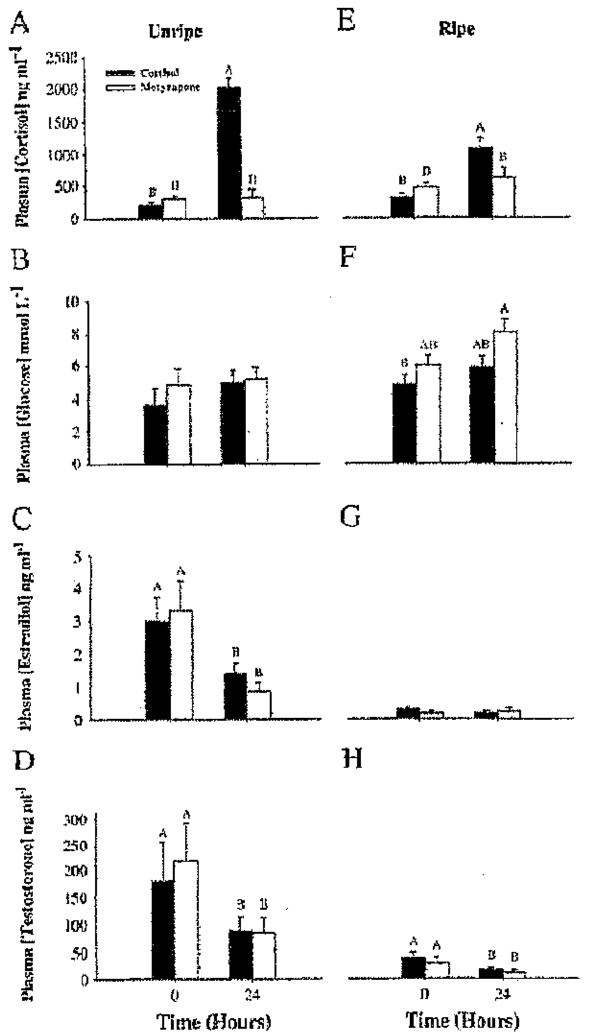

Fig. 2. A–H. Summary of pink salmon (*Oncorhynchus gorbuscha*) plasma hormone and glucose values for unripe (A–D) and ripe (E–H) fish both before and 24 h after treatment with cortisol or metyrapone. Values are stated as mean (±SE). Dissimilar letters denote significant differences among treatment groups and time periods (Tukey–Kramer HSD test, $p < 0.05$). $N = 6$ for each treatment for unripe fish; $N = 12$ for ripe fish. All Ranked Sum data were analyzed using a two-way repeated-measures ANOVA, with time and treatment as independent variables.

p = 0.4; Interaction: F = 1.2, df = 3, p = 0.3; Fig. 2G). Plasma testosterone was decreased 24 h after both treatments (Treatment effect: F = 0.83, df = 1, p = 0.4; Time: F = 21, df = 1, p < 0.001; Interaction: F = 0.27, df = 3, p = 0.6; Fig. 2H).

Longevity and reproductive study

Pink salmon treated with cortisol exhibited reduced longevity relative to all other treatment groups (log-rank survival time to 50% mortality; $\chi^2 = 13.1$, df = 5, p = 0.02; Fig. 3). Cortisol-treated fish also released fewer eggs during their time in the channel compared with all other treatment groups except the sham group [47% for cortisol-injected; 69% for sham-treated; > 85% for all other groups (one-way ANOVA, F = 13, df = 5, p < 0.001; Fig. 4)].

Enclosure experiment: reproductive status

Treatment with cortisol, metyrapone or acute stress did not influence the extent to which fish ripened during the experiment (Fig. 5A). For those fish that did ripen during the enclosure experiment, differences in egg release (%) were observed (Wilcoxon Rank Sum; $\chi^2 = 11.2$, df = 5, p = 0.04; Fig. 5B). Control and chased fish released more than 80% of their eggs, chase + 1 min air exposure and cortisol-treated fish released approximately 50% of their eggs, and metyrapone and sham-treated fish released the fewest eggs (< 10%). For ripe fish, there were no statistically significant differences in egg release among treatment groups (data not shown). However, cortisol-treated fish released ~50% of their eggs, whereas all other treatment groups released > 70% of their eggs.

Enclosure experiment: hormone profiles

Among unripe fish, cortisol-treated fish exhibited elevated cortisol concentrations 4 days following treatment (two-way repeated-measures ANOVA: Treatment effect: F = 4.6, df = 1, p = 0.002; Time: F = 0.4, df = 1, p = 0.9; Interaction: F = 2.5, df = 5, p = 0.04; Fig. 6A). Plasma glucose concentration increased in all fish during the 4 day experiment (Treatment effect: F = 0.7, df = 1, p = 0.6; Time: F = 15.6, df = 1, p < 0.001; Interaction: F = 0.6, df = 5, p = 0.7; Fig. 6B). Plasma estradiol levels decreased (Treatment effect: F = 0.5, df = 1, p = 0.8; Time: F = 72, df = 1, p < 0.001; Interaction: F = 0.6, df = 5, p = 0.7; Fig. 6C), whereas plasma testosterone concentrations remained unchanged over the 4 day experimentation period (Treatment effect: F = 1.1, df = 1, p = 0.4; Time: F = 3.3, df = 1, p = 0.08; Interaction: F = 0.3, df = 5, p = 0.9; Fig. 6D).

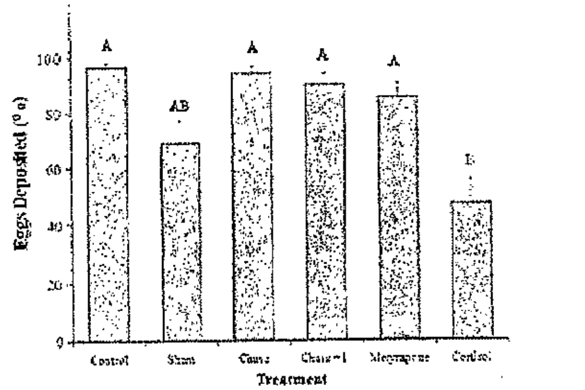

Fig. 4. A comparison across treatment groups (see text for details of treatment groups) of the percentage (%) of total possible eggs deposited by pink salmon (*Oncorhynchus gorbuscha*) in the Weaver Creek spawning channel during early October, 2009. All data were transformed into ArcSine (square root) values before analysis. Sample sizes were as follows; chase and control = 20, cortisol = 18, chase + 1 min air exposure and metyrapone = 17 and sham = 14. Dissimilar letters denote significant differences among treatment groups (Tukey–Kramer HSD test, p < 0.05).

For ripe fish, plasma cortisol levels varied across treatment groups after 4 days (Fig. 6E). Control fish exhibited the highest levels (1756 ± 274 ng ml^{-1}), and cortisol-treated fish displayed similar concentrations (averaging 1592 ± 207 ng ml^{-1}). Values were similar among sham-treated (1118 ± 211 ng ml^{-1}), chased fish (846 ± 289 ng ml^{-1}), and chased + 1 (757 ± 186 ng ml^{-1}) fish, whereas the lowest value (577 ± 193 ng ml^{-1}) was observed in metyrapone-treated fish (two-way repeated-measures ANOVA: Treatment effect: F = 2.7, df = 1, p = 0.03; Time: F = 55, df = 1, p < 0.001; Interaction: F = 3.2, df = 5, p = 0.01; Fig. 6E). Plasma glucose concentrations increased during the 4 day period, across treatments (Treatment effect: F = 1.7, df = 1, p = 0.1; Time: F = 5.4, df = 1, p = 0.02; Interaction: F = 0.93, df = 5, p = 0.5; Fig. 6F). Plasma estradiol levels were low and did not change (Treatment effect: F = 1.2, df = 1, p = 0.3; Time: F = 2.5, df = 1, p = 0.1; Interaction: F = 0.7, df = 5, p = 0.6; Fig. 6G), whereas plasma testosterone concentrations decreased after 4 days (Treatment effect: F = 0.4, df = 1, p = 0.8; Time: F = 91, df = 1, p < 0.001; Interaction: F = 0.2, df = 5, p = 0.9; Fig. 6H).

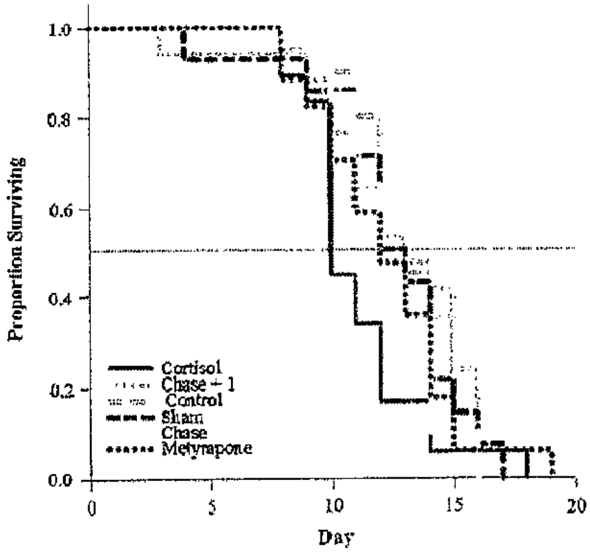

Fig. 3. Log-rank survival analysis to 50% mortality in each treatment group (see text for details of treatment groups), comparing longevity among pink salmon (*Oncorhynchus gorbuscha*) in the Weaver Creek spawning channel. Sample sizes were as follows; chase and control = 20, cortisol = 18, chase + 1 and metyrapone = 17 and sham = 14.

Enclosure experiment: behavior observations

Among unripe fish, treatment did not influence the rate of territory establishment (log-rank survival analysis; $\chi^2 = 2.4$, df = 5, p = 0.8). Based on behavioral observations for fish on territories, cortisol-treated fish spent ~10% less time holding their territory compared with controls (one-way ANOVA: F = 12, df = 5, p = 0.03; Table 2). Additionally, cortisol-treated fish were less aggressive and experienced more aggressive acts by conspecifics (F = 13, df = 5, p = 0.04; Table 2). Among ripe fish, no differences were noted for territory establishment (log-rank survival analysis; $\chi^2 = 4.0$, df = 5, p = 0.5). In addition, no behavioral differences were observed among the treatments groups (Table 3).

Discussion

By experimentally elevating plasma cortisol in unripe fish for between 2 and 5 days with a cortisol in cocoa butter implant, we negatively impacted the longevity, reproductive behavior, and reproductive

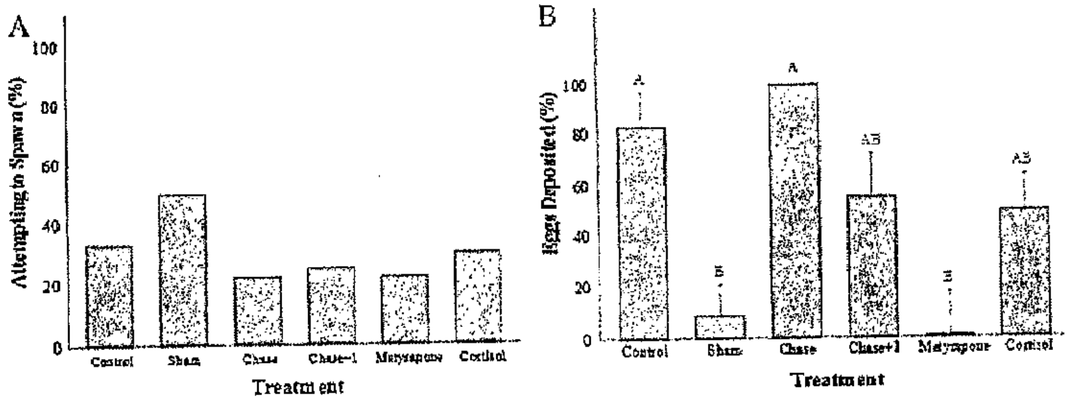

Fig. 5. (A and B). Figure A presents the percentage of pink salmon (*Oncorhynchus gorbuscha*) that became ripe during the behavior trials and thus were able to spawn during the enclosure experiment. Figure B presents the percentage of total eggs available (%) that were deposited during the 4 day trials by ripened fish across treatment groups. Sample sizes were as follows: chase = 1/9, chase + 1 = 2/8, control = 3/9, cortisol = 3/10, metyrapone = 2/9, sham = 4/8. All data were transformed into ArcSine (square root) values before being analyzed. Dissimilar letters denote significant differences among treatment groups (Tukey–Kramer HSD test, $p<0.05$).

outcome of pink salmon on their spawning grounds. Conversely, acute stressors that also presumably elevated plasma cortisol, namely exercise and air exposure, did not affect reproductive outcomes in either ripe or unripe fish. These results demonstrate that a sustained elevation of plasma cortisol carries significant reproductive costs for semelparous salmon on their spawning grounds (despite their high baseline cortisol levels), but that temporary elevations may not. In an ecologically relevant context, events that could elicit a prolonged stress response that might last 2–5 days include periods of high water temperature (Mathes et al., 2010), seasonally high (or low) river discharge (Rand et al., 2006), river obstructions or regions that are hydraulically complex (Hinch and Bratty, 2000), or disease (Wagner et al., 2005). In contrast, very short-term stressors, which might include fisheries interactions, failed predation events, and antagonistic interactions with conspecifics just prior to or during spawning may result in fewer effects on reproduction.

Cortisol manipulation and reproductive hormones

In a variety of fish species, elevation of glucocorticoids results in decreased reproductive hormone concentrations (see review by Barton and Iwama, 1991), which in iteroparous fish can lead to a postponed reproductive event. Additionally, a stressful reproductive environment (e.g., fish exposed to bleached kraft pulp mill effluent) negatively impacts reproductive fitness in various ways (Jardine et al., 1996; Janz et al., 1997; Bowron et al., 2009). In semelparous Pacific salmon exposed to a natural hydraulic challenge during their reproductive migration up the Fraser River system in BC (at the Hell's Gate fishway, Hinch et al., 2006; in the Thompson Canyon, BC, Young et al., 2006), reproductive hormone titers (i.e., 11-ketotestosterone, estradiol and testosterone) fall dramatically while cortisol levels increase. Further upstream, where the river is less challenging and perhaps less than 1 day later in the migration, baseline values of cortisol are restored (~100 ng ml^{-1}) and reproductive hormones return to their elevated levels (Hinch et al., 2006). Yet prior to the present study, the potential interactions between cortisol and reproductive hormone oscillations had not been investigated in terms of impacts on behavior at spawning grounds and reproduction for a semelparous species. The raceway blood profiles and hormone validation data collected in the present study indicated that, even though cortisol titers in cortisol-treated fish were increased to levels observed in senescing salmon (Stein-Behrens and Sapolsky, 1992; Barry et al., 2010; Hruska et al., 2010), cortisol treatment did not alter reproductive hormone titers in either unripe or ripe fish.

It is important to recognize that the experimental elevation of cortisol titers with IP implants is not itself a stress response, but instead results in elevated cortisol that is consistent with a stress response. Nonetheless, collectively these data are consistent with the notion that semelparous salmon may be resilient to the effects of stress hormones during the final phases of reproduction (Wingfield and Sapolsky, 2003). However, in the case of Pacific salmon, it is unclear when such a transition takes place during the migration. In main-stream riverine habitats, fish mount a cortisol response to a stressor and cortisol does, indeed, result in suppression of reproductive hormone titers (Hinch et al., 2006; Young et al., 2006). Yet, our data indicate that, upon arrival at spawning grounds, reproductive hormones are not altered by either certain acute stressors that are expected to elevate plasma cortisol levels (see below) or experimental cortisol manipulation. Because we did not observe any differences between ripe and unripe fish with respect to the influence of cortisol elevation on hormone titers, the onset of resistance to elevated cortisol appears to occur prior to ovulation, a point that warrants investigation in a further study. The transition may be associated with the decline from stable levels of reproductive hormones as the fish move into an ovulated state. During ovulation, there is a critical need to increase 17α-hydroxy-20 β-dihydroprogesterone (17α, 20β-P) to complete reproduction (Dye et al., 1986) because this hormone induces sexual maturation necessary for the ovulation process, whereas estradiol and testosterone mediate maturation and ovulation (Goetz, 1983; Mishra and Joy, 2006).

Channel longevity and reproductive success

Cortisol-treated fish exhibited decreased longevity and high egg retention during the channel experiment, despite our finding that cortisol treatment did not change reproductive hormone titers. Therefore, chronic cortisol elevation on spawning grounds negatively influences reproductive function and success. Even though egg release by metyrapone- and sham-treated fish during the unripe enclosure experiment was reduced when compared to other treatment groups, overall these fish still released the majority of their eggs and longevity was comparable to control groups. As such, even if the cocoa butter implant did prevent some egg release in the sham, cortisol, and metyrapone treatments (see discussion below), the existence of differences among these treatments lends support to the notion that the driver of the differences was of a physiological nature rather than an artifact of the use of cocoa butter.

This suite of findings is particularly important because fisheries managers are concerned with the largely unexplained phenomenon of "pre-spawn mortality"—fish that die on spawning grounds either without spawning or with significant egg retention (Quinn et al., 2000). The eggs of such fishes are often still viable (Tierney et al., 2009), so it appears that other factors are inhibiting reproductive behavior and/or are advancing senescence. In a study of sockeye salmon

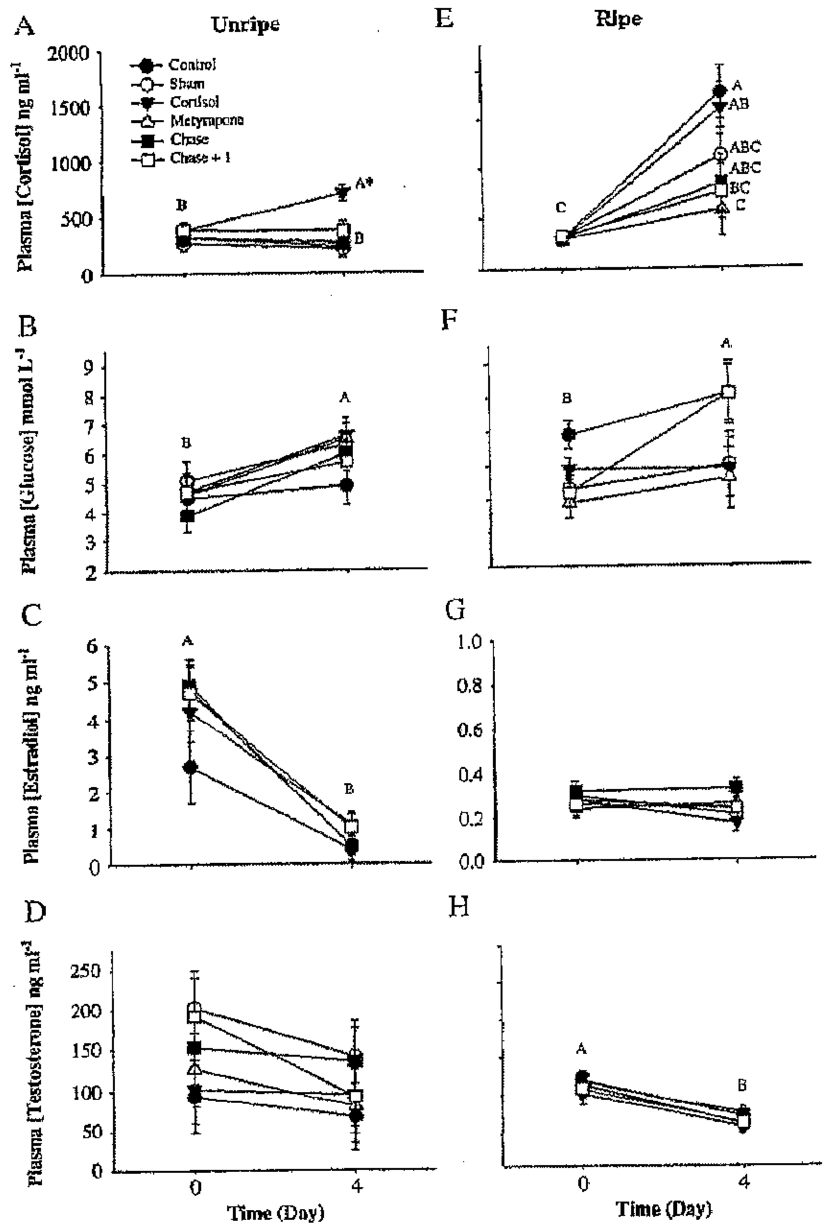

Fig. 6. (A–H). Blood hormone and glucose values of unripe (A–D) and ripe (E–H) pink salmon (*Oncorhynchus gorbuscha*) before experimentation and 4 days after treatment (see text for treatment details), stated as mean values (±SE). All Ranked Sum data were analyzed using two-way, repeated-measures ANOVAs with time and treatment as the independent variables. Dissimilar letters denote significant differences among treatment groups and time periods (Tukey–Kramer HSD test, $p<0.05$). Sample sizes were as follows for unripe fish: before: cortisol = 10, control, chase and metyrapone = 9, chase + 1 and sham = 8. After: cortisol = 10, chase and control = 9, chase + 1, sham and metyrapone = 8. Sample sizes were as follows for ripe fish: $N=10$ for all groups except for the "after" chase group where $N=9$.

Table 2

Pink salmon (*Oncorhynchus gorbuscha*) behavior profiles for unripe fish during 4 day trials; values are stated as mean (±SE). All data were analyzed using Wilcoxon Rank-Sum tests, and Tukey's HSD test was used to determine where differences lay when a significant effect was obtained (noted by letter scores). All data that are expressed as percentages were transformed into ArcSine (square root) values before being analyzed. Data for all variables except the aggression score were averaged over days that fish were on established territories. Aggression scores were added for all days spent on territories and divided by number of observational min. Each fish had a similar score for aggressive attacks against, and this score, divided by number of observational min, was subtracted from the previous value to obtain the overall aggression score. Sample sizes were as follows: chase = 9, control and sham = 7, chase + 1 and cortisol = 6, metyrapone = 5.

Variable	Treatment						Statistics	
	Control	Sham	Cortisol	Metyrapone	Chase	Chase + air	Stat	P-value
% Time on territory	100 ± 3^{A}	97 ± 3^{AB}	89 ± 3^{B}	94 ± 4^{AB}	98 ± 3^{AB}	90 ± 3^{AB}	12	0.03
% Time with male	40 ± 11	29 ± 11	38 ± 12	31 ± 13	37 ± 10	22 ± 12	7.9	0.2
Average # of digs	0.6 ± 0.7	0.7 ± 0.7	2 ± 0.8	0.2 ± 0.7	1 ± 0.7	0.2 ± 0.8	5.0	0.4
Aggression score	0.7 ± 0.2^{A}	0.3 ± 0.2^{AB}	-0.02 ± 0.2^{B}	0.4 ± 0.2^{AB}	0.2 ± 0.2^{AB}	0.1 ± 0.2^{AB}	13	0.04

Table 3
Pink salmon (*Oncorhynchus gorbuscha*) behavior profiles for ripe fish during 4 day trials; values are stated as mean (±SE). All data were analyzed using Wilcoxon Rank-Sum tests and Tukey's HSD test was used to determine where differences lay when a significant effect was obtained (noted by letter scores). All data that are expressed as percentages were transformed into ArcSine (square root) values before being analyzed. Data for all variables except the aggression score were averaged over days that fish were on established territories. Aggression scores were added for all days spent on territories and divided by number of observational min. Each fish had a similar score for aggressive attacks against, and this score, divided by number of observational min was subtracted from the previous value to obtain the overall aggression score. Sample sizes were as follows: metyrapone = 10, sham, cortisol, control and chase + 1 = 9 and chase = 7.

