WILD SALMON CENTER

Over-Escapement: Is there a Problem?

WHITE PAPER

Prepared for:

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Purpose

The Wild Salmon Center has produced this White Paper in response to the concept of "over-escapement" being used as a justification for increased commercial harvest of salmon. The purpose of this paper is to examine the origin and uses of this controversial concept, and to explore the variety of perspectives on over-escapement. Is it a problem, or is it simply a natural occurrence in wild salmon ecology. An improved understanding of the perspectives and factors influencing over-escapement, will hopefully contribute to better-informed decision making in Alaska, Canada, and the Russian Far East, where "too many fish" on the spawning grounds may sometimes be considered a problem. We refer readers seeking more information on over-escapement to a recent technical paper by Canadian fisheries biologists Dr. Carl Walters et al. (2004).

Introduction

Over-escapement is an easily misunderstood term. Taken out of context, it creates confusion because it implies "too much of a good thing." When the term is used, several questions come to mind:

- Can salmon stocks be jeopardized from too many fish on the spawning grounds?
- Are we wasting fish by not harvesting them?
- How have salmon stocks survived for the thousands of years prior to industrial and commercial management?
- Do excess salmon on spawning grounds serve other important ecological functions?

These questions reflect the many perspectives that exist in the overlapping realms of salmon management and salmon ecology. In this paper, we will briefly explore some of the key perspectives relevant to this complex issue. However, as with most complex issues, finding an effective resolution to conflicting theories and perspectives is a challenge. Resolving the conflicts surrounding over-escapement is especially difficult because relevant issues may be counter-intuitive, or may be based on conflicting value sets.

We will consider over-escapement within four major contexts. They range from "economics-based" to "theory-based," so we must recognize that the different adherents are often speaking different languages, and have different value-sets. The perspectives include:

- Commercial Fisheries
- Fisheries Management
- Fish Biology
- General Ecology

(See Fig 1 – concept map of perspectives)

The core questions that bring about such varied responses from the 4 perspectives are:

1) Is over-escapement a problem?
2) If “yes,” when does it occur, and why is it a problem?
3) If “no” what are the advantages of surplus spawners?

Predictably, the responses from individuals from each of the “perspective groups” fell into two categories. The harvesters and managers were practical and efficiency-oriented; the biologists and ecologists emphasized that surplus spawners serve multiple important biological and ecological functions.

Perspective	***Yes/No***	***When does it occur? OR Why is it not a problem?***
Commercial Fisheries	Yes	It occurs when the escapement goal is exceeded. Spawners in excess of the escapement goal are a lost resource, and represent lost revenue.
Fisheries Manager	Yes	It occurs when the Recruit/Spawner ratio drops below 1, indicating a negative return and non-equilibrium conditions.
Fish Biologist	No	Competition within a species promotes genetic diversity and species health.
Ecologist	No	Surplus fish feed a host of aquatic and terrestrial organisms and provide a mechanism for delivering important nutrients.

Table 1. Summary of divergent perspectives on the question: Is over-escapement a problem?

Adaptive Management

When managers try to include a broad spectrum of perspectives, they become part of the new and rapidly evolving realm of “ecosystem management.” Within this realm, adaptive management is the practice of periodically adjusting management practices based on the most current scientific information. One of the founders of adaptive management, Dr. Carl Walters has recently written a technical paper entitled: Does Over-Escapement Cause Stock-Collapse? (Walters, et al., 2004). He and his co-authors have conducted a comprehensive review of the topic, and respond to the question with a definitive “No.” The abstract to their paper states:

> The impact of “over-escapement,” the spawning of an unusually large number of salmon from a given population or run, is examined in data from 21 British Columbia sockeye stocks and two pink salmon stocks. While there is evidence of a decrease in spawning efficiency at high spawning numbers, there is no evidence for anything like a “collapse” or “near-collapse” of production following runs with very large numbers of spawners.

The authors demonstrate, based on over 50 years of data, that the classic Ricker stock-recruitment model still holds true (see Figure 2). The Ricker model predicts declines in spawner success, as spawning numbers grow very large, due to a variety of "compensatory factors" that naturally keep large populations in check. However, misinterpretation of the model can lead to the conclusion that not harvesting surplus salmon can cause harm to the run. Applications and interpretations of the classic Ricker model are discussed in more detail below. Unfortunately, the Ricker model does not take into account the diversity of social, political and ecological factors that permeate the realm of salmon fisheries management. A series of recommendations, compiled by E. Knudsen et al. (2003) are presented at the end of this paper to guide future directions in escapement-based management.

