

A  
Conceptual Foundation  
for the  
Management of  
Native Salmonids  
in the Deschutes River

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# A Conceptual Foundation for the Management of Native Salmonids in the Deschutes River

## *Table of Contents*

	<i>Page Number</i>
<b>CHAPTER I INTRODUCTION</b> .....	1
<b>A. Purpose and Scope</b> .....	1
<b>B. Organization of the Report</b> .....	1
<b>C. What is a conceptual foundation?</b> .....	3
<b>CHAPTER II. BACKGROUND</b> .....	7
<b>A. Historical Perspective</b> .....	7
<b>B. Stock Concept</b> .....	8
<b>1. The Stock Concept in Pacific Salmon</b> .....	9
<b>C. Life Histories</b> .....	12
<b>D. Genetics</b> .....	15
<b>E. Metapopulations</b> .....	18
<b>F. Natural Productivity Cycles</b> .....	24
<b>CHAPTER III. PATIENT TEMPLATE ANALYSIS</b> .....	28
<b>A. Introduction</b> .....	28
<b>B. General Description of The Deschutes Basin</b> .....	29
<b>1. The Physical Setting</b> .....	31
a. Crooked River .....	31
b. Metolius River .....	31
c. Mainstem Deschutes River .....	32
1) Upper Deschutes River.....	32
2) Lower Deschutes River.....	33
<b>2. Historical Habitat Alterations</b> .....	33
a. Beaver Trade.....	34
b. Irrigation .....	35
c. Grazing .....	38
d. Hydroelectric Development.....	40

<b>3. Subarea Habitat Conditions</b> .....	41
a. Crooked River .....	43
b. Metolius River .....	48
c. Mainstem Deschutes River .....	50
1) Upper Deschutes River .....	50
2) Lower Deschutes River.....	51
d. Lower River Tributary Habitat .....	54
<b>C. Salmonid Life Histories and Abundance</b> .....	58
<b>1. Redband Trout</b> .....	58
a. Distribution .....	59
1) Anadromous Form .....	59
2) Resident Form .....	59
b. Abundance .....	64
1) Anadromous Form .....	64
2) Resident Form.....	70
c. Life Histories .....	74
1) Anadromous Form .....	75
2) Resident Form .....	77
d. Genetics .....	80
1) Genetic Variation and Systematics .....	80
2) Geographic Relationship and Metapopulation Structure.....	80
3) Influence of Artificial Production .....	82
<b>2. Chinook</b> .....	88
a. Summer Chinook .....	88
b. Fall Chinook .....	93
1) Distribution.....	93
2) Abundance .....	94
3) Life History.....	95
c. Spring Chinook .....	96
1) Distribution.....	96
2) Abundance .....	97
3) Life History.....	103
d. Genetics .....	105

<b>3. Sockeye/Kokanee Salmon</b> .....	106
a. Distribution .....	107
b. Abundance .....	107
c. Life History .....	108
d. Genetics .....	108
<b>4. Bull Trout</b> .....	110
a. Distribution .....	110
b. Abundance .....	111
c. Life History .....	113
d. Genetics .....	115
<b>CHAPTER IV. CONCEPTUAL FOUNDATION</b> .....	117
<b>CHAPTER V. RECOMMENDATIONS</b> .....	135
<b>REFERENCES</b> .....	141

## *List of Tables*

### **Chapter III. PATIENT TEMPLATE ANALYSIS**

Table III-1.	Mainstem and tributary spawning populations of summer steelhead historically or currently present in the Deschutes River.....	61
Table III-2.	Wild, resident redband trout populations in the Deschutes Basin.....	63
Table III-3.	Steelhead spawning densities from redd counts in selected areas of the mainstem and tributaries of the Deschutes River.....	69
Table III-4.	Measures of abundance of resident redband trout in the Deschutes Basin.....	71
Table III-5.	Life history patterns identified on scales collected from a sample of 100 wild adult steelhead in the Deschutes River, 1971 and 1972 run years.....	75
Table III-6.	Average percentage of age classes of adult fall chinook entering the Deschutes River from 1975 to 1980.....	96

### **CHAPTER IV. CONCEPTUAL FOUNDATION**

Table IV-1.	Existing watershed level conceptual foundation for salmon and steelhead management in the Columbia Basin taken from Return to the River.....	118
Table IV-2.	Existing watershed level conceptual foundation for salmon and steelhead management in the Columbia Basin described by Northwest Power Planning Council.....	118
Table IV-3.	A proposed conceptual foundation for the management of Columbia River salmon and steelhead taken from Return to the River.....	119
Table IV-4.	A proposed alternative conceptual foundation for the management of Columbia River salmon and steelhead described by Northwest Power Planning Council.....	119
Table IV-5.	Proposed alternative conceptual foundation for the Columbia Basin.....	124
Table IV-6.	Management strategies consistent with the alternative conceptual foundation.....	126
Table IV-7.	Management strategies consistent with the current conceptual foundation.....	126
Table IV-8.	Elements of a conceptual foundation for chinook salmon in the subregion bounded by the steppe and steppe-shrub vegetational zones.....	127
Table IV-9.	Conceptual Foundation for the management of the Deschutes Basin.....	129

*List of Figures*

**CHAPTER I. INTRODUCTION**

Figure I-1. Approximate historical range of all anadromous salmonids in the Deschutes Basin. ....2

Figure I-2 Relationships among conceptual foundation, goals, strategies and uncertainties in salmonid restoration programs. ....5

**CHAPTER II. BACKGROUND**

Figure II-1. Schematic diagram of a core satellite metapopulation .....21

Figure II-2. Core-satellite metapopulations in a hypothetical watershed. The core is located in biological “hot spots” of the mainstem alluvial reaches. Satellites are located in headwater areas. ....21

Figure II-3. The consequence of habitat degradation to population structure in a hypothetical watershed.. .....23

Figure II-4. Total biomass of anchovy, sardine and hake in the California Current in thousands of metric tons. Standing stock inferred from contemporary stock size and scale deposition rates in 18<sup>th</sup> and 19<sup>th</sup> centuries. Commercial catch of coho salmon in millions of fish.....25

Figure II-5. Total biomass of anchovy, sardine and hake in the California Current in thousands of metric tons. Standing stock inferred from contemporary stock size and scale deposition rates in 18<sup>th</sup> and 19<sup>th</sup> centuries. Commercial catch of chinook salmon in thousands of kilograms of fish.....26

Figure II-6. Reconstructed annual mean temperature in Andrews Forest in Oregon's central Cascades. ....26

Figure II-7. Hypothetical representation of salmon abundance in the Northwest over the last 150 years.....27

**CHAPTER III. PATIENT TEMPLATE ANALYSIS**

Figure III-1. Schematic diagram of the Deschutes watershed describing environmental gradients.....30

Figure III-2. Percentage of days that the Oregon water quality standard of 58<sup>o</sup>F was exceeded in selected streams in the Crooked River Basin and in upper Trout Creek. ....43

Figure III-3. Relative estimated historical and current summer temperature profiles in the Crooked River showing thermal fragmentation in recent years. ....44

Figure III-4. A) Average flows for June, July and August 1961-67; B) average monthly discharge, 1961-67 in the Crooked River above Prineville Reservoir near Post, Oregon. ....45

Figure III-5.	A) Average discharge for June, July and August, 1942-91; B) Average monthly discharge, 1942-60; C) Average monthly, 1961-91, in the Crooked River near Prineville, Oregon. ....	46
Figure III-6.	A) Average discharge for the months of June, July and August; B) average monthly discharge in the Crooked River below Opal Springs, near Culver, Oregon, 1962-92. ....	47
Figure III-7.	Average maximum temperature for June, July and August, 1964-66 and 1968-71 in Crooked River, below Opal Spring near Culver, Oregon. ....	48
Figure III-8.	A) Average flows for the months of June, July, and August; B) average annual flow pattern for the Metolius River near Grandview, Oregon, 1922-92. ....	49
Figure III-9.	Average maximum temperature of the Metolius River near Grandview, 1956-74. ....	49
Figure III-10.	A) Average monthly temperature in June, July, and August for the Deschutes River near Pelton (disruptions in line indicate missing data.); and B) average monthly temperature in June, July, and August for the Deschutes River near Moody, Oregon. ....	53
Figure III-11.	Average annual flow pattern for the Deschutes River near Pelton and Moody, Oregon, 1925-92. ....	53
Figure III-12.	A) Average flows for June, July and August 1984-92; B) average monthly discharge 1984-92 in Warm Springs River near Simnasho, Oregon. ....	55
Figure III-13.	A) Average flows for June, July, and August 1975-91; B) average monthly discharge, 1975-91 in Shitike Creek, near Warm Springs, Oregon. ....	56
Figure III-14.	Maximum and minimum temperatures for July, August and September in the Warm Springs River at RM 1.0 and 37.5. ....	57
Figure III-15.	Estimated range of current and historical distributions of summer steelhead in the Deschutes Basin. ....	60
Figure III-16.	The number of steelhead captured at the Squaw Creek weir and the number of steelhead redds counted between the weir and the mouth of Squaw Creek, 1951-64. ....	65
Figure III-17.	Sport catch of adult steelhead in the lower Deschutes River; 1951-65. ....	66
Figure III-18.	The number of wild, Deschutes Hatchery and stray hatchery steelhead (fish not from the Deschutes System) collected at the Pelton Trap, 1971-96. ....	67
Figure III-19.	The estimated number of wild, Round Butte Hatchery and stray hatchery steelhead crossing Sherars Falls from 1977 to 1995. ....	68
Figure III-20.	Time of steelhead spawning at several locations in the Deschutes Basin. ....	76
Figure III-21.	Time of spawning for resident redband trout at several locations in the Deschutes Basin. ....	78

Figure III-22.	Estimated percentage of stray summer steelhead passing Sherars Falls in the Deschutes River.....	83
Figure III-23.	Percentage of wild, Round Butte Hatchery and out-of-basin stray summer steelhead passing Sherars Falls in the Deschutes River. ....	83
Figure III-24.	Wild and hatchery summer steelhead in the Umatilla River, 1980-97.....	85
Figure III-25.	Approximate historical spawning distribution of summer chinook in the Deschutes River. ....	90
Figure III-26.	Approximate historical and current distribution of fall chinook in the Deschutes Basin. ....	91
Figure III-27.	Approximate historical and current spawning distribution of spring chinook in the Deschutes Basin. ....	92
Figure III-28.	Proportion of fall chinook redds above and below Sherars Falls, 1972 through 1994.....	93
Figure III-29.	Number of jack and adult fall chinook salmon at the Pelton trap 1957-95.....	94
Figure III-30.	Total run of fall chinook salmon in the Deschutes River 1977-96. ....	95
Figure III-31.	Five-year running average of July and August flows in Umatilla River, near Umatilla, Oregon, 1904-1992.....	99
Figure III-32.	Number of adult spring chinook counted at the Metolius Hatchery rack, 1948-58.....	100
Figure III-33.	Number of spring chinook salmon observed in 5 spawning surveys of the Metolius River and its tributaries, 1951-66.....	101
Figure III-34.	Total number of spring chinook redds counted in the Warm Springs River, 1969-92. Counts from 1969-76 do not include index areas below Warm Springs National Fish Hatchery.....	101
Figure III-35.	Number of hatchery and wild spring chinook salmon allowed to pass the hatchery weir and spawn in the Warm Springs River, 1978-93.....	102
Figure III-36.	Adults, jacks and total spring chinook salmon captured in the Pelton trap, 1957-96.....	102
Figure III-37.	Average number of juvenile chinook salmon captured in the Pelton migrant trap, 1959-63 and 1969-73. ....	104
Figure III-38	Approximate historical and current distribution of bull trout in the Deschutes Basin. ....	112
Figure III-39.	The number of bull trout redds observed in the Metolius Basin.....	113
Figure III-40.	Age and length of bull trout in the Metolius River. ....	115

**CHAPTER IV. CONCEPTUAL FOUNDATION**

Figure IV-1. Total adult salmon and steelhead returns to the Columbia River and the cost of the salmon restoration program. Initially the program expended \$2 million/year (Laythe 1950). From 1949 to 1981 the average annual cost was \$15.4 million/year and from 1982 to 1991 \$122 million/year (GAO 1992) and has reached \$425 million/year in recent years (NPPC 1995). ..... 123

**A CONCEPTUAL FOUNDATION FOR THE MANAGEMENT  
OF NATIVE SALMONIDS IN THE  
DESCHUTES RIVER**

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**CHAPTER I.  
INTRODUCTION**

**A. Purpose and Scope**

The purpose of this report is to construct a conceptual foundation for the management of native salmonids in the Deschutes River. The geographical scope of the study covers those parts of the basin that are within the historical (~1800) range of anadromous salmonids (Figure I-1). Areas outside the range of anadromous salmonids are discussed only if they exert an influence on the habitat of the study reaches. Species and races covered are resident and anadromous redband trout *Oncorhynchus mykiss gairdneri* and bull trout *Salvelinus confluentus*, summer/fall and spring chinook salmon *O. tshawytscha*, and sockeye and kokanee *O. nerka*. The study is based on existing literature; no new information was collected, although previously published information may be interpreted from the perspective of a new set of assumptions or theories.

This report is a final draft. While Portland General Electric does not anticipate making further changes in the document, it reserves the right to make revisions or additions before the final submission of the license application to the Federal Energy Regulatory Commission in 1999.

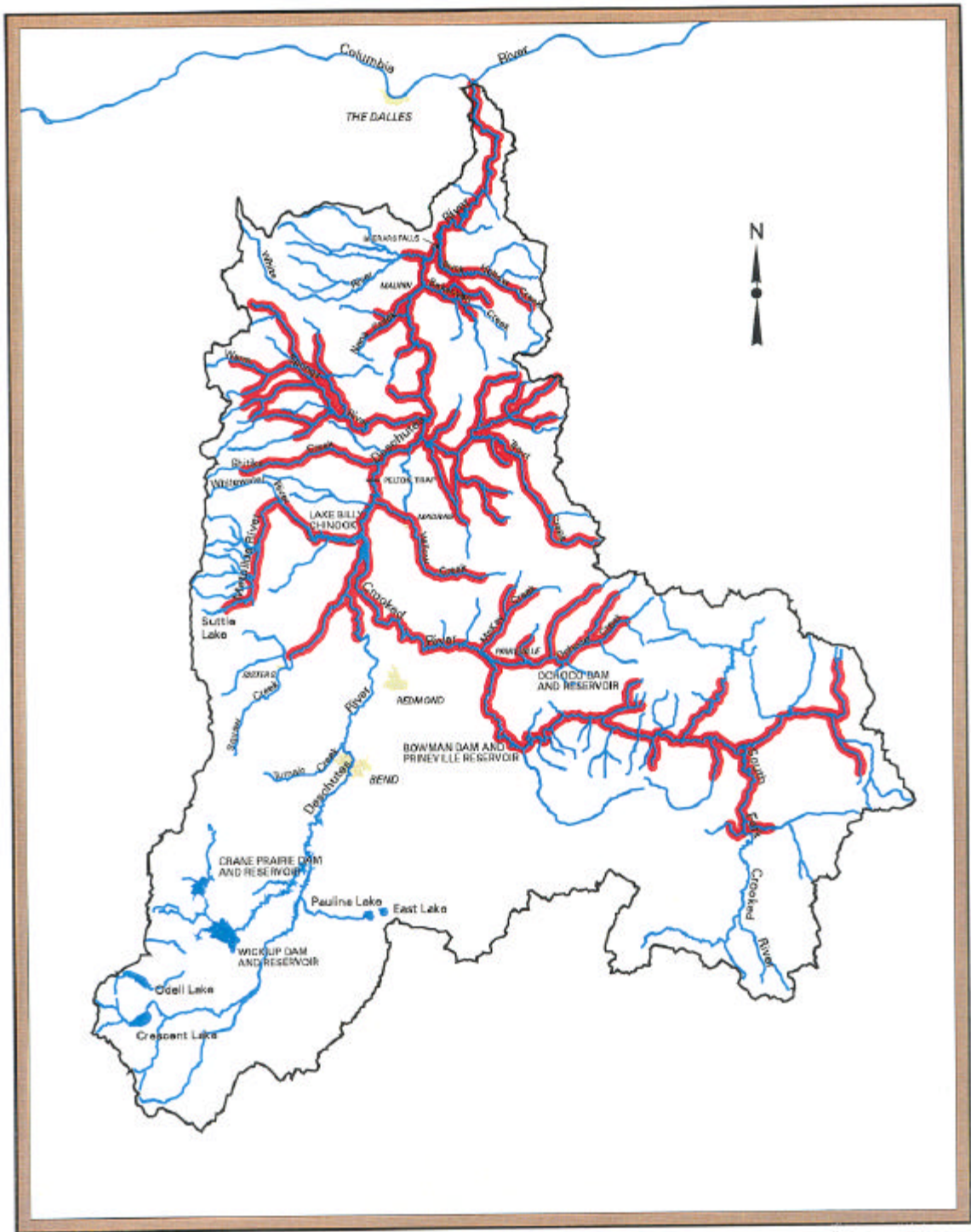
**B. Organization of the Report**

The report has the following five chapters:

**Chapter I — Introduction**— Explains the purpose and scope and defines the conceptual foundation.

**Chapter II — Background** — Provides general background on the structure and function of salmonid populations and their relationship to habitat. This chapter describes

the point-of-view and some fundamental principles endorsed by the authors. This chapter should help the reader understand the basis for the authors' conclusions and recommendations.



**Figure I-1.** Approximate historical range of all anadromous salmonids in the Deschutes Basin.

**Chapter III — Patient Template Analysis** — Describes predevelopment and current habitat conditions, life histories, distribution and abundance of native salmonids in the Deschutes Basin. This section will cover the period from settlement by Euroamericans (~1840) up to the present. The information on habitat, life histories, distribution and abundance will be combined, where appropriate, with current genetic information to develop a hypothesis regarding the historical metapopulation organization of salmonids in the Deschutes Basin.

**Chapter IV — Conceptual Foundation** — Describes the conceptual foundation and its implications.

**Chapter V — Recommendations** — Describes new research and management initiatives derived from the study.

### ***C. What is a conceptual foundation?***

Because conceptual foundation is not a common term or concept in fishery management programs, a definition is in order. A conceptual foundation is a set of scientific theories, principles and assumptions, which in aggregate describe how a salmonid-producing ecosystem functions. The conceptual foundation determines how information is interpreted, what problems are identified and as a consequence it also determines the range of appropriate solutions (Independent Scientific Group (ISG) 1996). It is through the conceptual foundation that fishery management goals are translated into the ecological conditions needed to achieve those goals and management strategies needed to achieve the appropriate ecological conditions (Northwest Power Planning Council (NPPC) 1997). The conceptual foundation plays a powerful, albeit often unrecognized, role in fishery management and restoration programs.

One way to grasp the importance of the conceptual foundation and its importance is to consider it an analog to the picture that comes with a jigsaw puzzle. The picture, usually on the box lid, illustrates what all the pieces will look like when placed in their proper order. Each piece of the puzzle is a small data set containing information, which is interpreted by continually comparing or referencing back to the picture. Assembling the puzzle without the guidance of the picture or with the wrong picture would be extremely difficult if not impossible. Unfortunately, biological systems do not come with a single clear picture or conceptual foundation we can use to interpret the information contained in the various pieces of the salmon management puzzle. The conceptual foundation must be constructed by biologists using a combination of information specific to the watershed, scientific theory and reasonable assumptions.

Historically, it was assumed that the design, implementation and success of salmon management programs were primarily limited by information and technology. However, we have known for 122 years that dams, habitat change and excessive fishing would

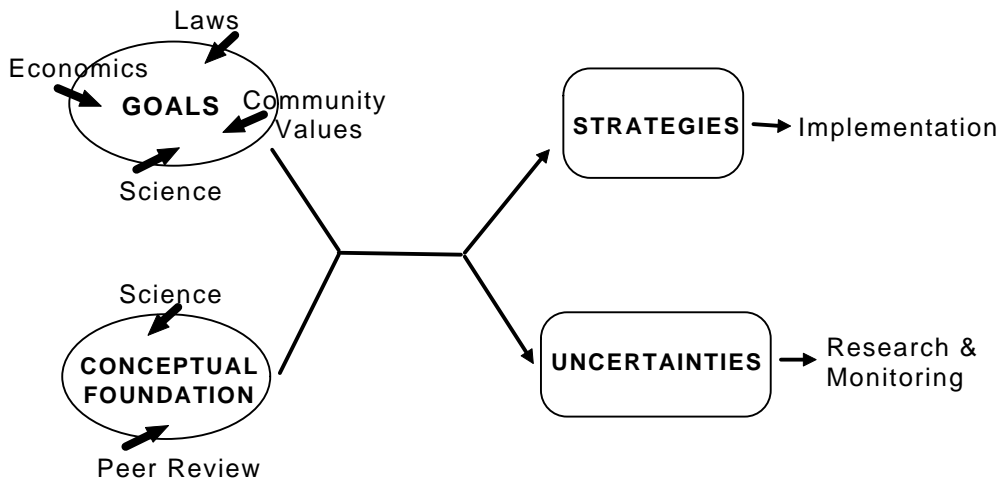
destroy the salmon (Baird 1875). Given the current status of salmon throughout the Pacific Northwest (Nehlsen et al. 1991; Huntington et al. 1994), it is obvious that knowing what would destroy the salmon was not enough to prevent it. Progress in environmental issues is not limited by “tape measures” and “account sheets” (information and technology) but by the often unspoken and unrecognized basic assumptions we make about nature (Botkin 1990; Langston 1995)—in the terminology used in this report, the conceptual foundation.

Conceptual foundations are influenced by new information which means they may change as scientific understanding of the Pacific salmon and their ecosystems change. So it should not be surprising that there are examples of programs that, with the benefit of hindsight, we now know were based on conceptual foundations that later proved to be wrong or inadequate. For example, in the 1970s an important argument for the development of large, private sea ranching operations was the assumption that there was vacant carrying capacity in the ocean rearing areas. Proponents of sea ranching believed that the ocean’s carrying capacity for salmon was highly stable and not being fully used because freshwater smolt production was reduced by the effects of logging, irrigation, grazing, dams, residential development and pollution. Fewer smolts leaving the river meant vacant capacity in the ocean. In this conceptual foundation, the ocean’s capacity to produce salmon could be realized by simply filling up the vacant spaces with smolts from large-scale artificial propagation facilities. Investments in salmon ranches inadvertently funded a large-scale experiment to test the assumption that the ocean was a stable ecosystem with vacant salmon habitat. The failure of ocean ranching showed that it was based on a false set of assumptions or conceptual foundation regarding the stability of the ocean’s productivity relative to salmon. We now know that the ocean underwent significant change about the time the larger sea ranchers began operating. An important consequence of that change was reduced ocean survival of salmon (Nickelson 1986). Stable oceanic carrying capacity for salmon did not exist.

If conceptual foundations play such an important role in the design, implementation and ultimately the success or failure of fishery management plans, why are they not commonly found in those plans? In fact, conceptual foundations are not new to fishery management and recovery plans, however, they are often left unstated (Botkin 1990). Biologists who write management plans have some idea how the production system that they are trying to manage functions. That understanding guides the development of the plan or program, but it rarely is explicitly stated. As long as the conceptual foundations remain unstated they cannot be reviewed, evaluated and debated in open forums. False assumptions, outdated science or unsupported principles in the conceptual foundation cannot be identified and corrected unless they are explicitly stated and publicly discussed.

Although they are derived from different processes, the goals, conceptual foundations and strategies are intimately linked in the internal mechanics of management and restoration plans (NPPC 1997). Goals are derived from a melding of science, economics, law and community values; whereas, the conceptual foundation is derived through the synthesis of scientific information and peer review (Figure I-2). The integration of goals with the

conceptual foundation produces two important products: 1) Implementation strategies consistent with the conceptual foundation and capable of achieving the goal; and 2) uncertainties that need resolution through research or monitoring and evaluation. When the conceptual foundation is hidden from view as it usually is, the separate scientific and public processes can become mixed and confused (NPPC 1997). Conflicts over management strategies are often at their root the product of differing, but unstated conceptual foundations. The seemingly intractable debates over strategies cannot be resolved as long as the roots of the conflict remain hidden. To a large degree, the debate among advocates of natural and artificial propagation is driven by differing, but unstated conceptual foundations. Failure of the NPPC's Fish and Wildlife Program to arrest the decline of salmon in the Columbia River can be attributed, in part, to the implied conceptual foundation and the failure of the strategies it produced (ISG 1996).



**Figure I-2.** Relationships among conceptual foundation, goals, strategies and uncertainties in salmonid restoration programs.

Strategies are derived from the integration of distinctly different processes (Figure I-2). Goals are a result of a public process, while the conceptual foundation is result of a scientific process. Strategies are derived from the combination of goals (what we want to achieve) and conceptual foundation (the ecological condition needed to achieve the goals). Decisions as to which strategies will be implemented are also part of a public process that takes into account economics, public policy, community values and tradeoffs of several different kinds.

Strategies may be rejected during the public review process because they are too expensive, conflict with policy or are inconsistent with community values. When this occurs, it's necessary to look for appropriate alternative strategies or re-examine the goals (NPPC 1997). Too often in the past, the implementation of inappropriate strategies was made possible by altering the science (conceptual foundation) until it was consistent with the favored strategy. That was possible as long as the conceptual foundation remained

unstated and hidden from view. In some hatchery and harvest management programs, as well as salmon restoration programs, scientific knowledge was suppressed or “bent” in order to justify the desired strategies (Lichatowich et al. 1996).

# CHAPTER II.

# BACKGROUND

The background section describes concepts important to the development of a conceptual foundation for the management of native Deschutes River salmonids. It is in part, a description of the point-of-view of the authors. It tells the reader how the authors view the biological world of the salmonids and therefore, gives some insight as to how or why we interpreted information as we did and reached the conclusions presented later in the report. The background section can be thought of as a primer on the basic principles in the conceptual foundation.

Management and restoration programs for native salmonids have a fundamental requirement: They must work in concert with the natural strengths of the fishes that compose the native community and the natural processes that form and maintain the habitats required by those communities. They must take into consideration the fishes' biological characteristics that evolved over thousands of years and adapted the native salmonids to the patchwork of unique environments in the Northwest. The failure of early restoration programs, especially those that emphasized artificial propagation, can be traced to hatchery practices that worked against the salmon's biological strengths. For example, the transfer of salmon and trout from their home streams to foreign streams worked against the stock structure of salmonids, broke down reproductive isolation and ignored the fitness benefits of local adaptation. Pacific salmon species are organized into locally-adapted populations and their natural economy exploits complex local habitats through a diversity of life history patterns. Local adaptation and life history diversity emphasize a close relationship between salmonids and their habitat, a relationship that has been ignored in most hatchery programs and even in some habitat restoration programs.

## ***A. Historical Perspective***

The background information will be presented as summaries of the stock concept, life histories, genetics and metapopulation theory. The summaries also give a historical context for each subject. It's important to understand the historical development of critical concepts and principles to avoid rediscovering old ideas. A historical perspective also provides an appreciation for the tentative, developing nature of some of the central concepts of fishery management.

## **B. Stock Concept**

The stock concept has its roots in the evolution of population thinking and the biological revolution precipitated by Charles Darwin and Alfred Wallace. Prior to publication of the *Origin of Species* (Darwin 1859), the dominant world view did not include the concept of populations as we understand them today.

Three European biologists, F. Heincke, J. Schmidt and J. Hjort, are credited with shifting the focus of fisheries from species to populations. In 1832, the Swedish zoologist, Nilsson challenged the long-standing belief that the Atlantic herring were composed of one large population. The so-called polar migration hypothesis attributed fluctuations in herring abundance, in local fisheries, to changes in migration in response to environmental changes such as a change in temperature. However, Nilsson showed that Atlantic herring were composed of many local populations and fluctuations in catch was due to overfishing of one or more local stocks. The possibility of overharvest meant restrictive harvests which touched off a heated debate. Nilsson's methods were subjected to valid criticism, however, even though his methods were weak, the question his work raised remained valid. Was the Atlantic herring composed of one or several populations (Sinclair and Solemdal 1988)?

In 1875, Heincke was asked by the Commission for the Scientific Investigation of German Seas to resolve the question: Is the Atlantic herring composed of several populations or one large population? The commission further instructed Heincke to conduct his study in a way that "*...can withstand the sharpest critique of science.*" Over 25 years and three major publications, Heincke achieved that goal. He measured as many as 65 characteristics on individual fish and developed statistical methods to analyze the resulting data. Heincke proved the existence of local populations. Schmidt later published a series of reports between 1917 and 1930 on racial studies of fish which integrated and generalized Heincke's work to several other species (reviewed in Sinclair and Solemdal 1988). Heincke's population concept was extended by Hjort in 1914 to Atlantic cod and haddock (Sinclair 1988). Hjort went beyond the documentation of individual populations and showed that variability in landings was the result of age structured populations with variable year-class strengths (Sinclair and Solemdal 1988). Since this pioneering work, a wealth of information regarding the population richness of fish species has accumulated. The evidence shows that not all species have the same level of complexity in their population structure (Sinclair and Iles 1989).