Variable	Treatment						Statistics	
	Control	Sham	Cortisol	Metyrapone	Chase	Chase + Air	Statistic	P-value
% Time on territory	97 ± 2	98 ± 2	97 ± 2	97 ± 2	99 ± 3	100 ± 2	7.8	0.2
% Time with male	45 ± 8	33 ± 8	54 ± 8	47 ± 7	36 ± 9	40 ± 8	4.1	0.5
Average # of digs	2 ± 0.7	1 ± 0.7	2 ± 0.7	2 ± 0.6	1 ± 0.8	2 ± 0.7	2.8	0.7
Aggression score	0.2 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.1 ± 0.1	0.6 ± 0.1	7.2	0.2

at the Weaver Creek spawning channel, Hruska et al. (2010) related mortality to changes in physiological condition and activity levels, providing a baseline of variables that change as Pacific salmon (specifically sockeye salmon) senesce. To complement that work, the present study attempted to identify whether stressful conditions can cause pre-spawn mortality on spawning grounds. It seems plausible that since cortisol treatment in the present study increased cortisol values to those found in senescing fish and at the same time reduced longevity, then the premature mortality we observed was a function of this senescence-like physiological state, a state that was not reached via the imposition of acute stressors, even though exposure to acute stressors was expected to acutely elevate circulating cortisol levels.

Enclosure study

Unripe cortisol-treated fish spent less time on their territory than all other groups. In addition, cortisol-treated fish were significantly less aggressive than fish in the other treatment groups, and were frequently subjected to aggressive attacks from conspecifics. A decrease in aggressiveness is detrimental to reproductive success because a female benefits from guarding its territory from other females looking for suitable habitat, and aggressive behavior is often associated with reproductive success (Heard, 1991; Quinn and Foote, 1994). These results are supported by previous studies that found that cortisol treatment increased the probability of individual fish (rainbow trout in these cases) experiencing increased fin damage indicative of both aggressive attacks (Gregory and Wood, 1999) and becoming socially subordinate (DiBattista et al., 2005; Gilmour et al., 2005). No behavioral differences were detected among treatments for ripe fish. This finding suggests that even in the face of chronically elevated cortisol levels, reproductively mature fish maintain key reproductive behaviors, further supporting the idea that fish with limited reproductive opportunity will still engage in spawning in what would be regarded as extreme situations during other life-history phases.

Metyrapone treatment

Metyrapone inhibits the enzyme 11-β hydroxylase, thereby preventing synthesis of cortisol from 11-deoxycortisol (Mommsen et al., 1999). No significant changes in cortisol titers, reproductive behavior, reproductive success, or hormone levels occurred as a result of metyrapone treatment. Doyon et al. (2006) determined that metyrapone inhibits the cortisol response to a stressor but does not reduce baseline (non-stressed) cortisol levels. There is also a suggestion that plasma cortisol does not turn over rapidly for semelparous salmon on spawning grounds (Donaldson and Fagerlund, 1972). Therefore, it is possible that baseline (i.e. non-stressed) levels of cortisol were maintained, but increases in cortisol levels with stress were prevented (although this was not tested in the current study). For future studies, responsiveness could be observed following injection to determine whether metyrapone-treated fish respond to acute stressors. This approach would provide a useful means of distinguishing between the effects of baseline cortisol and stress-induced cortisol on reproductive success.

There was evidence that metyrapone treatment caused some egg retention and delayed senescence, as observed in the enclosure study (i.e., significantly lower cortisol values compared with other treatment groups in ripe fish). If cortisol spikes immediately prior to ovulation (Milla et al., 2009), this process could have been inhibited through the action of metyrapone in blocking cortisol synthesis. Additionally, cortisol rises again during senescence (Hruska et al., 2010), and this process also could have been inhibited by the action of metyrapone. To examine these possibilities, more detailed time course of plasma hormone levels is needed. Ideally, metyrapone-treated fish should be monitored just prior to ovulation, immediately following egg release and before morbidity.

Elevated cortisol levels on spawning grounds

One of the most notable findings of this study was that exposure of pink salmon to acute stressors on spawning grounds did not alter spawning ground longevity, reproductive success, or behavior, in accordance with theory that semelparous animals in general should resist stress (i.e. attenuate stress responses and/or exhibit resistance to the effects of elevated stress hormone levels) in favor of allocating energy to their current, and only, reproductive opportunity (Wingfield and Sapolsky, 2003). Behavioral and physiological profiles of spawning Pacific salmon are well documented, but the function of (baseline) cortisol elevation in semelparous fish in their natural spawning habitat is not well understood. From a mechanistic standpoint, it has yet to be determined how semelparous salmon successfully breed despite circulating cortisol being elevated to a level that would inhibit reproduction in other species. However, our data indicate that there is a limit to this capacity because cortisol treatment did impair reproduction.

The scope of the present study does not enable us to speculate about the mechanism of cortisol elevation on spawning grounds. Moreover, we did not measure cortisol receptor occupancy or sensitivity, factors that will affect the ability of (high) cortisol levels to mediate target tissue responses, and an issue that ideally would be addressed in future studies. We can conclude, however, that acute elevation of cortisol levels does not hinder reproductive behaviors and outcome. In addition, it seems that the second spike in cortisol is an indicator of impending senescence, as noted in previous studies (e.g., Hruska et al., 2010). If high cortisol levels are evident before spawning is complete, key reproductive behaviors and outcome can be negatively affected, as evidenced in this study by the use of semi-chronic cortisol implants. It would have been useful to collect blood immediately following exposure of fish to the acute stressors to assess the extent of the stress response elicited. In a similar study on stress responsiveness, Cook et al. (2011) observed an increase in cortisol levels from 333 ± 17 to 497 ± 22 ng ml^{-1} following 2 min of air exposure using Weaver Creek sockeye salmon. Other Pacific salmonids (including sockeye, chum [*O. keta*], coho [*O. kisutch*] and Chinook [*O. tshawytscha*]), as well as pink salmon, all have been found to experience an acute stress

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response when exposed to short-term stressors, with cortisol levels recovering within 2–4 h (Mike Donaldson, UBC, personal communication). Therefore, the pink salmon in this study likely experienced an acute stress response with chasing and air exposure, but were not negatively impacted by these acute stressors in terms of reproductive physiology, behavior, or outcome.

Study limitations

Sham-treated fish were negatively affected by the administration of a cocoa-butter implant alone. Although longevity was not altered, sham-treated fish released only ~70% of their eggs on average in the channel experiment, somewhat less (but not significantly so) than control fish, and released only ~15% in the unripe enclosure trials, a value significantly lower than that of control fish. When fish were dissected afterwards, some eggs were observed within the body cavity intermingled with the cocoa butter, creating a mass that might not be easily expelled through the vent during spawning. This unexpected outcome might be prevented in future studies by using a vehicle with a lower melting point or by using less volume than used in the present study. Indeed, a recent study on brown trout (*Salmo trutta*) revealed that cocoa butter implants reduced egg and hatchling size (Hoogenboom et al., 2011) relative to controls, further emphasizing the need for additional research on improving the mechanisms for experimental delivery of lipophilic hormones, a technique that is becoming increasingly common in fish physiology research (reviewed in Gamperl et al. 1994). In our study, because cortisol-treated fish exhibited high cortisol levels with reduced longevity together with a decrease in the number of eggs released, we believe that our results support a real and significant effect of cortisol itself.

Conclusion

Because the migratory and spawning processes of Pacific salmon are regarded as remarkable challenges, we strive to understand the links among physiology, behavior and fitness in these animals. Salmon migrations historically have shown a large degree of consistency, but any environmental changes or anthropogenic perturbations are considered a potential threat to reproduction, and thus survival, of a given population. Our results suggest that acute stressors do not influence behavior or reproductive outcome when experienced upon arrival at spawning grounds. However, there is a limit to the ability of these fish to tolerate elevated cortisol levels because experimental cortisol elevation for several days negatively affected reproductive success and longevity. Collectively, our results address a void in current research, explaining how varying degrees of cortisol elevation can influence reproductive behavior and spawning success of Pacific salmon. Finally, our study is among the first field studies conducted to investigate the ecological consequences of stress during reproduction for a semelparous species.

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PC474

Group 5

Committee of the Whole

Kenai River Late-Run Sockeye Management Plan

Kasilof Sockeye Salmon Management Plan

Commercial Fishing Seasons, Periods and Permit Stacking

Proposals 157-171, 148-156, 126, 111-115, 118

Supporting Documents:

Kenai River Late-Run Sockeye Salmon Management Plan

Proposals 157-171

157 – Support – Add wording modify as neeeded, Kenai and Kasilof Sockeye drive the economy, provide food for America!

158 – Support – Add wording as needed, makes it clean as to priority and importance of sockeye salmon

159 – Support

Concepts:

A. SEG 700,000 to 1.2 million at all run strengths
B. Both the OEG and in-river references are removed from the plan
C. Keep the three major tiers for management and allocation:
   - Less than 2.0 million or 2.3 million
   - 2.0 to 4.0 million or 2.3 to 4.6 million
   - Greater than 4.0 million or 4.6 million
D. Major allocation between saltwater fisheries and freshwater fisheries
E. Saltwater fisheries share a common combined allocation
F. Freshwater fisheries share a common allocation
G. The ADF&G staff are directed to stay within the allocation matrix
H. In the middle tier, 2-4 million, if the Late Run Kenai River Sockeye return is near 2.0 million, the lower matrix allocation is followed. If the Late Run Kenai River Sockeye return is near the 4.0 million, the upper matrix allocation is followed.

See Amended Matrix on next page.

Allocation Plan for Kenai River Late Run Sockeye

SEG 700,000 to 1,200,000	Return Size	Pu/Sp Allocation		InRiver Goal	Salt Water Allocation	
700,000	< 2,300,000	200,000	13%	> 900,000	1,400,000	82%
1,200,000	< 2,300,000	200,000	18%	< 1,400,000	900,000	88%
700,000	< 4,600,000	500,000	13%	> 1,200,000	3,400,000	87%
1,200,000	< 4,600,000	500,000	15%	< 1,700,000	2,900,000	85%
700,000	6,000,000	700,000	13%	> 1,400,000	4,600,000	87%
1,200,000	6,000,000	700,000	15%	< 1,900,000	4,100,000	85%

The Middle Tier, 2.3 to 4.6 million, is the most common range of the Kenai River Sockeye returns. If the return is closer to 2.3 million, then the lower number is to be used. If the return is closer to the upper end of the range, 4.6 million, then the higher allocation is appropriate. Within the 203 – 4.6 million return range, an equitable apportionment is to be applied.

160 – Support – Modify to a single SEG for Kenai River Late Run Sockeye salmon of 700,000 to 1.2 million, eliminates all references to OEG's and in-river goals.

161 – Oppose – At less than 2.3 million saltwater fisheries will suffer total closures, economically a disaster for the Kenai Peninsula and the industry.

162 – ? – No Comment

163 – Support – Support concept of sharing the burden of conservation in proportion to harvests

164 – ? –

165 – ? –

166 – Oppose – This proposal does not fit with adaptive, abundance-based management

167 – Support – Supports adaptive, abundance-based management

168 – Oppose – Reduces flexibility for managers, oppose the allocation aspects of proposal

169 – Oppose – Reduces flexibility for managers, this proposal is not considering escapement goals

170 – Oppose – Allocative aspects of this proposal

171 – Support – Provides for "paired restrictions" – if the commercial fishery is closed for escapement, than other users should also have a "paired restriction closure."

Kasilof River Sockeye Salmon Management Plan

Proposals 148 thru 156

148 – Support – Clarity would help in this management plan, what is the management goal? Eliminate the OEG

149 – Support – Clarity in escapement goals is needed, eliminate the OEG

150 – ? – No position

151 – Support – Clarity needed as to escapement goals and hours of openings

152 – Support

153 – Oppose – Any time the Kasilof River Special Harvest Area is opened, it is because the ADF&G staff has not given sufficient openings to provide for an orderly fishery

154 – ? – No position

155 – ? – No position

156 – ? – No position

Commercial Fishing Seasons, Periods and Permit Stacking

Proposals 126, 111-115, 118

126 – Oppose – Dual permits or single drift vessel has been in place for 6 years and seems to work, dual permits could be improved by passing proposal 127

111– ? –

112 – Oppose – Oppose the allocative aspects of this proposal, the Kasilof sockeye returns start early, no need to increase the trigger point by 20,000 additional sockeye – if anything, this trigger point should be lowered by 20,000 – 25,000 sockeye

113 – Oppose – Oppose allocative aspects of this proposal, Kasilof River exceeded the upper end of the escapement goal by 150,000 – 175,000 sockeye in 2013

114 – Support

115 – ? –

118 - ? – Oppose, costs increased for other gear types

Group 6

Committee of the Whole

Central District Drift Plan

Fishing Periods and Permit Stacking

Cook Inlet Pink Salmon Management Plan

Coho Salmon – Commercial and Sport Fisheries

Proposals 135-147, 122, 127, 173-180, 107 – 110, 116, 117, 119, 120, 131, 132, 248, 263 – 265, 319, 320

Referenced Documents:

Central District Drift Plan:

- Cook Inlet Salmon Fishery Management (See Group 2 materials)
- Kenai River Sockeye Escapement Goal (See Group 2 materials)

Proposals 135 thru 147:

135 – Support to accomplish the following:

A. July 9th – 15th – Two Fishing Periods

- First Fishing Period – All or portions of the Central District that provides an opportunity to harvest sockeyes as these stocks move thru the Central District (Adaptive Management)
- Second Fishing Period – All or portions of the Central District that provides an opportunity to harvest sockeyes as these stocks move thru the Central District (Adaptive Management)

B. July 16th – 31st – Four Fishing Periods

- All four fishing periods all or portions of the Central District that will provide an opportunity to harvest sockeye stocks as they move thru the Central District (Adaptive Management)
- UCIDA is prepared to discuss how this may be accomplished with other interested parties, once the BOF accepts these opportunity concepts

C. August 1 – 31

- Area 4 be revised to Area 1 plus Expanded Corridor

136 – Support – Revised as follows:

A. Fishing Areas – As described in Proposal 135
B. Tiers – Leave as they exist – no change
    - less than 2.3
    - 2.3 to 4.6
    - above 4.6
C. Revise area descriptions to reflect areas described in proposal 135

137 – Support – Move Southwest corner of Expanded Corridor to 151°49.00' W longitude

138 – Oppose

- Unreasonable to ask for these restrictions on the drift fleet harvests
- Northern bound sockeye harvests have increased by 26% with the increased use of the Expanded Corridor
- Oppose the huge allocative aspects of this proposal

139 – Oppose

- Unreasonable to ask for all these restrictions on the drift fleet harvests
- Harvests of northern bound stocks went up by 26% with extensive expanded corridor openings

140 – Oppose

- Oppose allocative aspects of proposal
- Like the flexibility of Expanded Corridor and Area 1
- All old area descriptions are out of date and need revisions

141 – Oppose – In the Northern District, this is a directed fishery targeting nearly 100% northern bound stocks

142 – Oppose – Harvests of northern-bound stocks have increased by 26% with the Drift Fleet restricted to the Expanded Corridor

143 – Oppose – Abandons escapement goal management

144 – Oppose

- Some of the systems mentioned have huge pike populations
- Highly allocative proposal
- Takes commercial fishermen out of historic patterns and locations
- creates a new developing fishery

145 – Oppose – BOF cannot mandate biological studies

146 – Oppose – Cannot restrict drift fleet harvests on chum, pinks and other stocks and then use these reduced harvests as evidence of weak stocks – Circular Argument

147 – Oppose

- This and similar proposals have been before the BOF for over 10 years
- This proposal is allocative
- The few fish the drift fleet harvests does not hurt a single stock that is referenced in this proposal

Fishing Periods and Permit Stacking

Proposals 122 and 127

122 – Support – See new forecast area description

127 – Support

- This would enable a single person to own and fish two permits at the same time
- Will take fishing gear out of the fishery
- Costs are borne by the industry

Cook Inlet Pink Salmon Management Plan

Proposals 173 thru 180

173 – Support – Confusing, UCIDA would like to have a discussion with ADF&G on the area description for this fishery (See UCIDA's comments on proposals 135, 136, 137)

174 – Support – Willing to have discussions on when and where this fishery might take place (See UCIDA's comments on proposals 135, 136, 137)

175 – Support – There are economically viable pink salmon stocks that regularly pass thru the Central District waters

176 – Support – Support in concept

177 – Support – Support in concept

178 – Support – Support in concept

179 – Support – Support in concept

180 – Support – Support in concept

Coho Salmon – Commercial and Sport Fisheries

Proposals 107 – 110, 116, 117, 119, 120, 131, 132, 248, 263 – 265, 319, 320

107 – Oppose – Varied opening dates have occurred in and around Kalgin Island for a variety of reasons targeting different stocks

108 – Support – Chum, coho and pink salmon stocks are healthy and available to harvest

109 – Support – Chum, coho and pink salmon stocks are healthy and available to harvest

110 – Support – Chum, coho and pink salmon stocks are healthy and available to harvest

116 – Support – August 15 is a reasonable closing date, facilitates pink salmon harvests

117 – Support – August 15 is a reasonable closing date, facilitates pink salmon harvests

119 - ?

120 – Support – Chum, coho and pink salmon stocks are healthy and available to harvest

131 – Support if modified

- Needs to include appropriate closure for sports fishing
- Similar closed area some distance up the Little Susitna River for recreational fishing

132 – Support if modified

248 – Oppose

- Needs modification for Set Netting until August 15
- Start at two fish bag limit, return to pre-1999 regulations
- Highly allocative

263 – Oppose – The public has historically had Labor Day as "their" day free of guides

264 – Oppose – Mondays are always a fishing day for the general public

265 – Oppose – Mondays are the fishing day for the general public

319 – Support

- These stocks are heavily targeted
- High catch & release mortality of coho salmon

320 – Support

- Jim Creek is in a designated off-road vehicle area and has high impacts due to 4 x 4s and 4 wheelers
- The stock is small and under severe habitat stress

Group 2

Committee of the Whole

Kenai River Late Run King Salmon Management Plan

Sport and Commercial

Proposals 207 thru 218

Supporting Documents – Attached or Referenced:

- Kenai River Sockeye Escapement Goals
- Cook Inlet Salmon Fishery Management
- A King Without a Crown: Chinook Vulnerable to Ocean Forces – Morris Communications

Proposals:

207 – Oppose – Creating any form of an OEG that allocates Kings to benefit one stakeholder group

208 – Oppose – This proposal is attempting an allocation utilizing the establishment of a new OEG

209 – Oppose – Attempting to allocate Kings to one user group, no paired conservation burdens, catch & release effects on spawning grounds are ignored

210 – Support – Sets the SEG/BEG around the MSY escapement values, eliminates the imbedded 3,000, attempt at allocating Kings, proposal speaks to salt water harvests

211 – Oppose – Unnecessary, increases costs for all commercial users, we use similar 45 mesh nets, increases gear (webbing) costs for the drift fleet. Will the PU gillnet gear also be reduced to 29 mesh?

212 – Oppose – Unnecessary, complicates management with unspecified allocations

213 – Oppose – Unnecessary, complicated management with unspecified allocations

214 – Support – Housekeeping, simplifies management

215 – ? – Legal issues: Equal treatment? Allocative

216 – ? – Unspecified allocation will result

217 – Support – Restores balance to management plans

218 – Oppose – Kings in this area move around Anchor Point to Bluff Point with the tide, not sure what this proposal accomplishes

Kenai River Sockeye Escapement Goals

United Cook Inlet Drift Association

2014

Evaluating Sockeye Escapement Goals in the Kenai River Utilizing Brood Tables and Markov Tables

This presentation pertains to all proposals related to Kenai River late-run sockeye salmon escapement goals:
Proposal Numbers 157, 159-163
Committee of the Whole (Group 5)

Escapement Goals

The purpose of an escapement goal is to ensure sustainability and to maximize yield (harvest).

State policy requires that escapement goals be developed from the best available data and be scientifically defensible.

Kenai River late-run sockeye is the only stock in th
that is managed with five escapement goals.

These goals include a Sustainable Escapement Goal, an Optimum Escapement Goal and three Inriver Goals depending on the projected strength of the run.

Is this really best management?

90% of Kenai River late-run sockeye rear in either Skilak Lake (70%) or Kenai Lake (15-20%).

Tools for evaluating sockeye escapement g the Kenai River:

Brood Tables -

Are combined with other data sets to show the interaction of some of the significant factors that influence the returns and age class diversity of past escapements (e.g. food availability, average fry weight and returns per spawn year by age class).

Markov Tables -

Use historic data on escapements, returns, returns per spawner and yields to illustrate the relationship between escapements and returns.

All data comes from ADF&G

Utilizing the data provided by both of these tools make it possible to evaluate and optimize escapement goals.

Appropriate sockeye escapement goals provide for:

- Maximum sustained yield (harvest);
- A well-distributed range of age classes in each return. This diversity strengthens the stocks' resilience to periodic catastrophic events;
- Equal numbers of males and females.