Background

In order to reduce the confusion caused by the term over-escapement, it is useful to examine the origin of the term in the context of the 150-year evolution of fisheries management in western North America.

Salmon management has been taking place in a variety of forms for thousands of years. Historically, when intensive harvest is conducted in the absence of effective regulation, salmon stocks can collapse in just a few years. Dave Montgomery presents an historical overview of stock depletion and extinction in Great Britain and Northeastern North America in his recent book, *Salmon – King of Fish*. Montgomery explores how history repeats itself, often through a combination of over-harvest, altered and fragmented habitats, and technological hubris. History is repeating itself today in the Pacific Northwest, as many of the same mistakes are being made. As an exception, Alaskan and certain Russian Far East salmon stocks remain as some of the only fisheries that are comparable to historical levels of abundance. For this reason, we chose to examine the Alaskan fishery management experience as an example of a successfully managed salmon fishery.

A Brief Overview of Salmon Management in Alaska

Alaskan salmon stocks are healthy and abundant today, but during the very early days of salmon fishing, when there was no regulatory management, some stocks experienced near catastrophic collapse. Between the late 1850s and the early 1900s, salmon salteries and canneries sprang up all across coastal Alaska. The huge, seemingly endless runs of fish led to the development of highly efficient fishing methods that could capture nearly an entire run. Foul weather was sometimes the only factor that prevented every fish in a run from being harvested. These were the fish that "escaped" to the spawning grounds, and thus the term "escapement" came to represent the total number of fish that return and successfully spawn. When stocks showed signs of collapse, efforts were made to increase escapement to levels that would allow for sustainable harvest. In 1924, the White Act was passed by the U. S. Congress, requiring that at least 50% of an individual salmon run be allowed to return and spawn. This was the beginning of escapement-based management. Today, the Alaskan fishery is divided into 4 primary management regions, each with its own biologic and physiographic characteristics. Salmon runs in these regions are individually managed by the Commercial Fisheries Division of the Alaska Department of Fish and Game.

[Figure 3 – The four fishery management regions in the State of Alaska. (ADFG)

SIDEBAR: DEFINITION OF ESCAPEMENT, RECRUITMENT, AND SURPLUS

Escapement refers to the number of fish that return to the spawning grounds and successfully spawn. These "actual spawners" are derived from a pool of "recruits," i.e. those adult salmon who have survived the ocean phase of their life history, and have the potential to spawn. The number of recruits minus the escapement is the spawning surplus, and is the main target of commercial fisheries with the primary goal of Maximum Sustained Yield (MSY).

Escapement Based Management

Alaska has been using some form of escapement-based management since Congress passed White Act in 1924. Methods evolved in the late 1950s, when the State of Alaska gained jurisdiction over fisheries management. Today, Alaska's Department of Fish and Game conducts nearly "real-time" monitoring and regulation to assess whether salmon stocks are reaching or exceeding escapement goals. If escapement goals are not met, commercial harvest may be restricted, or even shut down.

Monitoring Escapement

The amount of effort spent monitoring escapement is enormous, and reflects the importance of the commercial fishery to the state of Alaska. Escapement monitoring is conducted by the Alaska Department of Fish and Game (ADFG), in cooperation with other State, Federal and Tribal agencies. During the spawning season, ADFG et al. use a variety of methods to keep track how many fish are returning to individual streams to spawn. Fish counting techniques include sonar counters, aerial surveys, counting towers, fish traps, counting weirs, and spawner surveys. They keep track of the actual escapement on a number of index streams, and use this information to guide the timing and duration of commercial salmon fishing efforts. If escapement goals are not reached at the monitoring stations, commercial fisheries are closed. If escapement goals are exceeded, the commercial fishery is allowed longer and more frequent open fishing periods.

[see photo 1 –more photos of escapement monitoring on website: http://www.thomasbdunklin.com/gallery/escapementmonitoring]

Establishing Escapement Goals in the Context of Maximum Sustainable Yield

Escapement goals and pre-season escapement estimates are established by ADFG biologists though a combination of historical observations and population models. While some of the methods used to set escapement goals can be fairly sophisticated, they often amount to educated guesses, generally supported by harvest and escapement data. Some of the uncertainty in establishing escapement goals is a result of the inherent variability of salmon populations and the number of variables that are unknown or unpredictable.