Population-rich species typically exhibit numerous breeding groups that are somewhat isolated from one another reproductively (usually as a result of geographic or physical separation). Individuals from these populations often co-mingle at some point in their life history. For example, immature fish might rear in the estuary and ocean in mixed aggregates of several populations. The mixing of stocks during parts of their life histories has important management implications. When fishes are harvested in the ocean in areas where many populations are mixed, the weaker populations are easily over harvested

(Ricker 1958). Persistent over harvest can lead to extinction, particularly when combined with habitat degradation and changes in climatic conditions. Like the discovery of individual, local populations of herring a century ago, the realization that ocean salmon fisheries do harvest mixed stocks has led to controversy and debate (e.g., Wright 1993) and concern over the loss of smaller and weaker stocks (Thompson 1965). To avoid inadvertent extinction of weak stocks, the basic unit of harvest management should be the population (Rich 1939; Sinclair 1988). Biologists have labeled this basic management unit the stock which Ricker (1972) defined as,

*...fish spawning in a particular lake or stream [or portion of it] at a particular season, which fish to a substantial degree do not interbreed with any group spawning in a different place, or in the same place at a different season. (Ricker 1972)*

Recently, Healey and Prince (1995) recommended that the basic management unit be expanded to include the population and its habitat.

## **1. The Stock Concept in Pacific Salmon**

Careful observers of nature, noticed as early as the 1700s that Atlantic salmon entering different New England rivers had different traits (Dunfield 1985). Early hatchery operators such as R. D. Hume also saw differences in Pacific salmon entering different rivers. In 1893, Hume wrote:

*The fact that in rivers which enter the sea within a few miles of each other, as well as the different tributaries of the same river, the fish [salmon] will have local characteristics which enable those who are familiar with the various streams to distinguish to which river or tributary they belong...*  
(Hume 1893)

However, the idea that the species of Pacific salmon were composed of distinct stocks was not readily accepted even after European biologists had confirmed the existence of population structure in fishes. In 1904, David Starr Jordan argued that Pacific salmon did not home back to the stream of their birth to spawn. According to Jordan, salmon rarely traveled more than 20 to 40 miles (32 to 64 km) from the mouth of the stream they left as juveniles. When they matured they simply swam into the first river they came to, which was usually their home stream (Jordan 1904). This view of the salmon's biology excluded the possibility of distinct stocks. Jordan's argument was derived from a faulty conceptual foundation.

Charles Gilbert, Jordan's colleague at Stanford University, reached a different conclusion. After analyzing the scale patterns of sockeye salmon in the Fraser and other rivers, Gilbert concluded that the salmon from different rivers showed consistent differences in their growth and maturity. From this study, he concluded in 1914,

*This fact disposes quite effectively of the general question concerning the return of our salmon to the river basins in which they were hatched. It can now be affirmed with entire confidence that they do so return, that they are effectively isolated, and that they interbreed thus within the limits of their colony. (cited in Dunn 1996).*

Gilbert's observation was the exception. Prior to the 1930s, it was generally thought that the spawning populations of salmon were genetically uniform and observed differences between salmon in different rivers were attributed to the effects of the environment (Ricker 1972). Biologists debated whether salmon returned to their home stream to spawn, and the existence of reproductively isolated populations until the late 1930s (e.g. Huntsman 1937; Rich 1937). With the publication of Rich's 1939 paper, the debate over homing and the existence of local populations was generally resolved. However, incorporating that knowledge into management programs has been slow. In 1939, Hugh G. Mitchell, Director of the Department of Fish and Culture for the Oregon Fish Commission understood an important implication of the stock concept—that interbasin transfers of salmon were detrimental.

*The older system of transferring by truck fish raised at a station on one stream to another stream for liberation is now considered undesirable on account of resulting disturbance to the homing instinct. With this in mind the policy has been adopted, insofar as the available funds will permit, to establish and operate small stations on such streams of the state as are suitable for salmon runs. (Oregon Fish Commission (OFC) 1939)*

Fifty-six years later, in a paper reviewing the causes for the extinction of lower Columbia River coho salmon, Flagg et al. (1995) recommended that inter-hatchery transfers of salmon be restricted. In other words, the inter-hatchery transfers continued even in the face of knowledge that they were detrimental. Hatcheries weren't the only management program to ignore the stock structure of salmonids. Harvest managers, especially in mixed stock fisheries, found it difficult to incorporate the stock structure of salmon into the regulation of fisheries. W. F. Thompson (1965) summarized the effects of harvest management's failure to protect individual stocks.

*We regulate our fisheries. But we concentrate them on the best races and one by one these shrink or vanish and we do not even follow their fate because we have not learned to recognize their independent component groups or to separate them one from the other. We continue our unequal demands, knowing only that our total catches diminish, as one by one small populations disappear unnoticed from the greater mixtures which we fish. (Thompson 1965)*

The stock structure of Pacific salmon was generally ignored in management until the 1960s and 1970s (e.g., Calaprice 1969; Berst and Simon 1981). The rising importance of stocks emerged out of the conflict between the conservation and environmental

movements. The conservation movement developed in the late 19<sup>th</sup> and early 20<sup>th</sup> centuries as a part of the desire to control and “conserve” water in western rivers for irrigated agriculture (Hays 1969). For most of its existence, conservation stood for development and maximum-efficient use of resources (Pinchot 1910). Salmon management agencies came into existence and developed their programs consistent with this early concept of conservation. Hence, hatcheries were a popular tool that permitted full development of watersheds. The stock structure of Pacific salmon was an impediment to the “conservation” of western rivers. If a unique stock inhabited each watershed or major tributary, development which caused the loss of habitat could not be maximized while at the same time preserving salmon production and its economic benefits. The stock concept introduced a major inefficiency to the efficient development of northwestern rivers and it was antithetical to the principles of the early conservation movement. The stock concept also impeded hatchery operations such as interbasin stock transfers and maximization of harvest. Consequently it was generally ignored.

The environmental movement of the 1960s emphasized a different set of values: Quality of life, environmental amenities, ecosystem health and public involvement in resource use issues. The differing values put the conservation and environmental movements into sharp conflict (Hays 1993). River development in the west became the focus of the conflict between the conservation and environmental movements. The conflict between the conservation and environmental movements is also being played out today within the fish and wildlife agencies. Most of the performance measures used by management agencies reflect the values of the old conservation movement (Lichatowich 1996). Biologists emphasizing the maximum-efficient-use principles of conservationist minimize the importance or even question the existence of the salmon’s stock structure, as well as local adaptation. Environmental oriented biologists stress the uniqueness of stocks, their irreplaceable genetic heritage and the importance of genetic diversity to sustainable management. The debate is still in progress.

### **C. Life Histories**

Cloudsley Rutter (1902), one of Charles Gilbert's students at Stanford University, conducted the pioneering study of Pacific salmon life history. He studied the life history and biology of chinook salmon in the Sacramento River. One of Rutter's assistants, Frederick Morton Chamberlain, completed a companion study of the life history of Alaska salmon (Chamberlain 1907). After Rutter's death in 1903, Gilbert became more involved in salmon studies and quickly gained recognition as the authority on Pacific salmon (Dunn 1996). In 1912, Gilbert used an analysis of circuli patterns on the scales of salmon to determine the age at maturity for sockeye, chinook, coho and chum salmon. Gilbert also used scale analysis to describe two basic juvenile life histories, which he labeled stream and sea types. Juvenile salmon of the stream type reared in freshwater and went to sea in the spring of their second year. Whereas juveniles of the sea type migrated to the ocean shortly after hatching (Gilbert 1912). The development of the scale method of determining the life history of salmon opened an important avenue of research which is still bearing fruit today (e.g. Reimers 1973; Schluchter and Lichatowich 1977; Borgerson and Bowden 1994; Borgerson and Bowden 1996).

Gilbert was one of the first biologists to associate changes in life histories of a salmon population with ecological changes in the environment (Dunn 1996). He also put knowledge of life histories to practical use. Because Gilbert found few adult sockeye salmon with the scale pattern showing migration to sea as a fry, he questioned the usual practice of releasing sockeye fry from hatcheries (Dunn 1996).

Gilbert's student, Willis Rich, continued the work of his mentor and advanced our understanding of the freshwater life history of chinook salmon in the Columbia and Sacramento rivers (Rich 1920). Chinook salmon in the Columbia River were not clearly divided into stream and ocean life history types, as Gilbert had earlier suggested. In the Columbia River, juvenile chinook salmon migrated to sea throughout most of the year creating a continuum of migration times between the fry and yearling stages (Rich 1920; Rich and Holmes 1929). Snyder (1931) observed a similar pattern of continuous migration in the chinook salmon of the Klamath River. Rich was the first to understand and describe the importance of life history diversity in understanding how salmon adapt to their environment (Rich 1920, 1925).

Rich also put his knowledge of life history to practical use and recommended operational changes in hatcheries. Like Gilbert, he recommended terminating the release of fry before absorption of the yolk sack. He also advised hatchery managers to release juvenile salmon to coincide with the natural timing of their migration from their home streams. Rich recommended that the hatcheries avoid releasing juveniles all at once. Instead, he suggested a volitional release technique (Rich 1920), a technique that is still used today.

In addition to the practical management implications of a knowledge of life histories, Rich believed that life history studies were an important means to link the salmon to their environment and to develop an understanding of how they maintain themselves in their

natural habitat. In explaining the importance of life history relative to genetics and physiological studies, Rich (1925) asked:

*Is it not as important to know how a species is maintained as to know how it arises? Is it not as important to know how a species is adjusted to its environment and how it responds and adapts itself to changes in its environment as to know these same things for the individual?* (Rich 1925)

Since Rich advocated the study of life history of the five species of Pacific salmon, researchers have accumulated information on life histories usually as part of studies with other objectives. It has only been in the last 20 years that researchers have rediscovered Rich's belief that life history studies can yield important information on how the salmon adjust or adapt to their environment (e.g., Reimers 1973; Schluchter and Lichatowich 1977; Carl and Healey 1984; Gharret and Smoker 1993; Lestelle et al. 1993).

In 1959, W. F. Thompson published a "thinking paper" in which he "*presented not facts, but working hypotheses, a logical framework for research.*" The paper is essentially a conceptual foundation constructed around habitat, life history and natural dynamics of salmon populations. Thompson (1959) visualized salmon habitat as "*a chain of favorable environments connected within a definite season in time and place in such a way as to provide maximum survival.*" Within a river system and population, there are many of these chains—many different combinations of season, time and place within which the salmon can survive. Each possible chain of environments through which members of a population can move and survive is a life history. Life histories are an expression of the underlying genetic possibilities in particular environments (Thorpe 1994) or in Thompson's conceptual foundation, in a particular chain of environments.

Diversity of life histories is the population's solution to the problem of survival in variable environments (Thorpe 1994). The more diverse a population's life histories are, the less likely a break would occur in one of the chains that would lead to extinction. Life history diversity can be viewed as a web of pathways spread across the time-space dimension of the environment (Mobernd et al. 1997). As habitat degrades, more and more of the chains are broken with a loss of diversity, stability and productivity. Continuation of this trend eventually leads to extinction of the population.

Life histories have been lost in part because management has been insufficiently attentive to the salmon's entire life cycle. Salmon managers generally attribute far greater importance to those parts of the salmon's life history that they can easily see, than to those parts that they can't (Thompson 1959). Historically, adult migration (observed as fisheries) and spawning were the points in the salmon life cycle that were readily visible. Simple causal chains between these two points were constructed and given great importance, as though, all the complex life histories in between spawning and harvest did not matter. One example of this is the use of stock-recruitment models to set escapement and harvest levels.

Life history variation is an important part of the salmon's biodiversity and it is expressed at several spatial scales: the landscape, ecosystem and population (Healey and Prince 1995). The relationship between habitat and life histories has led to the proposal that salmon management and restoration must treat the fish in its habitat as the management unit (Healey and Prince 1995). Viewing habitat as a template against which life histories are expressed has provided a new and potentially useful theoretical basis for salmon restoration (e.g., Healey and Prince 1995; Lichatowich et al. 1995; ISG 1996). Healey (1994) summarized the importance of life history in salmonid restoration.

*Conservation efforts must nurture the whole life history, not focus inordinate attention on elusive 'bottlenecks' to production. I believe conservation efforts will fail if primary attention is not directed to providing the habitat opportunities that historically supported the stock in its natural state. (Healey 1994)*

In the Deschutes Basin, a major focus of attention has been the obvious bottleneck to anadromous salmonids created by the Pelton Round Butte Project. The dams and their reservoirs have broken the chain of favorable environments in at least two places—juvenile and adult migration. The dams and their reservoirs may have disrupted life histories in other ways. The area now inundated under the reservoirs may have been an important rearing area for juvenile anadromous salmonids from the Crooked, Metolius and Upper Deschutes rivers (Nehlsen 1995). The reservoirs also inundate the region where the river splits into three main branches and that area may have been an important biological mixing zone, a place where genetic exchange between populations of resident salmonids in the Crooked, Deschutes and Metolius rivers took place. It's possible that the area of the three arms could have been important to the structure of resident salmonid metapopulations in the upper basin. The biological value may have been impeded by the existence of the reservoirs. Research into this question has recently been initiated. The movement of adults and juveniles past Pelton and Round Butte Dams is a crucial problem that must be overcome, if anadromous salmonids are to be restored to their historic habitat. However, planning for the reintroduction must also consider the restoration of life histories appropriate to the habitat above the dams.

#### **D. Genetics**

Remarkable advances have occurred in the field of fisheries and population genetics in the last three decades; however, until recently, genetic information has had little direct effect on the management of either anadromous or resident salmonid stocks (Allendorf et al. 1987; Allendorf and Leary 1988). Currently, the role that genetics can play in informed fisheries management has increased as fisheries managers are faced with decisions regarding recovery options for generally declining stocks, the need to identify appropriate management units for recovery (e.g., the evolutionarily significant units (ESUs)), and the legacy of a century or more of exotic fish introductions into western waters. Where possible, historical reconstruction of salmonid distributions and metapopulation structure can assist managers in identifying management and restoration strategies that are ecologically and genetically viable.

As noted above in the discussion of the stock concept, fisheries scientists have recognized population and genetic structuring in fish species since the pioneering work of three European biologists, Heincke, Schmidt and Hjort, who shifted the focus of fisheries science from species to populations. In the Pacific Northwest, early hatchery operators such as R. D. Hume saw differences in Pacific salmon entering different rivers and recognized these differences as adaptations to local environments (Hume 1893). Charles Gilbert, David Starr Jordan's colleague at Stanford University, analyzed the scale patterns of sockeye salmon in the Fraser and other rivers and concluded that salmon from different rivers showed consistent differences in their growth and maturity. In the early work of Gilbert and others notwithstanding, the stock structure of Pacific salmon was generally ignored in management until the 1960s and 1970s (e.g., Calaprice 1969; Berst and Simon 1981), a time period that coincided with the development of biochemical molecular techniques (protein gel electrophoresis, also called allozyme analysis), which would document definitively that stocks existed and differed from one another in genetic characteristics and population genetic structure (Utter et al. 1973a; Utter et al. 1973b; Allendorf and Utter 1974; Utter et al. 1974; Allendorf et al. 1975; Utter 1976; Allendorf and Utter 1979). Elsewhere in the scientific community, substantial theoretical and empirical advances were occurring with respect to genetic investigations of local adaptation and the role of founder events in population and species-level divergence (Templeton 1980; Carson 1984; Templeton et al. 1986; Carson 1987; Templeton 1989). Although these advances were integrated into our understanding of Pacific salmon by Fred Utter and his colleagues and students in the U.S. (Campton and Utter 1985; Utter et al. 1989; Utter and Ryman 1993; Utter et al. 1995) and by Yuri Altukhov and colleagues in Russia (Altukhov 1981; Altukhov and Salmenkova 1981; Altukhov 1985; Altukhov and Salmenkova 1991), subsequent integration into fisheries management has been much slower.

For example, one recent focus in conservation biology has been on identifying metapopulation structure and dynamics and describing its implications for species conservation efforts (Hanski 1982; Gilpin 1987; Harrison and Quinn 1989; Gilpin 1991; Hanski 1991; Harrison 1991). These studies are influencing fisheries management presently and many ongoing planning efforts involve consideration of metapopulation structure in their restoration strategies (Rieman and McIntyre 1993; Rieman and McIntyre 1995; ISG 1996; NRC 1996).

Although generally unrecognized, the recent focus on metapopulations was preceded by strong theoretical and empirical advances in the field of genetics, such as the "stepping stone" population model (Kimura 1953; Kimura and Weiss 1964), as well as empirical studies of population genetic structure among salmon species, particularly Russian studies, that frequently identified "population systems" where regional subpopulations were linked together through dispersal, migration, and gene flow (Altukhov 1973; Altukhov 1975; Allendorf and Phelps 1981a; Allendorf and Phelps 1981b; Altukhov et al. 1983; Altukhov and Varnavskaya 1983; Allendorf 1983; Utter et al. 1989). These studies and earlier genetic investigations by Wright (1931; 1940; 1943; 1968; 1969; 1978) and Fisher (1958)

laid the genetic groundwork upon which our contemporary ideas about metapopulations rest (Harrison 1994; Harrison and Hastings 1996).

Prior to the rise of biochemical genetics in the late 1960s and 1970s, most recognition of genetic differences among stocks and populations focused on aspects of local adaptation or on quantitative genetic differences (e.g., differences in morphological traits or life history parameters) (e.g., Rich 1939). Curiously, this information, which was well-recognized among fisheries scientists, seemed to have had little effect on the management of fish stocks and populations.

Throughout the first half of this century, both resident and anadromous salmonids were widely transplanted with little, if any attempt, to match the source of eggs and fry to the stocking locations. The widespread and indiscriminate stocking of hatchery rainbow trout (derived from coastal rainbow trout) (Needham and Behnke 1962) is an example of this management practice and has contributed to the loss of native interior rainbow trout (i.e., redband trout) (Allendorf et al. 1980; Wishard et al. 1984; Currens et al. 1990; ISG 1996; Williams et al. 1997a) and many populations of various interior cutthroat trout populations (Leary et al. 1987; Allendorf and Leary 1988; Behnke 1992, 1995).

Much of our present understanding of genetic diversity and structure in salmonid species comes from the efforts of the National Marine Fisheries Service (NMFS) lab in Seattle where Fred Utter and colleagues applied protein electrophoretic analysis to the problem of mixed stock fisheries (Grant et al. 1980; Milner et al. 1985; Seeb et al. 1986; Utter et al. 1987; Shaklee et al. 1990). The method, known as genetic stock identification is now referred to as mixed stock analysis (Utter and Ryman 1993). These studies described general patterns of genetic variation that are common to both anadromous and resident forms of salmonids. More recent direct analyses of mitochondrial and nuclear DNA variation, although frequently providing additional resolution beyond that provided by allozyme analysis, have largely revealed the same general principles of genetic structure within and among populations.

Genetic studies today focus on either the nuclear genome (DNA found in the chromosomes in the nucleus of the cell) using such techniques as allozyme analysis, DNA fingerprinting, DNA sequencing, DNA single locus probes, RAPDs (random amplified polymorphic DNAs) or microsatellite DNA analysis or on the mitochondrial genome (DNA found in the mitochondria in the cytoplasm of the cell) using DNA sequencing or RFLP (restriction fragment length polymorphism) analysis. The importance of these approaches lies not with the techniques used, but with the kind of information obtained from the nuclear versus mitochondrial analyses. Both analyses allow comparisons to be made among populations, but on very different time scales. Analysis of nuclear DNA essentially provides an ecological or near-term view of the population; whereas analysis of mitochondrial DNA provides an evolutionary or longer-term view.

Genetic changes occur slowly (hundreds to thousands of years) in mitochondrial DNA (mtDNA) as a result of mutation and substitution. Additionally, mtDNA genes are thought

to be conserved and unlikely to respond to selection, as they are key contributors to established and universal cellular metabolic pathways. In contrast, nuclear DNA (nDNA) can accumulate changes quickly (a few generations) as a result of sexual reproductions where genetic recombination occurs, or through exposure to new selection regimes, which can rapidly affect the nuclear genetic structure of a population. Therefore, analysis of the nuclear genome through allozyme analysis or microsatellite DNA analysis tends to give a current state or “snapshot” genetic profile of the population. Analysis of the same population years later may show that gene frequencies have been temporally stable, or that they have changed dramatically. Thus, analysis of the nuclear genome can provide fisheries managers with information for example, on the temporal stability of the population or on the effects of interbreeding with non-native fish (Allendorf et al. 1980; Allendorf and Phelps 1981b; Campton and Johnston 1985; Campton 1995; ISG 1996). Analysis of the mitochondrial genome provides the fisheries manager with a longer, more historical view of fish stocks within a region. Such analysis is particularly useful for identifying evolutionary relationships, native genotypes, remnant populations, and possible metapopulation structure. When both nuclear and mitochondrial data are available, even more inferences can be made about a stock’s present and historical genetic status (ISG 1996; Williams et al. 1997a).

In the Deschutes Basin, we are fortunate to have substantial genetic information on redband trout and steelhead trout, as well as some information on sockeye/kokanee salmon, bull trout, and chinook salmon. The genetic information for each species is discussed in the appropriate sections of Chapter 3. When possible the discussion will include comments or inferences on possible past and present metapopulation structure, as well as the identification of particular problems or genetic concerns that should receive priority consideration in future fisheries management planning and activities.

### ***E. Metapopulations***

Naturally reproducing populations of Pacific salmon exhibit two important traits that at times appear contradictory: homing back to their natal stream to spawn that leads to adaptation to the local habitat and climate regime (Taylor 1991) and natural straying of salmon into non-natal streams to spawn which allows the salmon to colonize habitats within the appropriate range of environmental characteristics (Lindsay and McPhail 1986; McPhail and Lindsay 1986). These two traits appear to be mutually exclusive, i.e., how can a population adapt to local habitats if there is a continuous stream of straying salmon introducing genes from different populations? In recent years, biologists have developed a theory of inter-population organization that accommodates local adaptation, straying and recolonization. The theory describes relationships among sets of populations, or a population of populations, what is now called metapopulations. The ideas embedded in the metapopulation concept go back at least to Andrewartha and Birch (1954). The term metapopulation and a theory of its function have been in the literature since the work of Levins, MacArthur and Wilson in the 1960s and 1970s (Hanski and Gilpin 1991). Metapopulation theory has only recently been used in fisheries as a framework for

interpreting salmonid population structure and ecology and to formulate management strategies (Rieman and McIntyre 1993, 1995; Gresswell et al. 1994; Li et al. 1994; Mundy et al. 1995; Schlosser and Angemeier 1995; NRC 1996; ISG 1996).

If the population is an ensemble of interacting individuals, the metapopulation is an ensemble of interacting populations. Metapopulations are groups of local populations spread across a heterogeneous landscape and linked by dispersal (Hanski 1991; Hanski and Gilpin 1991). Since the confirmation of homing and the realization that salmon are composed of local populations (Rich 1939), scientists have been concerned about the fate of individual populations. It followed from the stock concept that the extremely heterogeneous environment of the Pacific Northwest is occupied by spatially isolated breeding groups, each of which maintained unique adaptations to the local environment that had to be protected. Metapopulation theory recognizes that those populations spread across a diverse environment are spatially structured into interacting groups genetically connected by straying individuals. In other words, salmon biologists have begun to recognize that the ecological rule of thumb, that everything is connected, also applies to populations.

When populations are viewed as unique and isolated biological entities, extinction of a local population is an irrecoverable loss. Metapopulation theory treats extinction and colonization among closely related populations as natural events. The emphasis in metapopulation theory is shifted from extinction to the processes that bring about a balance between extinction and recolonization (Harrison 1994). Within a metapopulation, individual populations can go extinct, but the vacant habitat, if it is suitable, can be recolonized through dispersal of animals from other populations. Dispersal of individuals and connectivity between habitats occupied by populations making up the metapopulation is important to the maintenance of the extinction-colonization balance. Synchrony or asynchrony in the dynamics of member populations is also a critical characteristic of the extinction-colonization balance. If all the member populations of a metapopulation exhibit synchronized fluctuations in abundance, the likelihood increases that the whole metapopulation may go extinct as a result of a severe drought or change in ocean productivity. If fluctuations in abundance are asynchronous (i.e., unrelated) some populations will be in a production trough while others are at a peak, thus reducing the likelihood of mass extinction. Metapopulations that are not under stress (habitat degradation, fragmentation, over exploitation, etc.) are thought to generally be composed of populations that exhibit asynchronous fluctuations in abundance.

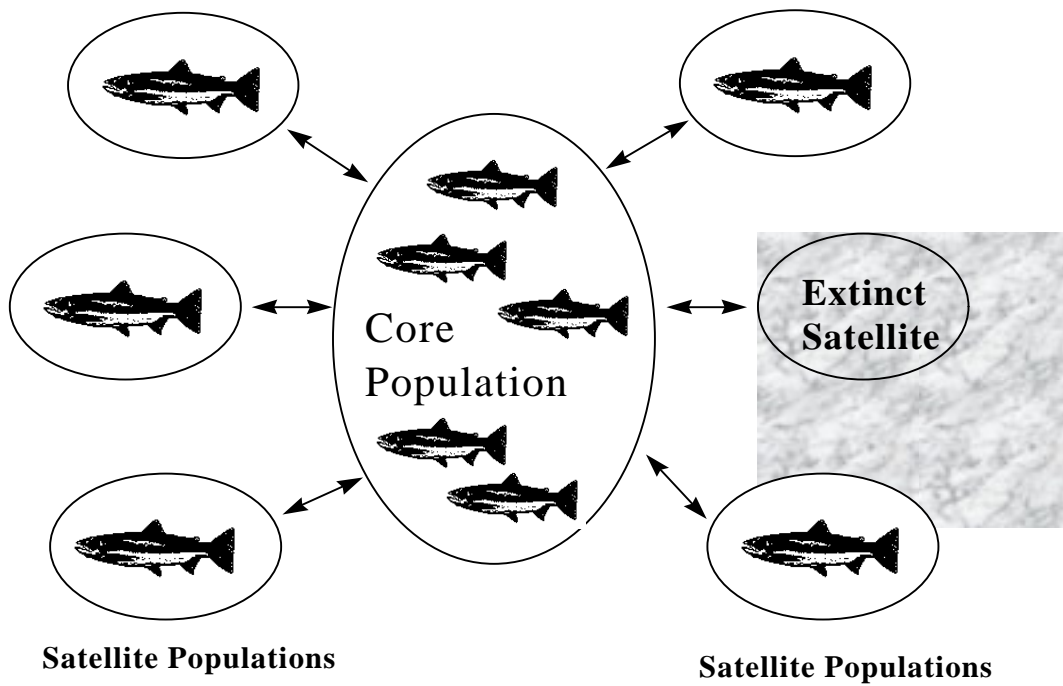
A shift of focus from concern over the extinction of individual populations to the balance between extinction and recolonization has injected optimism into salmon restoration. The optimism may be unwarranted. It derives from two interpretations of metapopulation theory: Extinction of individual populations is no longer an irreversible loss of unique populations and straying is treated as a natural and beneficial attribute of metapopulations and necessary for persistence of the population. To some, the message from metapopulation theory is that the extinction of a local population is not an irreversible loss, but a natural event; and likewise straying, even from hatchery fish, no longer poses a

threat to wild salmonid populations. Those who derive optimism from metapopulation theory for the above reasons fail to consider the difference in rates of extinction due to natural vs. human causes. The balance between extinction and colonization would most likely breakdown if the rate of extinction were accelerated due to human activities.

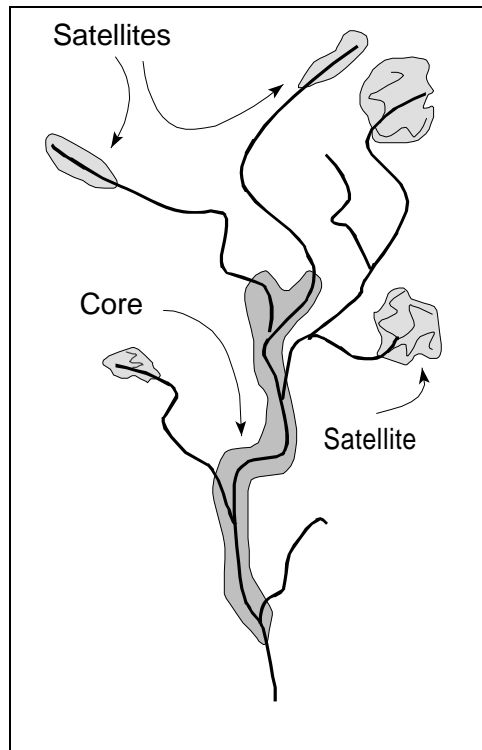
Another reason for caution with regard to the application of metapopulation concept to management is the tentative status of the theory—at least with regard to salmonids. The Independent Science Group (1996) correctly pointed out the metapopulation theory is a hypothesis and that the existence of metapopulation should be verified. Review comments on the earlier draft of this report reflect the tentative status of metapopulation theory. One reviewer believed it had strong value and application in parts of the Deschutes Basin whereas another reviewer thought it had little value.