Brood Table Overview

PC 476
8 of 78

Kenai River late-run sockeye salmon

Table 2. Kenai late-run sockeye salmon brood table, 1968-2013. Also included are total age-0 and age-1 fall fry abundances in Kenai and Skilak lakes, mean fall fry weights in Skilak Lake, summer (May-October) euphotic zone depth (EZD) and total zooplankton biomass during the ag

Brood		Fall Fry Abundance		Fall Fry Weight		EZD	Zoop Biomass	Adult Return														Total	
Year	Spawners	Age 0	Age 1	Age 0	Age 1	(m)	(mg/m2)	0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3	Return	Yield
1987	1,982,808	37,071,211	11,066,228	0.9	2.8	12.4	586.0	0	5,664	48,870	776,685	4,549	0	7,024,019	301,848	0	105,399	2,096,053	1,114	14,372	0	10,378,573	8,395,7
1988	1,174,729	13,987,502	782,393	1.2	4.0	10.5	693.2	408	1,156	0	151,779	7,105	0	1,491,124	292,377	596	21,963	576,976	2,873	4,586	0	2,550,942	1,376,2
1989	2,026,638	24,601,413	387,673	1.3	4.7	5.5	495.4	3,927	0	16,803	352,264	77,802	0	2,480,626	558,602	1,416	17,311	955,698	0	16,440	0	4,480,888	2,454,2
1990	733,155	7,126,711	104,391	1.5	7.0	6.3	368.8	1,133	3,457	5,947	223,830	13,944	0	778,479	191,364	0	10,973	284,029	2,423	3,405	0	1,518,983	785,8
1991	696,345	9,540,536	1,732,650	1.8	4.5	9.2	557.9	1,602	4,371	10,371	669,963	22,972	0	2,764,755	252,038	1,839	17,583	690,122	2,928	2,958	3,030	4,444,531	3,748,1
1992	1,188,534	35,687,389	1,280,854	1.2	3.6	7.0	761.9	0	2,651	8,468	345,482	10,423	0	3,443,710	140,781	0	19,993	293,962	2,775	4,497	0	4,272,741	3,084,2
1993	992,096	11,159,398	473,111	1.4	5.7	5.6	428.2	0	0	14,950	289,049	7,055	0	816,428	196,881	1,642	12,463	330,626	14,864	6,306	0	1,690,264	698,1
1994	1,307,440	8,812,895	368,644	1.7	4.0	8.0	507.0	0	1,762	0	484,193	77,318	0	1,727,679	439,434	1,822	17,644	291,755	9,532	0	2,322	3,053,461	1,746,0
1995	771,936	5,582,452	239,582	1.6	3.1	3.5	378.6	0	3,402	8,637	429,237	16,262	0	1,039,520	154,550	0	15,062	230,962	0	2,266	610	1,900,509	1,128,5
1996	916,244	25,316,385	2,459,746	0.9	1.7	5.5	342.5	0	0	13,177	254,848	26,314	0	1,533,117	158,035	0	25,387	246,833	2,554	2,402	0	2,262,667	1,346,4
1997	1,326,202	21,193,560	629,011	0.7	4.0	4.2	273.4	0	1,765	0	230,482	16,857	0	2,142,070	327,237	1,220	16,829	873,782	0	10,985	6,095	3,627,321	2,301,
1998	877,707	8,330,506	472,469	1.3	4.1	7.4	421.7	0	3,740	3,017	702,252	12,437	0	2,711,407	314,379	1,356	30,292	677,643	6,352	3,477	0	4,466,351	3,588,6
1999	916,632	19,950,396	520,673	1.2	3.2	6.7	489.8	1,833	0	11,713	499,505	4,233	0	3,958,012	426,787	0	18,160	807,764	14,996	10,902	2,295	5,756,200	4,839,5
2000	669,406	22,509,586	3,342,145	1.0	2.6	8.6	386.3	4,396	634	19,641	562,922	7,454	0	4,988,691	123,758	0	67,707	1,262,915	2,295	23,749	4,678	7,068,840	6,399,4
2001	714,201	8,748,692	434,724	1.0	2.8	9.0	535.5	0	0	12,693	133,865	4,838	0	1,110,286	104,717	0	52,176	279,589	4,678	3,511	0	1,706,353	992,1
2002	1,082,561	12,750,428	711,475	1.3	2.1	4.1	344.9	1,906	38	13,197	283,740	10,902	0	2,835,116	156,527	0	94,793	225,727	0	3,416	0	3,625,362	2,542,8
2003	1,395,976	27,574,335	106,971	0.6	1.5	5.9	407.1	0	0	4,678	213,380	23,749	0	1,256,677	149,314	0	20,985	236,693	3,416	0	0	1,908,893	512,
2004	1,679,806	41,936,000	7,859,788	0.5	2.0	6.0	489.9	0	0	7,228	313,292	14,663	0	1,772,029	240,110	0	7,444	772,210	3,884	7,978	15,342	3,154,177	1,474,3
2005	1,647,023	29,563,865	8,945,317	0.7	1.8	6.6	592.6	0	0	3,416	149,580	3,416	0	1,438,265	151,464	0	23,319	2,800,132	0	0	0	4,569,593	2,922,5
2006	1,876,180	9,138,282	186,842	0.9	4.0	5.4	563.9	0	7,076	3,884	756,998	90,943	0	2,389,594	333,831	0	78,758	1,159,210	0	13,577	0	4,833,873	2,957,6
2007	957,430	20,154,463	688,401	1.3	4.8	10.9	834.7	3,884	7,444	0	488,474	69,957	0	2,127,420	731,463	0	28,869	924,060	0			4,381,571	3,424,
2008	703,979	10,755,096	460,689	1.6	3.4	9.4	987.4	0	7,978	0	585,265	11,319	0	1,889,869	195,328	0							
2009	843,255	17,778,081	3,796,914	1.2	3.4	6.1	509.6	0	22,637	0	325,692	8,431											
2010	1,015,106	11,809,877	5,442,363	1.2	3.6	7.8	573.2	0	3,392														
2011	1,275,369	23,560,643	2,857,684	1.2	3.3	6.9	778.8																
2012	1,197,518	9,515,604		1.1		5.4																	
2013	1,054,554																						
20-year averag	1,198,781	18,183,240	2,206,202	1.2	3.6	6.8	493.7				398,431	26,143		2,140,250	272,182		33,712	754,634	3,734	6,741	1,719	3,888,195	2,664,7
	20	20	20	20	20	20	20				20	20		20	20		20	20	20			21	

Each row lists the data from one brood year including number of spawners, fall fry abundance and weights, euphotic zone depth (EZD), zooplankton biomass, the adult return in subsequent years by age class, total adult return, yield (harvest), harvest rate and return per spawner.

Brood Table Definitions

Brood Year	Spawners
1992	1,188,534
1993	992,096
1994	1,307,440
1995	771,936
1996	916,244
1997	1,326,202
1998	877,707
1999	916,632
2000	669,406
2001	714,201
2002	1,082,561
2003	1,395,976
2004	1,679,806
2005	1,647,023
2006	1,876,180
2007	957,430
2008	703,979
2009	843,255
2010	1,015,106
2011	1,275,369
2012	1,197,518
2013	1,054,554
20-year average	1,198,781
	20

Brood Year –

The spawning year.

Spawners –

Number of late-run sockeye spawners in that brood year.

The number of spawners is derived from the sonar escapement estimate minus the number of fish harvested by sport fisheries upstream of the counters at river mile 19.

Brood Table Definitions

Fall Fry Abundance		Fall Fry Weight	
Age 0	Age 1	Age 0	Age 1
35,687,389	1,280,854	1.2	3.6
11,159,398	473,111	1.4	5.7
8,812,895	368,644	1.7	4.0
5,582,452	239,582	1.6	3.1
25,316,385	2,459,746	0.9	1.7
21,193,560	629,011	0.7	4.0
8,330,506	472,469	1.3	4.1
19,950,396	520,673	1.2	3.2
22,509,586	3,342,145	1.0	2.6
8,748,692	434,724	1.0	2.8
12,750,428	711,475	1.3	2.1
27,574,335	106,971	0.6	1.5
41,936,000	7,859,788	0.5	2.0
29,563,865	8,945,317	0.7	1.8
9,138,282	186,842	0.9	4.0
20,154,463	688,401	1.3	4.8
10,755,096	460,689	1.6	3.4
17,778,081	3,796,914	1.2	3.4
11,809,877	5,442,363	1.2	3.6
23,560,643	2,857,684	1.2	3.3
9,515,604		1.1	
18,183,240	2,206,202	1.2	3.6

Fall Fry Abundance and Weight –

- Fry are counted and weighed in Skilak Lake every fall. Fry counts and weight are presented in the Brood Table according to the brood year (year spawned)
- Age 0 fry spend less than 1 year in fresh water
- Age 1 fry spend 1 year in fresh water
- Fry Weight is measured in grams.
- Fry tend to spend 2 years in freshwater if they do not grow large enough in their first year for out-migrating.

Brood Table Definitions

EZD (m)	Zoop Biomass (mg/m2)
7.0	761.9
5.6	428.2
8.0	507.0
3.5	378.6
5.5	342.5
4.2	273.4
7.4	421.7
6.7	489.8
8.6	386.3
9.0	535.5
4.1	344.9
5.9	407.1
6.0	489.9
6.6	592.6
5.4	563.9
10.9	834.7
9.4	987.4
6.1	509.6
7.8	573.2
6.9	778.8
5.4	
6.8	493.7

EZD -

Euphotic Zone Depth – depth in meters of the penetration of sufficient light in the lake to allow for photosynthesis to occur. It is affected by seasonal changes in turbidity and irregular effects like flooding. EZD is directly related to the Zooplankton Biomass (food levels).

Zoop Biomass – Food Supply

Zooplankton Biomass - (measured in micrograms of zooplankton per square meter) an estimate of food levels available for fry residing in lake.

Brood Table Definitions

Adult Return Age Class Columns –

Show the subsequent adult returns from the brood year in columns by fish age.

Each age class of returned adults is further broken down by the time the fish spent in freshwater before migrating. The first number is the number of years spent in freshwater, the second number is the number of years spent in saltwater.

The full age in years (in red) of the adult fish is the combined total of the fresh and saltwater years plus one.

Actual age in years of returned adult fish:

3	3	4	4	4	5	5	5	5	6	6	6	7	7
Adult Return													
0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3
0	2,651	8,468	345,482	10,423	0	3,443,710	140,781	0	19,993	293,962	2,775	4,497	0
0	0	14,950	289,049	7,055	0	816,428	196,881	1,642	12,463	330,626	14,864	6,306	0
0	1,762	0	484,193	77,318	0	1,727,679	439,434	1,822	17,644	291,755	9,532	0	2,322
0	3,402	8,637	429,237	16,262	0	1,039,520	154,550	0	15,062	230,962	0	2,266	610
0	0	13,177	254,848	26,314	0	1,533,117	158,035	0	25,387	246,833	2,554	2,402	0
0	1,765	0	230,482	16,857	0	2,142,070	327,237	1,220	16,829	873,782	0	10,985	6,095
0	3,740	3,017	702,252	12,437	0	2,711,407	314,379	1,356	30,292	677,643	6,352	3,477	0
1,833	0	11,713	499,505	4,233	0	3,958,012	426,787	0	18,160	807,764	14,996	10,902	2,295
4,396	634	19,641	562,922	7,454	0	4,988,691	123,758	0	67,707	1,262,915	2,295	23,749	4,678
0	0	12,693	133,865	4,838	0	1,110,286	104,717	0	52,176	279,589	4,678	3,511	0
1,906	38	13,197	283,740	10,902	0	2,835,116	156,527	0	94,793	225,727	0	3,416	0
0	0	4,678	213,380	23,749	0	1,256,677	149,314	0	20,985	236,693	3,416	0	0
0	0	7,228	313,292	14,663	0	1,772,029	240,110	0	7,444	772,210	3,884	7,978	15,342
0	0	3,416	149,580	3,416	0	1,438,265	151,464	0	23,319	2,800,132	0	0	0
0	7,076	3,884	756,998	90,943	0	2,389,594	333,831	0	78,758	1,159,210	0	13,577	0
3,884	7,444	0	488,474	69,957	0	2,127,420	731,463	0	28,869	924,060	0		
0	7,978	0	585,265	11,319	0	1,889,869	195,328	0					
0	22,637	0	325,692	8,431									
0	3,392												

Brood Table Definitions

It takes 7 years to see the total adult returns (escapement plus yield) on a single spawning brood year.

Healthy sockeye (and chinook) stocks include a variety of age classes in each return. This diversity strengthens the stocks' resilience to periodic catastrophic events.

Actual age in years of returned adult fish:

3	3	4	4	4	5	5	5	5	6	6	6	7	7
			Adult Return										
0.2	1.1	0.3	1.2	2.1	0.4	1.3	2.2	3.1	1.4	2.3	3.2	2.4	3.3
0	2,651	8,468	345,482	10,423	0	3,443,710	140,781	0	19,993	293,962	2,775	4,497	0
0	0	14,950	289,049	7,055	0	816,428	196,881	1,642	12,463	330,626	14,864	6,306	0
0	1,762	0	484,193	77,318	0	1,727,679	439,434	1,822	17,644	291,755	9,532	0	2,322
0	3,402	8,637	429,237	16,262	0	1,039,520	154,550	0	15,062	230,962	0	2,266	610
0	0	13,177	254,848	26,314	0	1,533,117	158,035	0	25,387	246,833	2,554	2,402	0
0	1,765	0	230,482	16,857	0	2,142,070	327,237	1,220	16,829	873,782	0	10,985	6,095
0	3,740	3,017	702,252	12,437	0	2,711,407	314,379	1,356	30,292	677,643	6,352	3,477	0
1,833	0	11,713	499,505	4,233	0	3,958,012	426,787	0	18,160	807,764	14,996	10,902	2,295
4,396	634	19,641	562,922	7,454	0	4,988,691	123,758	0	67,707	1,262,915	2,295	23,749	4,678
0	0	12,693	133,865	4,838	0	1,110,286	104,717	0	52,176	279,589	4,678	3,511	0
1,906	38	13,197	283,740	10,902	0	2,835,116	156,527	0	94,793	225,727	0	3,416	0
0	0	4,678	213,380	23,749	0	1,256,677	149,314	0	20,985	236,693	3,416	0	0
0	0	7,228	313,292	14,663	0	1,772,029	240,110	0	7,444	772,210	3,884	7,978	15,342
0	0	3,416	149,580	3,416	0	1,438,265	151,464	0	23,319	2,800,132	0	0	0
0	7,076	3,884	756,998	90,943	0	2,389,594	333,831	0	78,758	1,159,210	0	13,577	0
3,884	7,444	0	488,474	69,957	0	2,127,420	731,463	0	28,869	924,060	0		
0	7,978	0	585,265	11,319	0	1,889,869	195,328	0					
0	22,637	0	325,692	8,431									
0	3,392												

Brood Table Definitions

Total Return	Yield	R/S
4,272,741	3,084,207	3.6
1,690,264	698,168	1.7
3,053,461	1,746,021	2.3
1,900,509	1,128,573	2.5
2,262,667	1,346,423	2.5
3,627,321	2,301,119	2.7
4,466,351	3,588,644	5.1
5,756,200	4,839,568	6.3
7,068,840	6,399,434	10.6
1,706,353	992,152	2.4
3,625,362	2,542,800	3.3
1,908,893	512,917	1.4
3,154,177	1,474,371	1.9
4,569,593	2,922,570	2.8
4,833,873	2,957,692	2.6
4,381,571	3,424,141	4.6

•**Total Return** - escapement plus harvest of adults returned from the brood year.

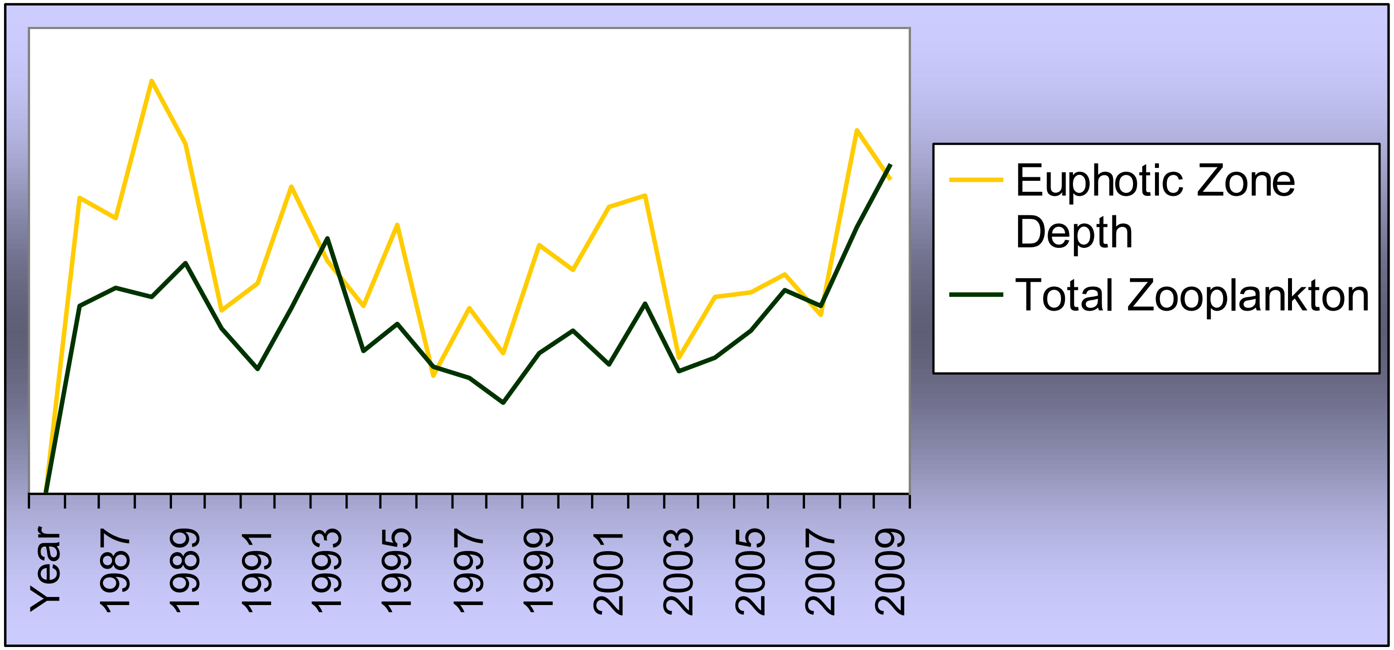
•**Yield** – the available, harvestable surplus of salmon.

•**R/S** - Return per spawner – number of adults returned per spawner for the brood year.

Brood Table Utilization

Organizing these data by brood year illustrates the relationships between some of the factors that influence sockeye production.

The Zooplankton abundance (food supply) is reflective of the EZD. (These are seasonally adjusted average values.)



Brood Tables Comparison

The importance of the relationship between the food supply and the number of spawners is illustrated in the comparison of these three data sets from the Brood Table.

An above average food supply will produce a higher yield from fewer spawners.

An average or below average food supply significantly reduces yield when the number of spawners is above average.

What the Brood Table Tells Us:

2003 - Lots of spawners – below average food supply – poor yields – worst yield we've seen in over 30 years

2007 - Fewer spawners with above average food supply – better yields

2008 - Even fewer spawners, best food supply – still waiting on yields*

* It takes a full 7 years to see the adult returns (escapement plus yield) on a single spawning year

A closer look at the results from the 2003 spawning year:

- •1.4 million spawners were put into the Kenai River with a below average food supply in Skilak Lake.
- •The average fall fry weight was only half of the 20 year average (.6 gm fry versus 1.2 gm fry).
- •Food supply could not support the number of fry in Skilak Lake and the return was significantly reduced (return per spawner was 1.4 versus 20 year average of 3.5)
- •Total Yield was 513,000; only 20% of the 20 year average yield of 2.6 million
- •No seven year olds came back.
- •No three year olds came back.
- •Majority of the fish came back as five year olds

Risks of maintaining excessively hig escapement goals:

•Continued excessive escapements will lead to density-dependent effects that result in poor returns and the eventual collapse of the fish stock.

•Examples of areas that were devastated by density dependent effects resulting from persistent over-escapements:

- •Coghill (Prince William Sound)
- •Karluk (Kodiak)
- •Frazer (Kodiak)

•Excessively high escapement goals cause density-dependent processes that lead to declines in reproductive success due to intensified competition for limiting resources including juvenile food, suitable rearing habitat and adult spawning habitat.

A closer look at the results from the 2007 spawning year:

- 960,000 spawners were put into the Kenai with an above average food supply in Skilak Lake.
- The average fall fry weight was 1.3 gm; eight percent above the 20 year average.
- Return per spawner was average (4.6) and the yield was 3.4 million sockeye, 38% greater than the 20 year average. (The seven year old class of fish from this year has not yet been counted)
- The return age classes were well-distributed across a wide range, providing a diversity that can buffer the effects of catastrophic events

What we need for healthy salmon stocks

- Correct escapement levels
- Good food supply in the lakes
- Wide range of age class in returns

The food supply (Zooplankton biomass) is one of the main predictors of healthy return but is not itself predictable.

Other variables include healthy habitat.

Brood Tables Summary

Brood Tables, with the inclusion of other data sets:

- Show the details of the return of each brood year of salmon from the number of spawners to the ratio of return per spawner.
- Indicate the interaction of some of the various factors that influence the returns and age class diversity of past escapements (e.g. food supply, average fry weight and returns per spawn year by age class).

Brood Tables provide a foundation for understanding and interpreting Markov Tables.

Markov Tables

- Use historic data on escapements, returns, returns per spawner and yields to illustrate the relationship between escapements and returns.

- Provide a straightforward model to predict return/yield based on escapement levels

Markov Table

We start with the following data for late-run Kenai River sockeye:

- •Brood Year
- •Spawners
- •Return
- •Return per Spawner
- •Yield (harvest)

Brood Year	Spawners	Returns	Return per Spawner	Yield
1969	72.901	430.947	5.91	358.046
1970	101.794	550.923	5.41	449.129
1975	184.262	1,055.374	5.73	871.112
1974	209.836	788.067	3.76	578.231
1979	373.810	1,321.707	3.54	947.897
1971	406.714	986.397	2.43	579.683
1972	431.058	2,547.851	5.91	2,116.793
1984	446.397	3,865.134	8.66	3,418.737
1973	507.072	2,125.986	4.19	1,618.914
1976	507.440	1,506.075	2.97	998.635
1978	511.781	3,785.623	7.40	3,273.842
1981	527.553	2,465.818	4.67	1,938.265
1986	546.614	2,174.842	3.98	1,628.228
1985	573.611	2,592.968	4.52	2,019.357
1980	600.813	2,675.007	4.45	2,074.194
2000	668.510	7,061.112	10.56	6,392.602
2001	713.484	1,705.699	2.39	992.215
1990	730.471	1,518.983	2.08	788.512
1982	755.413	9,591.200	12.70	8,835.787
1991	756.348	4,444.531	5.88	3,688.183
1995	771.935	1,900.509	2.46	1,128.574
1983	792.368	9,489.648	11.98	8,697.280
1998	877.434	4,466.351	5.09	3,588.917
1999	916.047	5,755.767	6.28	4,839.720
1996	916.244	2,262.667	2.47	1,346.423
1977	951.038	3,112.852	3.27	2,161.814
1993	992.096	1,690.264	1.70	698.168
2002	1,081.577	3,625.113	3.35	2,543.536
1988	1,173.656	2,550.942	2.17	1,377.286
1992	1,188.434	4,272.741	3.60	3,084.307
1994	1,307.269	3,053.461	2.34	1,746.192
1997	1,326.202	3,627.321	2.74	2,301.119
2003	1,395.432	1,908.893	1.37	513.461
2005	1,646.987	2,650.255	1.61	1,003.268
2004	1,678.521	3,149.511	1.88	1,470.990
2006	1,876.088	4,449.367	2.37	2,573.279
1987	1,982.501	10,378.573	5.24	8,396.072
1989	2,027.299	4,480.888	2.21	2,453.589

Markov Table

Markov Table for late-run Kenai River sockeye salmon, brood years 1969 - 2006						
Escapement	n	Mean	Mean	Return per	Yield	
Interval (000)		Spawners (000)	Returns (000)	Spawner	Mean (000)	Range (000)
0-200	3	120	679	5.7	559	358-871
100-300	3	165	798	5.0	633	449-871
200-400	2	292	1,055	3.6	763	578-948
300-500	4	414	2,180	5.1	1,766	580-3,419
400-600	9	495	2,450	5.0	1,955	580-3,419
500-700	8	555	3,048	5.3	2,493	999-6,393
600-800	8	724	4,798	6.6	4,075	788-8,697
700-900	7	771	4,731	6.1	3,960	788-8,697
800-1,000	5	931	3,458	3.8	2,527	698-4,840
900-1,100	5	971	3,289	3.4	2,318	698-4,840
1,000-1,200	3	1,148	3,483	3.0	2,335	1,377-3,084
1,100-1,300	2	1,181	3,412	2.9	2,231	1,377-3,084
1,200-1,400	3	1,343	2,863	2.2	1,520	513-2,301
> 1,300	8	1,655	4,212	2.5	2,557	513-8,396

We choose the Escapement (Spawner) Interval - 200,000 in this case

The brood year data is then grouped into the appropriate escapement interval.

“n” is the number of brood years in each interval.