The explicit goal of salmon management is to achieve maximum sustainable yield (MSY). The Pacific Fisheries Management Council defines MSY as:

> **An estimate of the largest average annual catch or yield that can be continuously taken over a long period from a stock under prevailing ecological and environmental conditions. Since MSY is a long-term average, it need not be specified annually, but may be reassessed periodically based on the best scientific information available.**

The commercial fishing industry wants to harvest the most fish possible thereby maximizing profit, while still allowing populations to maintain themselves. The Alaska Department of Fish and Game's primary goal is to "maintain fish populations at historical levels of abundance," and MSY has been the target that theoretically allows them to reach that goal. To understand MSY, it is necessary to look at some of the founding principles of fisheries management.

Stock-recruitment models are theoretical curves that predict the number of fish that are expected to return from a given number of spawners, and are often used to set escapement goals. The most widely accepted stock-recruitment model was introduced by Canadian fisheries biologist W. E. Ricker (1954) and is known as the Ricker Curve (Fig. 2).

Figure 2. Ricker Stock-Recruitment Curve (modified from Walters et al, 2004)

The curve indicates that there are an ideal number of spawners that will produce a maximum number of recruits. This "ideal number" is used to set the "optimum escapement goal" or OEG. The dome-shaped nature of the Ricker Curve indicates that as spawner numbers exceed the crest of the dome, relatively fewer fish survive for each fish that returns to spawn. This is largely due to natural limits in available spawning and or rearing habitats. When the habitat limit, or "carrying capacity" is reached, spawning and rearing success begin to decline. This recognition of "diminishing returns" is at the core of the over-escapement debate. If fewer fish return for each additional spawner, doesn't it make sense to harvest those fish for food and profit? Economically the answer is simple, but ecologically, there are other factors that should be considered.

Maximum sustainable yield goals do not factor in the various roles that the spawning surplus plays at the broader ecosystem scale or in the socio-economic context. There are many social and economic factors that influence whether or not it makes sense to harvest the most fish possible. For example, in years of abundance, or during a glut of farmed fish, salmon prices may be so low that the cost of harvesting the fish may not be recovered. Recognition of these non-fish factors led to the development of the Optimum Sustainable Yield concept (Larkin, 1977). Unfortunately the difficulty in quantifying many of these factors prevents them from being incorporated into most applied fisheries management efforts. At the ecosystem scale, reduction in the number of surplus spawners directly affects the total amount of nutrients returned to the freshwater aquatic ecosystem, which in the long-term affects the overall health and productivity of the system.

Ecosystem-based models are being developed that provide an alternative to MSY-based management. Eric Knudsen et al. (2003) present a model that produces a Ricker Curve for pre and post-exploitation conditions.

Figure 4 – Hypothetical coho salmon population total run size before exploitation and total run and escapement after. (Knudsen et al., 2003).

They use the model to present a new paradigm for fisheries management founded on life history based production limits and nutrient feedback. The model clearly predicts that total run size is larger and more stable with exploitation rates less than 20%, as compared with typical historic exploitation rates varying from 40% to 60%.

Figure 5 – Kvichak river sockeye salmon catch, escapement and exploitation rate from 1956 to 2003, (Fair, 2003).

Under higher exploitation scenarios, salmon abundance declines and remains low. The authors offer some recommendations for taking the next steps toward developing an ecosystem approach to salmon escapement management. These recommendations are summarized at the end of this paper.

Long-Term Perspectives
The first salmonids appear in the North American fossil record over 15 million years ago (Stearley, 1992), and by 6 million years ago, salmon species similar to modern species were present in Idaho and Oregon. Based partly on this, David Montgomery (2000) estimates that the origin of the five Pacific salmon species occurred as early as 20 and as late as 6 million years ago. During this time, ice ages came and went, volcanoes erupted, and mountain ranges grew and eroded. Salmon adapted to, and evolved with these changes by developing life-history patterns that have built-in mechanisms to survive both rapid and gradual stresses. Surplus spawners, and highly variable life histories are two of these mechanisms. The five different species of Pacific Salmon spend variable amounts of time in the freshwater and marine environments, and return to spawn over a period of many months. They also utilize different parts of the freshwater aquatic system, extending from lake margins and river deltas all the way into small tributaries.

Outside of the management context, there are no escapement goals and no efforts to maximize spawning efficiency. Over-escapement loses some of its negative connotation, when viewed in broader biological and ecological contexts, and over evolutionary significant time scales, such as geologic time. For example, Walters et al.(2004) note that over-escapement may lead to increased straying by spawning salmon, which would assist in the recolonization of areas with depleted runs. This may be one of the key roles that over-escapement serves in the evolution of wild salmon, especially following natural disasters such as volcanic eruptions or blockage of rivers by glaciers or landslide dams.