We have no idea what threshold extinction rate will ensure the persistence of metapopulations. Hatchery fish may stray at the same rate as wild fish, but a small straying rate from a large production facility could generate enough strays to swamp nearby wild populations. Interbreeding of the hatchery fish with the wild fish, particularly if the hatchery fish were not derived from that wild population, would be likely to disrupt local adaptation and long-term fitness. If large numbers of hatchery fish stray into many of the member populations of the metapopulation and interbreed with wild fish, genetic differences among the various member populations can be reduced or lost. What level of straying (the ratio of stray to native fish on the spawning grounds) permits the metapopulation to maintain local adaptations while also maintaining the extinction-recolonization process? That question has not been answered. The use of metapopulation theory in salmonid management does not free managers from past constraints, but forces them to confront a new set of questions, the answers to which we have just begun to explore.

Several models of metapopulation structure have been described (e.g. Schlosser and Angermeier 1995) but the mainland-island or core satellite model appears to describe the structure of Pacific salmon metapopulations (Li et al. 1995; Schlosser and Angermeier 1995; ISG 1996) (Figure II-1). Rieman and McIntyre (1993) describe a metapopulation structure for bull trout that shares some of the characteristics of the core satellite model. Core populations are large, usually occupying extensive and productive habitats such as alluvial reaches of river mainstems (Stanford et al. 1996) (Figure II-2). Under natural conditions, the core population is expected to persist indefinitely. In the core-satellite model, extinction and colonization of individual populations occurs, but is not important to the persistence of the metapopulation as a whole. A large core population generally minimizes the possibility of total extinction (Harrison 1994).



**Figure II-1.** Schematic diagram of a core-satellite metapopulation.



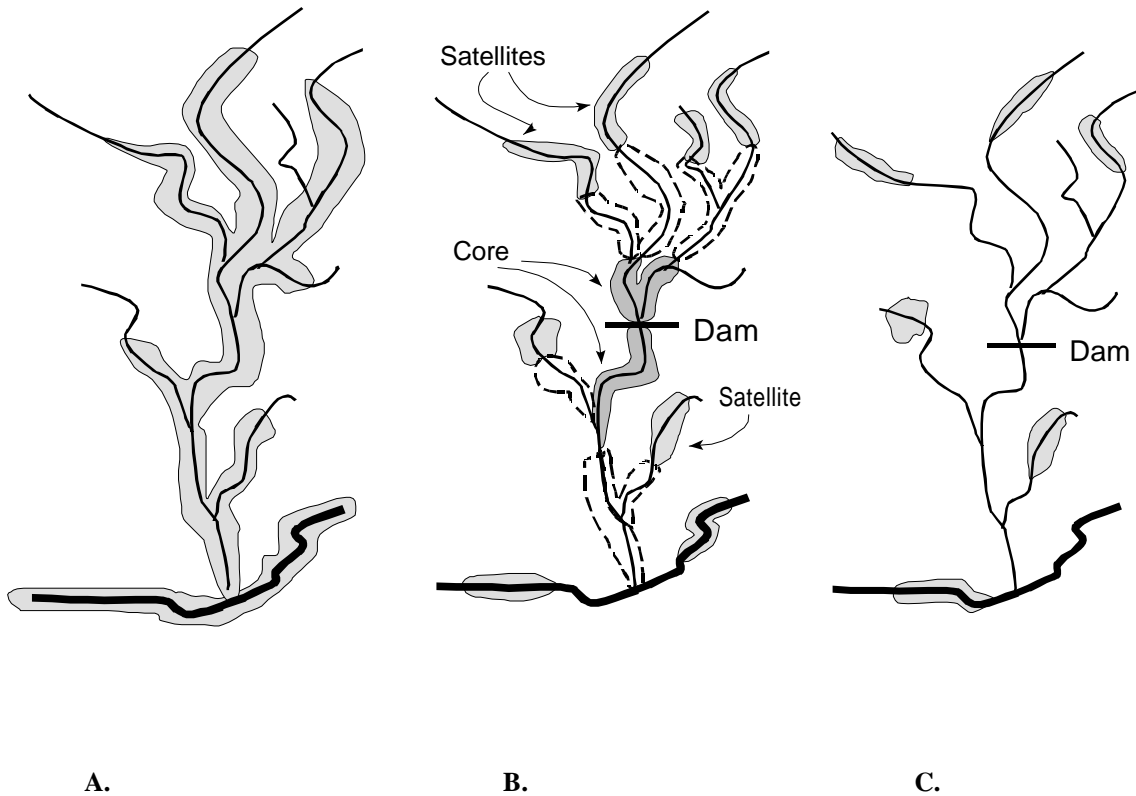
**Figure II-2.** Core-satellite metapopulation in a hypothetical watershed. The core is located in biological “hot spots” of the mainstem alluvial reaches. Satellites are located in headwater areas.

In a core-satellite metapopulation, the smaller satellite populations may occupy marginal habitat or habitat patches that are of good quality, but restricted size. Even though the satellite populations are smaller, occupy marginal habitat and are more likely to go extinct, they are critical components of the metapopulation and can make an important contribution to the development and maintenance of its genetic diversity (Scudder 1989). The marginal habitat occupied by satellite populations may induce rapid and radical selection fostering the development of new genotypes not possible in the larger, more stable core population. “*It is this type of marginally localized process that may be the mainspring of ongoing evolution in diploid species*” (Scudder 1989, p. 183). Genetic innovations produced in marginal habitats of the satellite populations may be incorporated into the core during periods of climate extremes that render marginal habitat uninhabitable. Under those conditions, members of the satellite populations retreat into the core and are incorporated into it. In fact, that may be the only way the large, stable core may be able to incorporate genetic novelties (Scudder 1989).

The core-satellite model like the theory of metapopulation has not been verified in salmonids. However, it does seem to fit with some observations especially of salmonids in fragmented habitat.

A metapopulation may be the natural organization of a group of populations distributed among patchy and heterogeneous habitats (Hanski and Gilpin 1991). Alternatively, metapopulation organization may be an artifact of the degradation and fragmentation of habitat which once supported large continuous populations (McCullough 1996). The tributary populations of redband (*O. mykiss gardneri*) trout in the upper Crooked River may be an example of a metapopulation that resulted from human degradation and fragmentation of the watershed.

In a watershed that is undergoing extensive habitat change, metapopulation structure may be a transitory phenomenon (Figure II-3-a, b, c). Under pristine conditions, fishes may have access to habitat throughout their entire range in a watershed. As habitat degrades, connectivity is diminished restricting access to some areas. Impassable dams built in the watershed further fragment and isolate segments of the native populations. At this point, the once panmictic population takes on the characteristics of a metapopulation (Figure II-3b). If habitat continues to degrade and become more fragmented, dispersal (gene flow) among populations may become unlikely or impossible and native resident salmonids may behave more like isolated populations rather than metapopulations. Presently, the Crooked River may be in the process of transition from the second to the third stage in Figure II-3c.



**Figure II-3.** The consequence of habitat degradation to population structure in a hypothetical watershed. Part A, panmictic population. Part B, habitat fragmentation produces core-satellite structure. Areas enclosed in dashed lines are suitable habitat on a seasonal basis. Part C, continued habitat degradation isolates individual populations.

Habitat degradation can also impose a condition known as regional stochasticity (Hanski and Gilpin 1991) which can threaten the persistence of a metapopulation, especially if it is composed of aggregates of small populations that are not linked to a large core population. Regional stochasticity occurs when fluctuations in abundance of the constituent populations are correlated, i.e., all populations increase or decrease in abundance together. Several factors create regional stochasticity. Habitat degradation and the loss of structural complexity could make all populations equally vulnerable to major climatic events such as droughts or floods. Human induced mortality experienced by the entire metapopulation such as high mortality of juvenile migrants at dams can also produce regional stochasticity.

The metapopulation model of salmonid population organization is a human construct, one which has yet to be verified. It is a way of thinking about populations, which may help explain what we observe in nature or in heavily altered habitats. It should be treated as a hypothesis (ISG 1996), which needs to be tested and evaluated. As with all conceptual models, it should be used to frame our interpretations of what we observe only as long as it is useful and effective in solving problems.

## ***F. Natural Productivity Cycles***

Long-term fluctuations in the abundance or productivity of salmonids need to be incorporated into analyses of stock status, the determination of factors causing that status and in the evaluation of restoration programs. Failure to do so can lead to serious errors in interpretation and lead to the wrong management decisions (Thompson 1927; Lawson 1993). For example, in this study it will be important to recognize that the earliest surveys of native salmonids in the Deschutes Basin were carried out in the late 1940s and early 1950s at a time when the region's anadromous salmonids were just beginning to recover from a natural depression in production during the 1920s to 1940s. Consequently, the abundance of salmonids in those early surveys indicate production during a natural productivity trough and not the long-term mean or the peak potential production.

Three recent papers present evidence for decadal scale fluctuations in fisheries productivity in the Northeast Pacific:

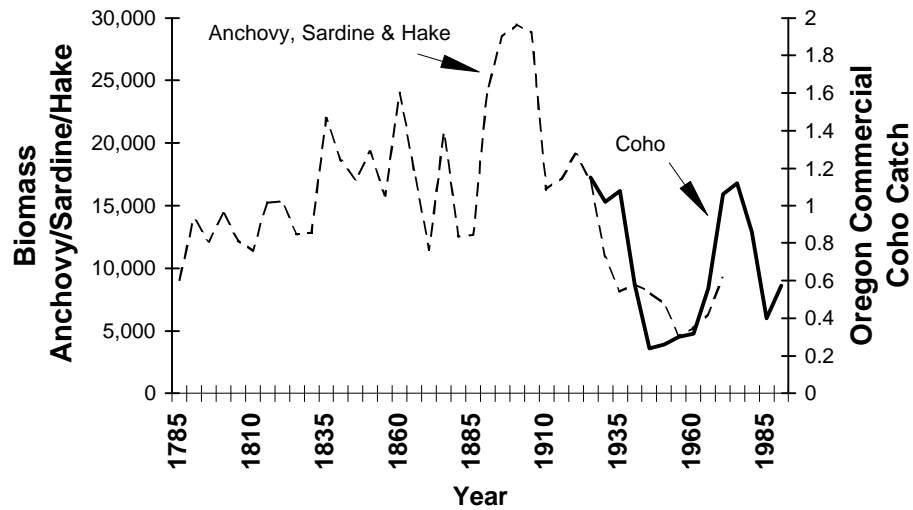
- Ware and Thomson (1991) reported that primary and secondary production and biomasses of pelagic fishes in the California Current fluctuate on a 40 to 60 year oscillation. Changes in ocean productivity caused a five-fold reduction in standing stocks of pelagic fishes off California between 1900 and 1950.
- Beamish and Bouillon (1993) observed a correlation between the abundance of salmon in the North Pacific and the long-term fluctuation in the Aleutian low pressure system; and
- Nickelson (1986) reported that survival of coho salmon in the Oregon Production Index (OPI) was determined by the intensity of coastal upwelling.

These papers are not describing three different production cycles, but different aspects of regional-scale processes that determine survival and production of salmon in the Northeast Pacific Ocean.

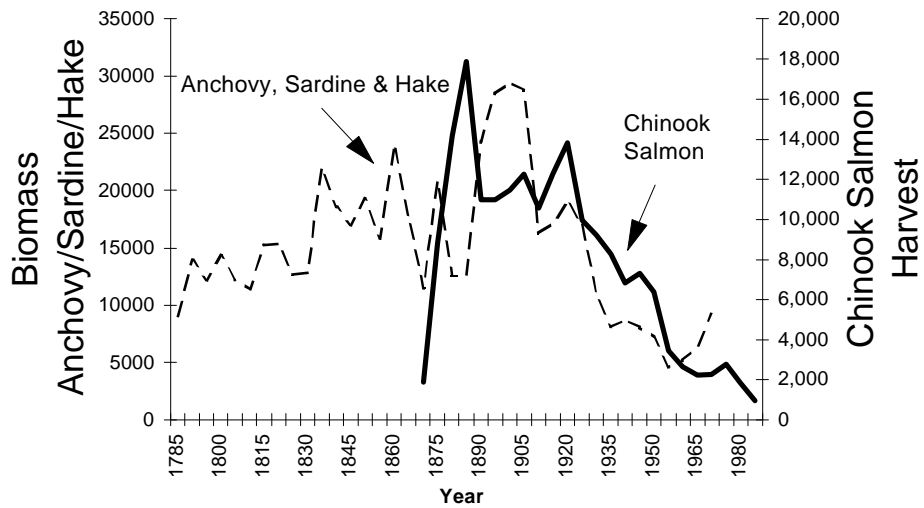
Standing stocks of pelagic fish in the California Current over the last 200 years were reconstructed through the analysis of fish scales found in core samples obtained from anaerobic sediments off the California coast (Soutar and Isaacs 1974). Historical standing stocks of hake, California sardine, and anchovy show three important features: 1) A 200 year peak in standing stocks near the turn of the century was followed by a 200 year low in standing stocks in the 1930s and 1940s; 2) the magnitude of the change between the peak standing stocks around 1900 and the lows in the 1940s was the largest in the 200 year data set; and 3) the Oregon harvest of coho and Columbia River harvest of chinook salmon appear to parallel the index of marine productivity (Figures II-4 and II-5).

Decadal fluctuations in the oceanic productivity also correspond to indices of climate in the Columbia River Basin. Historical climate reconstructed from an analysis of growth rings of trees in the Columbia Basin showed higher levels of precipitation around 1900 followed by dryer climate through the 1920s, 1930s and 1940s (Graumlich 1981). Reconstruction of historic temperatures in the Andrews Forest, Oregon (Figure II-6) show periods of cool temperature during 1892–1920 and 1947–1976. Warm temperatures prevailed in 1921–1946 and since 1977 (Figure II-6). The current decline of Pacific salmon in the Northwest to historic low levels appears to correspond to a change in ocean conditions that took place in 1976 (Ebbesmeyer et al. 1991) and a shift to warmer climate that started about the same time.

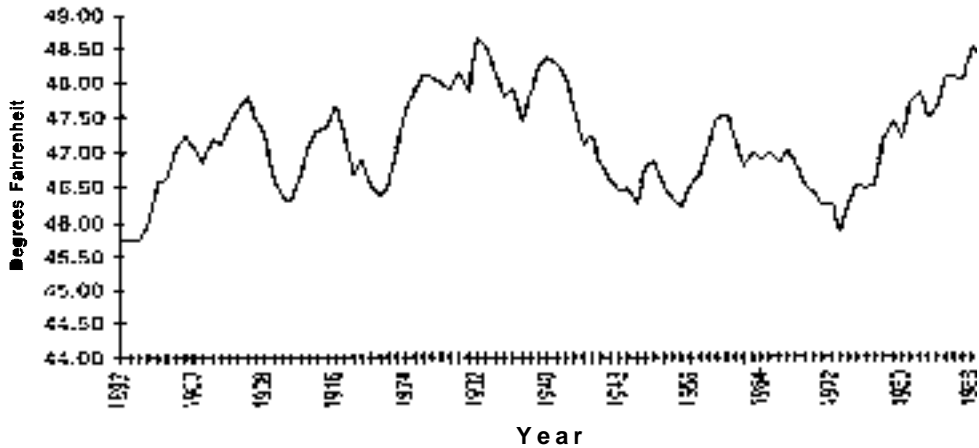
**Figure II-4.** Dashed line: Total biomass of anchovy, sardine and hake in the



California Current in thousands of metric tons. Standing stock inferred from contemporary stock size and scale deposition rates in 18<sup>th</sup> and 19<sup>th</sup> centuries. Solid line: Commercial catch of coho salmon in millions of fish. Annual coho salmon harvest averaged by 5 year intervals. (Source: Anchovy, sardine and hake, Smith (1978); Coho salmon, Lichatowich (1993))

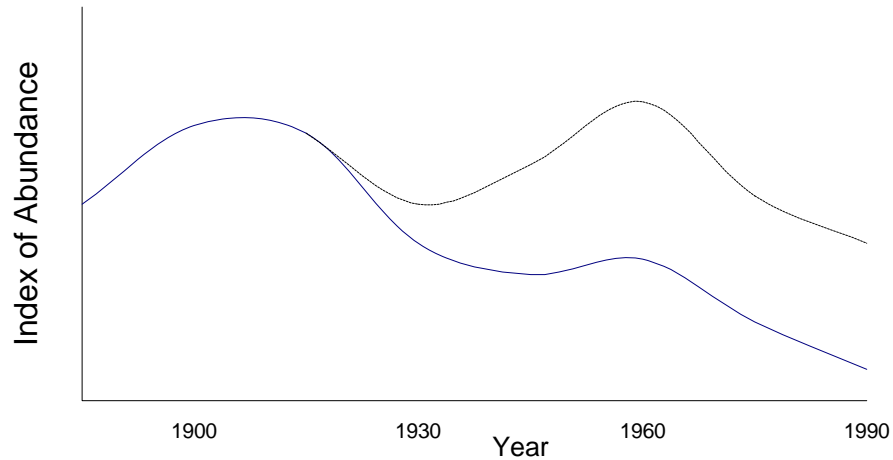


**Figure II-5.** Dashed line: Total biomass of anchovy, sardine and hake in the California Current in thousands of metric tons. Standing stock inferred from contemporary stock size and scale deposition rates in 18<sup>th</sup> and 19<sup>th</sup> centuries. Solid line: Commercial catch of chinook salmon in thousands of kilograms of fish. Annual chinook salmon harvest averaged by 5 year intervals. (Source: Anchovy, sardine and hake, Smith (1978); Chinook salmon, Beningan (1976))



**Figure II-6.** Reconstructed annual mean temperature in Andrews Forest in Oregon's central Cascades. (From Greenland 1993)

Conventional wisdom attributes the decline of Pacific salmon in the Columbia River and elsewhere in the Northwest to over harvest, habitat destruction, hydroelectric development and the side effects of artificial propagation. They were certainly major factors in the decline. However, if managers are to develop an understanding of the mechanisms of the decline and develop a sound approach to restoration, they have to incorporate into their analysis and planning the influence of cyclic changes in productivity. Natural fluctuations in productivity are an important context for restoration and management, which should not be ignored, although it often is. The interactions between natural fluctuations in productivity and human activities over the past 100 years probably increased the depth of the troughs and depressed the height of the peaks in the natural fluctuations in salmon production (Figure II-7).



**Figure II-7.** Hypothetical representation of salmon abundance in the Northwest over the last 150 years. The solid line illustrates the response of salmon to natural fluctuations in climate and productivity. The dashed line represents the probable production without intensive harvest, habitat destruction, and the negative effects of hatcheries. (Source: Lichatowich and Mobernd 1995)

# CHAPTER III. PATIENT TEMPLATE ANALYSIS

## *A. Introduction*

At the heart of the conceptual foundation is a patient-template analysis (Lichatowich et al. 1995) of the Deschutes watershed and its native salmonid populations. The patient describes the current status of habitat and life histories, where as, the template is a reconstruction of their historical status. A patient-template analysis is a comparative description of the historical and current life histories and habitats of the target populations and species. It tries to evaluate the habitat and salmonid populations as a single inseparable management unit (e.g. Healey and Prince 1995). The basic assumption underlying the patient-template analysis is that productivity of a salmonid population in freshwater is in part a function of the habitat complexity and connectivity and the population's adaptation to those conditions. Furthermore, the population's adaptation to the habitat structure and environmental gradients is exhibited as phenotypic or life history diversity (Lichatowich et al. 1995).

As originally envisioned the template for this study was the period from the arrival of Euroamericans to the construction of the Pelton Round Butte Project or prior to 1958-1964. The patient would have covered the period from 1964 to the present. Between the arrival of Euroamericans in the Deschutes Basin in the 1830s and the construction of the Pelton Round Butte Project, salmonid habitat underwent significant change. Much of that change was detrimental. In fact, in some parts of the watershed, pristine habitat was severely degraded before 1900. The first habitat surveys were not initiated until the 1930s so habitat and life histories of native salmonids underwent major change before they were described. A review of the historical information available suggested a change in the approach to the patient-template analysis as described by Lichatowich et al. (1995). Because there is so little information on historical habitats and life histories, the patient-template description is compressed into a single narrative. Lichatowich et al. (1995) point out that their guidelines "*were not rules to be followed in every detail.*" The guidelines should be adapted to the specific conditions and information existing in each watershed.

Historical reconstruction often takes the narrative form which cannot be tested directly (Mayr 1982), but from which hypotheses can be developed. That is the approach used here. The patient-template analysis will be completed in two steps: A narrative describing the current and historical habitat conditions, and narratives describing the status and life histories of native salmonids.

## **B. General Description of The Deschutes Basin**

The Pacific Northwest is an assemblage of some of the most diverse geologic, climatic and biotic features in North America. Spread throughout this complex landscape are populations of the various species of Pacific salmon that have adapted to those diverse habitat conditions. The Deschutes River is no exception, in that it too contains a diverse array of habitats. The Deschutes watershed lays along the eastern edge of the Cascade Mountains. Its eastern tributaries drain arid lands of the Cascade rain shadow and its western tributaries drain the wetter, cooler slopes of the Cascades. Because of its geographic location, the Deschutes River is influenced by widely different habitat forming processes (climate, geology and vegetation). For example, rainfall in the basin varies from 9-14 inches (22.9-35.6 cm) in the eastern side of the watershed and up to 100 inches (254 cm) at the western boundary. The headwaters in the Metolius and Little Deschutes rivers and the upper mainstem drain areas of porous Pleistocene lava flows giving the Deschutes the most uniform discharge for a river of its size in the country (Henshaw et al. 1914 cited in Grant et al. 1997). Under current conditions, the high flow events of record have little effect on the physical habitat of the lower Deschutes River making it one of the most stable rivers in the Northwest (Gordon Grant, presentation at the Spring Fisheries Workshop, April 9, 1997, Madras, Oregon). The Deschutes River is certainly one of the more unique ecosystems among the rivers of the Pacific Northwest.

Even though the mainstem below the three upper branches—Crooked, Metolius and upper Deschutes—is relatively stable, the ecosystem as a whole exhibits strong environmental gradients that influence the salmonid community. Habitat in the lowest reaches of the mainstem, for example, is influenced by increasing water temperature and from sediment originating in White River. Flow and temperature differences between the Metolius and Crooked rivers cause a strong divergence in local habitats. On a smaller scale, tributaries to the lower 99.4 miles (160 km) of the Deschutes River also exhibit strong environmental gradients. Tributary habitats differ from the mainstem in several obvious ways (flow, temperature, stability) and within the tributaries those entering from the eastside differ in their habitat characteristics from those entering from the westside. The Deschutes ecosystem then, is a stable core habitat (mainstem) connected to tributaries with strong environmental gradients (Figure III-1). The Pelton Round Butte Project has disrupted the biological connection between the mainstem and the upper tributaries, i.e., anadromous fish no longer migrate above the dams. However, it's important not to lose sight of the fact that the upper and lower river remains physically connected. Although the upper and lower rivers are managed as separate ecosystems what happens in the upper river eventually influences the lower.



For the purposes of this study, the Deschutes watershed has been divided into three physical/ecological regions: Crooked River Basin, Metolius River Basin, and mainstem Deschutes. The latter can be further divided into the Upper Deschutes (above the Pelton Round Butte Project) and the Lower Deschutes (below the Pelton Round Butte Project). All of these units exhibit different physical conditions or attributes.

## **1. The Physical Setting**

### ***a. Crooked River<sup>1</sup>***

The Crooked River flows east to west for 155 miles (249.4 km) before entering the Deschutes River at Lake Billy Chinook. Parts of the North Fork, South Fork and the mainstem Crooked River flow through carved canyons and much of the rest of the basin flows through rolling hills. The Ochoco Mountain Range extends into the watershed and south of the Ochocos, the Maury Mountains are drained by tributaries of the Crooked River. The climate is characterized as semiarid, with hot dry summers and cold winters. Temperatures range from a low of -30°F (-1.11°C) to a high of 100°F (37.8°C) and precipitation from 10-12 inches (25-30 cm) in lower elevations and 30-40 inches (76-102 cm) in higher elevations. Upland and higher elevation landscape include ponderosa pine, lodgepole pine and conifers such as white fir, Douglas fir, larch and Engelmann spruce. Riparian vegetation include mountain alder, black cottonwood, willow and quaking aspen. The transition uplands support sagebrush and western juniper. Irrigated croplands dominate the lower basin valleys. Soils in the flood plains, and low benches are mainly stream sediments. Public lands are managed primarily by the U. S. Department of Agriculture, Forest Service, Ochoco National Forest and the U. S. Bureau of Land Management Prineville District. Rangeland for grazing makes up 73% of the land base. Forests are 21% of the land base and 4% is irrigated agriculture.

### ***b. Metolius River<sup>2</sup>***

The Metolius Basin lies on the east side of the Cascade Mountains and flows through the Deschutes National Forest, the Warm Springs Indian Reservation and private lands. About 60% of the drainage is within the national forest. The remaining 40% flows through private or reservation lands. Climate is transitional between the Cascade

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<sup>1</sup> This summary description of the Crooked River Basin was taken from Stuart et al. (1966).

<sup>2</sup> This description of the Metolius Basin was largely taken from Fies et al. 1996a.

Mountains and the High Desert. Precipitation ranges from 10-50 inches (25-127 cm) per year and temperatures range from a low of -30°F (34.4°C) to a high of 80°F (26.7°C). The Metolius River rises from three springs at the base of Black Butte and is one of the largest spring-fed rivers in Oregon. The river flows along the base of Green Ridge through forested valleys and steep walled volcanic canyons. Drainage from Blue and Suttle lakes enter the Metolius River through Lake Creek, a major tributary. Most of the river is classed as wild and scenic under the Omnibus Oregon Wild and Scenic Rivers Act and cooperatively managed by the Confederated Tribes of Warm Springs Reservation of Oregon (CTWSRO) and state and federal agencies. The Metolius River enters the Deschutes River through Lake Billy Chinook.

The upper basin is landscaped with forests of pine, fir and cedar and wet meadows with alder, willows and grasses. The lower river basin flows through dryer landscape with sagebrush and juniper.

### ***c. Mainstem Deschutes River***

#### **1) Upper Deschutes River<sup>3</sup>**

The Upper Deschutes Basin is bounded by the Cascade Mountains to the west and the Paulina Mountains and high desert plateau to the east. The Upper Deschutes River flows 132 miles (212 km) from the headwaters at Little Lava Lake through Crane Prairie and Wickiup reservoirs and then into Lake Billy Chinook above the Pelton Round Butte dams. The upper basin's major tributaries include Snow Creek, Cultus River, Cultus Creek, Quinn River, Deer Creek, Little Deschutes River, Fall River, Spring River, Squaw Creek, and Tumalo Creek. Squaw Creek is the major tributary within the historic range of anadromous salmonids. Average annual precipitation in the lower elevations of the upper basin is between 9 and 14 inches (22.9 and 35.6 cm), while precipitation in the Cascade Mountains reaches 100 inches (254 cm). Temperatures in the region range from -30°F (-1.11°C) to 100°F (37.8°C). Riparian vegetation includes willow, alder and sedges. Higher elevation plant communities include hemlock, alpine and subalpine plants. Mid-elevation forests include mixed conifer and ponderosa pine. Lower elevation plant communities are composed of sagebrush, juniper, lodgepole pine and scattered ponderosa pine.

The subbasin's natural resources are substantial including forests, lakes, streams, and wildlife. Primary land ownership is the U. S. Forest Service, Deschutes National Forest. Designated wilderness areas include the Three Sisters Wilderness Area and the Oregon Cascade Recreation Area. Portions of Squaw Creek, Big Marsh Creek, Crescent Creek, the Deschutes River and Little Deschutes River are part of the Federal Wild and

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<sup>3</sup> This description of the Upper Deschutes River was largely taken from Fies et al. 1996b.

Scenic Rivers system. Fifty miles (80 km) of the Upper Deschutes River is in the Oregon State Scenic Waterway system.

## 2) Lower Deschutes River<sup>4</sup>

The Lower Deschutes River subbasin includes the area from Pelton Round Butte Project downstream 100.1 miles (161 km) to the confluence with the Columbia River, 205 miles (330 km) from the Pacific Ocean. Two of the major tributaries are the Warm Springs and White rivers. Other tributaries include the Shitike, Trout, Buck Hollow, Bakeoven, Wapinitia and Nena creeks. The lower river's flow is characteristically uniform and controlled by the Pelton Reregulating Dam. Water temperature at the mouth typically ranges from 39.2°F to 70.7°F (4.0°C to 21.5°C). Diurnal fluctuations in winter are approximately ~0.9°F (0.5°C) and in summer approximately ~7.0°F (4.0°C). The Cascade Mountains create a rainshadow effect on the eastern portion of the lower basin limiting annual precipitation to 9-14 inches (22.9-35.6 cm). The western portion of the basin has much higher precipitation, reaching 100 inches (254 cm) in the Cascade Mountains, primarily from winter snow. The lower river flows through a canyon 700 to 2,200 feet (213 to 670 m) deep. Management of the largest portion of river frontage is by the Bureau of Land Management (BLM), Oregon Department of Fish and Wildlife (ODFW) and CTWSRO.