Markov Table

Markov Table for late-run Kenai River sockeye salmon, brood years 1969 - 2006						
Escapement	n	Mean	Mean	Return per	Yield	
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400-600	9	495	2,450	5.0	1,955	580-3,419
500-700	8	555	3,048	5.3	2,493	999-6,393
600-800	8	724	4,798	6.6	4,075	788-8,697
700-900	7	771	4,731	6.1	3,960	788-8,697
800-1,000	5	931	3,458	3.8	2,527	698-4,840
900-1,100	5	971	3,289	3.4	2,318	698-4,840
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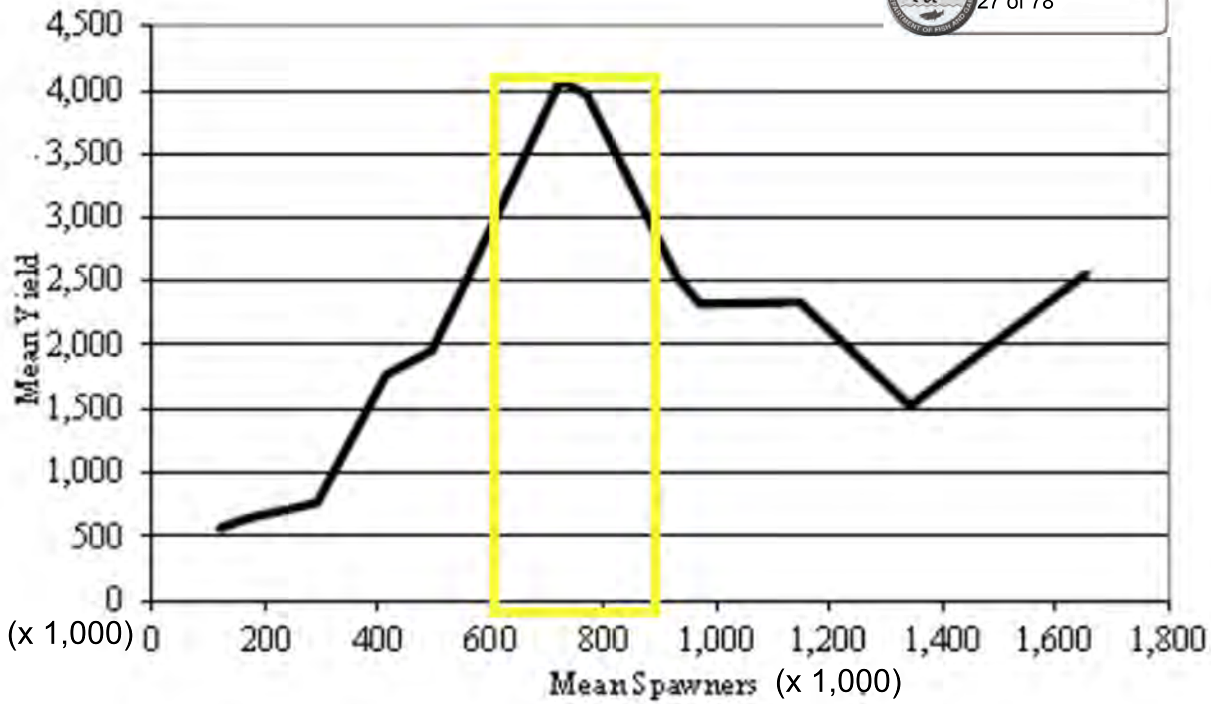
1,200-1,400	3	1,343	2,863	2.2	1,520	513-2,301
> 1,300	8	1,655	4,212	2.5	2,557	513-8,396

The table shows the escapement (spawner) interval level, the number of years the escapement fell within that level, the mean spawners, mean returns, return per spawner and yield (harvestable surplus).

The highlighted rows are the intervals that had the best returns, best return per spawner rates and best mean yields (harvestable surpluses).

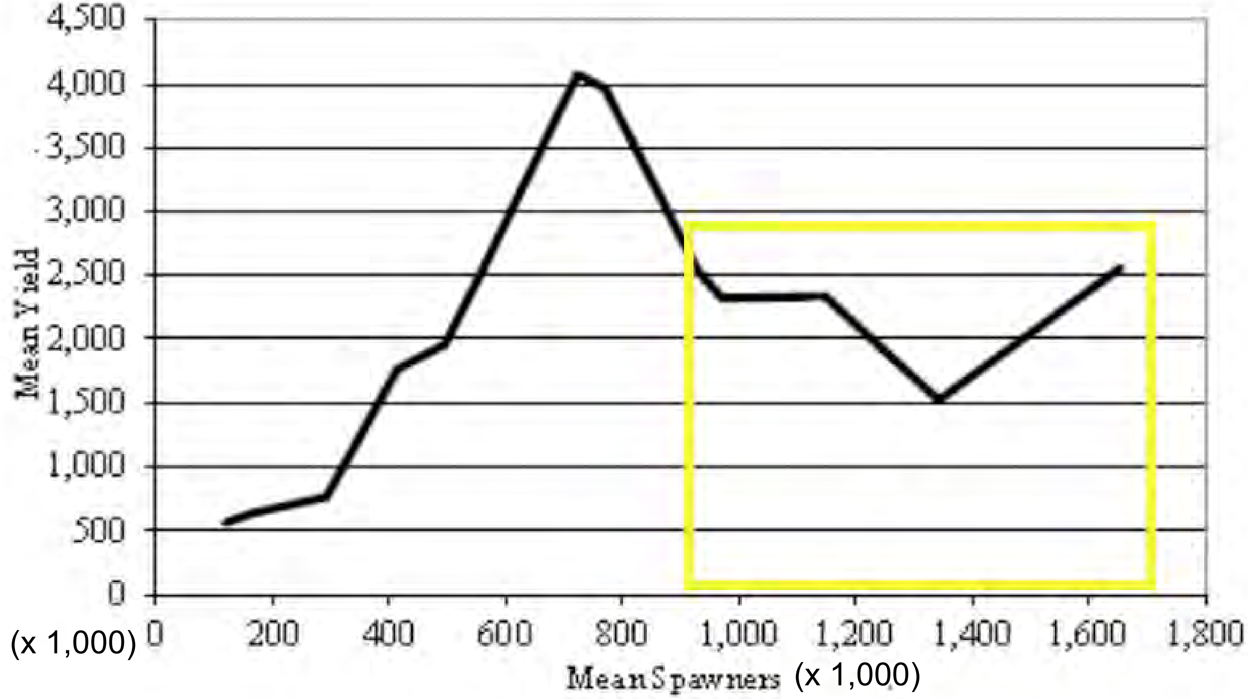
Markov Table Graph Kenai Late-run Sockeye



The graph clearly illustrates that for 37 years (1969 – 2006) the yields were highest when spawner levels were between 600,000 – 900,000.

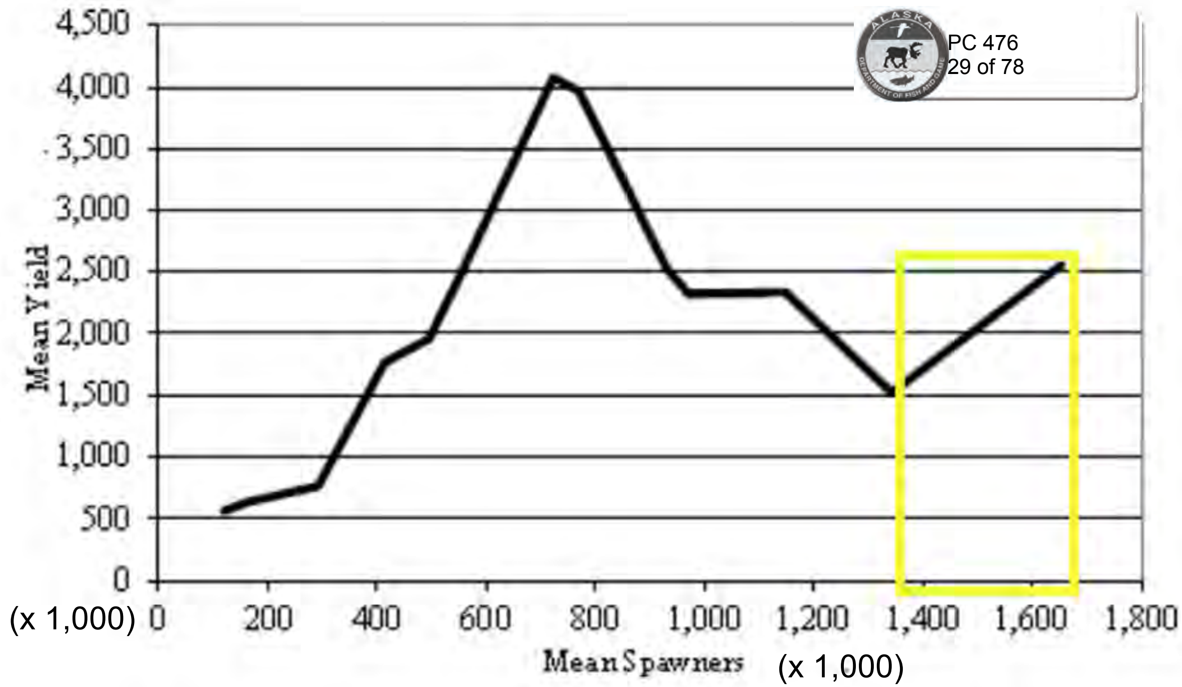
When spawner levels are between 600,000 – 900,000 we see the greatest potential for maximum returns and this means the maximum yield (harvestable surpluses) for all user groups.

Markov Table Graph Kenai Late-run Sockeye



Average yields drop significantly once the number of spawners surpasses 900,000.

Markov Table Graph Kenai Late-run Sockeye

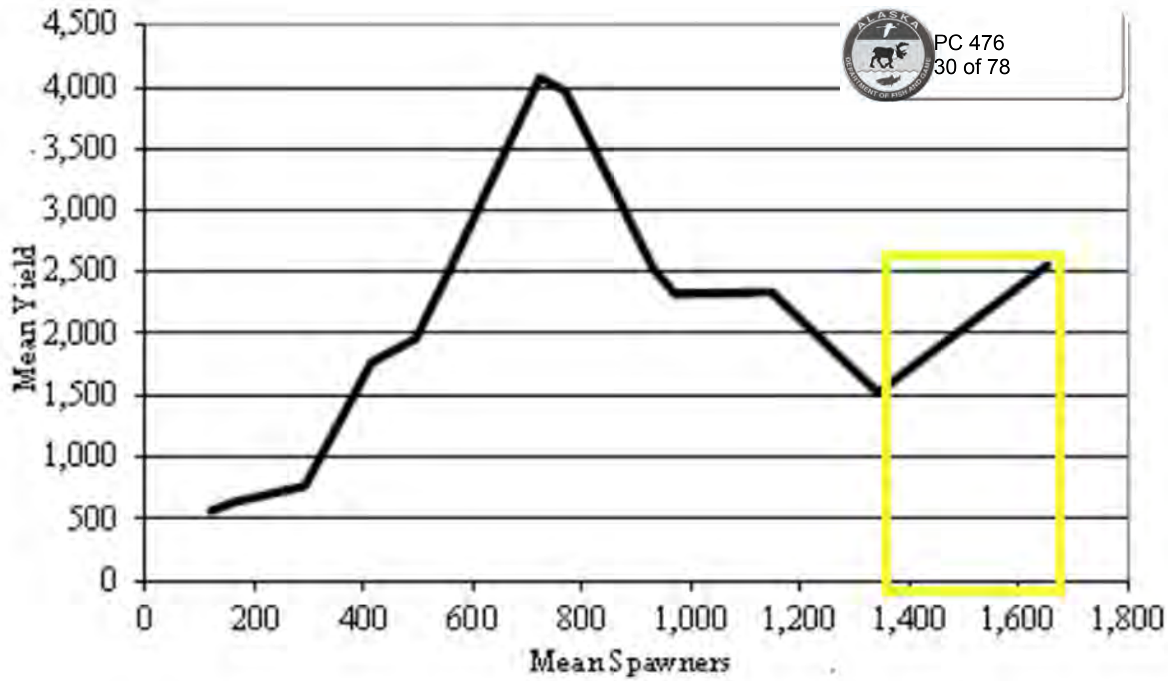


The data trend angles upward again once the escapement exceeds 1.3 million spawners.

However, if we refer back to the table, at these escapement levels we see a very wide range in the yield (513,000 – 8,396,000) and a significant drop in the Return per Spawner.

The extreme highs and lows reflect the variability and unpredictability of food supply and other habitat factors.

Markov Table Graph Kenai Late-run Sockeye



The extreme highs and lows also illustrate the oscillation of returns when escapement levels exceed habitat carrying capacity. Excessively high escapements cause returns to decrease in the next generation. Escapements then decrease, resulting in higher returns in subsequent generations.

These effects can be blurred by changes in habitat conditions and other factors. When factors aren't positively favorable, returns per spawner in the down cycles can fall below replacement levels.

Conclusions

"Overescapement, in general, is not sustainable…"

(Clark, Robert, et al, 2007, Biological and fishery-related aspects of overescapement in Alaskan sockeye salmon, ADF&G.)

Over-escapement is not a myth. Whether escapement goals are exceeded or escapement goals are set too high, salmon populations are at risk when they exceed the carrying capacity of the habitat.

Escapement goals should be based on production capacity, food supplies and historical data. Increasing escapement goals based on annual variations in run size is not scientifically defensible.

Large escapements produce oscillating returns, low return per spawner rates and other density-dependent effects. The extreme variability of returns on large escapements puts at risk future runs and the economies that are built around the harvest of the surplus stocks.

Conclusions

Historical data for Kenai River late-run sockeye indicate that spawner levels between 600,000 and 900,000 provide the best returns, best returns per spawner and best yields.

Kenai River late-run sockeye is the only stock in Alaska that is managed with three different inriver escapement goals depending on the projected strength of the run. This has led to Kenai River late-run sockeye spawner counts between 1.1 million and 1.28 million for each of the past 4 years.

Kenai River late-run sockeye should be managed for a Sustainable Escapement Goal and the Optimum Escapement Goal should be dropped from regulation. This management goal should apply to all user groups and will benefit all user groups.

Cook Inlet

Salmon Fishery Management

2014 United Cook Inlet Drift Association

Utilizing Salmon Migration Patterns and Run Timing

Cook Inlet Salmon Fishery Management

The management that has evolved for UCI over the past decades was largely based on a set of assumptions that we now realize were incorrect. (For further information see "Fishery Related Aspects of Faulty Sonar Data, Over-Escapement and Impaired Habitat for Susitna Sockeye" in Board packet.)

Scientific data from genetic stock identification, Test Boat fishing and the recognition that Susitna sockeye escapements had been grossly undercounted since 1982 have contradicted those previous assumptions.

Scientific data can now inform an empirically-based management plan.

Cook Inlet Salmon Fishery Management

Previous assumptions:

–The Yentna Bendix sonar counter was assumed to be accurate when it indicated that escapements goals in the Susitna were not being met;

–Northern-bound sockeye stocks were thought to migrate though central Cook Inlet at particular times in particular areas.

–Assumptions were made that time and area restrictions to the drift fleet would help conserve those northern-bound stocks.

Through multi-year studies on escapement counts, stock composition, Test Boat fishing and genetic stock identification, ADF&G has accumulated data that refute these assumptions. (See References, final slide.)

It is critical to change UCI management to reflect the new information because management based on the flawed assumptions has had significant adverse effects.

Cook Inlet Salmon Fishery Management

Issues with current management:

- Compressed escapement and harvest of Kenai late-run sockeye;
- There is no methodology for measuring the effects of commercial fishery restrictions currently in regulation;
- Management focus on commercial fishery restrictions has diverted attention from growing habitat problems affecting salmon production;
- Harvest opportunity has been lost.

In 2013 UCI sockeye salmon had "one of the most compressed, if not the most compressed runs in UCI history." (ADF&G 2013 UCI Commercial Salmon Season Summary)

Cook Inlet Salmon Fishery Management

These problems have been the result of efforts to restrict commercial fishing areas to allow the passage of Susitna salmon through the Central District. The restrictions were based on assumptions about fish migrations to solve a problem that did not exist.

These restrictions would not have been implemented if the Yentna sonar counter had been accurately counting sockeye salmon going back to 1982.

The restrictions were never scientifically evaluated. No studies were ever done, no data was ever generated that would allow the department or stakeholders to determine the effectiveness of the restrictions.

Cook Inlet Salmon Fishery Management

The restrictions placed on commercial fisheries to conserve northern sockeye stocks and other mandatory restrictions have been part of the state's prescriptive management approach to UCI salmon.

The management plans have been prescriptive and theory-based (on flawed assumptions.)

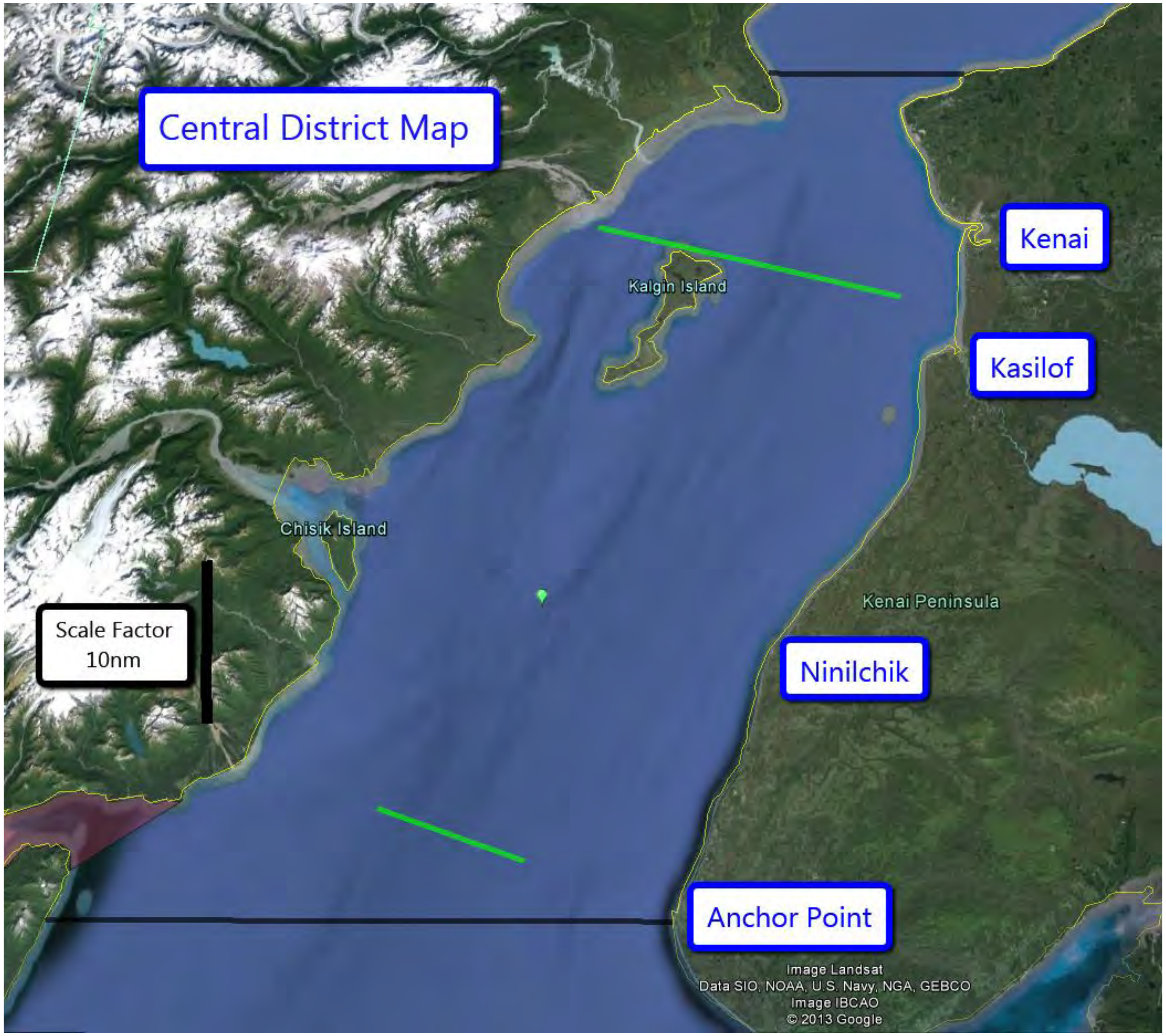
UCI salmon management plans should be adaptive and empirically-based.

We now have scientific data and tools to move in that direction.

Cook Inlet Salmon Fishery Management

The next seven slides illustrate the UCI Central District commercial fishing areas and restricted areas currently in regulation.

Upper Cook Inlet Central District Commercial Fishing Area



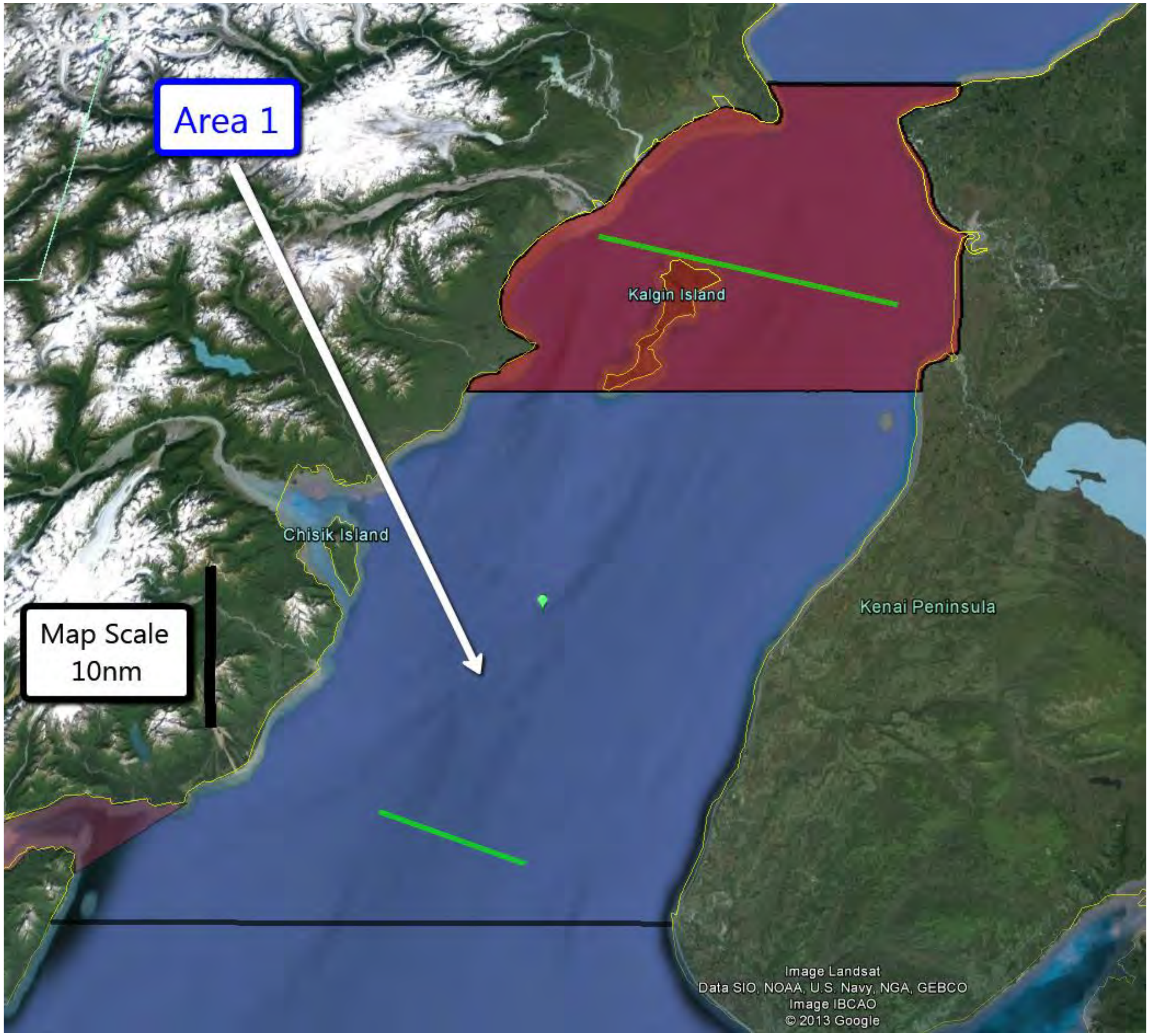
This is the Central District of UCI where all of the drift fishing and most of the setnetting occurs.