Biological Considerations
Not all salmon species are prone to over-escapement. Over-escapement is practically a non-issue for Chinook and coho salmon stocks, due to their smaller population numbers, and a less intense commercial fishery for these species. It is also less of an issue for pink salmon, because they outmigrate to the ocean very shortly after emerging from the gravel. The less time they spend in fresh water, the less they will tax the limited nutrient supply that freshwater systems provide. Sockeye salmon are therefore the primary species of concern when it comes to "over-escapement."

Sockeye salmon seem to have the largest population fluctuations due to their highly varied life history patterns. After emergence, sockeye can spend from 1 to 3 years in fresh water, and then can spend between 3 and 5 years in the ocean before returning to spawn. Many combinations of freshwater/saltwater residence exist, which contributes greatly to their genetic variability, and thus, to the overall resilience of the species.

Most female salmon carry between 1000 and 4000 eggs, so survival rates do not have to be high in order to maintain populations in an equilibrium state. When survival rates are high, salmon populations can increase dramatically, and the spawning grounds will be packed with fish. Due to the variety of factors influencing survival rates, it is very difficult to predict the actual survival for any given year. The factors influencing survival include:

- total number of spawners
- instream flow dynamics
- egg to fry survival
- freshwater rearing potential and growth rates
- ocean conditions
- predation
- interception (by fisheries and predators)
- access to spawning grounds

When these some or all of these factors are favorable, survival rates can be very high, and the surplus may be very high. If they are low, the opposite may occur. Widely fluctuating salmon populations are the result of the complex interactions of all of these factors.

Ecological Considerations
The nutrients provided to the river and lake systems where salmon spawn provide the basis for a vast food web. This food web feeds at least 140 animals, and provides nutrients for plants, trees and other organisms.

(Figure 6 – from Cederholm et al, 2000).

Without question, in the Pacific Rim, spawning salmon are the largest single source of nutrients to wildlife, rivers and riparian zones (Cederholm et al., 2000). If this surplus is removed, the system will eventually decline in nutrient richness, and overall productivity will be reduced. Simply put, you have to have salmon to produce salmon.

Recent work looking at correlation between salmon escapements and marine derived nitrogen in riparian tree-rings and plants has led to the recognition that forest growth rates are often closely linked to fish numbers (Helfield and Naimen, 2001). Gresh et al., (2000) compare the amount of marine-derived nutrients delivered to stream during historic periods of high escapement and during present day periods of low escapement. They note evidence for a nutrient deficit in most of the freshwater ecosystems of the Pacific Northwest(Washington, Oregon, Idaho, and California). This deficit is the result a greater than 90% decrease in the amount of marine derived nitrogen and phosphorus historically delivered by spawning salmon.

Summary and Recommendations

The term "over-escapement" is a relative one, and carries with it a judgement of mis-management. It says: "too many fish were allowed back to their spawning grounds". If fishermen could have taken some of these fish to market, they would be contributing to the economic health of the region, while keeping the population in a managed state of equilibrium. But, biologists and ecologists recognize the numerous roles that surplus salmon play in contributing to the overall health, productivity and diversity of wild salmon stocks.

The recent technical paper by Walters et al. provides a concise overview of over-escapement, and should be closely read by anyone interested in the topic. In their closing remarks, the authors conclude:

> Our ability to test for effects of over-escapement remains limited, but the examples compiled in this technical paper do not indicate any evidence of stock collapse after large spawning escapements. There is, however, evidence of declining rates of production (recruits per spawner) at high escapement levels.

The authors reinforce what we already know, and point to the difficulties of resolving some of the conflicts between different user groups with different perspectives. Regarding fisheries management and long-term conservation strategies, the authors state:

> It is also argued that larger escapements through lower harvest rates may be necessary to conserve salmon biodiversity, and that large escapements may be necessary to promote re-colonization of habitats or dispersal of salmonids.