## 2. Historical Habitat Alterations

Destruction of salmon habitat began almost immediately upon the arrival of Euroamericans in the basin. By the late 1880s, the combination of beaver harvest, irrigation and cattle grazing had a significant effect on the production of salmon in the Deschutes watershed, especially the dryer, eastside tributaries and Crooked River. In their 1888 report to the governor, the Oregon Fish Commissioners noted that there were few salmon left in the Deschutes River causing the Warm Springs Indians to travel to the Clackamas River to obtain their winter supply of fish (OSBFC 1888). By 1900, parts of Crooked River had already been thoroughly destroyed from the standpoint of attributes important to salmonids (Buckley 1992). The lack of salmon noted by the Fish Commissioners was probably a combination of habitat degradation and the intensive commercial fishery in the lower Columbia River and more specifically at the mouth of the Deschutes River.

In the early years of Euroamerican settlement no one measured or recorded the impacts of beaver harvest, irrigation and grazing on salmonid habitat. What follows are general historical accounts of those activities from which inferences about their effect on habitat can be drawn.

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<sup>4</sup> This description of the Lower Deschutes River was largely taken from Schroeder and Smith (1989).

### **a. Beaver Trade**

The land-based fur industry in the Pacific Northwest was firmly established by 1824. By that year, the Hudson's Bay Company dominated the fur industry and built outposts throughout the region, including the interior of the Columbia Basin (Gibson 1985). The beaver trade was relatively short lived. By 1839, it had run through the sequence of discovery, rich harvest, depletion and local extinction. By 1843, the center of the fur industry had moved north to Vancouver Island (Carey 1971).

The depletion and extinction of beaver in the Columbia Basin was a deliberate policy carried out by the Hudson's Bay Company. The company believed that the United States would eventually dominate the region and decided to leave no valuable resources for their American competitors. George Simpson, a company executive, summarized the policy, "*We have convincing proof that the country is a rich preserve of Beaver... which for political reasons we should endeavor to destroy as rapidly as possible*" (Gibson 1985). After the 1846 treaty settled the boundary dispute between Canada and the United States, trapping and depletion continued. By 1900, the beaver were nearly extinct, not only in the Pacific Northwest, but throughout North America. The destruction of salmonid habitat in the rivers of the Pacific Northwest started with the rapid depletion of beaver in the last half of the 19<sup>th</sup> century (NRC 1996).

Beavers change the ecology of rivers in ways that enhance salmon habitat. Beaver dams create pools that store sediments, organic material and nutrients releasing them slowly to the stream. They reduce fluctuations in flows, increase dissolved oxygen in the outflowing waters, create wetlands and modify the riparian zone, all of which have a net stabilizing effect on the ecosystem and act as a buffer against the effects of natural disturbances, such as floods and droughts (Naiman et al. 1986, 1988). Extensive beaver activity in a watershed stabilizes habitat and dampens fluctuations in salmon production. The conservation of water and wetlands due to beaver activities were particularly important to salmon in arid regions (NRC 1996), such as the Crooked River and eastside tributaries of the Deschutes Basin.

Beaver were probably found throughout the Deschutes Basin before the British and American trappers began exploiting them. The Crooked River was noted for abundant beaver. The first white explorers to enter the lower Crooked River were from David Thompson's Party in 1807. They named it au Riviere de Toure because of its meandering nature. Thompson noted abundant beaver sign. The beaver were not only abundant in the Crooked River Basin but they were large, weighing up to 100 pounds (Ontko 1993). Larger beaver were capable of building major structures which conserved water during the summer low flow periods. Beaver ponds are particularly important for summer rearing of juvenile steelhead (Personal communication, Errol Claire, retired ODFW Fisheries Biologist). Later explorers and trappers also noted abundant beaver in the Crooked River (Buckley 1992)

The depletion of beaver in the 1830s took place 100 years before the first extensive surveys and inventories of salmon habitat. The beaver dams and the benefits they imparted to the stream did not disappear as soon as the beaver were trapped out. But by the time the first habitat surveys were made, there would have been little evidence of their beneficial role in the stream ecosystems. The loss of the buffering effect of beaver activity on stream environments meant later the effects of irrigation and grazing on salmonid habitat caused more severe degradation.

### ***b. Irrigation***

In streams flowing through the rain shadow east of the Cascade Mountains, irrigated agriculture probably had the largest direct and indirect impacts on anadromous salmonids and their habitat. This was especially true prior to the 1930s before programs to screen federal irrigation diversions were initiated. Irrigation affected anadromous salmonids through: 1) Direct mortality of migrating juveniles that were deposited on agricultural fields. 2) Dewatering of river reaches. 3) Diversion dams that blocked passage of juvenile or adult salmonids. 4) Water losses that altered attributes of the streams, including increases in water temperature to lethal levels.

The state salmon managers repeatedly warned of the problems created by irrigation (OSBFC 1890, 1892; OSFGP1896). In 1900, the Oregon Department of Fisheries described the effects of irrigation east of the Cascades:

*Another more serious reason for salmon not entering many of the streams of eastern Oregon and Idaho in such large numbers as they did years ago, must be attributed to the settler. This part of the country being dry, requiring irrigation during the summer months, dams have been built on nearly all the streams, water being taken from them and carried in ditches for miles for this purpose, thus destroying much of the best spawning grounds. (ODF 1900 p. 31)*

Farmers and ranchers settling the Northwest began diverting water from streams to irrigate crops as early as the 1850s. The first diversions in the Crooked River and Squaw Creek took place in 1866 and 1871, respectively (Nehlsen 1995). None of the early irrigation works initiated measures such as screening to prevent juvenile salmon from being sucked, into the diversion and deposited on cultivated fields or pastures where they dried. In 1890, while visiting the salmon producing rivers in eastern Oregon, the State Fish Commissioners heard complaints about the loss of fish in the irrigation ditches:

*Another complaint was made by the people in that part of the State, and we find it general where irrigating ditches are in use, that during April and May, when the streams are full of water, a great many young fish of all species, as they are descending the stream, are run into these ditches and carried out on the farms and left to perish. A law should be enacted requiring the owners of all ditches, both for mining and irrigating purposes, to put a screen of fine wire netting across the mouth of all such ditches where water is taken from a stream inhabited*

*by fish, and to keep it there during the months of April, May and June. This will not be a hardship to anyone, as but very little water is used during those months, and the screens can be so arranged to interfere very little with the flow of water.* (OSFGC 1890)

Irrigation diversions quickly consumed the annual flow of rivers. For example, in 1914 filings for rights to water in the Deschutes River above the City of Bend, amounted to 40 times the river's flow (Nehlsen 1995). Irrigation tops the list of water uses consuming 10 times that of the municipal and industrial users (Wissmar et al. 1994). With the flows fully or over appropriated, many rivers went dry and the temperatures of the little water that remained rose to lethal levels.

In 1929, the Oregon Legislature finally responded to the loss of juvenile salmon and enacted a law requiring the screening of irrigation ditches, however, the law was killed in a court test. The legislature amended the law in 1941 and directed the Oregon Game Commission to screen all irrigation ditches less than 8 feet (2.4 m) in length (Cole M. Rivers, unfinished manuscript on the history and fisheries of the Rogue River Valley).

As late as 1931, salmon managers and salmon fishermen were still complaining about the irrigators careless disregard for state laws to protect salmon. Henry O'Malley, the U. S. Commissioner of Fisheries, felt that, "*the federal government in its consideration of dams and irrigation projects should conform to the laws of the state in which they operate*" (Pacific Fisherman 1931). The need to prevent wholesale destruction of salmon was eventually recognized, but effective action was slow and did not begin until after 1930. For 80 years, from the 1850s to 1930s the loss of juvenile salmonids continued unabated.

Although large numbers of salmon were killed by water diversions, there was little effort expended to actually document the mortality. In the Yakima River, biologists did try to estimate the number of juvenile salmon killed by irrigation diversions. In 1916, federal fishery biologist, Frank Bryant, subsampled 200 irrigated acres in the basin. He examined the entire 200 acres and counted each dead fish after the fields had been watered. Ninety percent of the fishes counted were juvenile salmon and there were an average of 20 fish per acre. So in the entire 200 acres there were 4,000 dead fish. However, 200 acres represented a small percentage of the total irrigated acreage. Bryant assumed 20 fish were killed per acre on all the acres of irrigated land at each watering, then expanded his subsample to obtain an estimate of the total mortality. He concluded that 4,500,000 juvenile salmon were killed in the basin with each watering (Winn 1919). As late as 1927, biologists estimated that 20 million juvenile salmon were still being killed by unscreened irrigation diversions in the Yakima River alone (Cowgill 1930).

Looking back with the clarity of hindsight it seems incredible that the region tolerated the massive mortalities that were occurring throughout a large part of the salmon's range. Even more incredible is the continued presence of unscreened diversions.

In 1996, the National Research Council reported that fewer than 1,000 of the 55,000 water diversions in Oregon were screened (NRC 1996).

Perhaps the biggest impact of unscreened irrigation withdrawals occurred when the diversions of water clashed with life histories. For example, juvenile salmon that migrated past open irrigation diversions during the spring and summer irrigation season were subjected to high mortality. The subyearling migration of chinook salmon fit this pattern. Juvenile spring chinook salmon in the Crooked River could have exhibited a summer migration pattern making them highly vulnerable to unscreened irrigation diversions. This possibility will be discussed later in the section on chinook salmon life histories.

Resident salmonids were also impacted by irrigation withdrawals. All the detrimental changes in physical attributes of streams caused by irrigation would effect resident as well as anadromous salmonids. The direct loss of resident salmonids in irrigation diversions in the Deschutes Basin can also be substantial (Lorz 1974).

Within the Deschutes Basin, the federal Bureau of Reclamation (BOR) began assisting private irrigation companies in the 1920s by constructing storage reservoirs (OSWRB 1961). The BORs work in the basin was countered by Oregon's Fish Commission and Game Commission, both of which succeeded in pressuring the legislature to pass a 1930s law that protected the Tumalo area from further appropriation of water so that other scenic and recreational attributes including fish life could be conserved (Reynolds 1989). The BOR returned to the Deschutes in the 1940s and 1950s and upgraded the upper basin reclamation system by completing additional storage reservoirs and repairing the labyrinth of feeder canals and ditches (Hall 1994; Deschutes County Historical Society 1985). By the time the BOR completed its work in 1955, all but 20 cubic feet per second (cfs) of water was diverted out of the river above Bend.

### ***c. Grazing***

Between the 1860s and 1890s, the fertile lands west of the Cascades and Sierra Mountains were fenced and converted to cultivated crops gradually squeezing out open-range cattle production in the western valleys and shifting it into the public grasslands east of the Cascade Mountains (Bunting 1997). In the arid grasslands, cattle were attracted to the riparian areas of streams and wetlands. As their numbers grew, cattle ate or destroyed the riparian vegetation drastically altering salmon habitat. The loss of riparian vegetation exposed the streams to the desert sun, heating the water to lethal temperatures, especially those streams whose flow had already been reduced by irrigation. Stream banks subjected to the constant pounding by hooves released heavy sediment loads smothering incubating eggs of salmon and trout as well as the aquatic food webs. Stripped of the stabilizing effect of riparian vegetation, as well as the earlier loss of the beaver, salmon habitat became more susceptible to natural disturbances such as floods and droughts. In the vulnerable stream channels, floods ripped out the banks and scoured the streambeds causing the channel to downcut. The resulting arroyo lowered the water table making

recovery of the riparian zone difficult (Platts 1991). Streams that once flowed all year with cool clean water, dried up in summer or were converted to a series of stagnant pools at the bottoms of raw gullies. The changes in salmon habitat due to cattle grazing were intensified by large withdrawals of water for irrigation.

The changes in habitat due to grazing can significantly reduce or eliminate salmonid production. In a review of 21 studies of the effects of grazing on stream habitat, Platts (1991) found habitat was degraded following grazing and in 15 of the 21 cases, fish populations decreased in abundance. In a study of Horton Creek, Idaho fish density was 10.9 times higher in ungrazed or lightly grazed stream reaches compared to heavily grazed reaches (Platts 1991).

Overgrazing literally destroyed many streams and their salmon habitat before the turn of the century. The environmental history of Camp Creek, a tributary to the Crooked River, illustrates the timing and extent of grazing related changes. The story of Camp Creek's destruction is adopted from a thesis by Geoff Buckley (1992).

Today, Camp Creek lies at the bottom of a deep vertical-walled gully, which cuts through an arid plain known as Price Valley. Water flows in Camp Creek only in the spring; the rest of the year it is dry. Sagebrush is the predominant vegetation throughout the valley floor right up to the edge of the gully. There are no signs of the healthy ecosystem—beavers, wetlands, grasses, willows and aspens—that the first Euroamericans found when they entered Price Valley.

The trapper, Peter Skene Ogdon, visited the Camp Creek area in 1826 and recorded what he saw. We can infer that salmon still returned to the Crooked River in the vicinity of Camp Creek. Ogdon's diary includes a description of an Indian fishing weir near the north fork of the Crooked River. That would have placed it close to the mouth of Camp Creek.

Between 1826 and 1885, Camp Creek still had a well developed riparian area consisting of willows and aspens, considerable numbers of beaver and good supplies of grass. Early visitors noted little difficulty in crossing the stream, which indicates that it had not yet downcut into the gully it flows through today. Abundant beaver and well developed wetlands in the flood plain were described by some of the early surveyors. As late as 1876, a survey by the General Land Office noted that the Camp Creek flood plain was dominated by bunch grass, wild rye and swamp grass.

The number of people living in the Crooked River/Camp Creek area increased from the late 1800s until 1910, after which the population declined as homesteads began to fail. As the human population increased so did the livestock. Buckley (1992) quotes one of the early residents of Price Valley discussing changes in the stream, "*there was too much stock... they'd eat the willows and everything and that's what did it.. There were too many people with too many cattle. Everybody had cattle.*"

Buckley (1992) found the first indication of a change in the physical appearance of Camp Creek, in a 1903 survey in which the valley was described as a sagebrush covered plain cut by a deep gully. The lush grass, riparian vegetation, wetlands and beaver were gone. In their place was a dry, sagebrush-covered plain cut by an arroyo 60-100 feet (18-30 m) wide and 25 feet (7.6 m) deep. The surveyor included in his notes speculation that the arroyo was the result of overgrazing.

Once the native vegetation was destroyed by intensive grazing in the late 1800s, the stream became vulnerable to periods of high rainfall and floods which scoured the channel.

The deterioration of the range after decades of over grazing, the heavy losses of cows in the severe winters of the 1880s, irrigation and agricultural settlement and the growing number of sheep all contributed to the decline of open range cattle grazing. However, as the cattle herds shrunk, there was a corresponding increase in the number of sheep. By 1900, sheep outnumbered cattle in most western states (Rowley 1985). Small towns in the High Desert, like Shaniko, Oregon suddenly found themselves surrounded by millions of sheep, and millions of dollars in wool sales earned Shaniko the title of Wool Capitol of the World in 1903 (Rees 1982).

Much of the land within the Deschutes watershed that could not be irrigated or harvested for timber, continued to be used by ranchers without regulation for decades. This practice ended, however, in 1934 when Congress passed the Taylor Grazing Act, which withdrew 80 million acres of land from the public domain and marked it for regulated grazing. However, the Grazing Service was too underfunded to be an active force and consequently the livestock industry continued its affairs with largely as much latitude as it had formerly enjoyed (Wilkinson 1992). Nonetheless, by 1946 when the Grazing Service merged with the General Land Office to form the Bureau of Land Management (BLM), pressure to restore damaged grazing lands and consider multi-purpose uses was increasing. Within Oregon, where 70% of the ranges were listed in poor or very poor condition and 30% were in a downward trend, the BLM tried to work toward the goal of land restoration without alienating its ranching constituency (Foss 1960; Gates 1979). Within the Deschutes watershed this meant that by the mid-1960s the BLM was cooperating with the Oregon Game Commission to implement restoration work in the Crooked River's Camp Creek tributary where erosion had created house-sized entrenchment (Wilkinson 1992; Lent 1998).

In spite of the important restoration work, grazing practices continue to degrade salmonid habitat (NPPC 1986) although strategies for reducing or eliminating those impacts are available (e.g. Platts 1991).

#### **d. Hydroelectric Development**

Incoming settlers quickly identified the Deschutes' water as a resource they could use to generate power and built at least two small hydroelectric dams within the

watershed. Cline Falls Power Company and the Cove Power Plant were in operation by 1901 and 1910, respectively (Bend County Historical Society c.1930). These early dams did not provide for fish passage and given the fact that this problem was widespread throughout Oregon, a 1911 law made it illegal to construct, “any artificial obstruction across any stream in this State frequented by salmon or trout. . . without providing a passageway for such fish. . . .” (State of Oregon 1911). This goal was not easy to achieve. Consequently projects like those on the Deschutes continued to operate despite lacking fish ladders (Oregon Department of Fisheries 1913).

Oregon’s state engineer maintained that hydropower production should be the primary goal of water development on the Deschutes and engineers from the U.S. Department of Interior supported that view declaring that, “every drop of water [in the Deschutes Basin]. . .can and eventually will be put to beneficial use.” The engineers were referring not only to hydro development, but also to reclamation so that the profits from energy production could be used to offset the cost of irrigation not only in the Deschutes, but throughout the West (USDI 1914). In the 1920s a team composed of members of the Reclamation Service, Army Corps of Engineers, and Geological Survey evaluated the Deschutes River for the most efficient method of integrating hydro-development and reclamation. While the study did not result in the immediate construction of a large hydro facility, the team reported that once irrigation projects within the upper and middle sections of the Deschutes were bolstered by adequate storage capacity, the lower section of the river would be ready for a hydropower project that could generate approximately 500,000 horsepower (Chapman 1921; Gates 1979).

Even as plans for future production were made, problems associated with the lack of fish bypass on the small hydroelectric dams in the Deschutes continued. By 1921, the legislature had apparently determined that at least in some cases, monetary assistance to help resolve bypass problems was appropriate, and allocated \$15,000 to install or upgrade fish ladders within the Deschutes drainage (State of Oregon 1921). Despite this type of support, early dams within the Deschutes and throughout the state, continued to impact fish habitat. Finally in 1925, the legislature took a more punitive stance which empowered the state fish commissioner to condemn any hydro installations that had insufficient fishways (State of Oregon 1925; ODFW 1992; Nehlsen 1995).

The major dam building era, which began in the 1930s lasted through the mid-1970s. Before the period closed the state and federal vision of large hydroelectric development on the Deschutes, expressed six decades earlier, became a reality when Portland General Electric completed Pelton Dam in 1957 and Round Butte Dam in 1964. Because the construction of the Pelton project coincided with the earliest stages of environmental interest, the Oregon Fish and Game Commission challenged the Federal Power Commission who had approved the utility’s application for construction. Their challenge declared that the project would destroy anadromous fish habitat. Oregon lost its case because the U. S. Supreme Court decided the state could not prevent the construction of a federally licensed project.

Several dams were constructed in the Deschutes Basin for the production of hydropower and for irrigation. Specific dams are discussed in the appropriate subarea habitat section that follows.

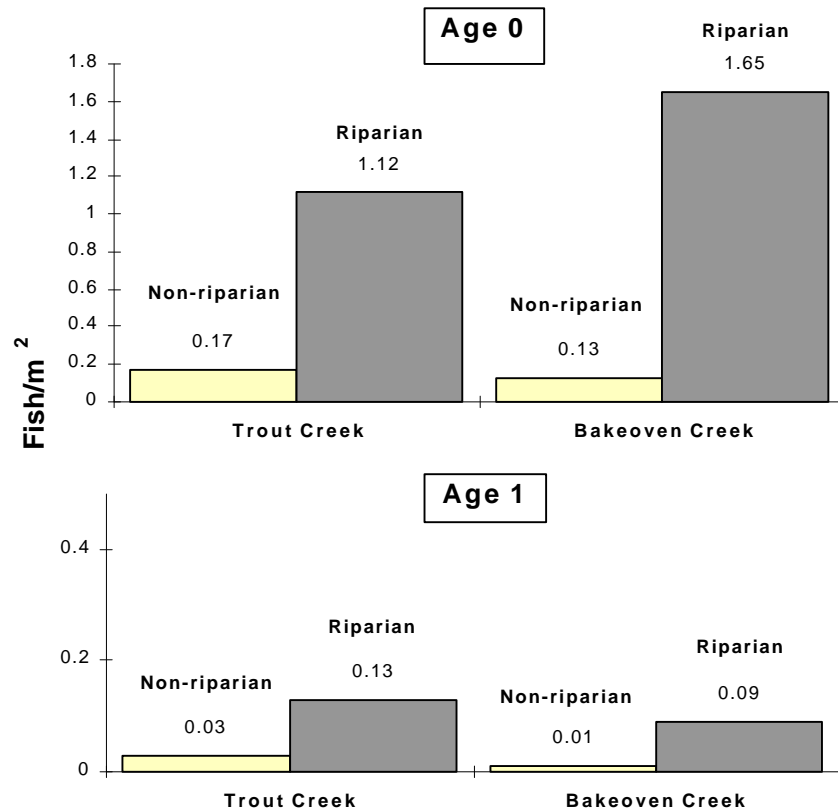
### **3. Subarea Habitat Conditions**

Historically, within the range of anadromous salmonids, the Deschutes River supported native salmonid populations in a habitat that had a high degree of spatial and temporal connectivity. Salmonids could move freely between mainstem and tributaries and between upper and lower river throughout the year. While habitats were connected and redband trout distribution was probably continuous over large areas of the basin, populations of individual species were not panmictic. The native salmonids even in the pristine river were distributed along strong environmental gradients that selected for attributes in salmonids compatible with local conditions. For example, redband trout or spring chinook salmon in the Metolius and Crooked rivers had to adapt to very different environmental conditions.

In the Pacific Northwest, perhaps the most important environmental attribute that salmonids adapt to is the local temperature regime (Miller and Brannon 1981). In the Deschutes Basin, there was and is considerable variation in stream temperatures, owing to its unique location and physical attributes. The basin straddles widely different geographic, climatic and ecological provinces. The lower mainstem and eastern tributaries are in the arid steppe, shrub-steppe and desert shrub ecological provinces. The upper mainstem and western tributaries flow from forested regions including the mixed conifer and evergreen and subalpine forests (Franklin and Dyrness 1973). In some cases the lower reaches of those streams also flow through arid landscape. Some of the hottest summer temperatures in Oregon are found within the basin (Franklin and Dyrness 1973). Given the historical range in variation in the environmental attributes, it's likely that salmonids in the Deschutes River exhibited a wide diversity of life histories.

Even under pristine conditions, many of the streams in the eastern side of the watershed were probably marginal during periods of prolonged natural drought. Under more favorable climate, water in the eastern tributaries was probably still warm, but within the tolerance range of salmonids. Those streams could have been very productive spawning and nursery areas for anadromous and resident salmonids. However, they were also highly vulnerable to the early activities of Euroamerican settlers. A sense of their vulnerability is evident in a comparison of trout populations in stream reaches with and without the cooling shade of riparian vegetation (Figure III-2). In Bakeoven and Trout creeks age-0 redband trout in stream reaches with riparian cover were six times as abundant as redband trout in stream reaches without riparian cover. The number of age-1 trout in the riparian reaches was four times that in the non-riparian reaches (Maciolek

1979). In the arid interior subbasins, removal of riparian cover can have dramatic effects on native salmonid communities (Li et al. 1994).



**Figure III-2.** Abundance of age 0 and 1 redband trout in stream reaches of Bakeoven and Trout creeks with and without riparian vegetation. (Source: Maciolek (1979))

### a. Crooked River

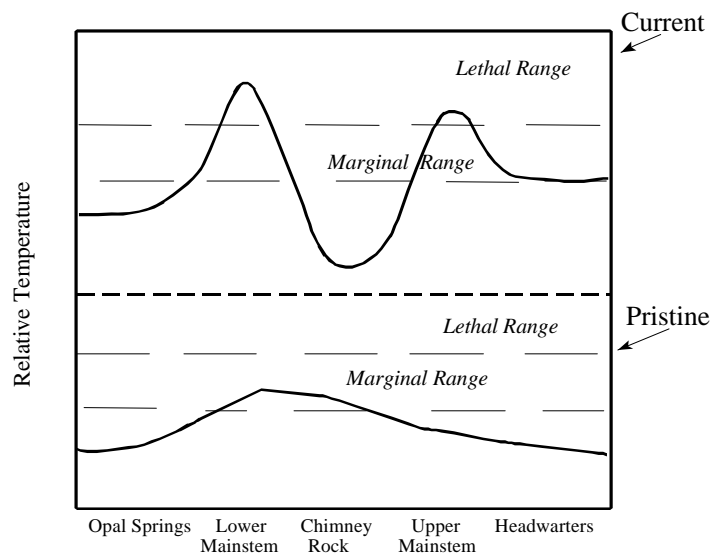
Unfortunately, all we have are brief glimpses of the Crooked River before its salmonid habitat was destroyed. These glimpses come from the diaries of beaver trappers and early Euroamerican settlers, surveyors and explorers. The Crooked River was once shaded by dense riparian vegetation and supported abundant fish populations. The river valleys were covered in bunch grass that could grow to a height of 7 feet (2.1 m) (Stuart et al. 1996). Those conditions were altered drastically about a century ago as described earlier in the section on grazing (Buckley 1992) and have degraded further in the intervening years.

The depletion of beaver probably had its greatest impact on salmonid habitat in the streams that flow through arid landscape (NRC 1996), such as the Crooked River and the

eastside tributaries of the lower mainstem. Loss of impoundments created by beaver dams eliminated rearing habitat during the critical summer months. Also lost was the buffering of flows and temperatures during the summer—a critical attribute for streams that flowed through arid landscapes.

Nehlsen (1995) lists 26 major water development projects in the Crooked River Basin. Those developments included two power plants in the lower river, Opal Springs (RM 8 or RK 14) and the Cove Power Plant (RM 3.7 or RK 6) which created blocks to salmon migration during low flow periods (Nehlsen 1995) but probably passed fish at some flows. Opal Springs has been a complete block to salmonid movements since refitting in 1982 (Stuart et al. 1996). Bowman Dam, another major water development project on the mainstem above Prineville was completed in 1961 without fish passage facilities.

Irrigation and grazing in the basin altered the thermal quality of the basin's waters. The intensive use of water in the basin combined with the hot/dry climate has thermally fragmented the basin (Figure III-3). Water temperatures are marginal in the headwaters and they can reach lethal levels in the mainstem above Prineville Reservoir. Below the reservoir in the Chimney Rock Reach cold water and adequate flows have created a tailrace fishery. Below Dry Creek the temperatures can once again reach lethal levels. Temperatures are most likely to reach lethal levels in the 20 mile reach from below Smith Rock State Park to above O'Neil. Flow augmentation from springs begins to cool the river about RM 18 (RK 30) with the largest inflow at Opal Springs just above the reservoir. Fragmentation whether it is due to thermal or another environmental attribute, limits or disrupts the natural ecological process, constrains life history possibilities and is a major limitation on salmonid production. Thermal fragmentation will limit restoration of naturally reproducing anadromous salmonids in the Crooked River. Loss of riparian cover in overgrazed watersheds limits or eliminates salmonid production in streams flowing through eastern

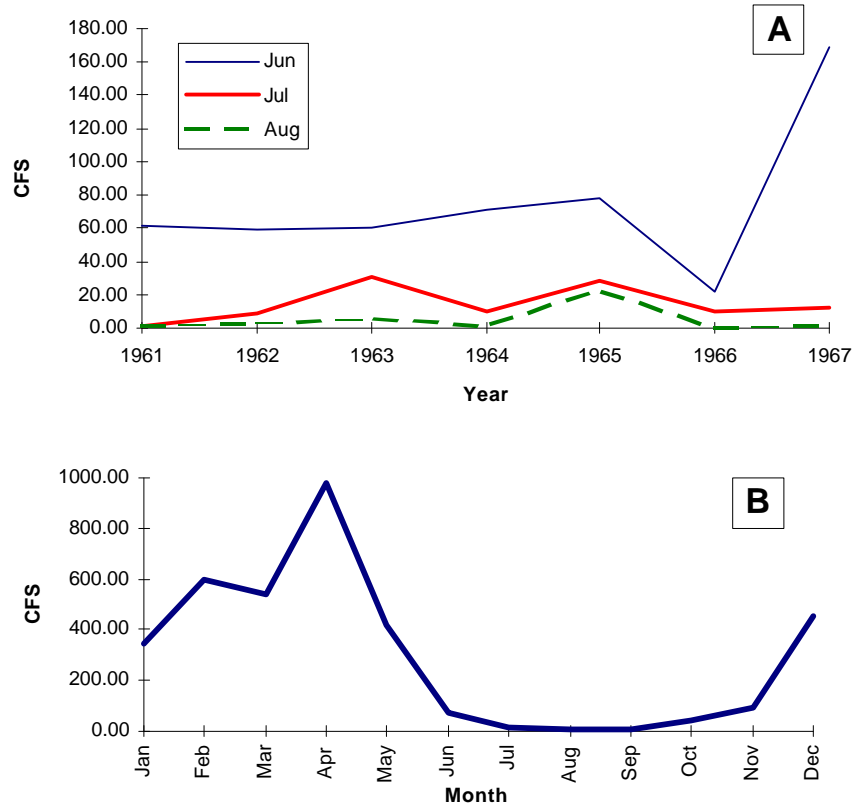


**Figure III-3.** Relative estimated historical and current summer temperature profiles in the Crooked River suggesting thermal fragmentation in recent years.