The black lines mark the southern and northern boundaries of the district.

The Susitna River is about 50 miles north of the northern boundary of the Central District.

The green lines mark the transects of the North and South Offshore Test Boat Fisheries.

Restricted Area 1



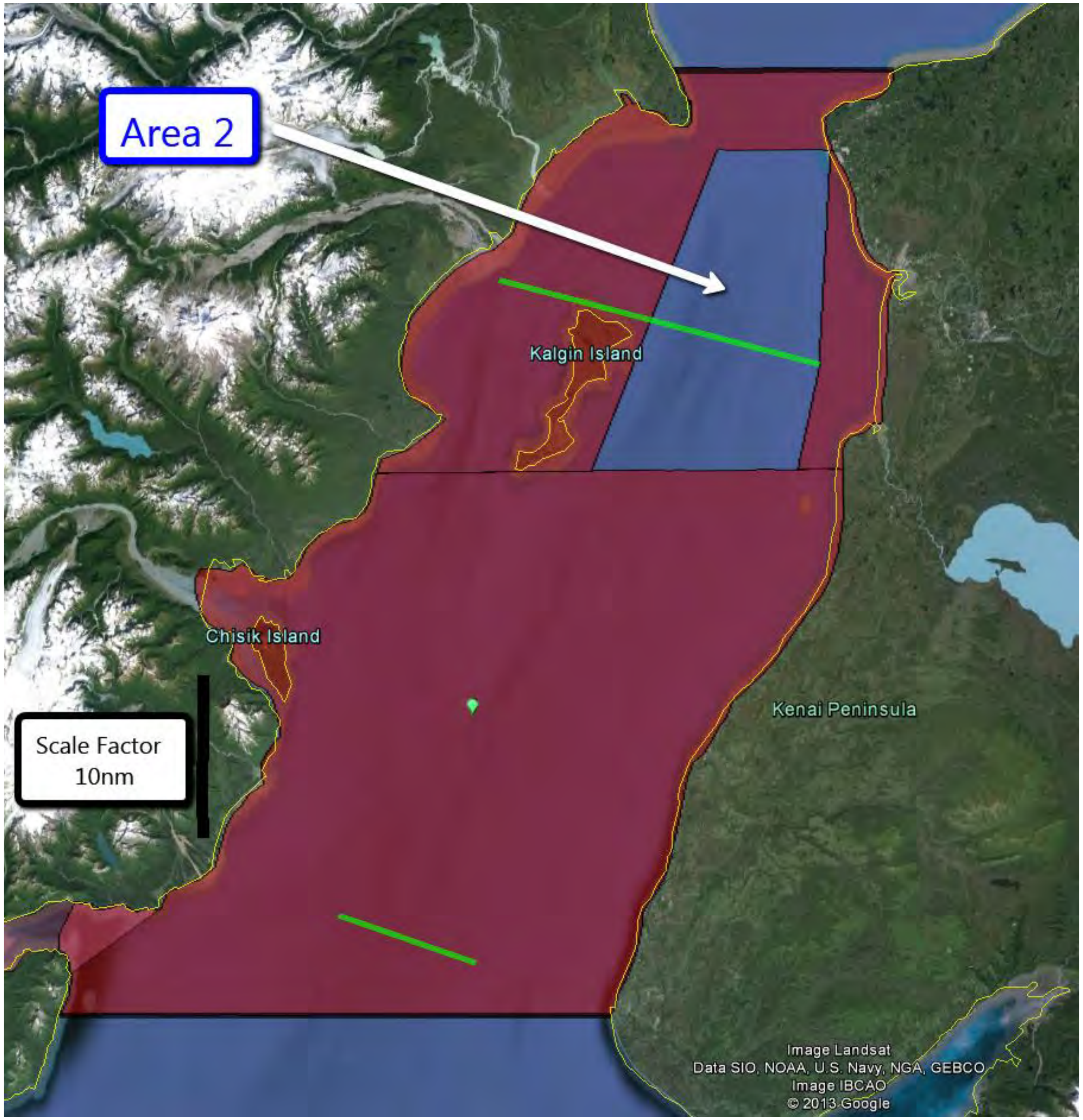
Area 1 is shown on the map in blue and is currently in regulation.

The red shaded area is closed to drift gillnetting when the drift fleet is restricted to Area 1.

Area 1 was created with the assumption that northern stocks might be more prevalent within the closed area at particular times.

There is no method for measuring the effectiveness of this restriction.

Restricted Area 2

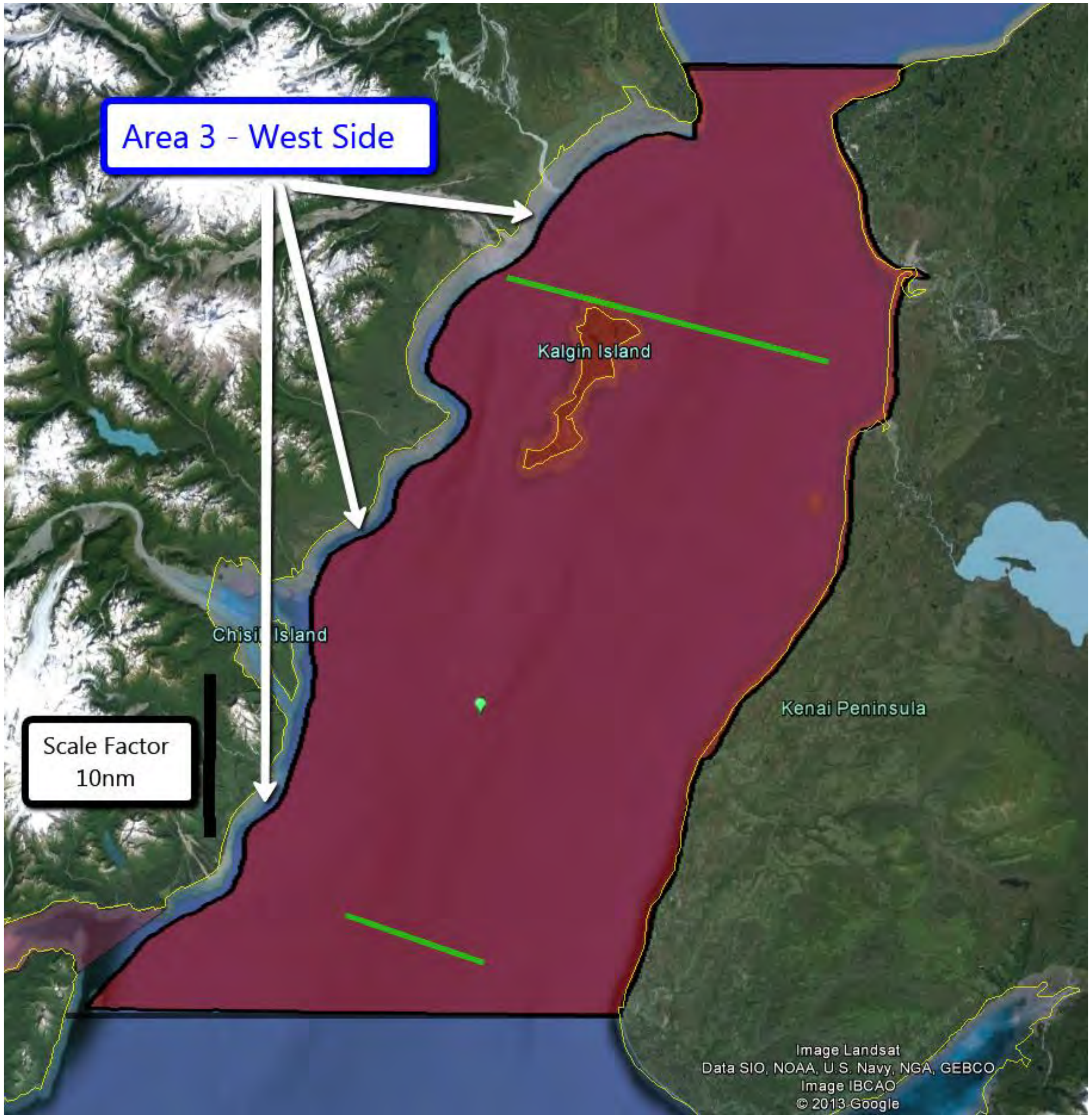


Area 2 is shown on the map in blue and is currently in regulation. Restricting the commercial fishery to this area is based on assumptions about northern bound sockeye.

There is no method for measuring the effectiveness of this restriction.

Studies utilizing genetic stock identification have found that northern-bound sockeye are intermingled with other Cook Inlet stocks both spatially and temporally.

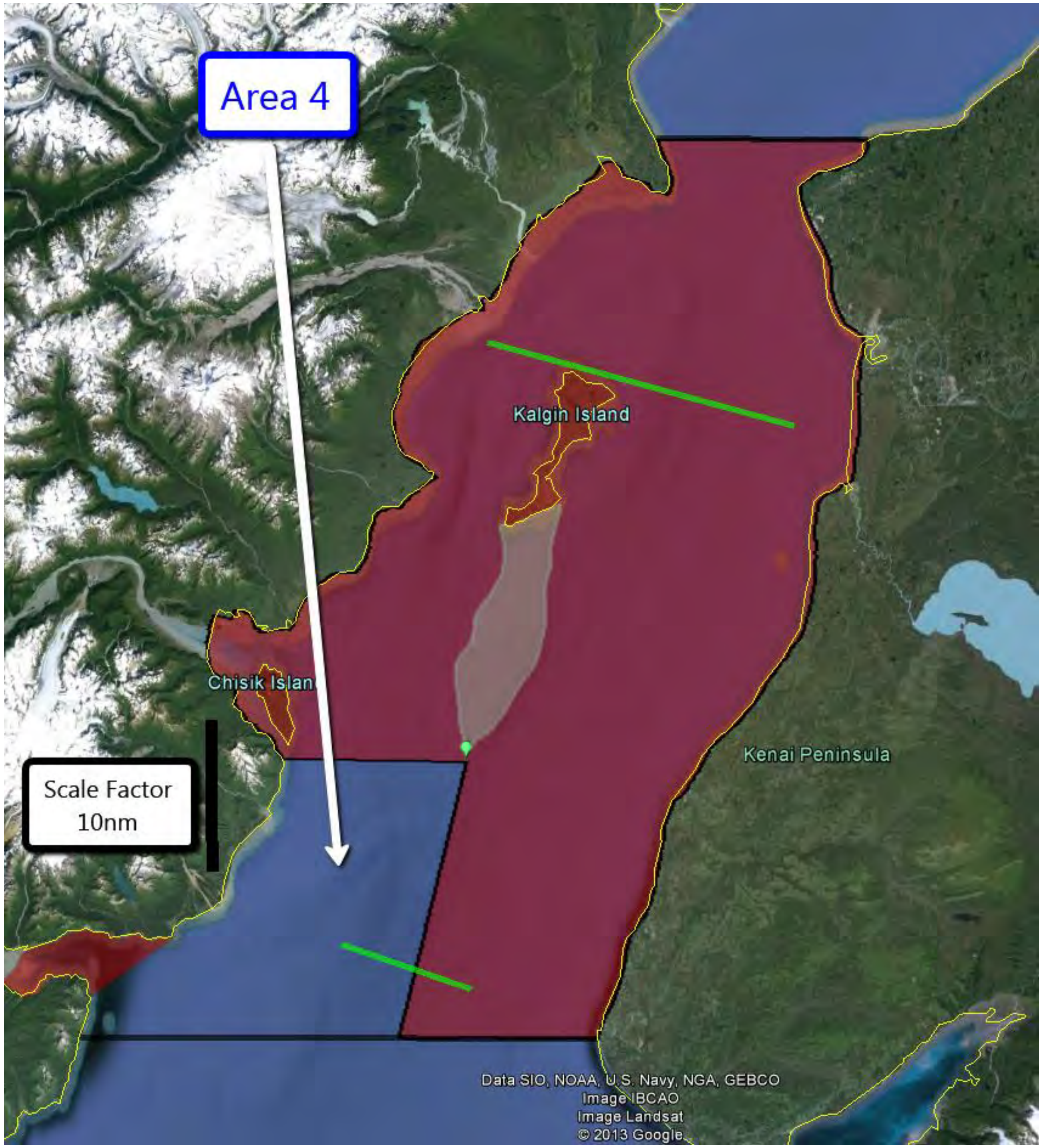
Restricted Area 3



Area 3 was placed in regulation 9 years ago to provide for coho fishing opportunities in August.

Area 3 is a coho fishery rather than a sockeye fishery. It functions for its purpose.

Restricted Area 4

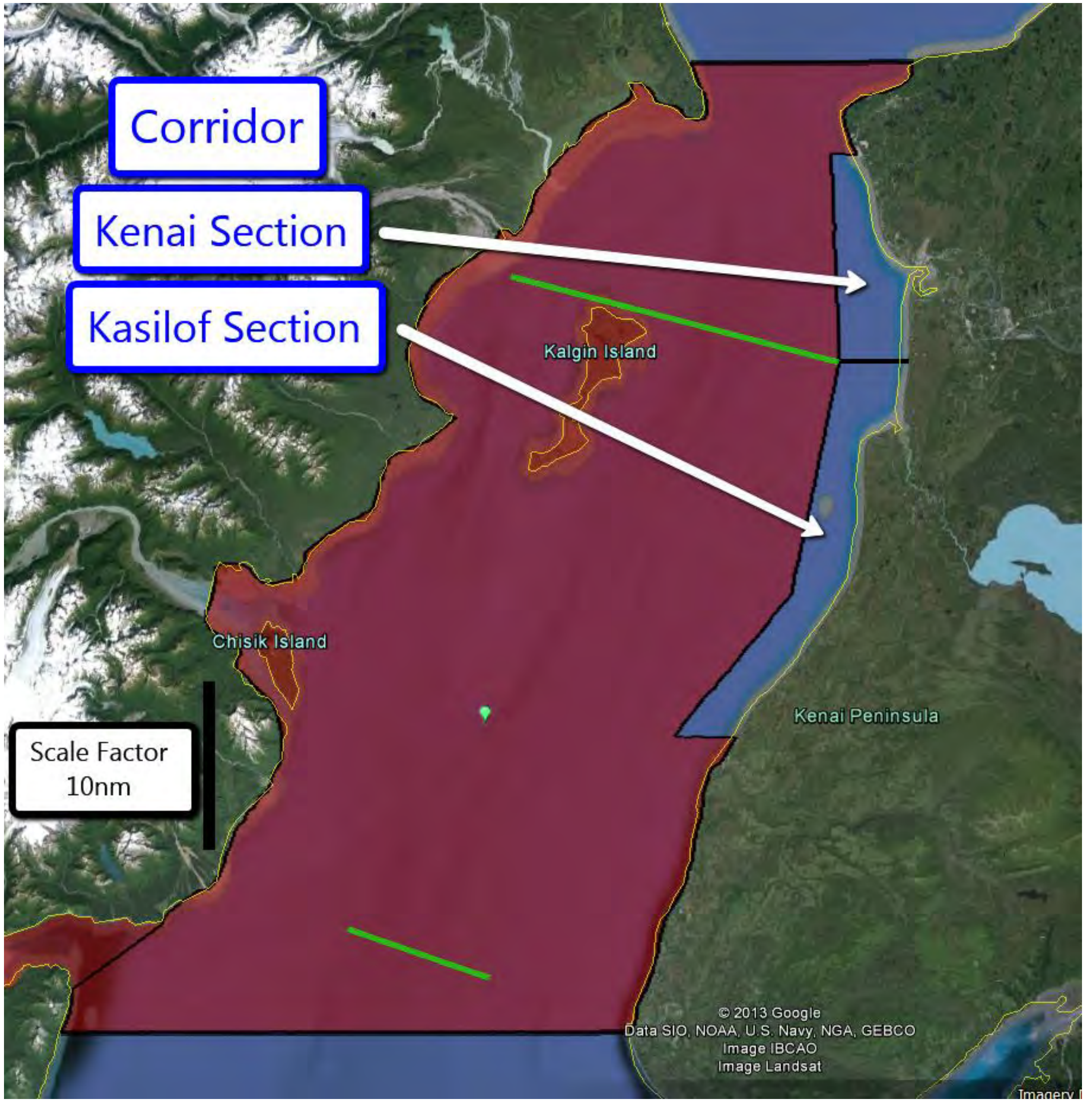


Area 4 was put into regulation 9 years ago. It was intended to provide coho, late sockeye, pink and chum fishing opportunities in August.

The boundaries were based on assumptions with no method for measuring the effectiveness of this restriction.

The green dot at the northeast corner of the area is the Kalgin Navigation Buoy (the "Can") marking the southern tip of a sandbar that extends north to Kalgin Island and is dry at low tide.

Restricted Area - Corridor



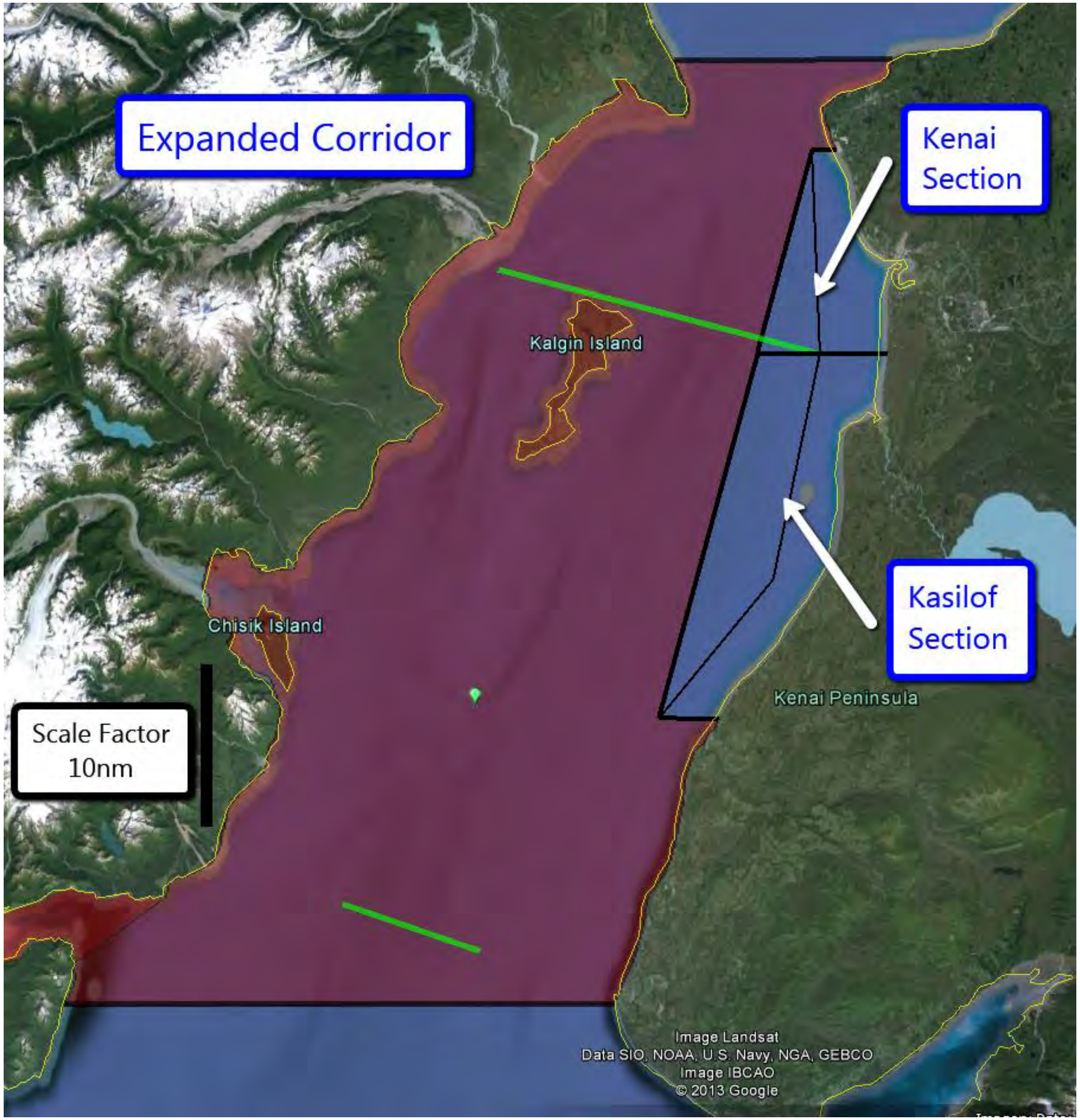
This Corridor is a revision of the Corridor that has been in regulation since 1982 to target Kenai and Kasilof sockeye.

Genetic testing has shown that salmon stocks, including northern-bound sockeye, can be as intermingled in the Corridor as they are in the central inlet.

The first mile and a half offshore in this area is open to setnetting only.

This Corridor is difficult to fish and greatly reduces efficiency.