Future Directions for Escapement Management (Knudsen, et al, 2003)

Field Research to support escapement management

- Study ideal carrying capacities and bottlenecks in some experimental streams

- Study salmon ecosystems as escapement is allowed to increase
- Intentionally under-harvest some experimental streams
- Continue experimental nutrient replenishment
- Research on ocean survival, growth, competition, and driving factors
- Data feeds into new models

Escapement Management

- Continue to explore new management models
- When in doubt, harvest conservatively
- Consider all uses of salmon when estimating escapement needs

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List of figures

List of Tables

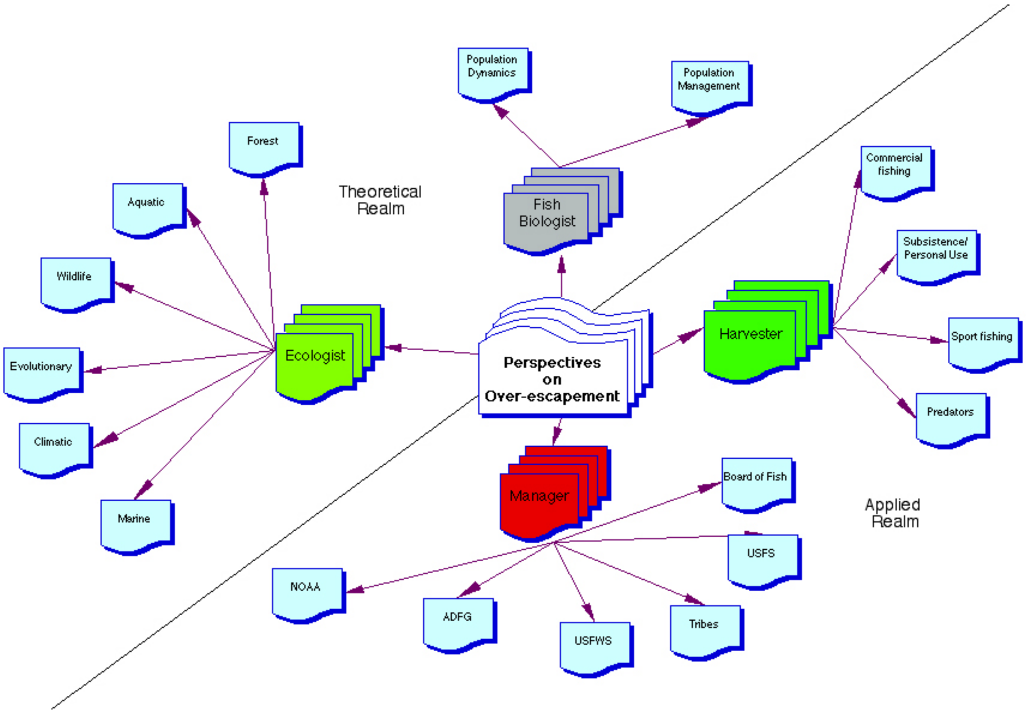

Figure 1 – Concept map of primary perspectives on over-escapement

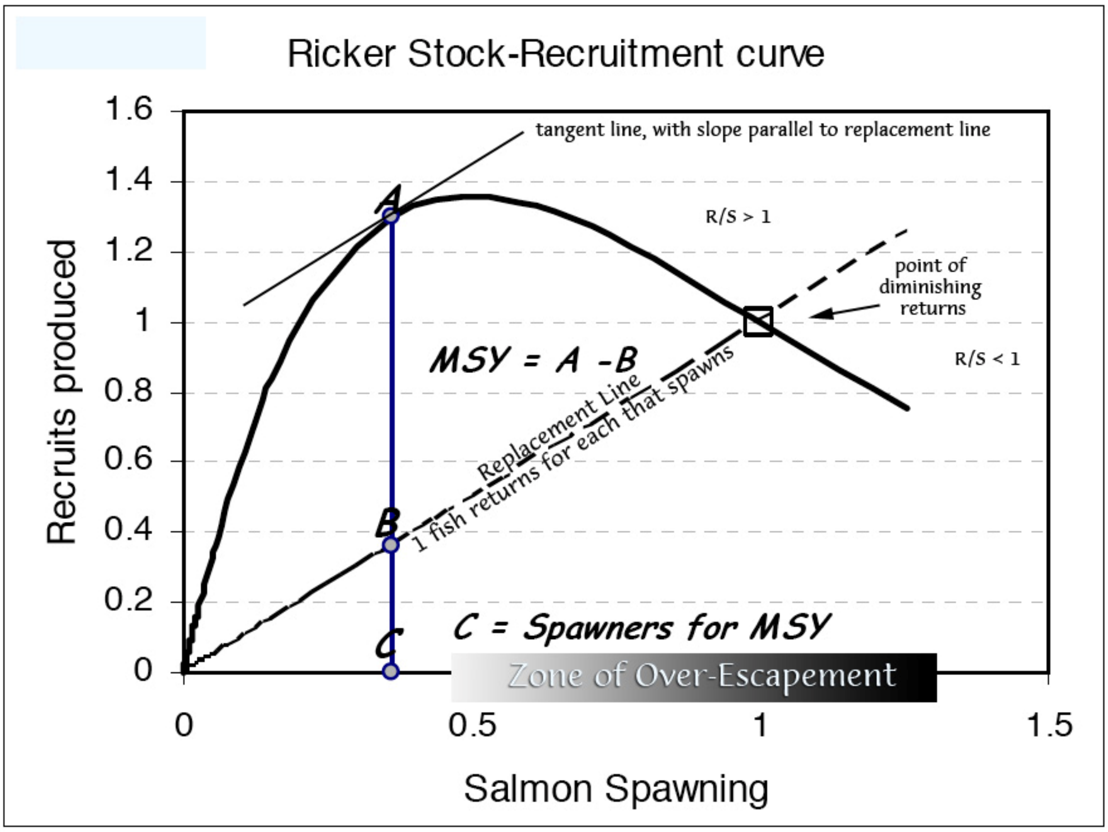