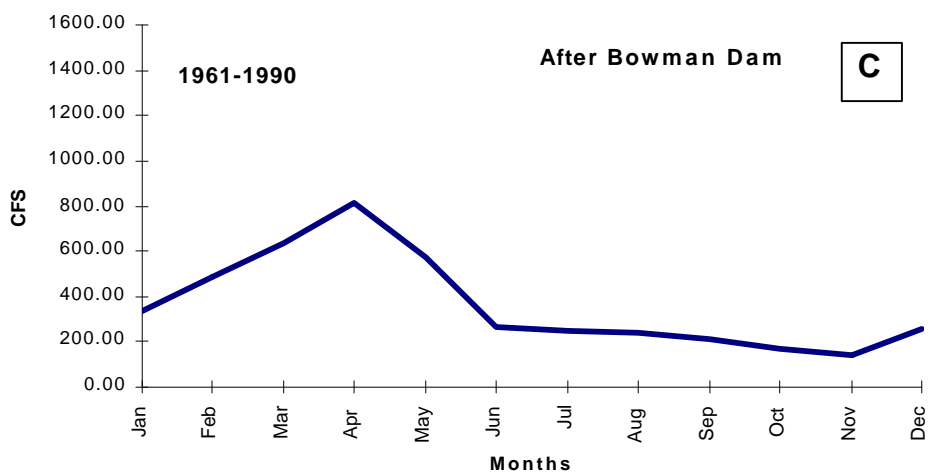
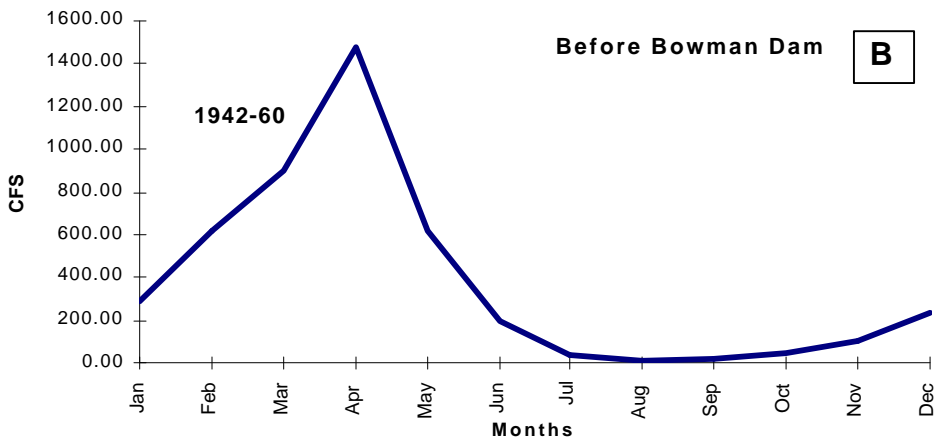
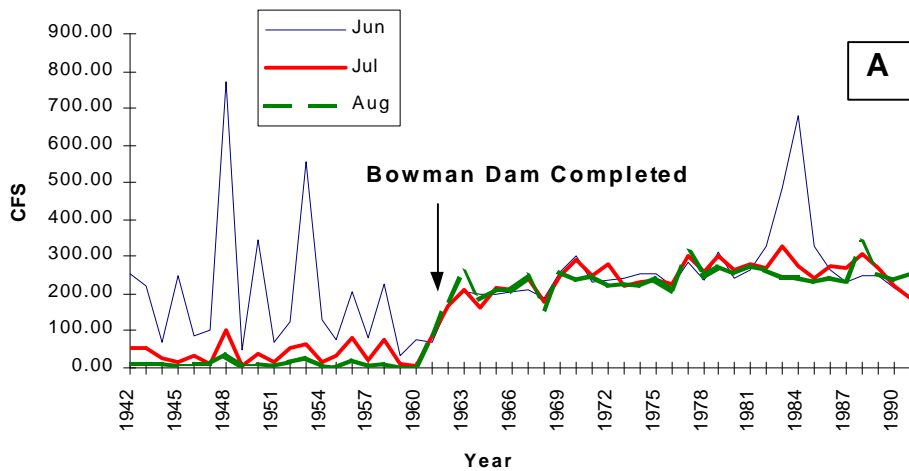
Oregon and Washington (Li et al. 1994). The lack of riparian vegetation is a major problem in many areas of the Crooked River (Stuart et al. 1996).

Figures III-4, III-5, III-6 and III-7 show the flow patterns in the upper river above Prineville Reservoir, below the reservoir before and after construction of Bowman Dam and the flows and temperatures below Opal Springs. Bowman Dam clearly increased summer flows below the reservoir and changed the annual flow pattern (Figure III-5). Springs in the lower Crooked River clearly improve flow and stabilize temperatures (Figures III-6 and III-7).

Low summer flows and elevated temperatures are the two most important symptoms of habitat degradation in the basin. The Crooked River may be one of the most degraded streams in Oregon (Stuart et al. 1996). In addition to the problem of low flows and elevated temperatures, the 14 mile reach of Crooked River from Bowman Dam to Dry Creek and a section of Ochoco Creek below the reservoir are subjected to flow reversal. To serve the irrigation interests in the basin, flows in those river reaches are kept abnormally high in the summer during the irrigation season (Stuart et al. 1996). The reversal of the normal flow pattern is detrimental to salmonid life histories keyed to the historical flow pattern.

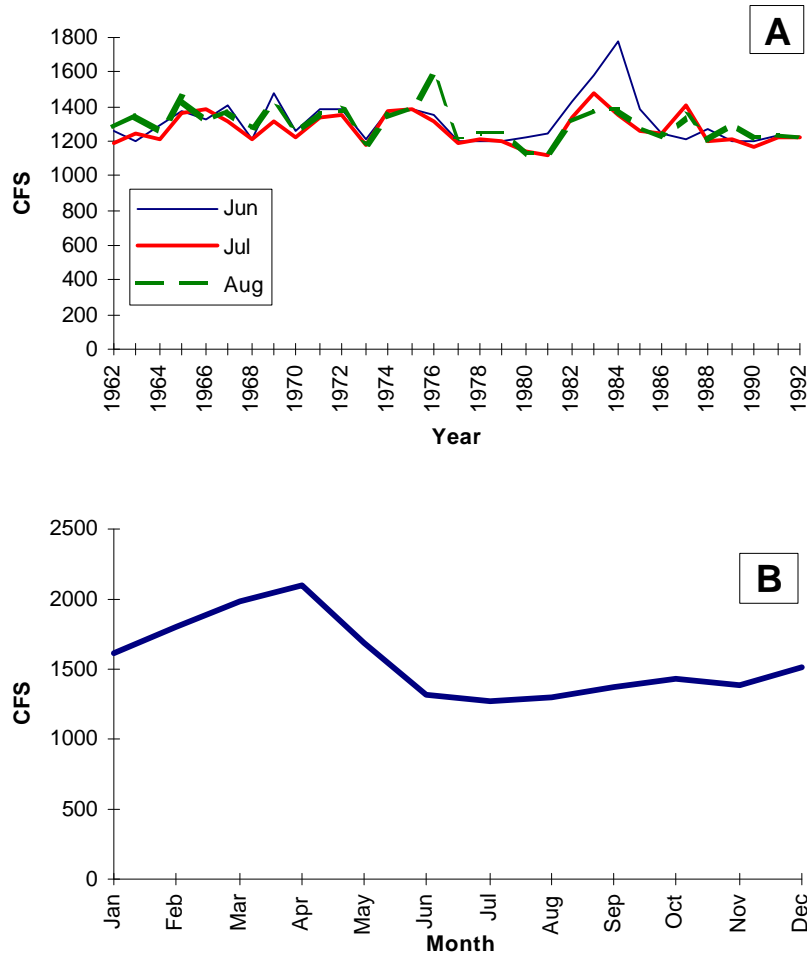


**Figure III-4.** A) Average flows for June, July and August 1961-67; B) average monthly discharge, 1961-67 in the Crooked River above Prineville Reservoir near Post, Oregon. (Source: U. S. Geological Survey data from Station 140798800.)

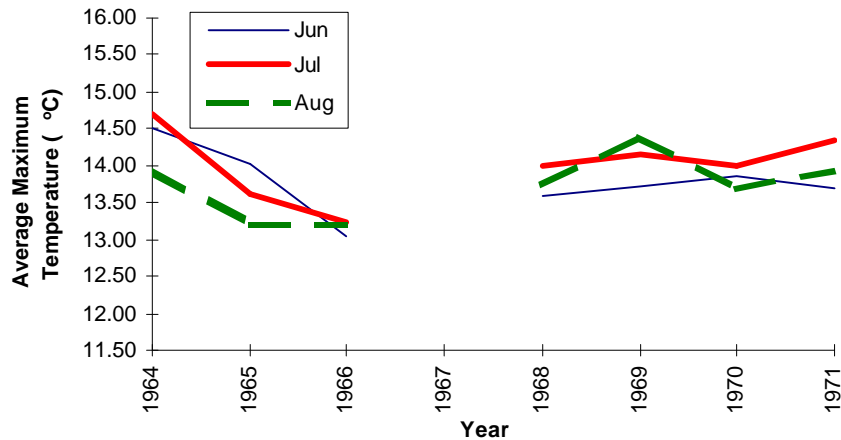


**Figure III-5.** A) Average discharge for June, July and August, 1942-91; B) Average monthly discharge, 1942-60; C) Average monthly, 1961-91, in the Crooked River near Prineville,

Oregon. (Source: U. S. Geological Survey Station Number 14080500)



**Figure III-6.** A) Average discharge for the months of June, July and August; B) average monthly discharge in the Crooked River below Opal Springs, near Culver, Oregon, 1962-92. (Source: U. S. Geological Survey Station Number 14087400)

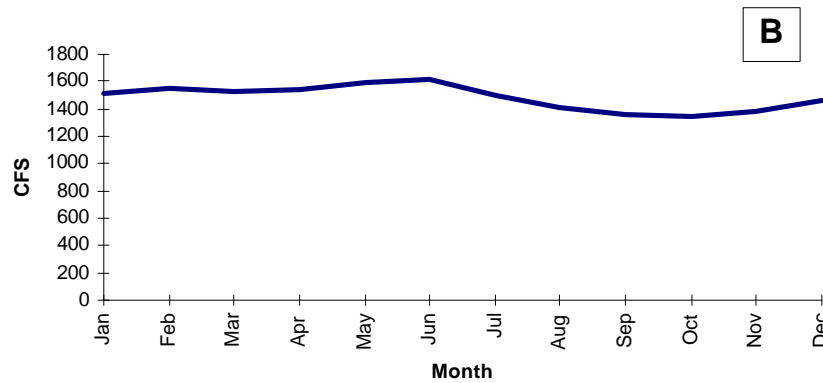
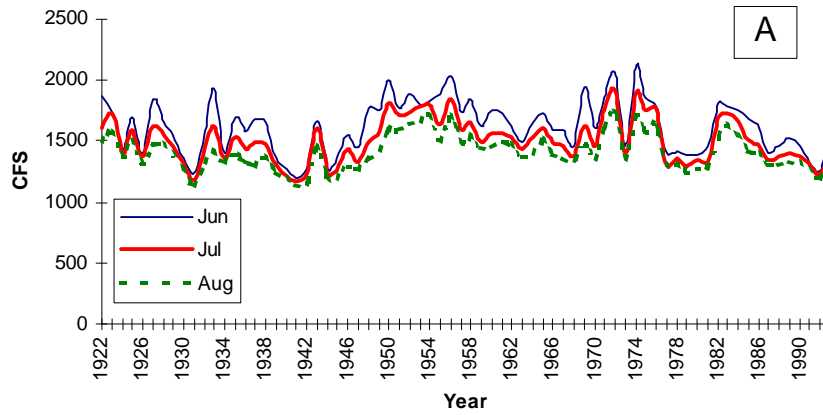


**Figure III-7.** Average maximum temperature for June, July and August, 1964-66 and 1968-71 in Crooked River, below Opal Spring near Culver, Oregon. (Source: U. S. Geological Survey Station Number 14087400)

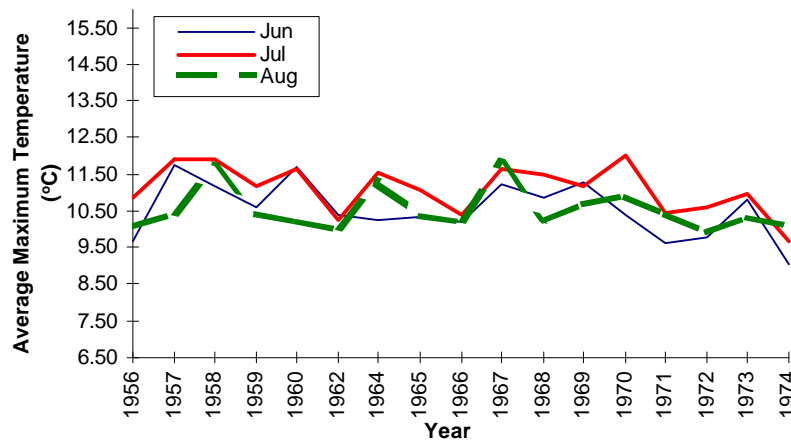
#### **b. Metolius River**

From the standpoint of physical habitat for salmonids, the Metolius River is the least disturbed major watershed in the upper Deschutes Basin. Nehlsen (1995) lists only one major water development in the Metolius Basin and that was the Suttle Lake Power Dam built in 1930. The Metolius River does not have the problem of low flows and elevated temperatures during the summer months (Figures III-8 and III-9) common to the other tributaries in the upper basin. Average high and low flows at the mouth are about 1600 and 1300 cfs, respectively. The lowest discharge on record was in 1932 at 1087 cfs. Temperatures are cool throughout the year, cooler than optimal for growth of redband trout (Fies et al. 1996a). Unlike most rivers, the Metolius actually cools as it moves downstream because of the influence of natural cold springs.

Temperatures are not distributed along a continuous gradient from headwater to mouth. Several spring fed streams introduce cold water to the Metolius River causing it to cool as it proceeds downstream. Among these are Jefferson, Candle and Roaring creeks. Patches of elevated temperature also occur where tributary streams enter the Metolius (Currens et al. 1997; Riehle 1992). For example, during high flows, the warmer discharge from Lake Creek can elevate temperatures in the mainstem Metolius River. The widely different temperatures create a complex habitat mosaic characterized by the presence of trout with very different thermal preferences—brown trout in the warm water of Lake Creek, bull trout in the cold water especially in some tributaries and redband trout in the mainstem (Personal communication, Don Ratliff, Portland General Electric Company).



**Figure III-8.** A) Average flows for the months of June, July, and August; B) average annual flow pattern for the Metolius River near Grandview, Oregon, 1922-92. (Source: U. S. Geological



Survey Station Number 14091500)

**Figure III-9.** Average maximum temperature of the Metolius River near Grandview, 1956-74. (Data for 1961 and 1963 are missing.)  
(Source: U. S. Geological Survey Station Number 14091500)

The warm thermal patches have been implicated in the loss of productivity in the redband trout population in the upper Metolius River. Introgression with hatchery trout not native to the Metolius River reduced the resistance of native trout to *Ceratomyxa shasta* when conditions for infection occur. Those conditions are associated with the patches of warmer water (Currens et al. 1997). Although the loss of fitness is a serious problem it is not the only possible cause of reduced productivity. An alternative explanation for the status of redband trout suggests that the removal of large woody debris in the mainstem eliminated cover and exposed the redbands to increased predation by bull trout. This explanation is supported by the low levels of *C. shasta* normally found in the Metolius River (Personal communication, Don Ratliff, Portland General Electric Company). Another factor is the habitat degradation and the inundation of the lower river by Lake Billy Chinook. The real cause for the decline in redband trout is probably a combination of these factors.

Perhaps the greatest habitat degradation in the river occurred in the 1930s when downed trees were removed from the channel to facilitate rafting of logs downstream to the Deschutes River (Nehlsen 1995). The loss of large woody debris was particularly detrimental in the Metolius River because the stream offers little natural cover for salmonids (Fies et al. 1996a).

Lake Creek flows from the surface waters of Suttle Lake and is a major tributary to the Metolius River, which still has unscreened diversions. Temperatures in Lake Creek can reach 75°F (23.9°C).

### **c. Mainstem Deschutes River**

#### **1) Upper Deschutes River**

Historical habitat conditions in the upper mainstem of the Deschutes River have to be inferred from indirect anecdotal information. In the early years of this century, the upper Deschutes River supported very popular and productive trout fisheries. Anecdotal evidence of this was summarized by Mathisen (1985a). From the accounts of the magnitude and apparent productivity of the fishery, it seems safe to infer that habitat conditions in the upper mainstem were excellent.

Irrigation withdrawals in the upper basin are the single most important factor contributing to habitat degradation (Fies et al. 1996b). Diversions for irrigation began later in the upper mainstem than in many of the tributaries in the watershed. The first irrigation project in the upper river began diverting water at Cline Falls in 1892 (Nehlsen 1995).

Irrigation diversions in the upper river have had a major impact on salmonid habitat between Bend and Lake Billy Chinook. Four projects which divert a total of 1,005 cfs are still either without screens or adequate screens to prevent fish loss (Fies et al. 1996b). The North Canal Dam and Diversion take almost all the water in the Deschutes

River near the City of Bend. Flows remain extremely low until springs add more water near Lower Bridge. From RM 155 to RM 132 (RK 249 to RK 212) (Tumalo to Lower Bridge), stream temperatures can reach 80°F (26.7°C) causing a nearly complete elimination of redband trout in this section of the river (Fies et al. 1996b).

That part of the upper Deschutes River inundated by Lake Billy Chinook apparently contained excellent habitat. Descriptions in Nehlsen (1995) suggest this area may have been rich in alluvial habitats, which are often associated with high biological productivity (Stanford et al. 1996). The confluence of three major subbasins at this point (Metolius, Crooked and upper Deschutes) suggests possible genetic exchange among the salmonids inhabiting the widely different environments in the three subbasins. The Pelton Round Butte Project permanently altered habitat in this reach. The dams eliminated the use of the alluvial reaches by redband trout. However, the reservoir habitat has been colonized by kokanee and is being used by bull trout.

Squaw Creek is a major tributary to the upper Deschutes River and was once an important spawning area for steelhead and spring chinook (Nehlsen 1995). Water was diverted from Squaw Creek as early as 1871 and by 1912 the stream was completely fragmented into upper and lower segments, at least during the summer, by diversions that completely dried up the channel for about three miles (32 km) near the town of Sisters, Oregon. Springs below Sisters maintain about 20 cfs in the lower reaches during the summer months (Nehlsen 1995).

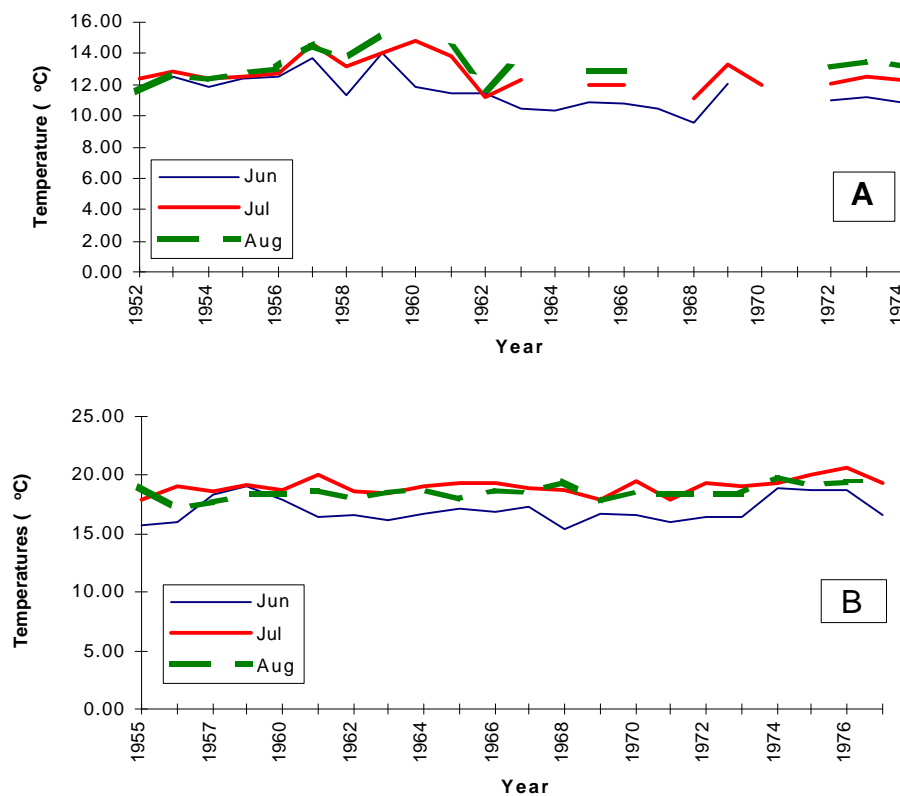
## 2) Lower Deschutes River

**Lower Mainstem** — Large springs produce a uniform flow and moderate temperature regime in the lower mainstem of the Deschutes River (Huntington 1996). In fact, the flows in the Deschutes are the most uniform of any river of comparable size in the United States (Henshaw 1914 cited in Grant et al. 1997). Uniform flows suggested low sediment transport rates which was confirmed after the flood event of 1996. The flood caused little change in the channel. The absence of a longitudinal trend in grain size and gravel compaction also suggests that neither the 1996 flood nor the dams have caused major changes in bed characteristics (Grant et al. 1997). However, it appears the dams did cause small changes in the seasonal temperature patterns in the upper reach. The temperature regime has changed little since construction of the Pelton Round Butte Project. Temperatures immediately below Pelton Dam are slightly lower in the winter, spring and early summer and slightly higher in the late summer and fall since construction of the dam (Huntington 1996). The changes in temperature may have advanced the emergence of fall chinook fry five days (Beaty 1996).

The flow and temperature regimes before diversion of water in the upper basin were not described, however, given the moderating effect of the springs discussed above it is reasonable to assume the river would have maintained a relatively stable flow and temperature regime. Flow, stream temperatures and channel configuration in the lower mainstem apparently did not undergo major changes with Euroamerican settlement and the construction of Pelton and Round Butte Dams. The reach from Pelton Dam to the

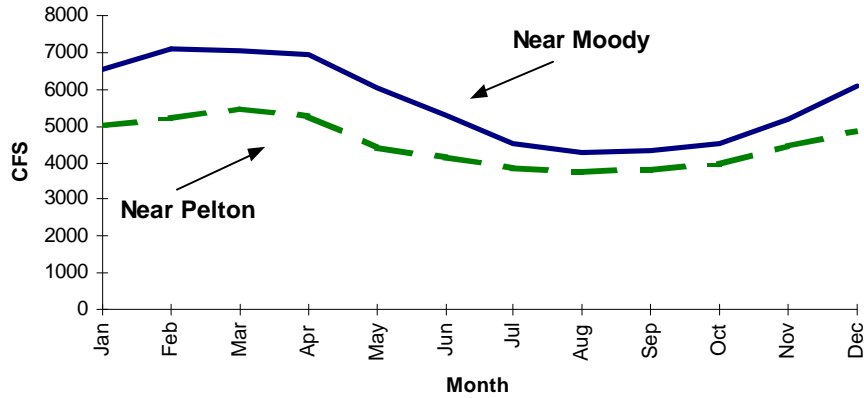
confluence of White River still supports robust production of redband trout. A uniquely stable environment in the lower watershed is not without potential problems. If life histories of native salmonids in the lower mainstem evolved in an environment whose important attributes such as flow and temperature were very stable, small changes in those attributes may disrupt adaptive life histories and have significant effects on survival, production and productivity.

Temperature and flow gradients are part of the environment of the lower mainstem of the Deschutes River. Summer temperatures increase downstream and are higher at Moody, Oregon near the mouth of the river than at Pelton (Figure III-10). Flows increase due to the contribution from tributaries (Figure III-11). Life histories may vary in response to these environmental gradients. For example, the redband trout at Nena Creek and North Junction exhibited different life history traits (see the redband section) (Schroeder and Smith 1989). Those sites are about 10 miles (16 km) apart suggesting the possibility the redband life histories at Nena Creek and North Junction are responding to different environmental conditions.



**Figure III-10.** A) Average monthly temperature in June, July, and August for the Deschutes River near Pelton (Interruptions in line indicate missing data.); and B) average monthly

temperature in June, July, and August for the Deschutes River near Moody, Oregon. (Source: U. S. Geological Service, Stations 14092500 (Pelton) and 14103000 (Moody))



**Figure III-11.** Average annual flow pattern for the Deschutes River near Pelton and Moody, Oregon, 1925-92. (Source: U. S. Geological Survey Station Numbers 14092500 and 14103000)

**d. Lower River Tributary Habitat**

The east and westside tributaries to the lower Deschutes drain very different landscapes, with different vegetation and subjected to different climate. All of these factors contribute to differences in salmonid habitat and habitat quality.

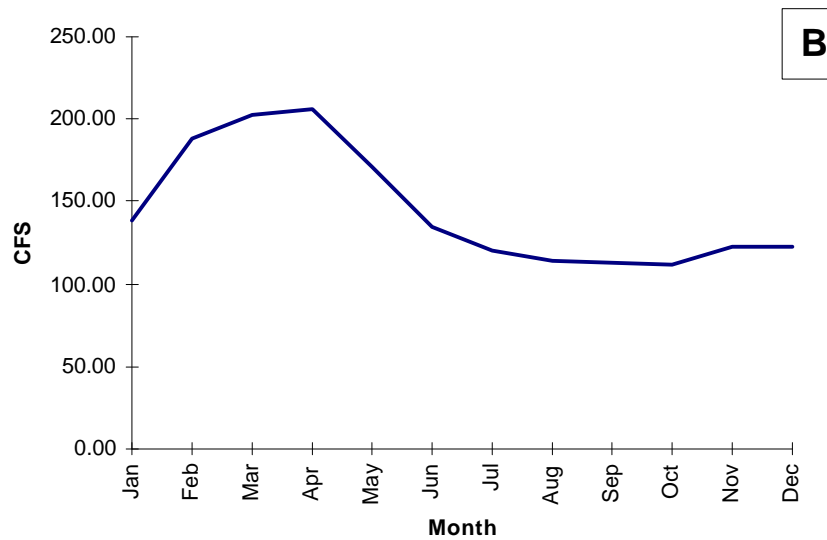
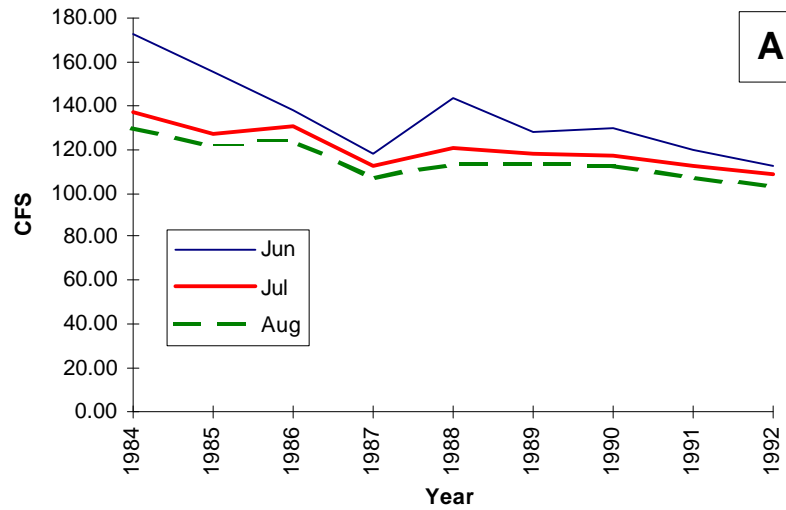
The principal eastside tributaries are Willow, Trout, Bakeoven and Buck Hollow creeks. These streams flow through arid landscape and probably contained salmonid habitat that was close to marginal under conditions of extended drought. Principal habitat constraints on production include low flows and high temperatures during summer and fall and high levels of sediment (ODFW and CTWSR 1990). Loss or degradation of riparian areas aggravates the naturally low summer flows and reduces production of salmonids in these tributaries (see Figure III-2).