Restricted Area - Expanded Corridor

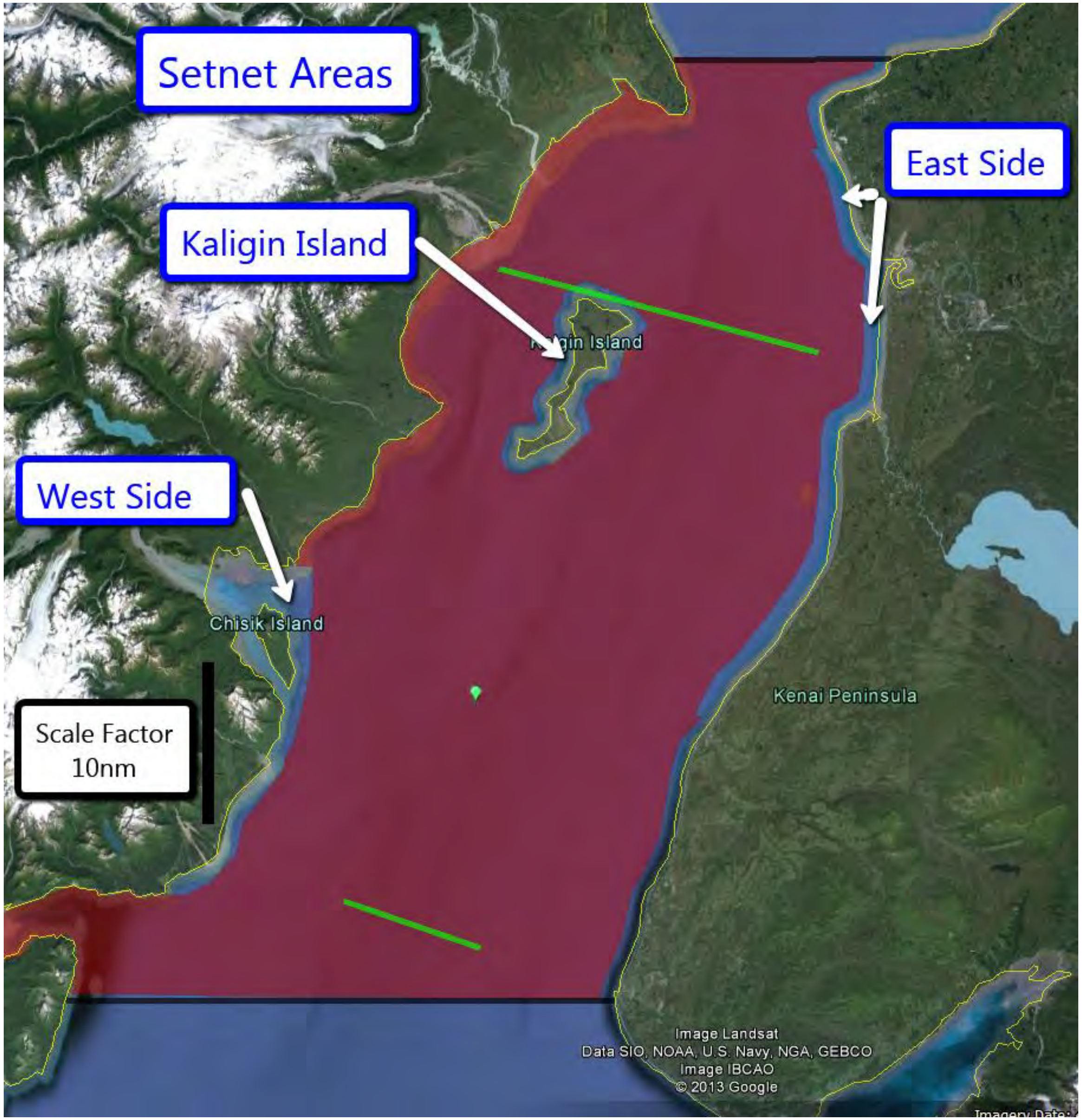


This Expanded Corridor was put into regulation 3 years ago. It has been used in place of regular Monday and Thursday Central District or Area 1 fishing periods.

It was based on assumptions about the movement of northern stocks.

In 2011 the percentage of Susitna sockeye caught in this Corridor was slightly higher than the percentage caught during inlet-wide openings.

Setnet Areas



Setnet Areas have been in use and regulation for over 75 years.

Cook Inlet Salmon Fishery Management

There is no evidence that the fishing restrictions used in the Central District work to conserve northern stocks.

What we have learned from the use of mandatory restrictions is that they prevent fishery managers from reacting to real-time information during the season and they interfere with their ability to manage the whole fishery.

The results of restrictions have been compressed harvests and escapements and over-escapements. Compressed escapements and over-escapements both contribute to adverse density effects.

Compressed harvests undermine the ability of all users to harvest salmon and significantly reduce the quality of the processed product.

Cook Inlet Salmon Fishery Management

The science-based tools and data sets that are available to manage the fishery include:

- Commercial harvest in real-time
- Commercial catch records
- Escapement counters
- Genetic stock identification
- Off-shore Test Boat fishing

Upper Cook Inlet Offshore Test Boat Fishery

Data is now available from two test boats to track how, when and what salmon are moving through Cook Inlet.

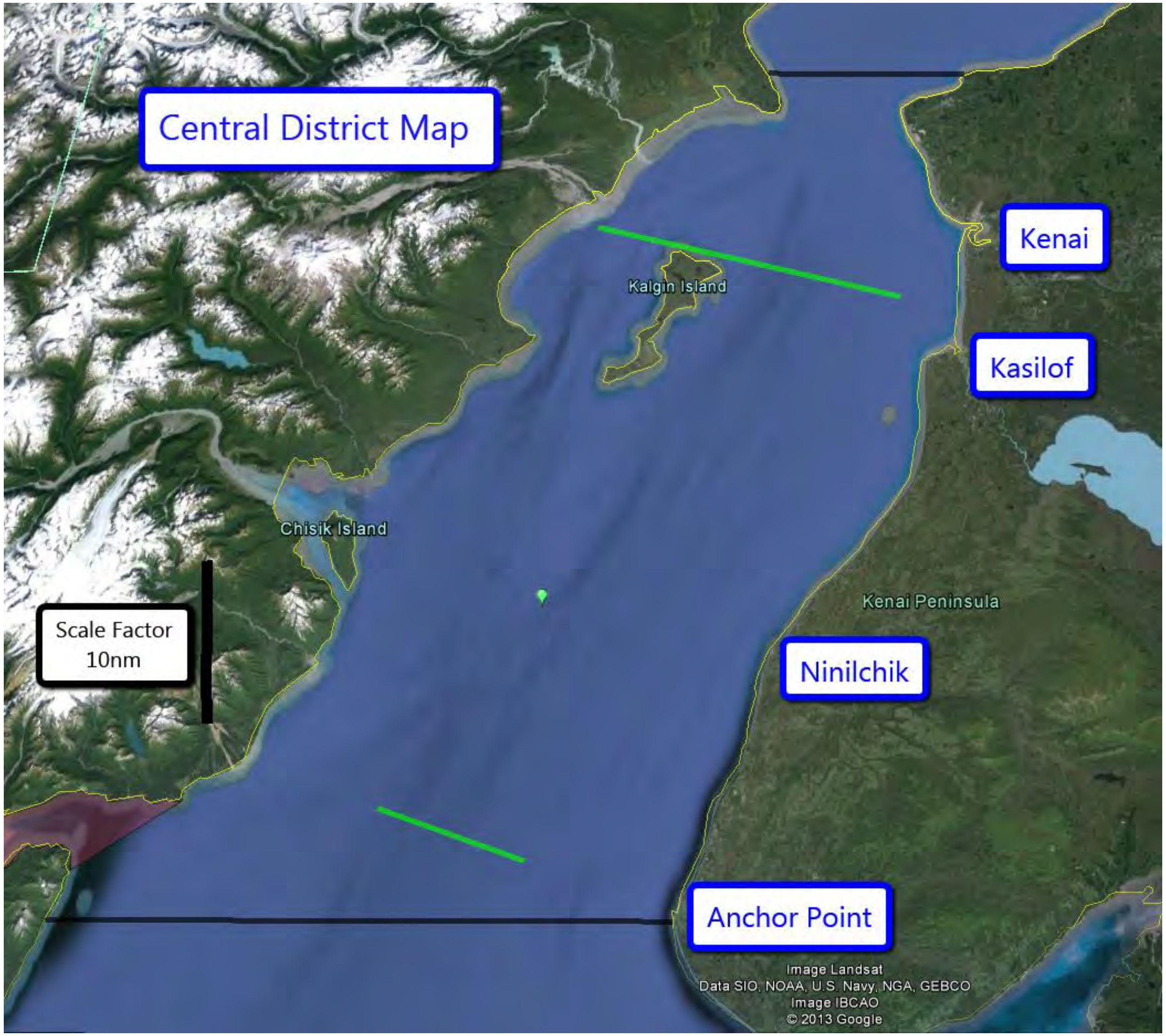
The program is designed to estimate the number of sockeye salmon that enter the district per index point or "CPUE."

Chartered gillnet vessels fish in predetermined locations for a specific time period. These stations are fished every day starting July 1 for about a month. Time, air and water temperature, wind direction and speed, turbidity and salinity are all recorded.

An ADF&G technician on board selects sockeye and coho salmon for measurement and genetic sampling. The genetic samples are sent to the ADF&G laboratory for testing.

A numeric index based on the number of salmon caught is generated for all species to estimate run strength.

Upper Cook Inlet Offshore Test Fish Project



The 2 green lines show the locations of the Offshore Test Fishery

North Boat - Kasilof Line

Fishes 7 locations on a transect line that runs just north of Kalgin Island

South Boat - Anchor Point Line

Fishes 6 locations on a transect line that runs between Anchor Point and the Red River Delta

What do the test boats tell us?

Salmon can move very quickly through Cook Inlet.

Northern stocks are intermingled with other stocks both temporally and spatially.

Many variables including wind, tide and water temperatures all affect the entry patterns.

Kenai River stocks often move toward the river in large groups.

There is a high level of variability in migration patterns from year to year.

2011 Test Boat Index and Kenai Escapement

Date	South Test Boat Index	Kenai River Mile 19 Daily Sonar Count	Kenai River Mile 19 Sonar Count Total
7/1/2011	18	2,256	2,256
7/2/2011	62	4,260	6,516
7/3/2011	57	3,084	9,600
7/4/2011	13	2,244	11,844
7/5/2011	19	4,272	16,116
7/6/2011	13	4,647	20,763
7/7/2011	4	5,302	26,065
7/8/2011	7	4,737	30,802
7/9/2011	34	6,522	37,324
7/10/2011	257	6,846	44,170
7/11/2011	158	3,510	47,680
7/12/2011	172	3,102	50,782
7/13/2011	312	3,822	54,604
7/14/2011	243	6,400	61,004
7/15/2011	378	2,916	63,920
7/16/2011	291	27,826	91,746
7/17/2011	131	230,643	322,389
7/18/2011	109	177,053	499,442
7/19/2011	36	87,978	587,420
7/20/2011	135	113,178	700,598
7/21/2011	54	90,426	791,024
7/22/2011	263	37,974	828,998
7/23/2011	162	106,313	935,311
7/24/2011	153	110,772	1,046,083
7/25/2011	121	79,518	1,125,601
7/26/2011	138	77,982	1,203,583
7/27/2011	29	73,092	1,276,675
7/28/2011	138	55,470	1,332,145

In 2011 ADF&G used only the South Test Boat.

The numbers in the second column (”Index”) are mathematically derived to reflect sockeye passage.

The spike in the index on July 10 indicates a large movement of sockeye into the Central District.

Seven days later those fish had moved 40 miles up Cook Inlet and 19 miles up the Kenai River.

(Source – ADF&G)

2012 Test Boat Index and Kenai Escapement

Date	South Test Boat Index	North Test Boat Index	Kenai River Mile 19 Sonar Daily Count	Kenai River Mile 19 Sonar Total Count
7/1/2012	66	23	3,970	3,970
7/2/2012	25	5	8,970	12,940
7/3/2012	45	11	7,067	20,007
7/4/2012	49	7	5,514	25,521
7/5/2012	64	10	4,913	30,434
7/6/2012	58	7	3,426	33,860
7/7/2012	70	10	3,648	37,508
7/8/2012	62	8	5,466	42,974
7/9/2012	11	7	6,470	49,444
7/10/2012	53	24	6,774	56,218
7/11/2012	151	15	12,054	68,272
7/12/2012	181	84	9,726	77,998
7/13/2012	127	431	10,548	88,546
7/14/2012	136	381	20,214	108,760
7/15/2012	67	109	119,274	228,034
7/16/2012	16	285	196,356	424,390
7/17/2012	196	284	72,726	497,116
7/18/2012	84	273	31,606	528,722
7/19/2012	137	240	28,722	557,444
7/20/2012	217	217	40,230	597,674
7/21/2012	91	278	97,914	695,588
7/22/2012	43	258	110,898	806,486
7/23/2012	15	142	88,255	894,741
7/24/2012	5	168	51,222	945,963
7/25/2012	3	126	61,420	1,007,383
7/26/2012	7	106	61,812	1,069,195
7/27/2012	47	49	65,250	1,134,445
7/28/2012	15	57	63,438	1,197,883

In 2012 ADF&G used the South and North Test Boats.

The highlighted cells show the rapid movement of sockeye salmon up Cook Inlet and 19 miles up the Kenai River.

(Source – ADF&G)

2013 Test Boat Index and Kenai Escapement

Date	South Test Boat Index	North Test Boat Index	Kenai River Mile 19 Sonar Daily Count	Kenai River Mile 19 Sonar Total Count
7/1/2013	47	1	7,530	7,530
7/2/2013	46	4	4,380	11,910
7/3/2013	73	24	4,164	16,074
7/4/2013	60	13	10,655	26,729
7/5/2013	93	6	11,454	38,183
7/6/2013	49	4	4,915	43,098
7/7/2013	101	6	3,508	46,606
7/8/2013	6	39	3,514	50,120
7/9/2013	105	52	6,814	56,934
7/10/2013	11	32	18,270	75,204
7/11/2013	113	107	33,702	108,906
7/12/2013	88	3	10,086	118,992
7/13/2013	17	49	9,090	128,082
7/14/2013	No Data	632	24,520	152,602
7/15/2013	18	807	93,151	245,753
7/16/2013	183	217	247,084	492,837
7/17/2013	No Data	162	215,636	708,473
7/18/2013	No Data	116	117,785	826,258
7/19/2013	No Data	51	92,771	919,029
7/20/2013	20	93	81,281	1,000,310
7/21/2013	12	12	38,302	1,038,612
7/22/2013	64	15	24,900	1,063,512
7/23/2013	14	16	29,796	1,093,308
7/24/2013	108	18	17,993	1,111,301
7/25/2013	42	48	13,542	1,124,843
7/26/2013	6	15	21,954	1,146,797
7/27/2013	21	20	29,100	1,175,897
7/28/2013	5	13	28,039	1,203,936

In 2013 the South Test Boat did not detect a large movement of sockeye into the Central District.

On July 14 the North Test Boat detected a very large body of fish.

Within 24 hours those fish were starting to show at the Kenai sonar counter 19 miles up the river.

(Source – ADF&G)

Utilizing Migration Patterns and Run Timing

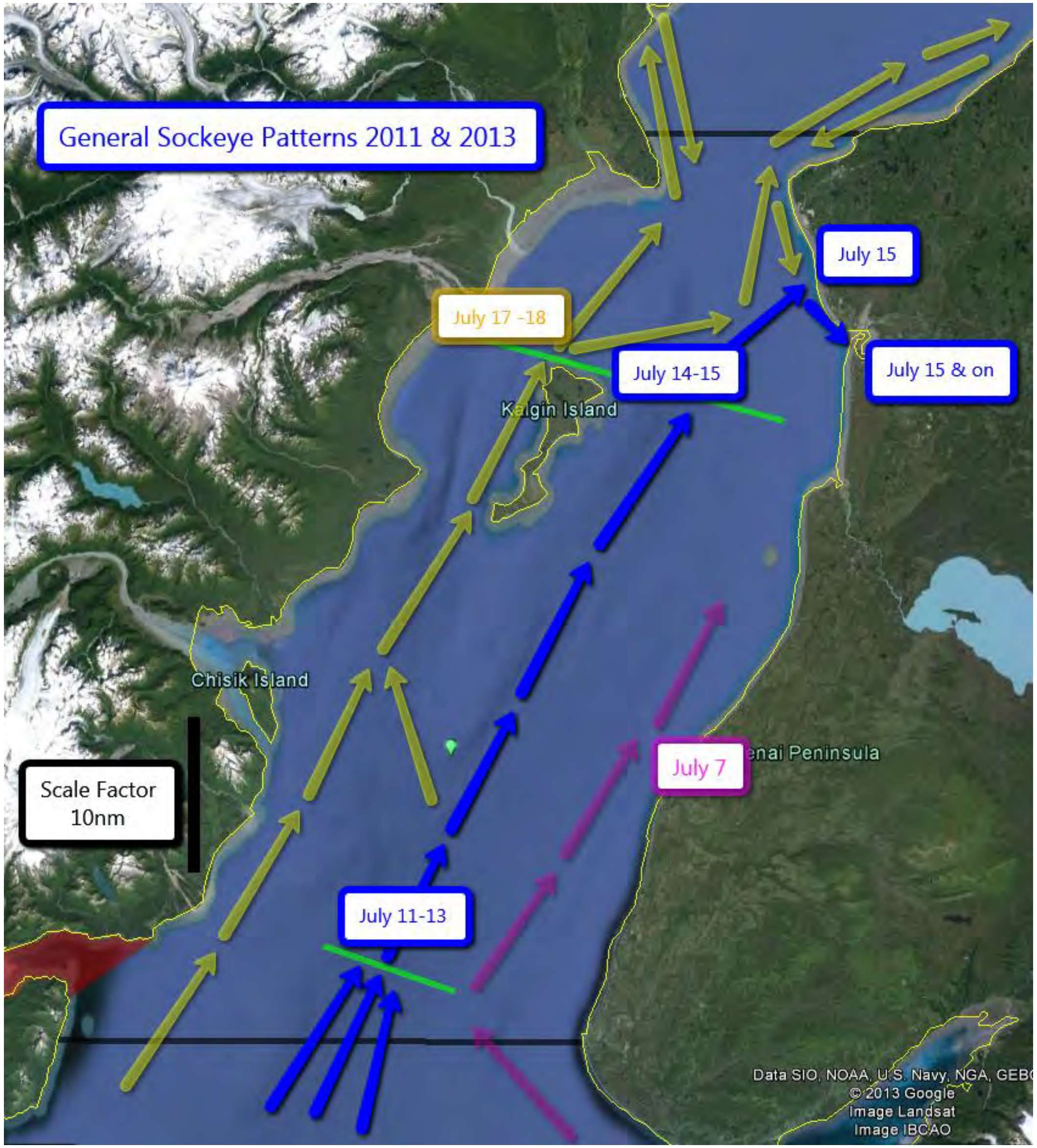
Adaptive management is essential in order to respond to this rapid movement of salmon.

Managers should be able to open fisheries with as little as one hour notice, regardless of any pre-determined restrictions to time or area.

Timely responses utilizing both the drift and setnet fleets to observed fish movements can prevent compression of escapement timing.

Historical observation has shown that commercial fishing activity disperses large schools of fish, slowing their migration to the river.

General Sockeye Patterns 2011 & 2013

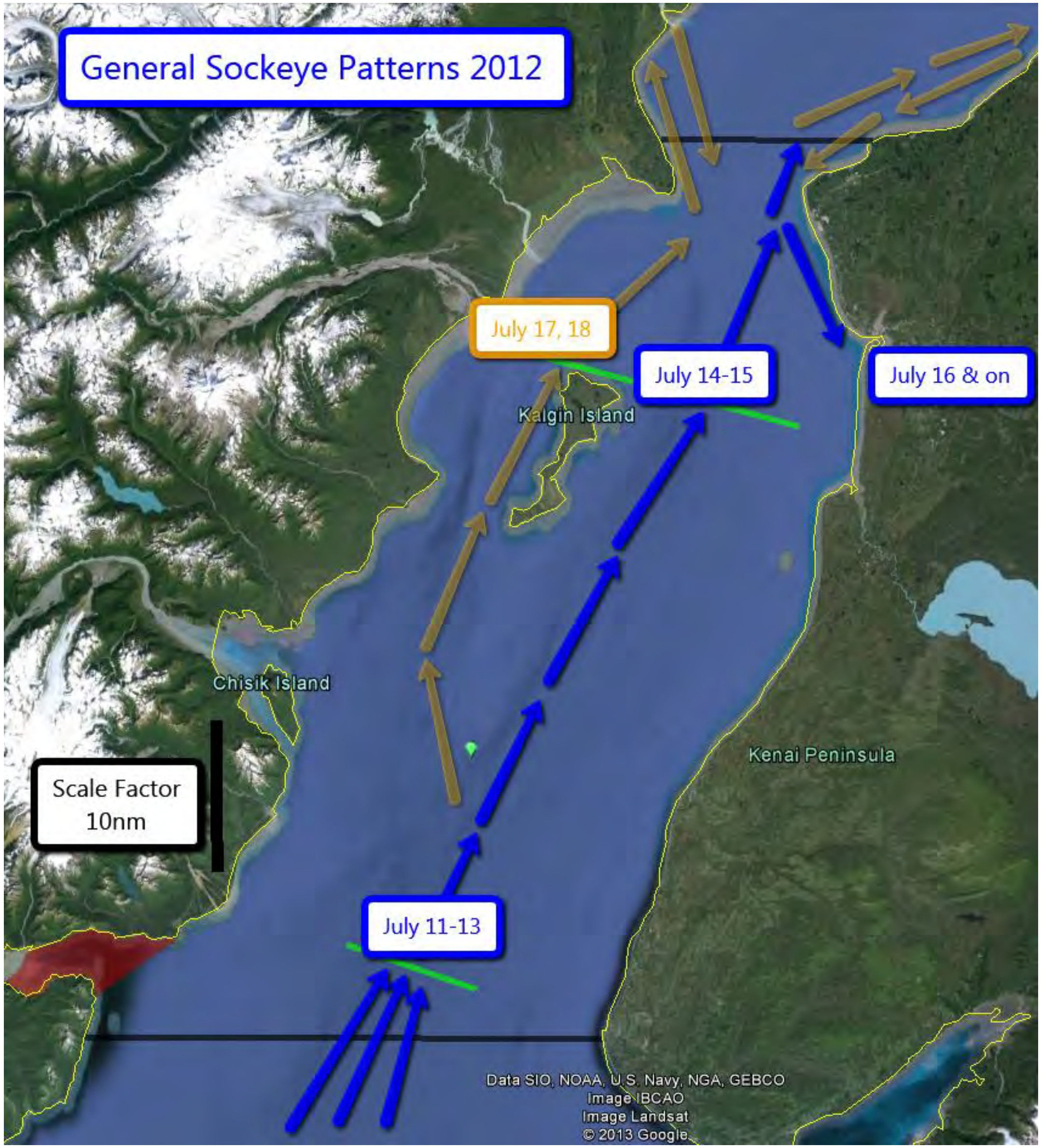


This map depicts movements of sockeye through the Central District in 2011 and 2013. Major fish movements are shown with the blue arrows, minor movements in other colors.

The arrow segments represent approximate half-day, or 12 hour, movements in the direction of the arrow. Dates, where known, are placed appropriately.

Both years had similar patterns with east and west components. 2011 had a steady east side pattern throughout the season. In 2013 there was an east side movement, but only during the early part of July.