Figure 2 – Ricker Stock-Recruitment Curve. The difference between the number of recruits indicated by Ricker's curve (point A) and a number of recruits equal to the number of spawners, as given by the one-to-one replacement dotted line (point B) is the "surplus production" available to the fishery. It reaches a maximum value, called the Maximum Sustainable Yield, for an optimum number of spawners (point C). Beyond the intersection of Ricker's curve with the replacement line (small box), there are fewer recruits than spawners and the population decline. (modified from Walters, et al., 2004)

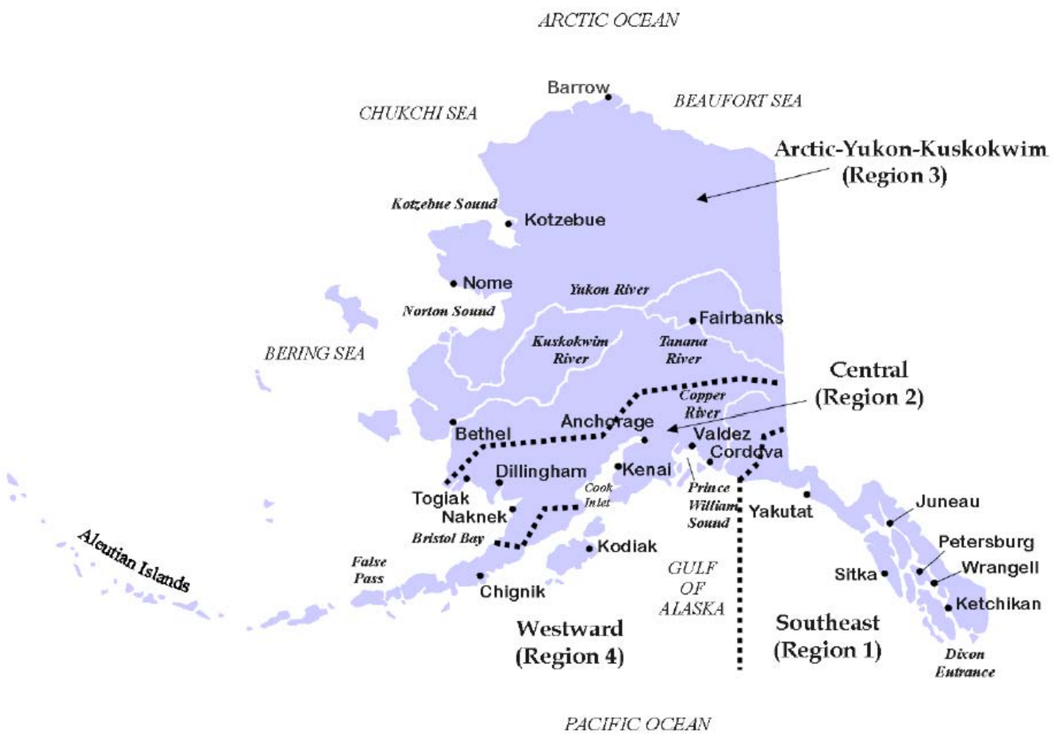

Figure 3 – The four fishery management regions in the State of Alaska (Southeast, Central, Arctic-YukonKuskokwim, and Westward) of the Alaska Department of Fish and Game, Division of Commercial Fisheries. (ADFG).

Photo 1 – Fish counting weir on the Buskin River – Kodiak, Alaska. Panorama by Thomas B. Dunklin.