In 1988, the screening of ten diversions in Trout Creek was credited with saving 13,000 juvenile steelhead annually (Pribyl et al. 1997). Upper Trout Creek riparian areas have been degraded by past management practices and are now outside the historic range of variability. Sediment levels are above natural levels and they impact water quality and fisheries habitat. There is a lack of key habitat attributes (large woody debris, pools and high quality spawning gravels) needed to sustain redband trout and steelhead populations.

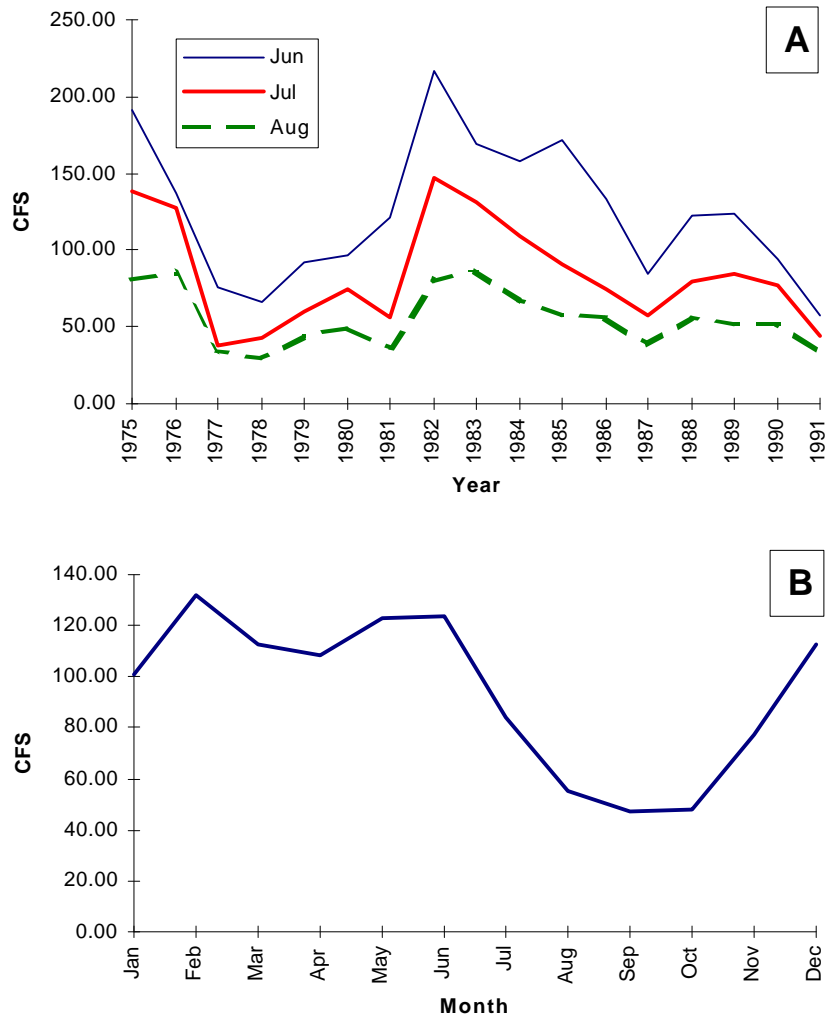
Habitat connectivity is below desired and water temperatures are excessive (USDA Forest Service 1995).

The lower river eastside tributaries were once important spawning areas and were used for rearing by juvenile steelhead, but continued habitat degradation has severely reduced their productivity especially in recent years. Several habitat improvement projects are now underway in these basins (Pribyl et al. 1997).

The principal westside tributaries are Shitike Creek, Warm Springs River and White River. The use of White River by anadromous fish is limited to the lower 2 miles (3.2 km) below the falls. Both Shitike Creek and the Warm Springs River flow through the Warm Springs Indian Reservation. Historically, there were about 169 miles (272 km) of stream habitat for anadromous fish on the Warm Springs Reservation. Today, due to flow changes, about 128 miles (206 km) of anadromous fish habitat remains (Fritsch 1995). The Warm Springs River and Shitike Creek, with their headwaters on the forested eastern slopes of the Cascade Mountains, drain a landscape with higher annual precipitation than the eastside tributaries. Flows in the larger Warm Springs drainage were more stable showing less of a decline during the summer than flows in Shitike Creek (Figures III-12 and III-13). Flows not only show a great change during the summer low flow period, but during the summer months, flows in Shitike Creek are more variable than the Warm Springs River (Figure III-13 and III-14a).



**Figure III-12.** A) Average flows for June, July and August 1984-92; B) average monthly discharge 1984-92 in Warm Springs River near Simnasho, Oregon. (Source: U. S. Geological Survey data from Station 14095500)

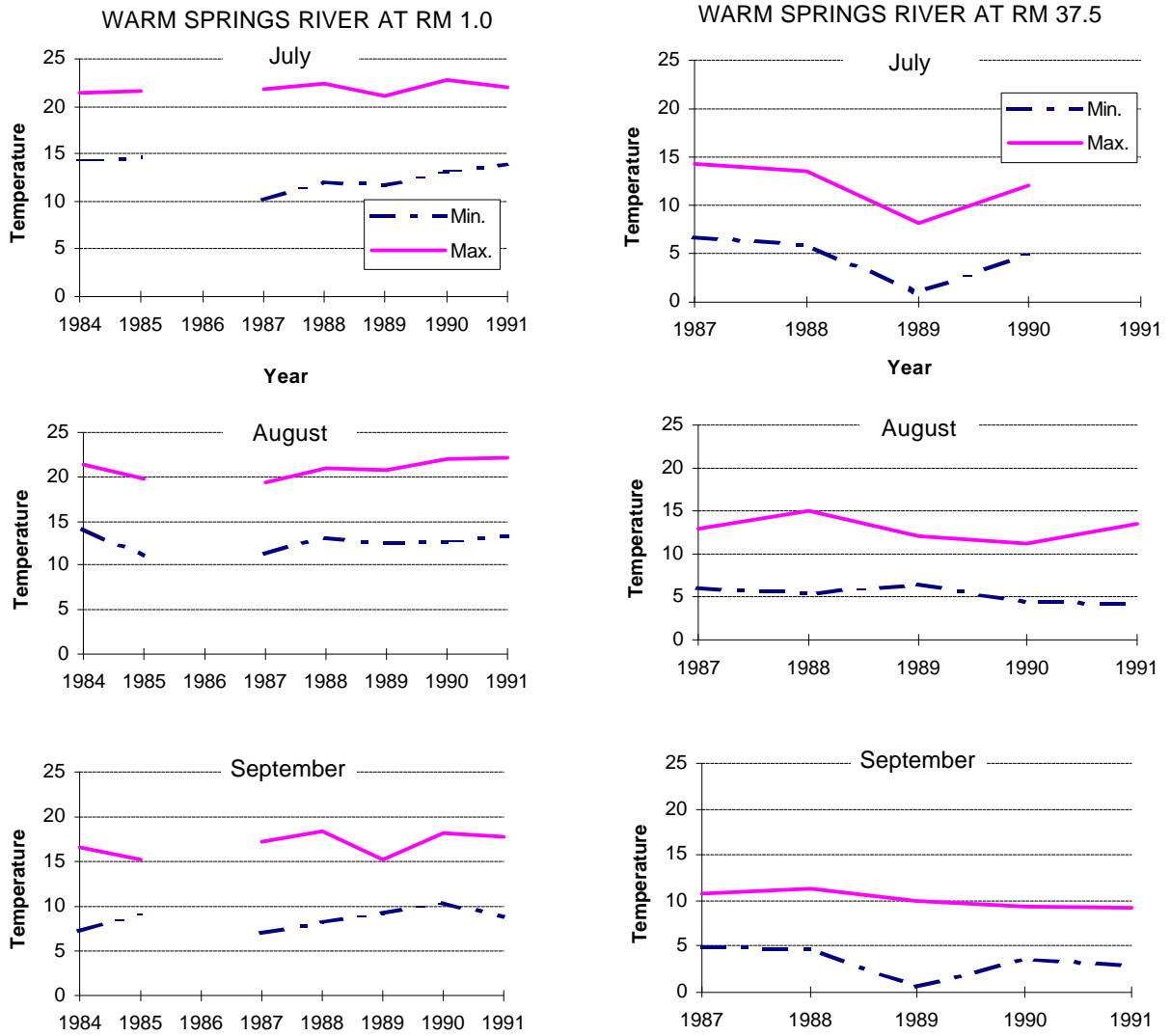


**Figure III-13.** A) Average flows for June, July, and August 1975-91; B) average monthly discharge, 1975-91 in Shitike Creek, near Warm Springs, Oregon. (Source: U. S. Geological Survey data from Station 14092885)

Many of the tributaries to the lower river are characterized by intermittent or low flows in some cases directly related to consumptive water diversions and degraded stream corridors (Pribyl et al. 1997). In some cases intermittent flow is a natural attribute of a stream to which native salmonids have adopted their life histories. Shorter westside streams that do not drain well-watered areas on the east slope of the Cascade Mountains are often intermittent. Recent surveys of three of these streams, Boulder, Eagle and Nena creeks, confirm that they are used by steelhead. Boulder Creek is part of the Warm Springs system and the other two discharge directly into the Deschutes River. The steelhead have apparently adopted a life history compatible with the lack of summer flows in these streams. The adults may spawn early giving the juveniles an emergence timing that

lets them leave the tributary before the stream dries up in summer (Cates 1984). Everest (1973) noticed a similar life history in the Rogue River summer steelhead.

Habitat constraints on production in the Warm Springs River include high water temperatures particularly in the lower 10 miles of the river (Figure III-14), and sedimentation in some areas. Some of these constraints, like the eastside tributaries are associated with degraded riparian zones. Temperatures in the lower Shitike Creek are also excessive (ODFW and CTWSR 1990).



**Figure 111-14.** Maximum and minimum temperatures for July, August and September in the Warm Springs River at RM 1.0 and

37.5 (RK 1.609 and 60.3). (Source: Data from DeePak Sehgal of Warm Springs Indian Reservation)

## **C. Salmonid Life Histories and Abundance**

### **1. Redband Trout**

Columbia Basin redband trout are found east of the Cascade Mountains to barrier falls on the Kootenay, Pend Oreille, Spokane and Snake rivers (Behnke 1992). Throughout a large part of its range within the Columbia Basin the redband trout exists as sympatric resident and anadromous populations. Redband trout from parts of the Columbia Basin have adapted to marginal habitat conditions. Behnke (1992) reported catching a redband trout on a fly in Chino Creek, Nevada from water that was 82°F (28.3°C).

The anadromous redband trout are primarily summer run fish. There are only four winter run populations of redband trout in the Columbia Basin, all located at the western edge of the distribution. The Deschutes Basin does not support, now or historically, a winter steelhead run. The summer run fish are divided into A and B runs. The B run grows to a larger size and migrates to Idaho's Snake River tributaries. Some A run fish also return to Snake Basin tributaries. All the anadromous redband trout populations in Oregon are A run fish (Kostow 1995). Historically, the anadromous form of the redband trout may have been more abundant than chinook salmon in the Deschutes River. A 1903 survey of the river by the Oregon Fish Commission concluded that "...it was the 'Steelhead' variety of salmon that was so abundant in this stream and that the 'Chinook' variety never did frequent it to any great extent." (VanDusen 1903 p. 17).

The Deschutes River redband trout have been assigned to three gene conservation groups (GCG): Mid-Columbia (Deschutes to Walla Walla River), White River (above the falls) and the upper Deschutes River (above the Pelton Round Butte Dams). The separation of the upper and lower Deschutes redband into different GCG is based on a real separation of the two groups by artificial barriers at the Pelton Round Butte Project (Kostow 1995). The distinction between the upper and lower Deschutes may disappear if adequate passage for salmonids is provided past the dams and through the reservoirs. Oregon's Mid-Columbia gene conservation unit is probably similar to Washington's proposed Columbia Gorge genetic conservation management unit, which extends from the Washougal River on the west to Rock Creek on the east (Leider et al. 1994). Many of the redband populations in tributaries to the mid-Columbia River have been studied biochemically, but comparisons between populations have not been completed (Kostow 1995).

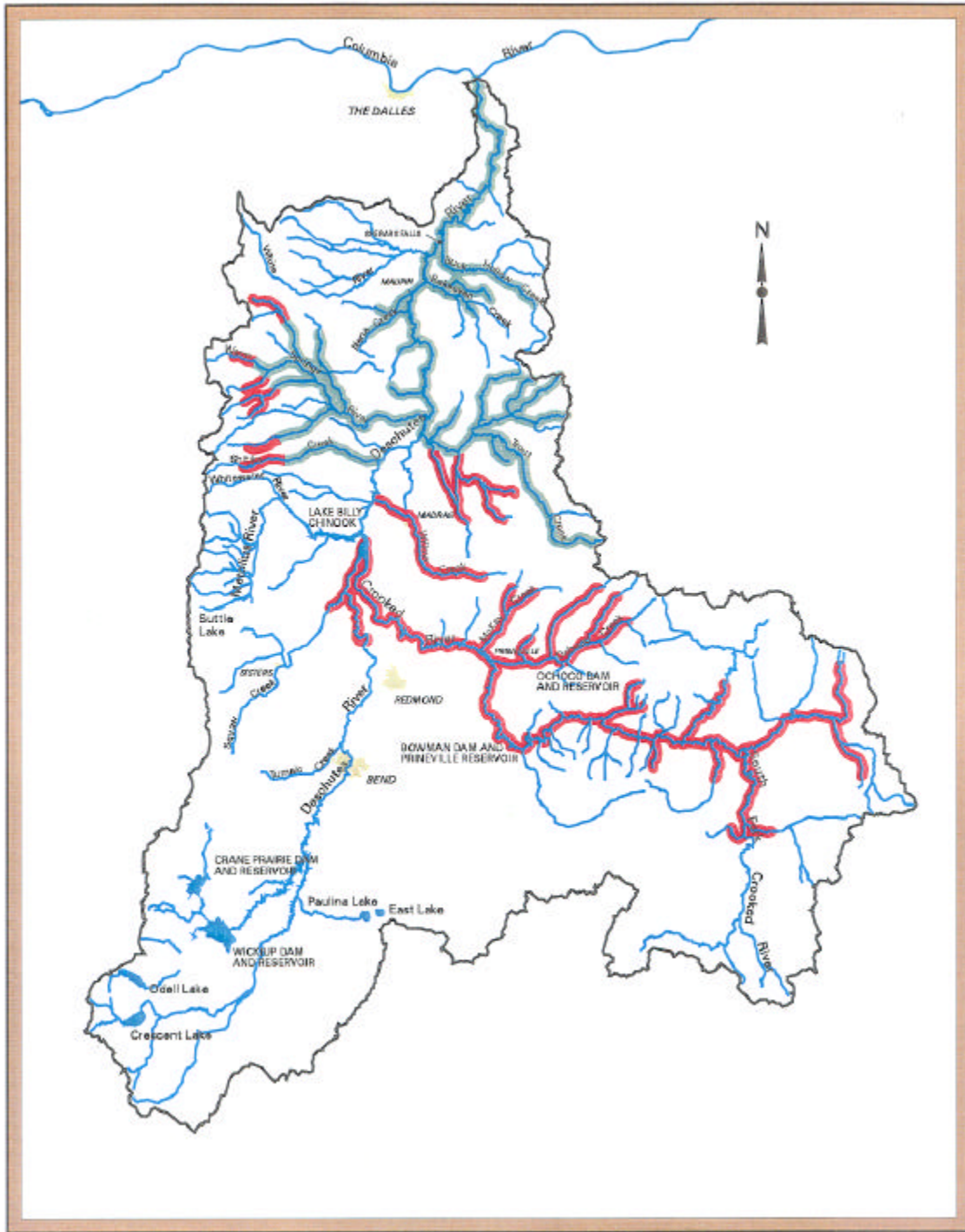
## **a. Distribution**

### **1) Anadromous Form**

The historical distribution of summer steelhead in the Deschutes Basin extended from the mouth up to Big Falls on the mainstem, throughout the entire length of Crooked River (Nehlsen 1995) and in numerous tributaries (Figure III-15). A cursory survey in 1903 suggested that steelhead spawned throughout the upper river between Sherars Falls and Big Falls (VanDusen 1903). The status, migration and distribution of salmonid populations in the Deschutes River were not studied or described in any detail prior to 1950, just before construction of the Pelton Round Butte Project began, so there is no documentation of steelhead distribution before irrigation and grazing caused major habitat degradation. Historical distribution of steelhead was pieced together from several sources and should be considered preliminary and conservative (Figure III-15 and Table III-1). With the exception of Willow Creek, we did not extend steelhead distribution beyond reported observations. We agreed with Stuart et al. (1996) that summer steelhead probably spawned in Willow Creek because there were no obvious barriers to prevent it. The historical occurrence of steelhead in the Metolius River remains uncertain.

### **2) Resident Form**

Resident redband are distributed throughout the basin, including above falls (Kostow 1995). ODFW recognizes 46 wild populations of resident/fluvial redband trout in the basin up to Big Falls (Table III-2). The strongest populations are located in the lower mainstem. In fact, the lower mainstem has the strongest population of resident redband in Oregon (Kostow 1995). How much the current distribution differs from historical distribution is not known. It's likely that the distribution of redband has been constricted and fragmented due to habitat degradation especially in the eastside tributaries to the lower mainstem and in Crooked River.



**Figure III-15.** Estimated current and historical distributions of summer steelhead in the Deschutes Basin (Source: Distribution maps from Confederated Tribes of the Warm Springs Reservation; Fulton 1970; Nehlsen 1995; Stuart et al. 1996)

**Table III-1.** Mainstem and tributary spawning populations of summer steelhead historically or currently present in the Deschutes River.

<b>Stream</b>	<b>Comment</b>	<b>Source</b>	
<b>CROOKED RIVER</b> <u>Mainstem</u>	Summer steelhead migrated the entire length of Crooked River (up to 120 miles [193 km] from mouth) late winter to spring.	Oregon State Game Commission 1951 cited in Nehlsen 1995.	
	Summer steelhead spawned in the mainstem below McKay Creek and between the North Fork and Beaver Creek.	Fulton 1970	
<u>Tributaries</u> McKay Creek Ochoco Creek Drakes Creek Horseheaven Creek Beaver Creek North Fork Twelve Mile Creek Paulina Creek	These were either sightings of steelhead, observed redds or fish captured in traps.	Frey 1942; Montgomery 1952, 1953, 1954; all cited in Nehlsen 1995.	
<b>UPPER DESCHUTES R.</b> <u>Mainstem</u>	Mainstem up to Big Falls. Steelhead Falls were passed during favorable flows.	Nehlsen 1995	
	<u>Tributaries</u> Squaw Creek	Observed spawning from RM 16 (RK 25.7) to 1 mile (1.609 km) above the mouth. This observation made in 1951 was after irrigation dewatered the river in the Sisters area. Steelhead probably migrated upstream of Sisters under natural flows.	King 1966 Nehlsen 1995
	Willow Creek	Willow Creek probably supported a run of steelhead, although they were not observed there before Pelton Round Butte blocked migration.	Stuart et al. 1996
<b>METOLIUS RIVER</b>	No steelhead were observed spawning in the Metolius River. Some believe they were never present, however, there may have been a small population.	Fies et al. 1996a Nehlsen 1995	

<b>Stream</b>	<b>Comment</b>	<b>Source</b>
<b>LOWER DESCHUTES R.</b> <u>Mainstem</u>	Approximately 97% of the present steelhead spawning in the mainstem occurs between RM 40 (RK 64.4) and	Olsen et al. 1992

<p><b><u>Tributaries</u></b>  Warm Springs River  Mill Creek  Boulder Creek  Beaver Creek  White River  Shitike Creek  Trout Creek  Bake Oven Creek  Buck Hollow Creek  Wapinitia Creek  Eagle Creek  Nena Creek  Jones Canyon Creek  Oak Branch Creek  Cove Creek  Skookum Creek</p>	Pelton Reregulating Dam. It is not known what the spawning distribution was prior to the construction of Pelton Round Butte Project.	
	Oregon Considers the steelhead below Pelton Round Butte one population. <sup>1/</sup>	Kostow 1995
	Steelhead are currently found spawning in these streams. Habitat degradation has reduced the quantity and quality of steelhead habitat.	Olsen et al. 1992

<sup>1/</sup> Given the different life history patterns between eastside tributaries and mainstem steelhead populations (Figure III-20), the stock status of steelhead in the lower river should remain open until further investigation.

**Table III-2.** Wild, resident redband trout populations recognized by ODFW in the Deschutes Basin. (Source: Kostow 1995)

<b>Gene Conservation Group</b>	<b>Population</b>
<b>Mid-Columbia</b>	Mainstem below Pelton Dam Buck Hollow Creek Upper Buck Hollow Cr., upper basin Finnegal Cr., upper basin Oak Springs Cr., above barrier Bake Oven Cr., upper basin Nena Cr., upper basin Eagle Cr., upper basin Warm Springs River Shitike Creek Mud Springs Cr. above man-made barrier Little Trout Cr., above falls Willow Creek (above Madras) Willow Cr. (below Madras)
<b>White River</b>	<b>White River above High Falls</b> Tygh Creek above falls Badger Cr. above Diversion Dam Jordan Cr. above falls

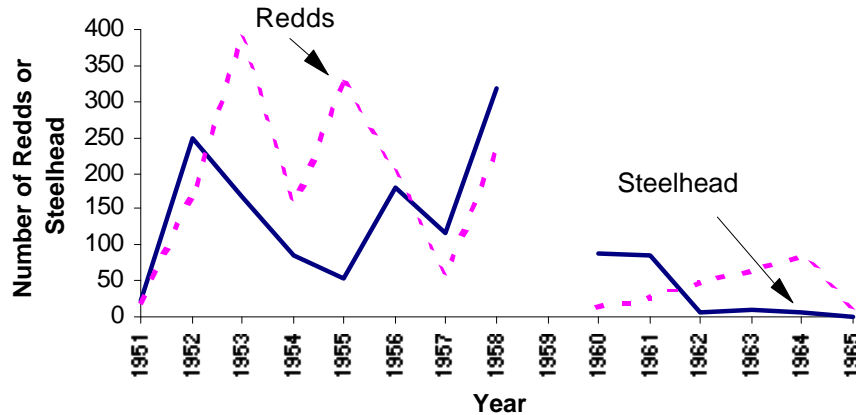
Gene Conservation Group	Population
	Crane Creek Forest Creek
<b>Upper Deschutes</b>	<b>Deschutes River</b> Crooked River Lower Crooked River McKay Creek Ochoco Cr. (below Ochoco Dam) Ochoco Cr. (above Ochoco Dam) Marks Creek Bingham Springs Bear Creek Upper Bear Creek N. Fk. Crooked River N. Fk. Crooked River below falls N. Fk. Crooked River between falls Fox Canyon Creek Upper N. Fk. Crooked R. (above all falls) Deep Creek Peterson Creek Allen Creek Big Summit Tributaries Camp Creek S. Fk. Crooked River Beaver Creek Metolius River Lake Creek Link Creek Squaw Creek Tumalo Creek Deschutes R., to Steelhead Falls Deschutes R., to Big Falls

**b. Abundance**

1) Anadromous Form

Spawning surveys, which might have yielded a historical estimate of steelhead abundance, were not initiated in the Deschutes River until 1951. Those first surveys took place during a natural low in ocean productivity. Reduced primary production in response to climate changes in the California Current have been linked to a five-fold decrease in pelagic fish production off California between 1900 and 1950 (Ware and Thomson 1991). Salmon abundance throughout the Pacific Northwest during the same period was also in decline (Lichatowich 1996). Therefore, the number of steelhead observed in the early surveys should be considered conservative and not indicative of the productivity during more favorable ocean conditions. Those surveys certainly do not reflect steelhead abundance before major freshwater habitat degradation.

Part of the reason the Deschutes River lacks historical information on all its salmonid species was the lack of attention given to the stream by the management agencies early in this century. The Deschutes River was not a priority because it was not deemed suitable for hatchery operations (VanDusen 1903). One measure of the steelhead production above the Pelton Round Butte Project is the agreed mitigation target for the Round Butte Hatchery, which is 1,800 adult steelhead. The mitigation level was a negotiated settlement which took into account Squaw Creek surveys, Pelton counts, redd counts, habitat conditions and potential production (Nehlsen 1995). The available information on historical and current abundance of steelhead in specific areas is



summarized below.

**Crooked River** — There were enough salmon and steelhead migrating into the upper Crooked River to justify the construction of a fish weir just below its confluence with the north fork. The weir, constructed by Native Americans, was observed in 1826 by Peter Skene Ogden (Buckley 1992). The Oregon State Game Commission (OSGC) conducted spawning surveys in the Crooked River and its tributaries in 1953 (OSGC 1954). The information collected was useful in determining presence or absence of steelhead in the 17 miles (27.35 km) of mainstem and tributaries surveyed, but it cannot be used to estimate abundance. Bowman Dam, constructed in 1961, eliminated steelhead from the upper Crooked River (Nehlsen 1995). An unknown number of steelhead continued to spawn in the Crooked River below Bowman Dam until 1968, when passage of anadromous fish above Pelton Round Butte Project was abandoned.

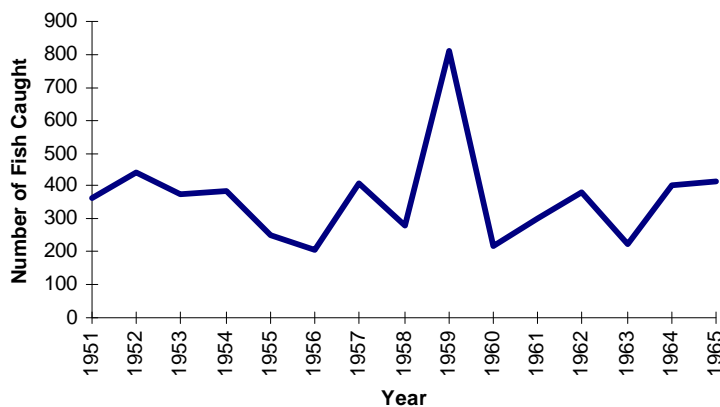
**Squaw Creek** — At the time of the first anadromous fish surveys in the Deschutes River, Squaw Creek supported the largest spawning population, or at least the most easily observed spawning population of steelhead in the upper river. In 1951, the Game Commission installed a weir at RM 16 (RK 25.7) to collect broodstock for Wizard Falls Hatchery (King 1966). All natural spawning took place below the weir. Three to four hundred steelhead spawned in Squaw Creek or were captured at the weir until 1958. After that the abundance of steelhead in Squaw Creek declined (Figure III-16). Construction of Pelton Dam was completed in 1958. Access to Squaw Creek was completely cut off in 1968 when passage over Pelton Round Butte Dams was terminated.

**Figure III-16.** The number of steelhead captured at the Squaw Creek weir and the number of steelhead redds counted between the weir and the mouth of Squaw Creek, 1951-64. 1959 data missing. (Source: King 1966)

**Upper Deschutes** — No estimates of steelhead abundance in the upper mainstem Deschutes River were made although steelhead did spawn in this reach of river. In 1953, 14 steelhead were trapped at Steelhead Falls (OSGC 1954). Those fish would probably have spawned between Steelhead Falls and Big Falls.

**Metolius River** — Fulton (1970) indicates steelhead spawned in the Metolius River, but documentation of steelhead spawning is lacking and it is generally believed they were not indigenous to that stream (Nehlsen 1995).

**Lower Deschutes River** — Steelhead abundance in the lower river was not estimated prior to 1951. After 1951, an index of relative abundance comes from an annual creel census of anglers from the mouth of the river upstream to the Kloan area at RM 7



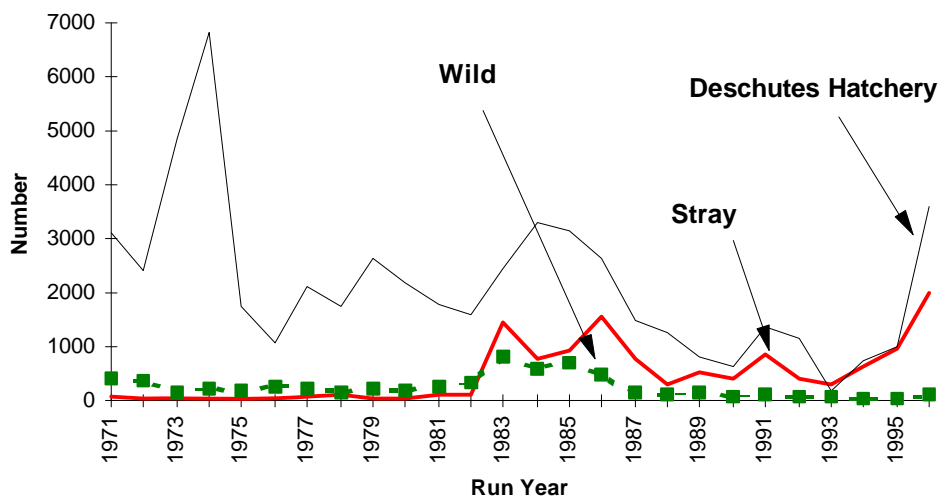
(RK 11.3) (Figure III-17).