General Sockeye Patterns 2012

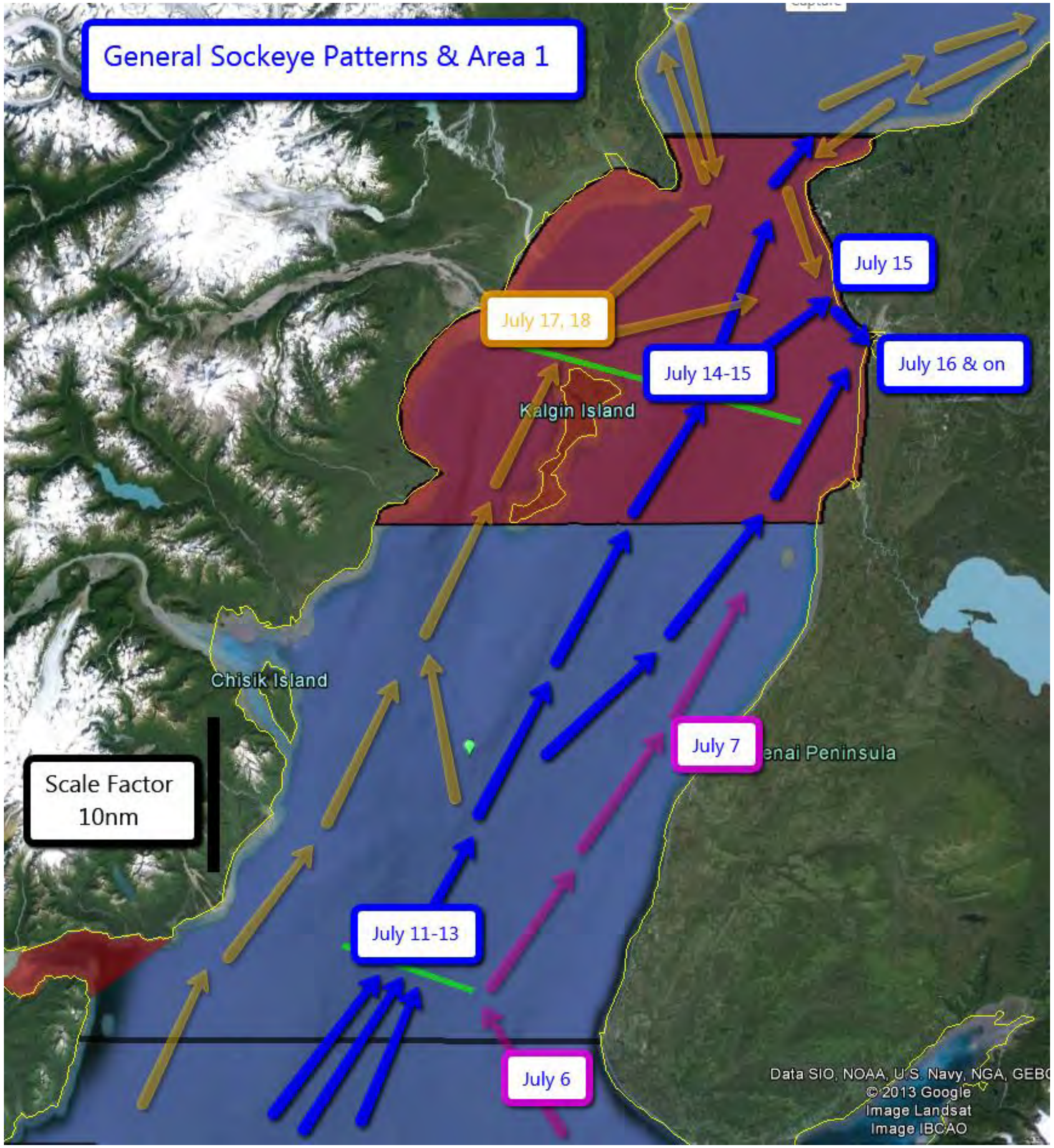


In 2012 almost the entire fish movement pattern was concentrated in the center of the inlet.

As seen in the previous slide, some salmon moved into the Northern District before heading back south. This is a typical pattern. Kenai and Kasilof sockeye can exceed 50% of the stock composition of the Northern District setnet harvest.

It is also typical for those fish to move close to shore along Salamatof Beach on their way back south.

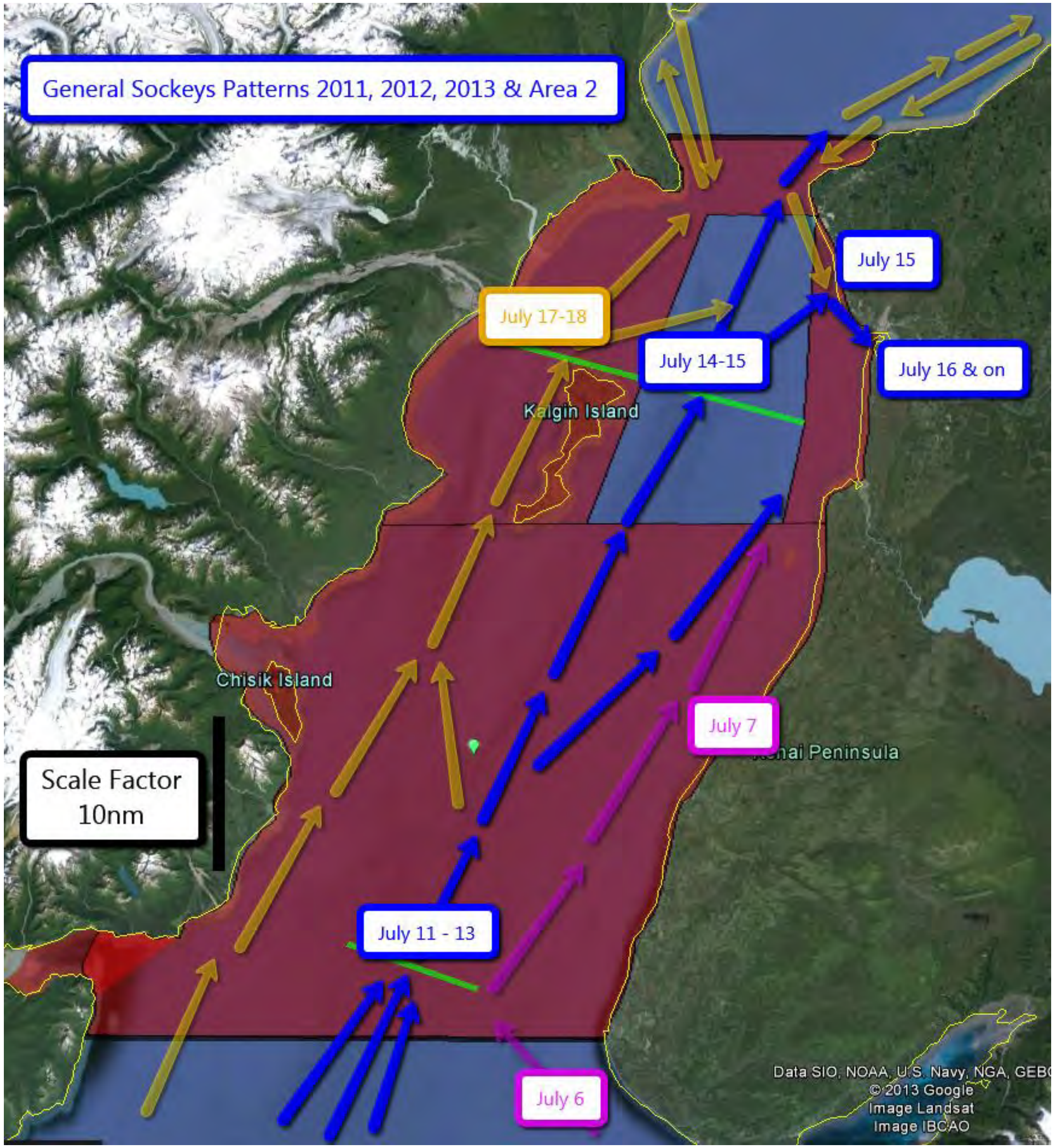
General Sockeye Patterns 2011, 2012, 2013 and Restricted A[r



As this map indicates, all northward movements of sockeye pass through Area 1.

They generally spend 2 to 2.5 days in Area 1.

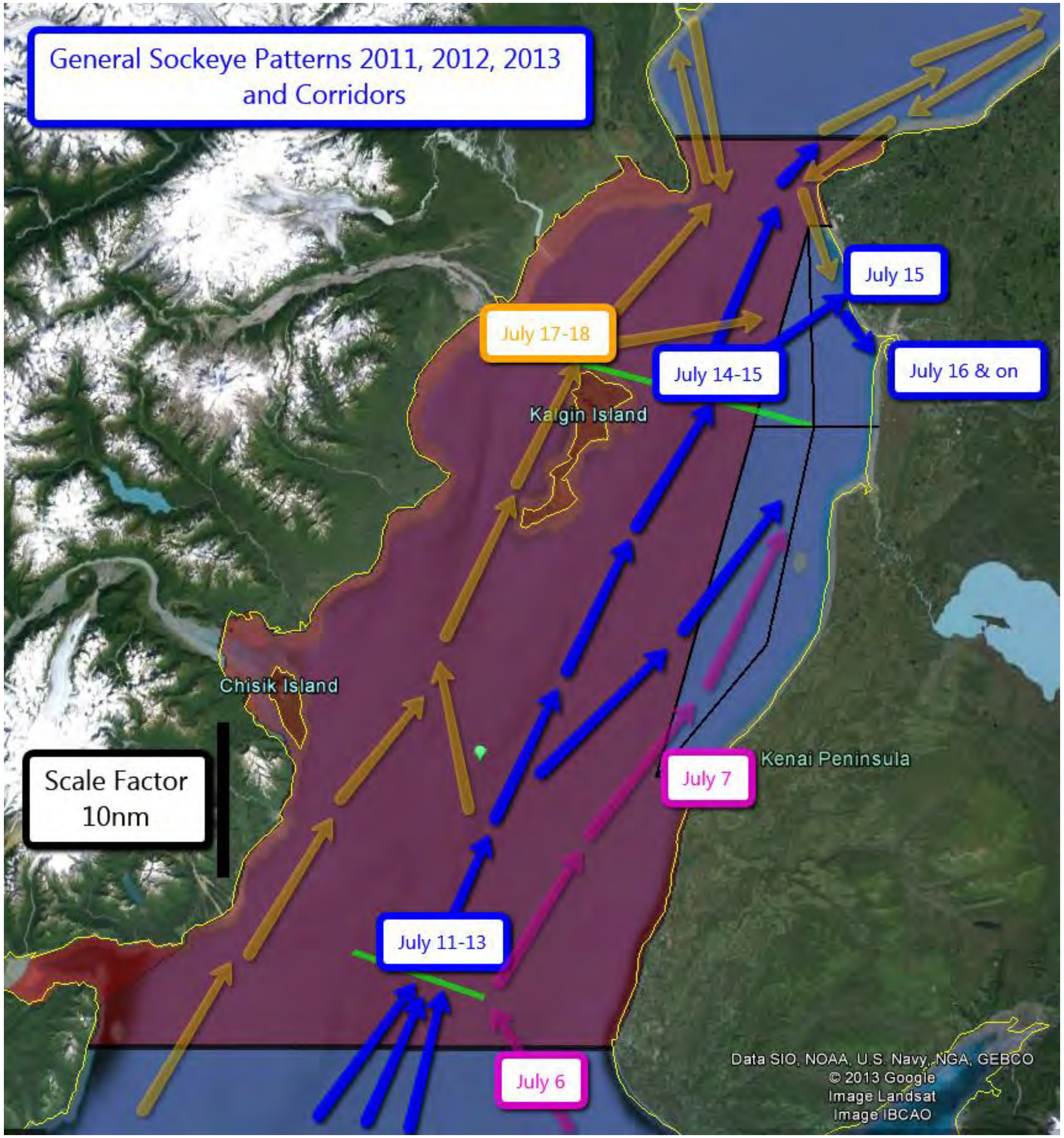
General Sockeye Patterns 2011, 2012, 2013 and Restricted A



This map shows that sockeyes may be in Area 2 for only 12-24 hours before moving out of the area.

If Area 2 is intended to be used for harvesting fish detected at the North Test Boat line, then Emergency Openings with 1-2 hour notices should be utilized.

General Sockeye Patterns 2011, 2012, 2013 and Corridors



Sockeye spend a day or less moving through both Corridors.

Genetic testing has shown that salmon stocks, including northern-bound sockeye, are as intermingled in the Corridor as they are in the central inlet.

Utilizing Migration Patterns and Run Timin

This salmon movement information can be used to spread the harvest and the escapement throughout the run.

It is ADF&G policy to spread the escapement throughout the run.

- Compressed run timing and escapement decreases biological diversity. Diversity adds to a stock's resilience
- Diversity decreases the risk of a local catastrophic event that could jeopardize an entire stock.
- Spreading escapement reduces potential for adverse density dependent effects.
- High densities of salmon passing through the sonar beam leads to undercounting of escapement.
- All user groups benefit as harvest opportunity is spread out over time.

Current UCI management amplifies compressed run and escapement timing.

The restrictions placed on the drift fleet to conserve northern sockeye stocks and other mandatory restrictions such as setnet fishing "windows" have been part of the state's prescriptive management approach to UCI salmon.

These restrictions have prevented fishery managers from responding appropriately to real-time information during the season.

In 2012, from July 15 through 23, at least 785,981 sockeye entered the Kenai River. This was 50% of the total escapement (1,581,555) in just 9 days.

In 2013, from July 15 through 20, at least 844,462 sockeye entered the Kenai River. Over 62 % of the total escapement (1,354,554) in just 6 days. Possibly the most compressed run in Cook Inlet history.

Current UCI management amplifies compressed

Compressed harvests result from compressed runs.

In recent years Cook Inlet seafood processors have been forced to purchase 25% of their entire season's sockeye pack in one day.

Compressed harvests lead to significant decreases in the quality and value of fish harvested. Harvesters don't have the time to chill and handle the fish carefully. Seafood plants get plugged and can't process the fish in a timely manner. In response, the seafood companies often have to put the harvesters on limits, with economic losses for all.

The additional consequence is that the harvestable surplus of salmon at that point cannot be effectively harvested, resulting in over-escapements into the rivers.

Premium quality fish destined for a fresh market are worth 2 to 3 times more than a lesser quality frozen product.

Conclusions

The management that has evolved for UCI over the past decades was largely based on a set of assumptions that we now realize were incorrect.

Scientific data from genetic stock identification, Test Boat fishing and the recognition that Susitna sockeye escapements had been grossly undercounted since 1982 have contradicted those previous assumptions.

Scientific data can now inform an empirically-based management plan. Any fishing restrictions should be scientifically justifiable, have set goals and measurable objectives.

UCI salmon management plans need to be adaptive rather than prescriptive so that fishery managers can respond appropriately to real-time run information.

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A king without a crown: Chinook vulnerable to ocean forces

By Abby Lowell, Morris News Service-Alaska/Juneau Empire
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Joe Edwards of Houston, Texas, watches as his king salmon weights in at 16.2 pounds at the Douglas Harbor for the Golden North Salmon Derby in August of 2011. Scientists with the National Oceanic and Atmospheric Administration in Juneau said the 28-inch size limit for chinook salmon, while intended as a conservation measure, may be removing fast-growing fish from the population over time.

Photo/Michael Penn/Juneau Empire

Editor's note: This is the ninth in the Morris Communications series "The case for conserving the Kenai king salmon."

Alaska's long-lived monarch — the king salmon — has fallen from its throne.

The species, which once thrived as a fabled ruler in state waters, was sought-after by fisherman from all over the world. Their massive presence in rivers like the Kenai, the Yukon and the Taku, to name only a few, brought sport and commercial fisherman to banks and river mouths for a chance to harvest this mighty resource.

The largest known king — weighing in at 126.5 pounds — was caught in a fish trap off Prince of Wales Island in Southeast Alaska in 1938.

Today, fish of that caliber are seemingly nonexistent. Alaska has seen unprecedented declines in recent years resulting in declarations of economic disasters in some regions, or simply empty freezers in others. Researchers, management officials, commercial fisherman, subsistence users and sport fisherman are coming to the same conclusion — the fish are fewer and the sizes smaller.

That's why scientists like Joe Orsi and Jim Murphy, both fisheries research biologists with the National Oceanic and Atmospheric Administration, are digging deeper into decades of research to put forth evidence and findings that may lead to a solution or at least a clue to the cause of the startling downward trend.

Orsi has studied chinook salmon, *Oncorhynchus tshawytscha*, for nearly his entire career. As part of NOAA's Ecosystem Monitoring and Assessment Program he has helped to gather data for the Southeast Alaska Coastal Monitoring project, which aims to understand and examine ocean conditions and the factors that affect king salmon. He and his team have collected and sampled juvenile salmon, as well as any data they may be packing, migrating through Southeast Alaska waters since 1997.

He said the first step to understanding what factors and forces may be affecting the chinook is to take a look at the ecological niche they occupy.

"chinook salmon are different from the other salmon species," he said. "For instance, they tend to prefer colder, deeper waters than the other four salmon species, and they're more long-lived. So that takes them to different parts of the ocean."

Kings are also primarily fish-eaters, while the other four species of salmon feed on invertebrates. Like the coho, for instance, which migrates far into the Gulf of Alaska to prey on squid.

Second, it's important to understand the lifecycle and migration trends of this species, Orsi said.

Scientists speculate that king salmon migrate great distances during their time in the ocean, though the exact patterns of migration are still largely a mystery. Historically, before the construction of dams on the Columbia and Snake rivers in the Pacific Northwest, kings from those systems would be caught in Southeast Alaska waters. In an article published this spring, Orsi references "one exceptional chinook salmon stock harvested in this fishery, the Columbia River 'summer hogs,'" which he said was a summer run fish that returned to the Columbia at an average weight of 30 pounds.

Researchers do know, however, that chinook typically move northward and westward in the ocean with respect to their stream of origin. So a juvenile king salmon leaving the Kenai River, for instance, would likely spend a portion of its time in Cook Inlet, before later moving westward down the Alaska Peninsula. They also know king salmon hang closer to coastlines than other species.

But when it comes to digesting the impacts affecting the productivity of king salmon in Alaska, both Orsi and Murphy said it's tough, to say the least. Many of the impacts affecting king salmon in the state are unique to particular stocks; each group will migrate in a different pattern during their five-year tenure in salt water.

Hence, each king salmon, as it follows its unique migration pattern, will encounter different influences, different factors and hurdles, and to varying degrees. And stocks that migrate in the Bering Sea, for instance, do not show up in Southeast. And those that originate in Cook Inlet aren't caught off the coast of the Panhandle. Both researchers said it's unlikely the movements of the juveniles in each of the areas interact much over the course of their lives. Furthermore, there's just not a good way to accurately monitor the timing and pattern of how each stock moves. Orsi said they know what research needs to be done, they just don't have access to the proper technology to do so.

Take sharks in Hawaii, for instance. This year, researchers have been able to fit sharks with satellite tracking devices to monitor their movements and real-time updates are available regularly. But when it comes to king salmon, Orsi said even the big size of the species isn't large enough to support the size of today's satellite devices. However, such a technological development may be on the horizon, he said, providing opportunities for scientists to monitor exactly where Alaska's king salmon are swimming.

"Once we know where they are going and when, we can better identify the interactions they face and subsequently provide better recommendations for management tools," Orsi said.

Murphy, a researcher who has studied Southeast stocks, but has more recently focused on Bering Sea kings, said the species doesn't live up to its mighty moniker.

"Kings are very fragile, the most timid fish in the river," he said. "Chums, for instance, will just barrel through … even a tiny shadow will cause the kings to scatter."

Physically, Murphy said the kings are also not as stout as they seem.

“We catch these fish in trawls,” he said. “They’re beat up, so they lose a lot of scales. The coho we catch are tanks — they’re just tough. All the kings are just … dead.”

Yet the chinook have evolved with resilience to colder waters, Orsi said.

“In the winter time, they can go to areas that other salmon can’t go to because they can tolerate the colder temperatures,” he said.

That’s also why they like to swim deep in the ocean column, and where commercial and sport fisherman have learned to target the species with downriggers that take herring-baited hooks down to where the juveniles are feeding.

Encounter rates

“Most recently, there’s been more use of downriggers than ever and more targeting of immatures that are revolving around through fisheries,” Orsi said. “And as a result, the encounter rates are increasing.”

In other words, fisherman and king salmon have been interacting more and more over the course of the five years they spend maturing in the ocean. And more interactions mean more potential for mortality.

Officials have also set a size limit of 28 inches on the king salmon in Alaska, meaning only fish that size or larger may be harvested.

Orsi said the harvest size requirement is another factor that could be contributing to population declines throughout the state.

“What that does is it tries to ensure that the fish basically live three ocean winters before they are harvested in the spring, so a three-ocean fish in May is probably always 28 inches or larger, which I think is a good assumption,” Orsi said. “But the flipside of it is, the really fast-growing two-ocean fish will grow into that size limit in the fall.”

Those fast-growing fish are being culled from the population, which over time removes from the existing population the genetic predisposition to grow king-sized quickly.

In order to retain the characteristics most valued in king salmon — the large size, for instance — it’s not in the best interest of fisherman to harvest fish that most readily show those characteristics, Orsi said. Instead, he and others have suggested that current management techniques — specifically the size limit of 28 inches — are set up to fail over long periods of time. We may be starting to see the effects of harvesting the largest and fastest-growing fish, he said.

“If they’re genetically predisposed to grow fast, that’s why they’re reaching legal size in two-ocean winters and we’re taking those out of the population continually and you add a few decades on there and pretty soon, fish start getting smaller,” Orsi said. “That’s one of those concepts examining how the increased fishing effort using size limits is having on productivity, because we may be having the same size fish coming back, and their fecundity — the amount of eggs they have in their skeins — is lower, too, because the females are smaller size.”

Fewer eggs being laid by smaller females have effects that go beyond the obvious. Not only can they not produce as many eggs as their larger counterparts, but they also cannot swim up the strongest of currents or carve out redds, or spawning nests, quite as deeply.

Hence, the eggs that do get deposited may be further downstream, in areas that might be more congested and that means increased competition. Furthermore, it's likely the eggs from smaller females will be deposited in shallower redds, ultimately lessening their chance at survival, Orsi said.

Back on the water open water, commercial fisheries have expanded and developed over the decades in Alaska. For example, there's now a chum salmon troll fishery in Southeast's Icy Strait that targets adult returning chums.

"Well there are also immature chinook out there, too," Orsi said. "They're being handled and released … and there is increased charter fishing everywhere. You have to ask the question: What's the mortality of those fish that were handled?"

Orsi and his team launched a series of studies to determine just that. Essentially, the team observed commercial troll-caught-and-released king salmon in marine net pens after their release.

"When they release a fish, they bring it up out of the water and they grab it with the crook of the gaff, and they shake it off, so there's one hook point into it, and the fish is rolled out — they're pretty good sized hooks, too — and what we had them do is roll them out into a tub, and we assessed the injury location at the time of shaking, and then the fish were run out to net pens where they were tagged and transferred into the net pens and then they were observed for three days."

After that time the fish were released en masse … the ones that could, anyway. Orsi said the dead ones were tallied, as were the dead on arrival, and the team came up with mortality estimates for that fishery. They found 20 percent of legal-sized fish died after being released, as did 25 percent of sub-legal fish.

The larger fish — those of legal size — had a higher likelihood of surviving a commercial fishing encounter. In this case, an encounter with a trolling boat. But those of sublegal size — 28 inches or smaller — were less likely to survive, based on Orsi's findings. He said it comes down the location of key features on the fish, such as the eye and the gill arches, which may or may not come in contact with a gaff or fishing hook.

A smaller fish has features that are closer together and a "frisky" attitude that raises the potential for injury. He found a king may swim away just fine immediately after being released, but within three days that fish may die anyway from injuries sustained while being caught, or face predation due to being impaired from the interaction.

"That's a one-time hook and release," Orsi said.

Just one. Over the course of a king salmon's time in the ocean, this type of interaction has the potential to could occur hundreds, if not thousands of times.

"When we do studies in Icy Strait, we see injury locations on fish that have been released. We know that it's happening. Then you look at the sport and charter fisheries. Many of those fish get handled by a net, which is not good for fish that are immature and have real deciduous scales; they flake off easily. If you use a knotted dip net on a fish and you peel of 20 to 30 percent of the scales, chances are its probably going to die," he said.