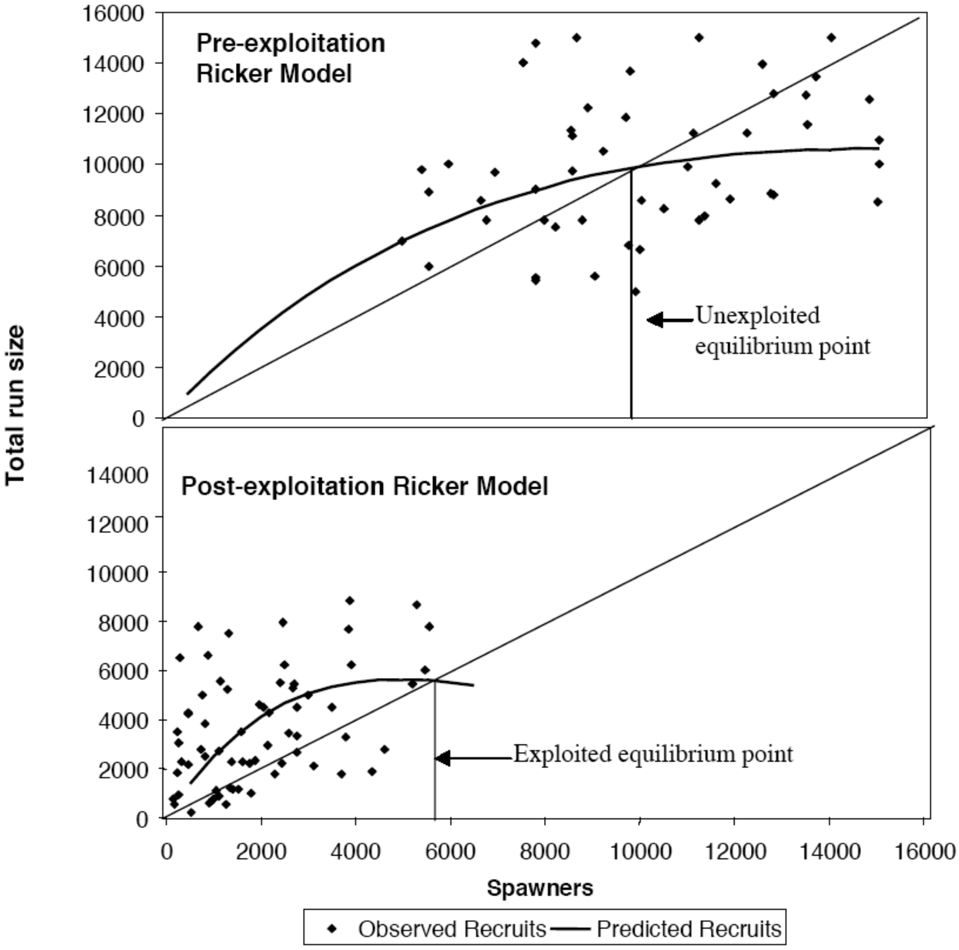

Figure 4 – Hypothetical coho salmon population total run size before exploitation and total run and escapement after exploitation (top panel). Ricker spawner-recruit plots of the pre-exploitation data (middle panel) and post-exploitation data (bottom panel) from the same habitat. Note that the equilibrium population replacement point has shifted to dramatically fewer spawners under exploitation even though the habitat has not changed. (Knudsen et al., 2003).