**Figure III-17.** Sport catch of adult steelhead in the lower Deschutes River; 1951-65. (Source: King 1966)

After construction of the Pelton Round Butte Project, several indices or estimates of steelhead abundance are available. These include the count of steelhead entering the Pelton Trap, which was the upper end of the steelhead distribution after 1968; mark-recapture population estimates in the Kloan-Macks Canyon area (RM 7 to 40 or RK 11.3 to 63.4); counts of steelhead passed above the weir at the Warm Springs National Fish Hatchery; and estimates of the number of steelhead migrating past Sherars Falls. The Sherars Falls estimates are based on mark-recapture methodology.

With the decision to use artificial propagation to mitigate for steelhead production above Pelton and Round Butte Dams, the trap at the base of the Pelton Reregulating Dam

became the upper end of the steelhead distribution in the mainstem Deschutes. Since 1970, steelhead entering the trap have been separated into three categories: Wild, Deschutes Hatchery and stray hatchery fish not of Deschutes origin (Figure III-18). After 1982, the number of stray hatchery steelhead from outside the basin showed a large and persistent increase. Out-of-basin hatchery strays made up 35% of the steelhead captured in the Pelton Trap in 1989. In 1994 and 1995, out-of-basin hatchery strays made up 62% and 66%, respectively, of the escapement in the Deschutes River. In 1996 and 1997 this increased to 73% and 72%, respectively. This straying has translated to an increase in the percentage of hatchery steelhead observed in the tributary spawning areas. In 1970 and 1990, 17% of the steelhead spawning in Bakeoven and Buck Hollow creeks were of hatchery origin. This increased in 1996 and 1997 to 71% (Chilcote 1997).



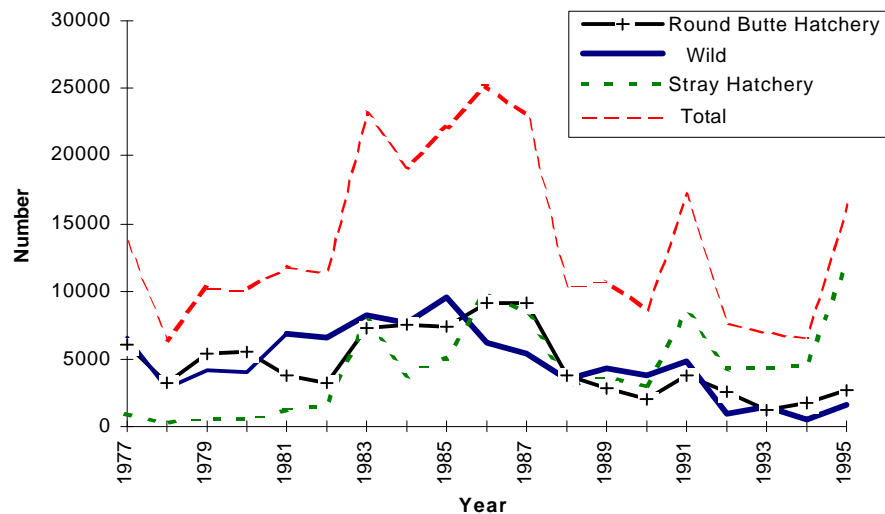
The increase in out-of-basin strays is real, i.e., it's not a function of better monitoring or marking programs. It may be a consequence of the smolt transportation program. Steelhead smolts barged or trucked from the upper Columbia River to below Bonneville Dam may not retain the same homing fidelities as smolts that undergo natural migration. The increased level of straying may also be a function of the large increase in the artificial propagation of steelhead in the upper basin. In this regard, the movement of fish among facilities during rearing may increase the incidence of straying. A large percentage of non-native steelhead spawning with native fish could be detrimental to the long-term productivity of the Deschutes River stock. The ramifications of this problem will be discussed in the section on redband genetics.

It should be noted that steelhead are dipping into other streams including Little White Salmon and White Salmon rivers at rates equal to or greater than the Deschutes River.

**Figure III-18.** The number of wild, Deschutes Hatchery and stray hatchery steelhead (fish not from the Deschutes System) collected at the Pelton Trap, 1971-96. (Source: Olsen et al. 1992 - draft; Scott Lewis unpublished data)

The Oregon Game Commission used mark-recapture methodology to estimate the abundance of steelhead in the lower river (Kloan-Macks Canyon area) in 1970, 1971, 1972 and 1975. The total run averaged 25,000 fish of which 65% were wild steelhead, 31% were Deschutes hatchery steelhead and 4% were stray hatchery fish from out of the basin (Olsen et al. 1992). These estimates were made before the large increase in out-of-basin strays in the early 1980s.

In 1977, the estimates of population size shifted from the Kloan-Macks Canyon area to the river above Sherars Falls (Figure III-19). Since 1977, the total run past Sherars Falls has ranged from a low of 6,300 in 1978 to 33,036 in 1996. The 1996 total is not shown in Figure III-19. Wild steelhead experienced a decline starting in 1992, causing Chilcote (1997) to suggest that the wild steelhead run in the Deschutes River is at serious risk. He hypothesized that the decline is due to the large number of out-of-basin strays spawning with wild Deschutes River steelhead. If out-of-basin strays have placed the wild steelhead at risk, the solution to that problem will be difficult because the cause of straying and possible corrective actions have not been identified.



**Figure III-19.** The estimated number of wild, Round Butte Hatchery and stray hatchery steelhead crossing Sherars Falls from 1977 to 1995. (Source: Olsen et al. 1992; Chilcote 1997)

A comparison of Figures III-18 and III-19 suggests that a large number of steelhead spawn or are caught between Sherars Falls and Pelton Dam. However, the relative distribution of the spawners within the mainstem areas or between the mainstem and the tributaries has not been determined. Spawning surveys in the mainstem from

Shitike Creek to the Pelton Reregulating Dam counted an average 68 redds per mile for the years 1963-1970 (Table III-3). It's possible that resident redband redds were mistaken for steelhead redds in that stream reach. However, this number of steelhead redds is consistent with observations by management biologists (Personal communication, Steve Pribyl, Oregon Department of Fish and Wildlife).

**Lower River Tributaries** — Steelhead redds per mile have been monitored in various tributaries over varying time periods since 1960 (Table III-3). Tributary spawning of steelhead in the Deschutes River was probably more important historically than it is today and it may have been more important than the mainstem (Jim Newton, ODFW, personal communication). Habitat degradation in the smaller streams has been severe, reducing their contribution to total steelhead production. However, even in their degraded state, the tributary production of steelhead is still significant although less than in the past. Managers estimate that 40 to 70% of the steelhead spawning takes place in the tributaries (ODFW 1996). The eastside tributaries appear to be more productive than the westside tributaries in terms of the total number of juvenile steelhead produced (Olsen et al. 1992).

**Table III-3.** Steelhead spawning densities from redd counts in selected areas of the mainstem and tributaries of the Deschutes River. (Source: Olsen et al. 1992; Jim Newton, ODFW, unpublished data; Jim Eisner, BLM, unpublished data)

Location	Average Redds/Mile	Survey Years
<b>MAINSTEM</b> 3-mile (4.83 km) reach between Pelton Reregulation Dam and Shitike Creek	68.2	1963-70
<b>TRIBUTARIES</b>  <u><b>Warm Springs</b></u> Mill Creek - 8.1 survey miles (13.03 km)  Beaver Creek - 9 survey miles (14.5 km)  <u><b>Shitike Creek</b></u> - 11 survey miles (17.7 km)  <u><b>Bakeoven Creek</b></u> (Not known)  <u><b>Bake Oven Creek</b></u> - 3.5 to 12 survey miles (5.63 to 19.3 km) <u><b>Buck Hollow Creek</b></u> Mouth to about RM 12 (RK 19)  <u><b>Buck Hollow Creek</b></u> - 6.5 to 25.7 survey miles (10.5 to 41.4 km)  <u><b>Trout Creek</b></u> Trout Creek - 9.4 to 23.5 survey miles (15.1 to 37.8 km) Ten-Mile Creek Ten-Mile Creek - 2.85 survey miles (4.6 km)	  1.7  3.9  3.0  7.9  3.2  9.4  4.3  1.3  2.1 2.5	  1986-92  1987-92  1986-92  1960-71  1990-97  1960-71  1990-97  1988-97  1995 1996

## 2) Resident Form

The Deschutes River historically has had a strong reputation for its abundant, resident trout populations, which produced a world class fishery (Mathisen 1985b). The resident redband populations, especially in the lower mainstem, have been the subject of long-term research and monitoring. However, estimates of historical abundance are lacking, except in the anecdotal accounts summarized by Mathisen (1985b).

**Crooked River** — Historically redband trout in Crooked River were composed of two populations: One above the falls on the North Fork the other throughout the rest of the basin (Stuart et al. 1996). Today, the basin contains as many as 28 isolated populations of redband trout (Stuart and Thiesfeld 1994). Habitat degradation has fragmented redband trout distribution into isolated populations which severely limits productivity in major areas of the Crooked River. Within the known occupied habitat in the Crooked River, 85% of the redband trout populations are depressed and only 15% are considered strong (Personal communication, Dean Grover, USDA Forest Service).

A recent survey of 138.5 stream miles (222.8 km) in Deep, Beaver, West, Wolf and Peterson creeks found redband trout in 42% or 59 miles (94.9 km) out of the total miles surveyed (Stuart and Thiesfeld 1994). Density of redband trout in four streams—Brush, Porter, E. Porter and Roba creeks—ranged from 0.2 to 0.06 fish/m<sup>2</sup> (Table III-4). Below Prineville Reservoir, in the Chimney Rock reach of the mainstem, recent surveys found high densities of trout ranging from 826 to 8,228 trout/mi in 1989 and 1994 respectively (Table III-4). Environmental conditions in the Chimney Rock reach are influenced by the higher flows and the lower temperatures of the water released from Prineville Reservoir (Stuart et al. 1996).

**Metolius River** — In a 1938 survey of the Metolius River, biologists concluded that the upper river had excellent potential productivity and moderate to low productivity potential in the lower reaches. Cold water temperatures from the source springs, high gradient and habitat quality in the lower river were considered an important factor limiting production. Excessive harvest, predation, and disturbance of the spawning area by humans were other possible limiting factors. Since aquatic food organisms were very abundant, and harvest was perceived to be beyond the stream's capacity, biologists recommended that the stream be stocked annually with artificially propagated trout (Holloway et al. 1938).

Recent snorkel surveys of the upper RM 3.98 (RK 6.4) of the Metolius River found extremely low abundance of wild redband trout (Table III-4). While low stream temperatures are a factor two other explanations for the reduced abundance have been offered. First, reduced fitness due to interbreeding between hatchery and wild trout. Hatchery trout from a stock with low resistance to the parasite *C. shasta* have apparently interbred with the native Metolius redband trout lowering their resistance to the parasite (Currens et al. 1997). Introgression between hatchery and wild trout, although common in the upper Metolius was not detected in the redband population in the lower river

(Williams et al. 1997a). Second, reduced cover has exposed redband trout to predation by a growing population of bull trout. Low incidence of *C. shasta* suggest it is not a significant source of mortality (Personal communication, Don Ratliff, Portland General Electric Company).

**Table III-4.** Measures of abundance of resident redband trout in the Deschutes Basin.

<b>Location</b>	<b>Density</b> fish/mi or fish/m <sup>2</sup>	<b>Years</b>	<b>Note</b>
<b>MAINSTEMS</b> <b>CROOKED RIVER</b> Chimney Rock (below Prineville Res.)  Prineville Valley about RM 56 (RK 90)	826/mi. 2,289/mi. 8,228/mi. 6,098/mi. 142/mi.	1989 1993 1994 1995 1993	(Source: Stuart et al. 1996)
<b>LOWER DESCHUTES</b> Nena Creek* North Junction* Trout Creek* Trout Creek** Whiskey Dick* Beavertail - Macks Canyon* Pinetree - Macks Canyon* Jones Canyon* Jones Canyon**	2,560-639/mi. 2,139-764/mi. 1,586-1,572/mi 1,117/mi. 2,174-1,293/mi 31/mi. 55/mi. 519/mi. 1,115/mi.	1973-1988 1972-1988 1972-1975 1996 1971-1979 1971 1972 1986 1996	Total of all redband 19 cm. and larger  (Source: *Schroeder 1989 **Newton and Nelson 1996)
<b>UPPER DESCHUTES</b> Big Falls to Lake Billy Channel	3,002/mi.	1989-91	2-16 in. (3.2-5 cm) redband estimated from snorkeling  (Source: Fies et al. 1996b)

Location	Density fish/mi or fish/m <sup>2</sup>	Years	Note
<b>TRIBUTARIES</b>			
<i>CROOKED RIVER</i>			
Ochoco	2.64/m <sup>2</sup>	1992	Redband trout densities All ages (Source: Stuart et al. in preparation)
Canyon Creek	2.66/m <sup>2</sup>	1992	
Ochoco Creek	0.31-0.77/m <sup>2</sup>	1992	
Marks Creek	0.04-0.069/m <sup>2</sup>	1991	
Mill Creek			
North Fork Crooked River			
Cray Creek	0.068/m <sup>2</sup>	1994	
Lookout Creek	0.81/m <sup>2</sup>	1991	
Brush Creek	1.42/m <sup>2</sup>	1991	
E. Fork Howard Creek	0.54-0.68/m <sup>2</sup>	1991	
W.Fork Howard Creek	0.96/m <sup>2</sup>	1991	
Howard Creek	0.77/m <sup>2</sup>	1991	
Porter Creek	0.44/m <sup>2</sup>	1992	
North Fork Creek	0.01/m <sup>2</sup>	1990	
Beaver			
Dippingvat Creek	1.01/m <sup>2</sup>	1992	
Roba Creek	0.2/m <sup>2</sup>	1992	
<i>METOLIUS RIVER</i>			
Source to Gorge Campground	.0008-.002/m <sup>2</sup>	1992	Snorkel Counts Adult trout
	.0003-.003/m <sup>2</sup>	1993	
	.00008-.018/m <sup>2</sup>	1992	5-9 cm. Trout
	.00004-.006/m <sup>2</sup>	1993	
	.004-.0004/m <sup>2</sup>	1992	10-19 cm trout
	.002-.00004/m <sup>2</sup>	1993	
<i>TROUT CREEK</i>			
Auger Creek	.23/m <sup>2</sup> <sup>a</sup>	1994	Ave. of 4 reaches
Upper Trout Creek	.30/m <sup>2</sup> <sup>b</sup>	1994	Ave. of 3 reaches
Potlid Creek	.09/m <sup>2</sup> <sup>c</sup>	1994	Ave. of 5 reaches
Dutchman Creek	.35/m <sup>2</sup> <sup>d</sup>	1994	Ave. of 2 reaches
Dick Creek	.09/m <sup>2</sup>	1994	1 reach sampled
			(Source: Groshens 1995)

a/ - 3 of the 7 reaches sampled had no redband trout

b/ - 2 of the 5 reaches had no redband trout

c/ - 1 of the 6 reaches need no redband trout

d/ - 2 of the 4 reaches sampled had no redband trout

The Metolius River exhibits the effect of both physical attributes (cool temperatures) and biological attributes (reduced fitness). The latter is imposed on the redband population through introgression with maladapted hatchery trout. It's interesting to note that the density of redband trout in the Metolius River is lower than trout densities in tributaries to Crooked River, many of which have been subjected to severe habitat degradation. Natural differences in habitat in the two basins—the Metolius is a much colder stream—makes direct comparison between the two streams fraught with uncertainty. The comparison does deserve additional inquiry, which is beyond the scope of this report.

**Upper Mainstem Deschutes River** — The only estimates of abundance are from snorkel surveys. The density of trout from Big Falls to Lake Billy Chinook (RM 132-120 or RK 212-193) was about 3,000 trout/mi. (Table III-4). Warm water and low flows have nearly eliminated redband trout from RM 155-132 (RK 249-212), Tumalo to Lower Bridge (Fies et al. 1996b).

**Lower Mainstem** — The resident redband population in the lower mainstem of the Deschutes River is one of the most robust in Oregon (Kostow 1995). Within the lower mainstem, the highest abundance is found between the Pelton Reregulating Dam and Maupin and least abundance below Sherars Falls (Table III-4).

Habitat degradation and persistent drought has reduced the abundance of redband trout in the lower river tributaries, especially those entering on the eastside of the mainstem (Kostow 1995) (Table III-4).

Schroeder and Smith (1989) compared redband trout densities in the lower mainstem of the Deschutes River with other western rivers. The density of rainbow trout 7.48 inches (19 cm) or larger in the Deschutes River above Sherars Falls was two to three times higher than trout densities in the North Platte River in Wyoming and Colorado and the Madison River in Montana. The Deschutes was similar to the Colorado and Gunnison rivers in Colorado; 50-75% higher than the best sections of the Big Wood River, but 30-60% lower than Henry's Fork Snake River (both of the latter are Idaho streams).

Platts and McHenry (1988) reviewed data on trout and char in 234 western streams and found a mean density of 0.25 fish/m<sup>2</sup>. Within the Columbia ecoregion, which contains the Deschutes River, the mean density of trout in 42 streams was 0.22 fish/m<sup>2</sup>. Many of these estimates were mixed populations of more than one salmonid species. With the exception of the Metolius River and some of the eastside tributaries, the density of trout in the smaller tributaries is comparable to the ecoregion average. The density of trout in the Metolius River was much lower than the regional average. We do not know how well the estimates of trout density from the Crooked River and Trout Creek represented densities throughout those watersheds.

Throughout the Deschutes Basin, the density of redband trout was obtained through different methods, the data were collected in different years and reported in different units. This inconsistency makes comparative analysis of trout densities from a basin perspective difficult. The agencies should develop a coordinated and standardized approach to the collection and reporting of basic information throughout the basin.

### **c. Life Histories**

Over the past century, habitat in the Deschutes Basin was degraded with the resulting loss of life history diversity in the native salmonid populations. Unfortunately, most of this loss took place before biologists were able to sample, describe and understand the full range of salmonids biodiversity in pristine habitats. Under pristine or near pristine conditions, steelhead are capable of extraordinary variation in life history. The joint Russian American Expedition for research on steelhead has been studying the steelhead in four rivers of Russia's Kamchatka Peninsula. In three years of study, the expedition has discovered an "*extraordinary diversity of age classes, migratory patterns and life strategies.*" In the Utkholok River alone, the steelhead had 19 different age classes (Soverel 1997). The rivers of Kamchatka Peninsula flow through relatively undisturbed landscape.

Peven et al. (1994) found a surprising level of diversity in steelhead life histories in the mid-Columbia. Smolts captured at Rock Island Dam ranged from 1-7 years in age. There appears to be a continuous stream of juvenile steelhead migrating downstream in the mid-Columbia tributaries. The steelhead migrate out of the cold unproductive tributaries such as the Wenatchee River to warmer and more productive habitats downstream. The steelhead undergo parr-smolt transformation at various points in the sequence of habitats depending on when they reach a threshold size. The seven smolt ages suggest a complex rearing and migration pattern for juvenile steelhead, i.e., diverse juvenile life histories.

On the regional scale that encompasses the entire northeast Pacific from central California to southern British Columbia, steelhead life histories respond to a latitudinal gradient in stream temperatures. Repeat spawning, adult length, length of freshwater residence, and length of saltwater residence varied in response to that temperature gradient (Withler 1966). Temperature gradients are also an important part of the Deschutes River environment. The steelhead and resident redband life histories that respond to those thermal gradients or to other environmental variation in the Deschutes River have not been determined (but see Zimmerman and Reeves 1996). The relationship between life history and habitat variation and ultimately to production is an important area of research that has received little attention.

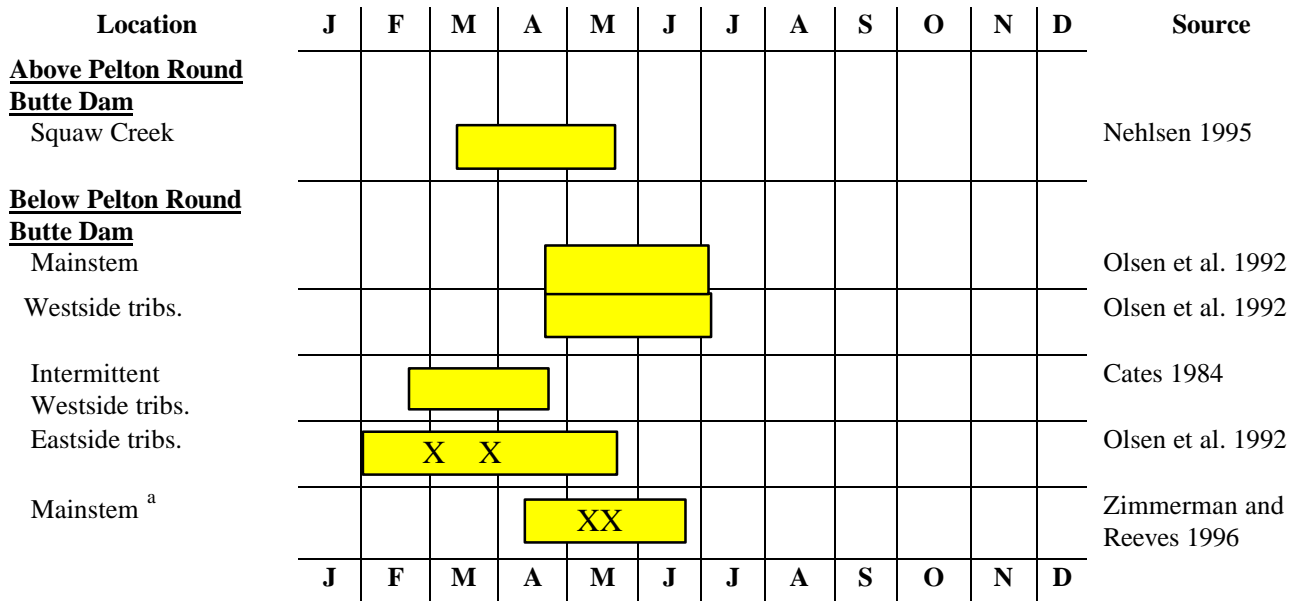
## 1) Anadromous Form

Patterns of freshwater and saltwater residence were determined from an analysis of steelhead scales collected from 100 adult fish caught in the Deschutes River sport fishery in 1971 and 1972 (Table III-5). Fifty-five or slightly more than half of the steelhead in the sample, smolted and went to sea after their second annuli was formed. While these data show eight life history patterns, the information has limited value because the life histories were determined from a composite sample so they cannot be related to the specific habitats from which the fish originated. It's not known which of the life history patterns belong to steelhead that were produced in eastside or westside tributaries or specific reaches in the mainstem.

**Table III-5.** Life history patterns identified on scales collected from a sample of 100 wild adult steelhead in the Deschutes River, 1971 and 1972 run years. (Source: Olsen et al. 1992)

<b>Number of Annuli in fresh or salt water</b>	<b>Number of Fish</b>
One freshwater: one saltwater two saltwater	7 22
Two freshwater: one saltwater two saltwater	35 20
Three freshwater: one saltwater two saltwater	10 4
Four freshwater: one saltwater two saltwater	1 1

Steelhead spawned in the upper Deschutes mainstem and in Squaw Creek in March and April (Figure III-20). However, this information was collected in 1952 and both the upper mainstem and Squaw Creek had undergone significant habitat change by then. It's quite possible that the data collected in the 1950s does not reflect the historical range of spawning times in the upper mainstem or Squaw Creek. Timing of steelhead spawning in Crooked River or its tributaries was not determined before Pelton Round Butte Dams blocked passage.



a/ X's denote peak spawning

**Figure III-20.** Time of steelhead spawning at several locations in the Deschutes Basin.

The timing of steelhead spawning in the lower mainstem and its tributaries reflects environmental gradients in a west to east direction. Steelhead spawn in the eastside tributaries from January through April which is earlier than in the mainstem and most westside tributaries (Figure III-20). Earlier spawning in the eastside tributaries might be a response to the arid conditions in those watersheds. Flow in the eastside tributaries decreases in the spring, earlier than in westside tributaries and by summer, flow in many of the eastside tributaries is intermittent (Olsen et al. 1992). Juvenile steelhead from early spawning parents could emerge and migrate out of the stream before extreme low flows. Cates (1984) observed similar life history patterns in westside tributaries with intermittent flows (Figure III-20).

Juvenile migration is a critical life history trait whether it is the migration of smolts to sea or the migration of presmolts to different rearing habitats within the freshwater ecosystem. The low variation in the timing of juvenile migration in salmon and steelhead populations suggests that the timing of migration events has survival value (Lichatowich and Cramer 1979). This hypothesis appears to explain the migration of juvenile steelhead in eastside tributaries. Juvenile steelhead migration from Bakeoven and Buck Hollow creeks was monitored from 1970 through 1973 and in Trout Creek from 1971 to 1973. Juvenile migration in the Warm Springs River has been monitored since 1976 (Olsen et al. 1992). Juvenile steelhead migrated from Buck Hollow and Bakeoven creeks by mid-May and from Trout Creek prior to mid-June. Most of the smolt migration in the Warm Springs River takes place between the first week in April and early June (Olsen et al. 1992). Steelhead fry migrated from Buck Hollow and Bakeoven creeks from late May to early

June following the smolt migration. In the Warm Springs River, steelhead fry migrate during the spring and fall.

The fry migration from the eastside tributaries might represent movement to better rearing habitat as suggested by Peven et al. (1994). However, in the eastside tributaries, the steelhead fry are not migrating to escape cold water, but to avoid summer low flows and high temperatures. There has been no attempt to define the relationship between juvenile migration and environmental conditions in the eastside or westside tributaries or to determine the fate of fry migrants.

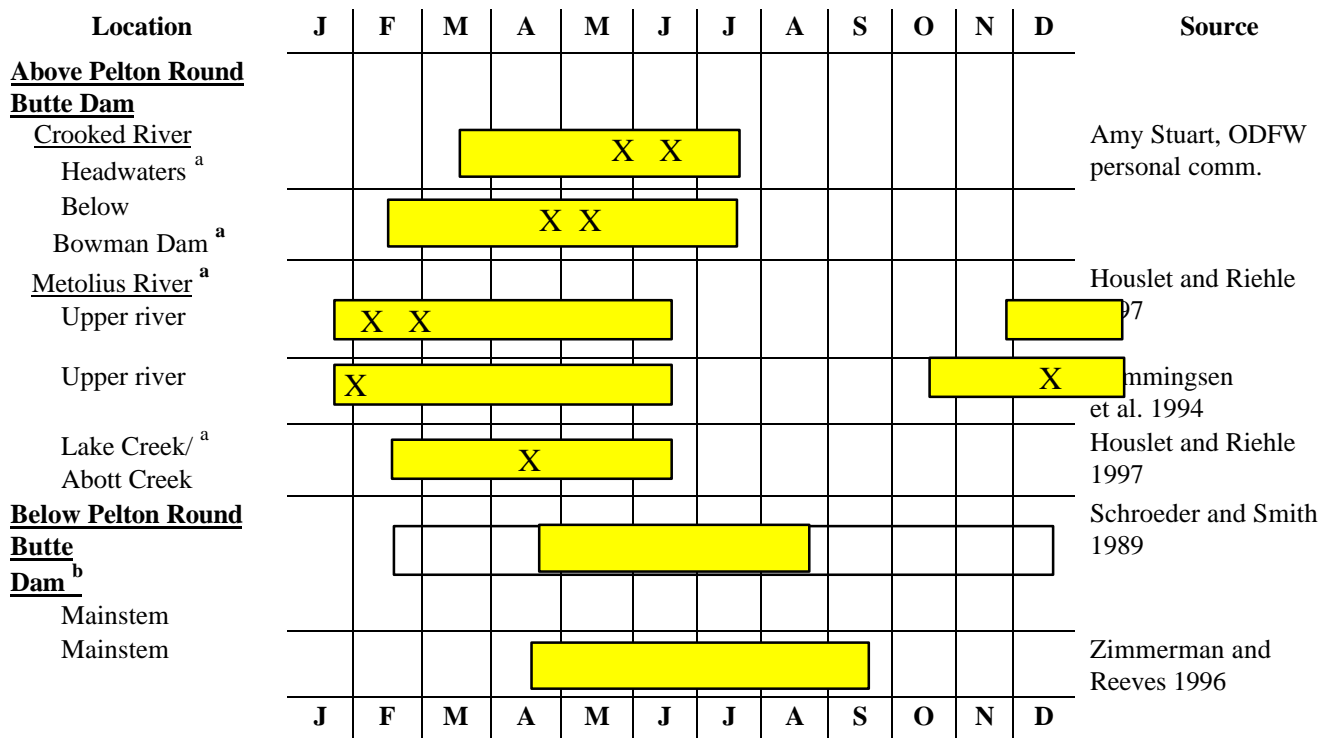
Information on steelhead life histories in the Deschutes Basin suggests that considerable diversity still exists, although, what fraction of historical diversity remains cannot be determined. In addition, it's very likely that more existing life history diversity remains to be identified. The general lack of information on life history diversity of salmonids in the Northwest is more the result of not looking, rather than a failure to find it. The out-of-basin strays may be introducing additional life history diversity and they may complicate any future assessment of life history diversity of native steelhead.