The importance of scales on a fish is paramount — it serves to not only protect the fish from bacteria and parasites, but it also goes a step farther — it supports proper osmoregulation, which regulates the proper salt balance in their bodies.

An improper balance "will stress them out the make them more vulnerable to predation," Orsi said.

Inexperienced fishermen

When it comes to catch-and-release, commercial fisherman are quite adept at the process — they have to be. But sport fisherman may not have the process down pat.

"Imagine someone picking a fish out of the water — with two hooks in it — off a herring, it's wiggling around in a dip net, it's pulled in the boat, bouncing around, get it back, measuring it to see if it's legal, get it back over the boat (for release) … I suspect the mortality on fish that encounter those situations is higher than what we saw on troll-caught fish," he said.

Also consider the predation factor, too, Orsi said. "The fish may seemingly swim away just fine, but if they have an eye rupture, for example … we don't see too many one-eyed fish coming back to weirs or that you catch on a hook-and-line. They just don't survive."

The most dramatic example of size selection affecting the size of returning king salmon, according to Orsi, is the proliferation of salmon derbies in the Southeast region and around the state.

Of the historic derbies in Alaska's panhandle, the Golden North Salmon Derby is perhaps one of the most well known. According to an article written in 1989 by Karleen Alstead Grummett titled "The First Golden North Salmon Derby," the initial derby kicked off in the summer of 1947 and was organized by the Territorial Sportsmen, in an effort to "establish Juneau as the greatest tourist and sports center in Alaska." The winning prizes, a 1947 Plymouth "Deluxe" automobile and an outboard boat and motor, to name a few, went to the participant who turned in the largest king salmon. That year, on Sept. 7, Dick Harris was proclaimed the winner with a 38-pound, 4-ounce king salmon. In 2013, the winner of the Golden North Salmon Derby turned in a 29.2-pound king, the largest the derby had seen since 2008.

Orsi said organizers of the Golden North Derby have made efforts to preserve the region's king salmon stocks.

"Around the 1970s, (the derby) was shifted to occur in August, instead of earlier in the year, because of conservation issues," he said. "The adults were declining in numbers."

Today, king salmon derbies are held in nearly every community in Southeast Alaska; two are annually held in Juneau. Private lodges, too, will hold chinook salmon derbies for guests. Farther north in Alaska, these derbies also continue. Take the Winter King Salmon Tournament in Homer, for example. That event has been held annually for 20 years.

Regardless of where the derbies are held, each event clings to the historic trend of catching and awarding fisherman for turning in the biggest fish.

"All (the derbies) are selectively pulling the large fish out of the population," Orsi said. "So, it may not seem like it at the time — and I'm guilty of it too — but all these little incremental ticks against the population could be catching up with us. I know of folks who will actually sort through fish during derbies to keep the biggest one. So, (the participants are) releasing fish because they are not going to win them a prize. At the same time, as they release them, they could be imparting mortality."

Orsi supports the idea of catch it, keep it, call it good enough. Instead of having a derby based on fish weight, he suggested organizers should consider running the event like a lottery, where fish of legal size are turned in and a winner is selected at random, like drawing a name out of a hat.

In short, the idea prevents participants from not only pursuing only the largest fish, but also aims to prevent hook-and-release encounters.

One big mixing pot

While not much is known about the specific migration patterns, scientists do believe the stocks mix to some degree. Hence, similar factors could be affecting both Kenai River and Southeast Alaska stocks.

"These factors would be the ocean conditions or distant coastal fisheries where both stocks might be present, such as areas off Kodiak and in the western Gulf of Alaska," he said.

When it comes to fisheries in Alaska, fishing pressure is consistently put "on two-, three-, four-, five-ocean fish all at once," he said.

"It's not like it's a returning stream (of king salmon) coming back," he said. "So you have multiple age classes that are being affected."

In other words, current commercial and sport fishing practices aimed at ocean swimming chinook are not effectively targeting only the most mature fish, which would be ideal to ensure that younger kings have a chance to fully develop. Whether it's the trollers or trawlers, the gear is being set deep enough to reach juvenile king salmon of varying age. As the fishing pressure increases from each user group, so does the potential for encounters and subsequently the potential for increased mortality.

Meanwhile, farther north

While researchers may not know the exact forces and factors contributing to the decline in both abundance and size of Alaska's king salmon, one this is for sure: The stocks that swim in the Gulf of Alaska and those that swim in the Bering Sea don't face exactly the same challenges.

"It depends on the stock group and the factors they get exposed to," Orsi said.

His counterpart at NOAA, Jim Murphy, has spent more than a decade studying the kings that swim the waters of the Bering Sea. From his perspective, Murphy sees the chinook salmon as one quite unlike any others — the mighty king is actually quite fragile.

"chinook salmon are an entirely different beast than the other salmon," he said. "They like their protein (and therefore) are piscivorous, meaning they feed on fish, much more so than other species. Even the small chinook, they feed on fish prey very early in their life. In Southeast they'll feed on invertebrate prey and fish prey, when available. In the northern Bering, there's not a lot of invertebrate prey. (Instead) they're feeding on the larval fish. That holds true for most of their life."

Murphy said it's this protein-rich diet, which mostly consists of a small, oil-rich fish called a capelin that may be contributing to their decline. More specifically it's a little enzyme found in high concentrations in the capelin that may be causing a vitamin deficiency in king salmon.

The enzyme is called thiaminase and it effectively breaks down thiamine — vitamin B1 — rendering it impossible to be absorbed by the body. But, as Murphy explained, thiamine is vital.

"It's what's used in the Krebs cycle, a basic biochemical dependency that all animals have," he said.

Vitamin deficiencies are rare in wild populations due to the variety of foods consumed. Yet Murphy said these types of deficiencies have been well studied and documented in the Great Lakes, and researchers have been able to link population crashes of Great Lakes salmon to a deficiency in thiamine. Similar shortages crop up in groups of animals kept in captivity, as well.

"In the embryonic development stage is when it's most vital," he said. "In some cases it causes complete mortality. In other cases (the fry) would have impaired vision, or an immune system that is compromised — all of which would arise from thiamine deficiencies in the eggs."

All nutrients for a healthy egg and embryo come from the female, Murphy said. When he and his team examined thiamine tallies in king salmon eggs, they found average levels showed evidence of some deficiency.

He and his team have also studied the diets of juvenile chinook in the northern Bering Sea and found 70 percent of their diet consists of capelin.

"That hasn't always been the case," he said. "But it is true they are very dependant on fish. Hence, they always run the risk of becoming deficient."

Yet in the early 2000s, research indicated there was no deficiency, Murphy said.

"That's important; the 2001 brood run on the Yukon River was reasonable — about two recruits per spawner," he said. "Right now, and the way it's been for the past six to seven years, the returns per spawner are just above one. In other words, the fish are barely replacing themselves."

At that rate, you cannot harvest, he said. "It's obvious there is a significant issue with the productivity of the Yukon."

When it comes to the historic size of kings on the Yukon, most accounts will share the same story — they were prolific and huge. But Murphy, like Orsi, points out the long-term and highly effective use of gillnets, which have been widely used on the lower Yukon, to harvest the largest fish. Others in the state have said the problem was further compounded by the widespread use of drift nets, beginning in the 1970s, as a likely factor that contributed to the decline in king runs.

"There's no doubt (gillnets) had a culling effect by removing the large females and males from the population for many years," Orsi said. "And (the Yukon) stock may have lost that large size component because of it."

These days, the 2013 regulations on the lower Yukon River restrict gillnet size to six inches, according to the management strategies outlined in the Alaska Department of Fish and Game Yukon River Salmon Fisheries Outlook, which is a reduction from years past.

"But if you think about it, the (larger fish are) an ecological legacy, in that they may have gone to areas way up the river, in faster water, selected bigger cobble to spawn in that smaller fish just couldn't utilize," Orsi said.

He said influences on Yukon stocks such as these — aggressive selective fishing that went on for so many years — may have already altered the makeup of the population.

Yet Murphy said tightened management of the Yukon River king runs, including blanket fishing closures, reduced mesh sizes on nets and the closure of other fisheries, such as the strong chum fishery, were all good steps to take toward rebuilding a struggling population.

But Murphy shares some of the same concerns voiced by Orsi about incidental catches on the river leading to increased mortality rates, especially when one factors how many miles those fish have left to swim and spawn.

For years Alaska has had a king salmon management agreement with Canada that outlines how many chinook should pass over the border on the Yukon. It's all about making sure enough salmon reach their natal spawning grounds.

"They've not been able to meet the border passage requirements and they haven't been making them consistently over the past few years," Murphy said. "That has an undesirable effect down the road because you're not allowing spawners."

It's not all dismal, however. Murphy said the effects felt as a result of selective harvest are not irreversible and the right management techniques could see a potential reversal of trends within a few generations.

Cooling waters

Since 2002, Murphy and his team have conducted surface trawl surveys in the Bering Sea to assess, along with the Japanese and Russians, the ecology of the area and the abundance of juvenile chinook leaving the river.

A paper published this year, titled "Linking abundance, distribution, and size of juvenile Yukon River chinook salmon to survival in the Northern Bering Sea," authored by Murphy and others, points to the fact winter and spring ice in the Bering Sea had not declined. Instead, the authors found the opposite to be true; the extent of winter and spring sea ice had actually increased in recent years.

In other words the Bering Sea has cooled.

Juvenile king salmon primarily use marine habitat on the eastern Bering Sea shelf, according to Murphy, to feed. But colder water means sea ice is forming a bit sooner and staying a bit longer, subsequently forcing young kings to either limit their migrations or forage in fewer places — or both. Traditionally, according to Murphy their conventional forage habitat is in the northern Bering Sea.

"Sea ice begins to form in coastal habitats utilized by juvenile chinook in early November and the entire northern shelf is ice covered by early January," Murphy wrote.

Those that do migrate too far north, or accidentally get trapped by the ice, are facing death due to the freezing water temperatures. But since king salmon stocks in the Bering Sea feed primarily on capelin, which grazes on plankton hanging near the edge of the ice shelf, it makes sense the young salmon would also swim nearby.

The paper also indicates the cooling of the Bering Sea is altering the migration range of juvenile chinook. A graph showing distribution patterns from surface trawl surveys on the eastern Bering Sea Shelf from 2002-2007, a time when the sea was warmer, show strong distributions of fish stretching from Bristol Bay to north of the Bering Strait. Yet the same surveys done from 2009-2011, at a time when sea water temperatures were lower, show limited distributions of fish and at lower concentrations. This time, juvenile kings ranged from roughly Nunivak Island in the south to Point Spencer in the north.

In addition, Murphy and his team found a high mortality rate for juvenile king salmon. Murphy also found juvenile abundance and size were lower in colder years.

"If the juvenile numbers are tracking with the numbers of adults coming back, it can provide an indicator for management," Murphy said. "It helps to identify when and where are the critical periods. Is it happening in freshwater? Or is it tied to something that is happening offshore?"

Another one of his main areas of concern are the Asian hatcheries, which use the Bering Sea as a summer rearing area for hatchery chum salmon.

With surveys, Murphy said he's been able to show the number of juveniles can provide an indicator for adults down the road — "it's correlated with the adult return," he said. "Which implies whatever factors are impacting them, are happening prior to their first year at sea."

What he's not sure of, he said, is whether it's happening in the river or in the estuaries.

Bycatch

For many years, bycatch has been to blame, or so it seems, for the production decline of king salmon in Alaska. In response, fisheries managers have implemented monitoring plans, sampling guidelines and catch caps to help regulate incidental catch of chinook in fisheries such as pollock in the Gulf of Alaska, and chum salmon in the Bering Sea by trawlers.

According to ADF&G Commissioner Cora Campbell, there have been solid improvements to the methods for collecting chinook salmon bycatch samples in the Gulf of Alaska.

"The 2014 observer plan changes the methods for collecting chinook salmon samples in the GOA to improve the representativeness of the samples and increase the number of samples," she said. "For vessels with less than 100 percent coverage, (the National Marine Fisheries Service) will sample chinook salmon from randomly selected observed trips for both pollock and non-pollock trawl vessels. NMFS will not rely on dockside observers for genetic sampling and will instead put all resources toward at-sea coverage, which should result in a considerable increase in the number of genetic samples obtained."

She said they expect to generate more than three times the number of samples.

Indeed, the sampling of bycatch done by observers does reap valuable information, such as the DNA samples referenced by Campbell that could help scientists understand what stocks are being incidentally harvested.

Yet of the recent papers penned by longtime researchers such as Orsi, few mention bycatch directly as a factor in the decline of king salmon production in Alaska.

According to Orsi, there's not quite enough being done with the samples being gathered from king salmon bycatch. In a letter he penned to the 2012 chinook Salmon Symposium organizers Eric Volk and Robert Clark, he pointed out one hurdle in particular: "Scales are sampled in the bycatch from federal fisheries, but there is presently no project to digitize or read them." Digging into this information would reveal, he said, if compounding fishing effects occur regularly in particular ocean stocks of kings and in particular age groups, such as juveniles.

"It is conceivable that the same brood year of a given chinook salmon stock from Cook Inlet is encountered and harvested at 'low' levels in the bycatch of both the (Bering Sea) and (Gulf of Alaska) trawl fisheries over successive ocean years," he said, "thus having a compounding effect on the stock's overall productivity."

His point circles back to the issue of size limit and underscores the importance of identifying where exactly certain stocks of kings migrate in Alaska waters and when.

Fukushima

Since 2011, when a large-scale earthquake off the coast of Japan sent a tsunami of devastating proportions careening into the country's coastline, the Fukushima Dai-ichi Nuclear Power Plant has been leaking nuclear waste into the Pacific Ocean. Current reports from news outlets around the world have said leakage continues today, with some indicating the waste is as prolific as ever.

In August of 2013, the Juneau Empire penned an editorial that took a surface look at what may be happening in the Pacific surrounding to the flow of currents and the migration patterns of marine life. In short, they urged officials, as well as state and federal agencies "to be proactive about conducting research and monitoring our salmon species."

When asked about the potential impact Fukushima may be having on king salmon stocks in the Gulf of Alaska and elsewhere in the state, Orsi would not comment.

"I've been told to refer you to the (Environmental Protection Agency)," he said, "Because I'm not an expert on the topic."

Calls and emails to the EPA were not returned and digging on the federal agency's site revealed no current information on radiation from the Fukushima disaster; the last posted monitoring results occurred in June of 2011. In a report issued by the EPA after the disaster, the agency stated the "Japanese sand lance is only fish that exceeded radiation standards — does not migrate … Migratory patterns of North American Pacific salmon most commonly do not reach the coastal or offshore waters of Japan … The majority of Alaska salmon spend most of their ocean residence in the Gulf of Alaska."

In a September 2013 update from the Food and Drug Administration, the FDA stated it "has no evidence that radionuclides from the Fukushima incident are present in the U.S. food supply at levels that would pose a public health concern. This is true for both FDA-regulated food products imported from Japan and U.S. domestic food products, including seafood caught off the coast of the United States."

The notice went on to state the FDA is not advising consumers to alter their consumption of particular foods "imported from Japan … including seafood."

So while it appears seafood is safe to eat, it remains unclear if there are factors negatively and specifically affecting Alaska's king salmon production.

In an Oct. 24 article the New York Times reported emissions from the damaged plant are such that oceanographer Michio Aoyama believes "radioactive cesium 137 may now be leaking into the Pacific at a rate of about 30 billion becquerels per day, or about three times as high as last year. He estimates that strontium 90 may be entering the Pacific at a similar rate. … scientists suspect that the new releases are having measurable effects beyond the harbor."

The final word

Understanding the complex migration and fishery interactions of chinook stocks is foundational to unraveling causes of the production decline. Researchers stress the importance of knowing where king stocks are swimming in Alaska's salt water and when is paramount.

"Stock-specific chinook salmon distributions need to be mapped for all three life history phases," Orsi said. We need to know the "early marine migration of juveniles (in) their first ocean winter, (the) seasonal ocean-rearing localities of immatures and (the) return migrations of maturing adults."

Next week: The conclusion of our series.

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Re: Opposition to Proposal 290

Dear Board of Fisheries Members,

Thank you for the opportunity to comment on Proposal 290. I am opposed to this proposal and ask that you reject this attempt to further limit Alaskan resident's access to our commonly held natural resources. Additionally, I ask that you reject this proposal since the King salmon data available on this fishery is both incomplete and inaccurate. More time is needed to gather complete and accurate data to distinguish between Crooked Creek Hatchery Kings and Kenai River Kings before making a decision to further restrict the Kasilof River Set-net Fishery.

I have been a personal use set-net fisherman on the Kenai Peninsula for more than 20 years. When my family first started personal use set-netting on the Kenai, all publicly owned beaches from Ninilchik to Nikiski were open for personal use set-net fishing. Imagine the entire beach without another fisherman in sight. One tide filled the freezer. Unfortunately commercial interests who fish those same gravel beaches for money didn't appreciate resident Alaskans fishing for food near "their" property. A proposal, much like Proposal 290, was put forward and adopted to limit the Kenai Peninsula personal use set-net fishery to the mouth of the Kasilof River.

So that's where we personal use set-net fishermen are today, a two mile stretch of mud flats that goes dry for 16 hours a day. Why was the Kasilof River Mud Beach site available? Because no fishermen in their right mind would ever set a net in the Kasilof River mudflats when there was 50 miles of gravel beach just around the corner. Literally from the end of the Kasilof River mudflats are miles of nice gravel beaches in both directions. But for some reason the Personal Use Set-net Fishery was jammed into a 2 mile stretch of mudflats. **Continuing limitations on beach and salmon access for Alaskan set-net fishermen seems to be the norm.** I ask that you reverse this trend and these continuing limitations on the fishing rights of Alaskans. Please reject Proposal 290.

Over the past 20 years, the Kenai Peninsula Set-net fishery has become the Kasilof mud flats rat race, where people get in arguments over limited space. It's a rat race because everyone is just 100 feet apart. I have seen tape measures and heated exchanges between otherwise nice people who are forced to fight just to get a little piece of that limited space. If you don't get one of those spaces, you're not going to fish. No fishing means no food for your family. **Limited space is just another restriction placed on this personal use set-net fishery by proposals such as Proposal 290.** Protecting salmon for the benefit of local Alaskans should be the goal, not restricting access to fishing grounds and moving the fishery to conflict with the Commercial Set-net fishermen. (Commercial fishing opens on 6/22. From that moment on the Kasilof River Set-net fishery catch drops to zero and many fishermen are furious about this situation already. Moving the two openings closer together will only create more animosity between Personal Use and Commercial Fishermen.)

The Kenai Peninsula Set-net Fishery is gone. Now if you can find a space on the Kasilof mud flats to set a net, it takes 10 days to catch your limit. That's because the mud flats and imposed fishing time restrictions limit our net soaking time down to an average of five hours fishing over a 24 hour period. With Proposal 290, we are facing yet another commercial interest trying to limit resident Alaskans access to our commonly owned resource. These are limits placed on Alaskans trying to fill their freezers with Sockeye salmon for the winter. These are not people trying to catch King salmon. Catching a King salmon in a Kasilof sockeye net is a rare occurrence.

Proposal 290 seeks to move the fishing times to protect the early run of Kenai River King salmon. Protecting this valuable Kenai River King salmon run is an admirable goal. But I ask that you look at some facts before you further limit the Kasilof Set-net fishery.

I can tell you from experience that **the majority of King salmon caught in the Kasilof Set-net Fishery are Crooked Creek Hatchery Kings.** That is immediately apparent from the size of the fish and the small missing fin on the lower back of these Kings. Any King landed in these small-mesh Kasilof River mud nets are in the 30 lbs range. A large Kenai River King salmon seldom, if ever, remains in the Kasilof set-net for more than a few minutes. These large and powerful Kings get their teeth caught in the webbing. The webbing is too small to catch a large King by the gills. One shake and that big Kenai River King salmon is long gone, often leaving behind a big hole in the net. Our nets are designed to let these large Kings escape.

The next fact to consider is that the Kasilof River Set-net fishery lands approximately 100 king salmon over the entire 10 day opener. (June 15th – June 24th) That is **an average of 10 King salmon per day.** If there are approximately 3,000 Alaskan residents participating in this fishery, it is very unlikely that any of them will ever catch a King salmon. These Alaskans are after Sockeye salmon, not Kenai River King salmon. If they get extremely lucky they might land a King from the Crooked Creek Hatchery. From experience I can tell you that a Kasilof Set-net fisherman will almost never land a large Kenai River King salmon in a Kasilof Sockeye net. The size of the mess and the tear away webbing virtually eliminate any change of catching a Kenai King.

The Alaska Dept. of **Fish and Game (F&G) does not collect data on which species of King salmon are being caught** and reported at the Kasilof River set-net fishery. However, anecdotal evidence tells us that the King Salmon that are caught in the Kasilof Set-net fishery are Crooked Creek Hatchery Kings. Since the reporting cards don't request that we distinguish between Kenai and Crooked Creek Kings, there is no way to determine from the data whether that lucky catch is a Kenai River King or a Crooked Creek King landed at Kasilof Set-net sites. Therefore, the data upon which you may rely to adopt Proposal 290 is incomplete. For this reason I ask you to reject this proposal.

I request that in coming years F&G gather specific data which will give you accurate information on which species of King salmon is being caught at the Kasilof Set-net fishery. Before you act to further limit and restrict this Personal Use Set-net Fishery please insure that the data collected provides you with an accurate picture of what is really going on in the Kasilof Set-net Fishery.

The Crooked Creek/Kasilof River escapement goals for King salmon have been met every year. (750-1,700). There is no problem on the Kasilof River that needs to be addressed concerning King salmon returning to Crooked Creek Hatchery or the natural run in the Kasilof River for that matter. In 2011, the Kasilof River Set-net Fishery caught 167 Crooked Creek King salmon. That same year Dip-netters at the mouth of the Kenai River took home 1,247 Kenai River Kings. In 2012, the Kasilof Set-net Fishery caught 103 Crooked Creek King salmon. Last year (2013) the Kasilof Set-net fishery was closed after only five (5) days of fishing and caught a total of 46 Crooked Creek Kings. This drastic measure of closing set netting, which inconveniences thousands of Alaska residents, saved about 50 Crooked Creek Hatchery King salmon from being caught. Closing the Kasilof Set-net fishery early did not save a single Kenai River King salmon. That was just bad science and improper management.

100 King salmon caught over a 10 day period is evidence that proves that catching a King salmon in a Kasilof set-net is a very rare experience. Those odds drop even further when Kenai River King salmon are involved because of their massive size and power and our break away gill nets. Restricing or closing the Kasilof River set-net Fishery will not enhance the Kenai River King salmon escapement goals.

Since 2011, Kenai River Dip-netters have been required to release all Kings caught. It appears that this conservation method is targeted properly to save the Kenai River King salmon runs. Those 1,250 Kenai River King salmon are now escaping to spawn in the upper Kenai River. However, **restricting or closing the Kasilof River Set-net fishery to protect Kenai River King salmon**, is not based on proper data and **is not going to help save the Kenai River King.** The damage to Alaskan families created by closing or moving the last remaining Kenai Peninsula Personal Use set-net fishery far outweighs any unproven benefit for the Kenai River King salmon escapement numbers.

On behalf of the thousands of Alaskan residents who participate in the Kasilof River Set-net Fishery and because of the lack of proper data to determine if changing this fishery yet again will help save the Kenai River King salmon, I ask that you reject Proposal 290.

Again thank you for your time and good luck in your deliberations,

V. Fate Putman, Esq.