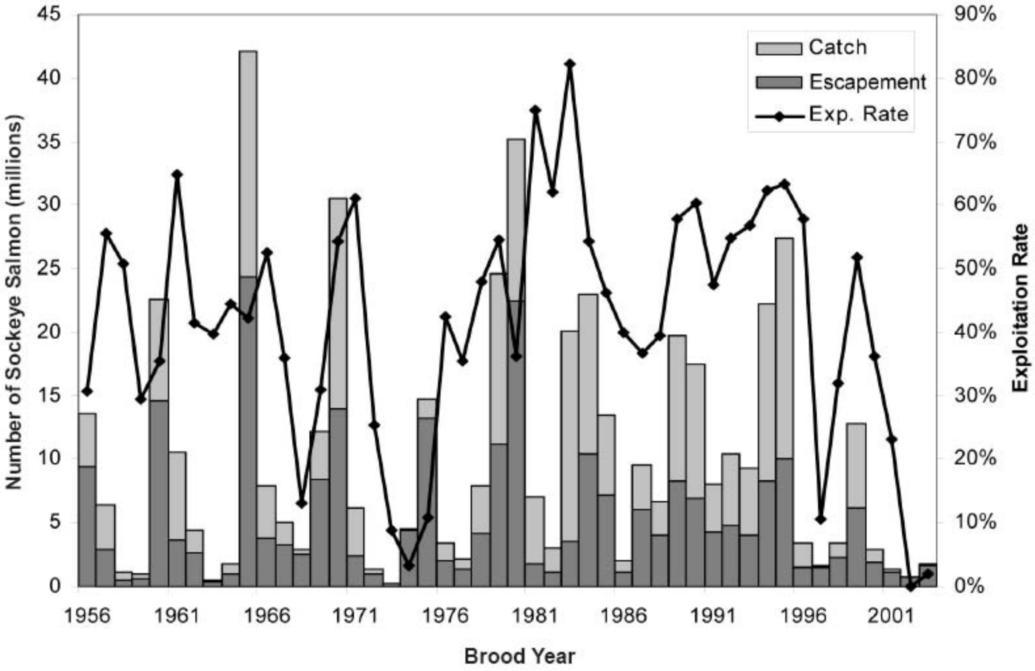

Figure 5 – Kvichak river sockeye salmon catch, escapement and exploitation rate from 1956 to 2003, (Fair, 2003).

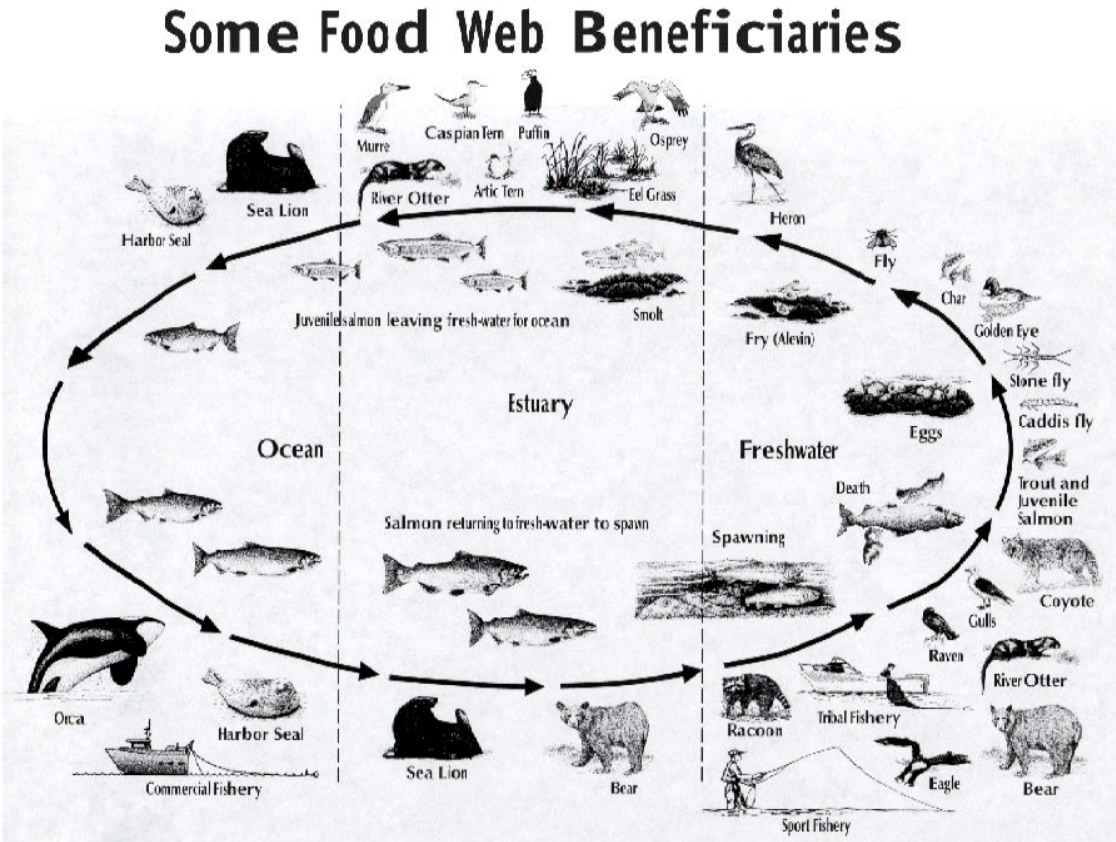

Figure 6 – Overview of the complex food-web relying on salmon and carcass-derived nutrients. (Cederholm et al., 2000)