## 2) Resident Form

Schroeder and Smith (1989) described the life history of resident redband trout in the Deschutes River below the Pelton Round Butte Project. Parts of the life history of redband trout in the Metolius River were described by Hemmingsen et al. (1994) and Houslet and Riehle (1997). Life histories of redband trout in the Crooked River and in the upper Deschutes River have not been reported.

Prior to construction of Pelton and Round Butte Dams, peak spawning of resident redband trout in the lower mainstem occurred between late March and May. Today, most redband trout in the lower mainstem of the Deschutes River spawn between April and July (Schroeder and Smith 1989), although maturing fish may be observed in the river in almost every month (Kostow 1995) (Figure III-21). The shift in peak spawning may have been a response to a small change in the seasonal temperature pattern following construction of the dams.

Redband trout in the upper Metolius River spawn primarily above the confluence with Lake Creek (Houslet and Riehle 1997). Time of spawning in the Metolius differs markedly from other areas in the Deschutes River (Figure III-21). Spawning begins in the fall and continues through the following May with the peaks between December and February (Hemmingsen et al. 1994; Houslet and Riehle 1997). The extended period of spawning may be a response to the environmental conditions in the Metolius River or due to introgression between the fall spawning hatchery rainbow trout and the native spring spawning fish (Houslet and Riehle 1997).



a/ X's denote peak spawning

b/ dashed lines indicate a few ripe fish may be found throughout the year.

**Figure III-21.** Time of spawning for resident redband trout at several locations in the Deschutes Basin.

Spawning in the Metolius River was related to river temperatures. Earliest spawning occurred in the upper reaches of the river where spring water maintains a temperature of 46.4°F (8°C) throughout the winter. The redbands spawned lower in the Metolius River later in the spring when river temperatures warmed to 43.7°F (6.5°C) or warmer. Tributaries such as, Lake and Abbot creeks, were used by spring spawners only.

The occurrence of a genetically pure redband population in the lower Metolius raises some interesting questions. If that population were fluvial, and migrated to the upper Metolius to spawn, the lower population should have shown evidence of introgression with hatchery rainbows, but it didn't (Williams et al. 1997a). That finding suggests that the lower river population is spawning separately from the upper river population. Nothing is known about the life history of the lower river population, but because the lower river seems inhospitable for spawning, it might be that the lower river redbands are utilizing tributary creeks of the lower Metolius for spawning and rearing.

Redband trout below Bowman Dam in the Crooked River spawn from February through June with a peak from late April to early May. Spawning in the headwaters starts

in March and continues to mid-June peaking mid-May to early June (Figure III-21) (Amy Stuart, ODFW, personal communication).

Age and size at first spawning varied by location in the lower mainstem Deschutes River between RM 34 (RK 54.7) and RM 72 (RK 115.8). In the Nena Creek area, redbands matured at age 3 and at a size of 11.8 inches (30 cm). In the North Junction area, they matured at age 4 and at a size of 12.6 inches (32 cm) and in Jones Canyon, at age 4 and 12.2 inches (31 cm) (Schroeder and Smith 1989).

ODFW lists one resident/fluvial population of redband trout in the lower mainstem of the Deschutes River (Kostow 1994). However, redband trout in the lower mainstem exhibit little movement. About 75% of tagged redband trout over 8 inches (20 cm) were recovered 1 to 5 years later in the same area in which they were tagged. Movement between areas of the river was low enough to suggest the existence of distinct local populations (Schroeder and Smith 1989). The study reaches at North Junction and Nena creeks are only 10 miles (16 km) apart, but the trout populations in those areas exhibited differences in size and age at maturity, the percentage of repeat spawners, and in annual mortality rates (Schroeder and Smith 1989). Life history differences among fish inhabiting different areas in the mainstem may indicate a response to environmental gradients, genetic differences among local populations or an artifact of differential harvest (Schroeder and Smith 1989). If the mainstem were composed of several local populations of redband trout, it would have important implications to their management and to the interpretation of population structure based on metapopulation theory.

Age and size at maturity influence the growth of redband trout in the lower mainstem of the Deschutes River. Growth slows after the fish reach age 3 or 4 or when they reach maturity. As the fish grow older, growth slows even more. In the first two years they can grow to about 4.3 inches (11 cm), but by their sixth year they add only .4 inches (1 cm) of growth annually (Schroeder and Smith 1989).

In addition to the single mainstem population, ODFW lists 13 breeding populations in the tributaries to the lower Deschutes River, not including those in White River, and 26 populations in the upper Deschutes River up to Big Falls on the mainstem and in the Crooked and Metolius rivers (Kostow 1995). However, in the Crooked River there may be as many as 28 physically isolated populations of redband trout (Stuart and Thiesfeld 1994). With the exception of the Metolius River little is known regarding the life histories of these individual tributary populations in the upper and lower river.

#### **d. Genetics**

Genetic analyses of native fish populations are important because of the inferences it allows us to draw concerning the present and historical status of the populations (or species). Those inferences might include such things as historical distributions and metapopulation structure, evolutionary lineages or bottlenecks and genetic interactions with hatchery fish.

Considerable genetic information exists for Deschutes Basin rainbow trout populations, including several comprehensive allozyme studies. Currens (1987) and his colleagues (Currens et al. 1990) examined morphological and allozyme variation among 22 populations of rainbow trout in the lower Deschutes Basin (below the Pelton Round Butte Project). Currens (1987) and Williams et al. (1997a) analyzed four populations of rainbow trout from the Metolius River. Phelps et al. (1996) examined 25 rainbow trout populations from the Upper Deschutes and Crooked rivers.

##### **1) Genetic Variation and Systematics**

Rainbow trout in the Deschutes Basin are part of a widely distributed inland group of rainbow trout and steelhead recognized by Behnke (1992) as *O. mykiss gairdneri*, a subspecies distinct from the coastal form of rainbow trout *O. m. irideus*. Genetic and morphological differences occur between the two forms (Allendorf and Utter 1974; Behnke 1992; Currens et al. 1990; Williams et al. 1996).

All rainbow trout in the Deschutes system appear to be monophyletic; i.e., they are descended from a common ancestor. Nevertheless, isolated and divergent populations occur within the Deschutes system. For example, rainbow trout populations isolated above a major waterfall in the White River had morphological and allozyme characteristics highly divergent from other Deschutes Basin rainbow trout populations (Currens et al. 1990).

##### **2) Geographic Relationships and Metapopulation**

###### **Structure**

Studies of genetic variation within fish species over large geographic scales, such as one or more watersheds, typically reveal a pattern of geographic variation (Avice et al. 1987; Avice and Felley 1979; Bermingham and Avice 1986; Williams et al. 1997b). Such geographically structured variation is the result of the interplay between natural selection at the local scale (i.e., local adaptation) and the exchange of individuals between adjacent local populations (i.e., migration, dispersal and gene flow). Given the great environmental heterogeneity of local habitats in the Deschutes system, such as the difference between the spring-fed, cold and stable Metolius River and the ephemeral nature of some eastside tributaries, it is reasonable to expect natural selection and local adaptation to be strong forces in the Deschutes system and to exert a strong structuring force in creating and preserving genetic and life history diversity in Deschutes Basin rainbow and steelhead

trout populations. Consequently, the existence of genetically differentiated locally adapted populations in specific habitats within the Deschutes drainage should be expected.

In spite of the considerable amount of genetic analysis of Deschutes River rainbow trout populations, little analysis of geographic patterns of variation and relationships has occurred among trout populations within the basin. Most studies have examined variation among populations within Deschutes River subbasins or tributaries, rather than over the entire Deschutes watershed. Currens et al. (1990) documented that White River rainbow trout populations (above the major falls) are unique and isolated from other Deschutes River populations. Remaining studies are of a more limited scope (Williams et al. 1997b), or are confined within a single Deschutes tributary (Phelps et al. 1996), such that only limited inferences can be made about historic geographic or metapopulation structure.

Because a number of genetic studies of Deschutes rainbow trout populations (Chilcote 1976; Currens 1987; Currens et al. 1990; Ward 1995; Phelps et al. 1996; Williams et al. 1997b) have been completed, we expected to be able to describe or infer from this literature base the historic geographic pattern of relationships among populations and the existence of any metapopulation structure. Because the genetic studies have not been coordinated and a uniform data base does not exist, it's difficult to make inferences about the historic population structure of Deschutes rainbow trout. Indeed, with few exceptions, such as the White River example above, the data do not allow us to determine whether historic or present differences occur between rainbow trout in the Metolius River, Crooked River, Squaw Creek, Upper Deschutes and Lower Mainstem Deschutes. It might be possible to address some of this, if Currens' and Phelps' datasets could be merged for a joint analysis. Indeed, the authors have discussed this possibility and should be encouraged to do so. Additional samples might also be required to fill in missing locations for such a geographic analysis.

At a finer scale, both Currens (1987) and Phelps et al. (1996) allozyme analyses reveal three geographic clusters of redband trout populations within the Crooked River system. These relationships are difficult to infer from the original analyses. However, recently Amy Stuart and colleagues (Stuart et al. in preparation) reviewed numerous characteristics of redband trout in the Crooked River Basin, including previous genetic analyses. The Stuart et al. review shows clearly that redband trout in the Crooked River group into three distinct geographic clusters (see Stuart et al. in preparation, Figure 2). One group of related populations occurs in the lower Crooked River (below Bowman Dam) and includes populations from the lower mainstem Crooked River, as well as McKay Creek, Mill Creek, Mark's Creek, and Ochoco Creek. A second group of related populations occurs in the mainstem Crooked River above Prineville Reservoir and Bowman Dam and the various small tributaries in this section including Bear Creek and Pine Creek. The third group of related populations occurs in the North Fork of the Crooked River and the mainstem above Prineville and their various headwater tributaries.

Geographic variation at this scale (that of major tributaries within a sub-basin) is common in many fish species, including rainbow trout and other salmonids (Kanda et al.

1997; Williams et al. 1997b; Williams and Trotter unpublished data). A genetic sampling of redband trout populations throughout the Deschutes Basin at the scale done in the Crooked River would probably reveal additional patterns of geographic structure and clusters of related populations. Such an effort would be worthwhile and likely to identify population clusters for specific management goals and strategies.

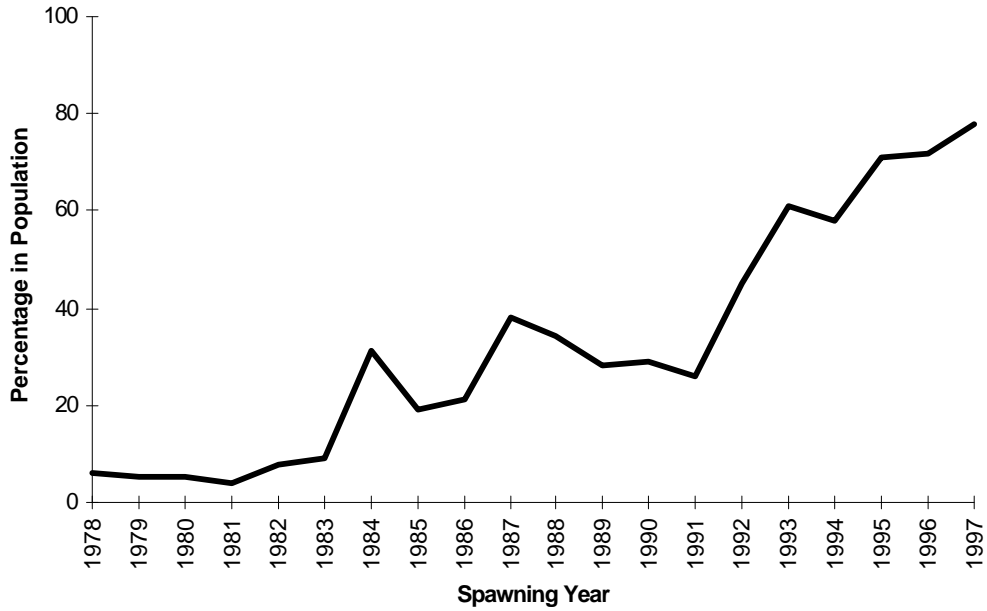
Unfortunately with respect to steelhead, no genetic data exist from historic populations above the Pelton Round Butte Project. Genetic tools capable of discriminating among populations were not available at the time the dams were completed. Consequently, any inferences about metapopulation or geographic population structure on Deschutes Basin steelhead have to be made on the basis of recorded life history differences, rather than on genetic data.

### 3) Influence of Artificial Production (hatchery stocking)

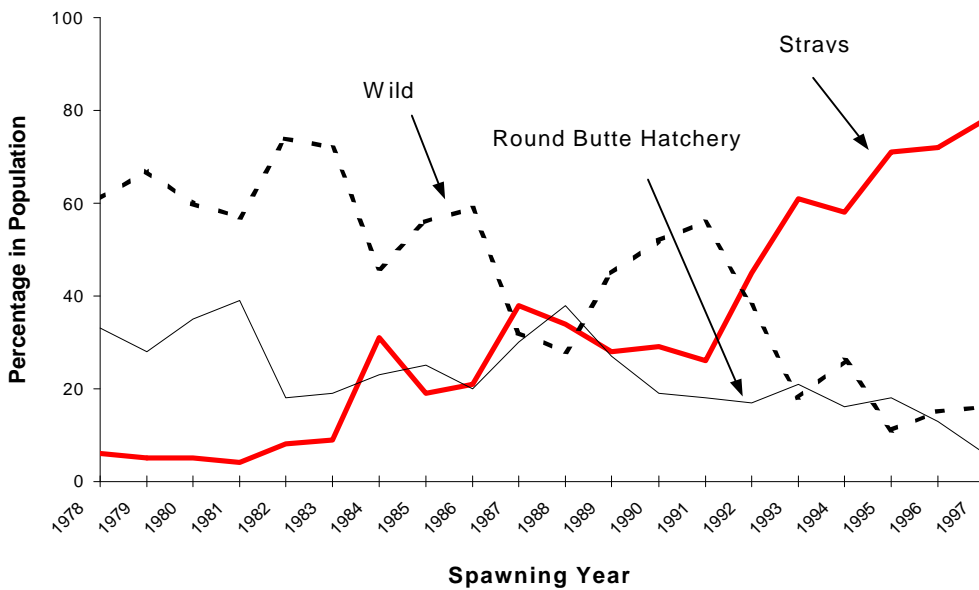
#### a) Anadromous Form

Recent data on straying rates of summer steelhead in the Columbia and Deschutes Basins (Chilcote 1997), as well as a small body of literature documenting genetic interactions between wild and hatchery rainbow trout and fitness declines (i.e., loss or reduction in reproductive success) (Chilcote et al. 1980; Currens et al. 1997; Reisenbichler and McIntyre 1977; Williams et al. 1997a), raise serious concerns for the Deschutes summer steelhead. Starting in the early 1980s, the number of out-of-basin hatchery strays from the Snake and upper Columbia Basin increased from less than 10% of the run to greater than 70% at present. In the same time period, wild fish have decreased to less than 15% of the run (Figures III-22 and III-23).

Straying rates of this magnitude far exceed any acceptable genetic modeling for conservation or preservation purposes. Straying rates from out-of-basin steelhead pose a real and imminent threat to the continued existence of Deschutes Basin summer steelhead. Concerns about metapopulation structure for Deschutes steelhead are virtually irrelevant with straying rates this high. Although there is a monitoring program underway in the Warm Springs River, an



**Figure III-22.** Estimated percentage of stray summer steelhead passing Sherars Falls in the Deschutes River. (Source: Chilcote 1997)



**Figure III-23.** Percentage of wild, Round Butte Hatchery and out-of-basin stray summer steelhead passing Sherars Falls in the Deschutes River. (Source: Chilcote 1997)

aggressive monitoring program should be established throughout the lower watershed to determine straying into lower river tributaries, such as Bakeoven, Buck Hollow and Trout creeks. ODFW (reported in Chilcote 1997) conducted steelhead spawning stream surveys in Bakeoven and Buck Hollow creeks. Hatchery spawners comprised 17% of the 1990 and 1991 spawners, whereas they comprised 71% of the 1996 and 1997 spawners. An expanded and aggressive monitoring program could determine whether this pattern is typical or whether small tributaries in the lower Deschutes might function as local refuges for native steelhead. If the problem is epidemic, as it appears to be, then consideration of control measures, such as the installation of weirs and removal of hatchery fish from lower Deschutes River tributary streams, should be considered for out-of-basin strays.

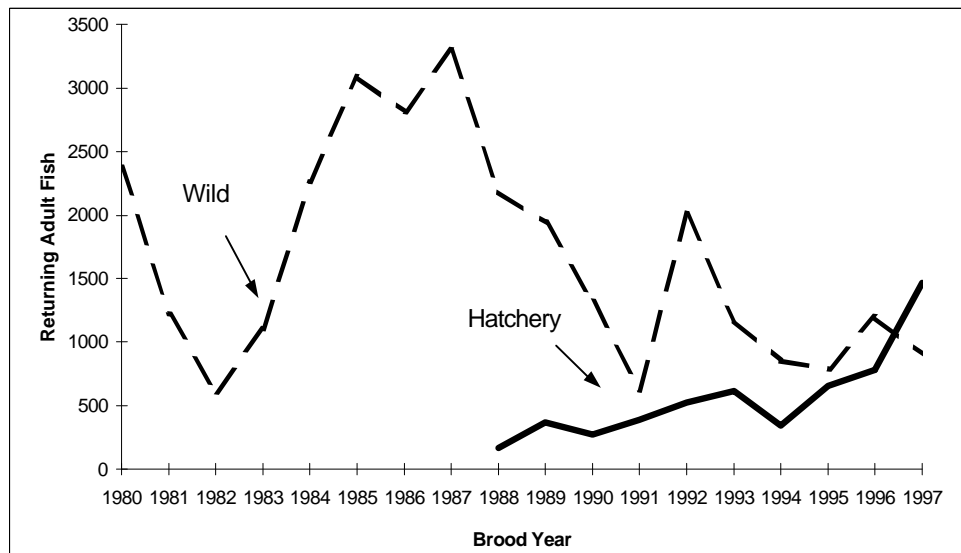
Chilcote argues that the majority of stray steelhead that pass Sherars Falls remain in the Deschutes and spawn there (Chilcote 1997 p. 82-83). Since the large increase in hatchery fish seem to be because of increased numbers of out-of-basin strays, there is considerable cause for concern regarding their effects on native Deschutes steelhead populations. Schreck et al. (1986) demonstrated that Deschutes steelhead differed genetically from Snake River Basin steelhead.

Most management strategies explicitly recommend against stock transfers, particularly as geographic distance or life history and genetic differences increase (Flagg et al. 1995). For example, stock transfers between wild steelhead populations from different ESUs would not be considered an appropriate management action, except in special and unusual circumstances. However, in the Deschutes this is precisely what is occurring. Inadvertently, out-of-basin strays (stock transfers) are entering the system and breeding with wild Deschutes steelhead. Additionally, breeding is occurring between wild fish and hatchery fish, including both Deschutes Basin hatchery fish and out-of-basin hatchery fish. With the exception of specifically designed and implemented supplementation programs where hatchery produced fish are intended to breed with wild fish, management agencies have attempted to avoid interbreeding between hatchery and wild fish. Indeed, most scientific data suggest that it is generally detrimental to the fitness of the wild population (Reisenbichler and McIntyre 1977; Chilcote et al. 1986; Reisenbichler and McIntyre 1986; Hindar et al. 1991; Currens et al. 1997).

Chilcote (1997 p. 89) noted that the decline observed in the Deschutes wild steelhead population was not matched by a similar decline in resident redband trout numbers. He therefore speculated that the steelhead decline may be due to a loss of reproductive capacity (i.e., fitness decreases) due to interbreeding with out-of-basin out-of-ESU strays. Such decreases in fitness are due to outbreeding depression, where “swamping” of locally adapted genes in a wild population occurs through interbreeding with genetically divergent hatchery populations. Empirical evidence for outbreeding depression is much less extensive than for inbreeding depression (Hindar et al. 1991; Lynch 1997) and most field examples come from plants (Wasser and Price 1989). Although few studies of outbreeding depression effects have been done on higher organisms including salmon (Gharrett and Smoker 1991), the evidence shows that they occur in every group of organisms studied (Lynch 1997). Additionally, it appears that the

effects of outbreeding depression may take several generations to become apparent. Out-of-basin stray steelhead numbers in the Deschutes have risen steadily from approximately 10% in 1983 to greater than 70% in 1996. This time period represents 2-3 generations for wild steelhead in the Deschutes system. Thus, it is possible that the sharp decline in reproductive capacity of wild Deschutes steelhead observed by ODFW (Chilcote 1997) over the last four years could be due to the accumulated effects of outbreeding depression and its apparent timelag for manifestation of those effects.

Examination of the increased straying rates by out-of-basin summer steelhead should be an issue of concern to the entire mid-Columbia region and the steelhead management plans specific to each of its subbasins. For example, a synchronous increase in straying of hatchery summer steelhead has also occurred in the Umatilla River (Figure III-24) (Chilcote 1997).



**Figure III-24.** Wild and hatchery summer steelhead in the Umatilla River, 1980-97.  
(Source: Chilcote 1997)

### b) Resident Form

Although the existing genetic studies did not provide a comprehensive view of relationships or metapopulation structure among Deschutes Basin rainbow trout, they provide a clear and compelling study of the genetic interactions between native and hatchery-produced rainbow trout. In brief, genetic studies have shown the redband trout populations in the lower Deschutes, lower Metolius, and the White River to be genetically pure native interior rainbow (e.g., redband) trout populations (Currens 1987; Currens et al. 1990; Currens et al. 1997; Williams et al. 1997a). In contrast, populations in the upper Metolius (Williams et al. 1997a) and some of the redband populations in the Crooked

River (Phelps et al. 1996; Stuart et al. in preparation) show evidence of genetic introgression with a hatchery stock that was derived from coastal rainbow trout

Currens (1987) and Currens et al. (1990) examined 22 populations of redband trout in the lower Deschutes below the Pelton Round Butte Project and its tributaries and found no evidence of genetic introgression with hatchery rainbow trout (of coastal origin) in spite of numerous stocking events. They attributed the lack of introgression, to a lack of survival of hatchery rainbow trout due to lethal infections by a myxosporean parasite, *C. shasta*. The native redband trout are less susceptible to infection.

In the Metolius River, Williams et al. (1997a) examined three rainbow trout populations and found that the two populations from the upper river (near Camp Sherman) showed significant allozyme and mitochondrial DNA introgression with hatchery rainbow trout, while the population from the lower Metolius appeared to be a genetically pure redband population. Because the entire Metolius River system is relatively small, coursing only 27.3 miles (44 km) from its headwaters to its confluence with Lake Billy Chinook, such marked differences in genetic attributes among the three sample populations were not expected. Earlier work by Currens (1987) documented hybridization between native and hatchery rainbow trout in the Metolius River, although his sample was confined to the Pine Rest area (approximately 6.2 miles [10 km] downstream from the headwater springs) where stocking has taken place since 1938. Williams' Riverside sample, collected 1.2-1.9 miles (2-3 km) downstream from the headwater springs in an area that was not stocked with hatchery trout, exhibited substantial allozyme and mtDNA introgression, as did the sample from the Pine Rest area. There are no barriers to fish movement throughout the entire Metolius River system. In contrast to the two upper river sample populations, the Lower Canyon sample, collected between 15.5-20.5 miles (25-33 km) downstream of the headwaters, showed no evidence of hybridization with hatchery rainbow trout in spite of the nearly 60 years of stocking in the upper river, much of it recently with catchable sized hatchery rainbow trout.

Williams et al. (1997a) believe that ecological factors are responsible for the genetic isolation of the lower river rainbow trout from the hybridized upper river populations. Unlike the upper 9.3 miles (15 km) of the Metolius River, which is characterized by numerous large deep pools, gravel runs, a moderate gradient, and small flow volume (3 m<sup>3</sup>/s near headwaters), the lower river lies within a constrained canyon and is characterized by a steep gradient with few pools and heavy flows (40 m<sup>3</sup>/s near the confluence with Lake Billy Chinook). Rearing in a protected hatchery environment does not prepare fish for survival in conditions like those found in the lower reaches of the Metolius River. Local anglers report that few hatchery rainbow trout (all are fin-clipped) are ever caught in the lower river (Personal communication, J. Judy, G. Kish, M. Leitheiser, and R. Robinson). Hatchery rainbow trout are also susceptible to predation by a robust bull trout population that exists in the lower Metolius River and Lake Billy Chinook. Additionally, hatchery rainbow trout are susceptible to the lethal effects of a myxosporean parasite, *C. shasta*, which is present in the Deschutes system, including the Metolius River and Lake Billy Chinook. Fishes native to the drainage appear to be

genetically resistant to the parasite (Ratliff 1981; Ratliff 1983). Water temperatures in the Metolius River (48.2-50°F (9-10°C)) appear to be below the temperature threshold for ceratomyxosis infection (>50°F (10°C)), thus hatchery rainbow trout in the Metolius River are not affected by the disease unless they migrate downstream into the warmer waters of Lake Billy Chinook (see Currens et al. 1997).

With the recent decision to curtail the hatchery stocking program and to direct management actions toward wild fish objectives in the Metolius system, the lower canyon population may have a valuable role to play in the restoration and rebuilding of native Metolius rainbow trout populations. The genetically pure interior rainbow trout population in the lower Metolius River offers the possibility that gene flow via a fluvial life history pattern could sustain an infusion of genes from native fish back into the hybridized upriver populations. This would shift the genetic attributes of the upriver populations toward those of the lower canyon population. Uncertainties about the extent of fluvial spawning migrations and rates of gene flow, need to be the focus of monitoring in order to estimate the possibility and degree to which such a process might occur. Future monitoring of both life history and genetic attributes of the upper and lower river rainbow trout populations could provide insight into whether these processes are occurring, as well as the length of time required to achieve natural restoration. In addition, the snorkel counts of redband trout conducted earlier, should be repeated as part of an assessment of the change in management practices in the river. Recent redd counts do suggest that the redband population may be increasing (Personal communication, Mike Riehle, USDA Forest Service, Sister, OR).

Genetic analysis of redband trout populations in the other major tributaries above the Pelton Round Butte Project are scattered, but include Currens (1987) and Phelps et al. (1996), however, they are best reported and interpreted in Stuart et al. (in preparation). These analyses, which notably do not include any specimens from Squaw Creek, show widespread introgression of redband trout populations in the Crooked River and the mainstem Deschutes River (above Pelton Round Butte Dam). Introgression in Crooked River populations (reported in Stuart et al. in preparation) ranged from 0-32%, but typically ranged between 5-10%. Only two of the fifteen populations exhibited introgression (based on allozyme analysis) greater than 11%. Indeed, of the four stream populations sampled in the Ochoco subbasin of the Crooked drainage, three had high levels of introgression, Ochoco (18.2%), Canyon (10.9%), and Marks (32.0%), while Desolation Creek fish showed no evidence of introgression with hatchery rainbow trout.

Finally it is worth noting that empirical examples of the loss or reduction of reproductive fitness in native salmonid populations are few in the scientific literature. However, in all instances where fitness effects have been measured or estimated, the effects are always negative (Hindar et al. 1991). Curiously, two of the best examples of fitness effects associated with genetic interactions between wild and hatchery salmonids come from studies of anadromous and resident forms of Deschutes redband trout (Reisenbichler and McIntyre 1977; Currens et al. 1997).

## **2. Chinook**

ODFW placed the chinook salmon from the Deschutes River into two GCGs: the mid-Columbia River spring and the Deschutes River fall chinook. The Deschutes River fall chinook GCG consists of a single extant population that spawns in the mainstem of the lower Deschutes River. Historically this GCG probably contained several populations that are extinct now including fish that once spawned in the John Day, Umatilla and Walla Walla rivers (Kostow 1995). The mid-Columbia River spring chinook salmon GCG<sup>5</sup> is composed of four populations from two watersheds, the Deschutes and John Day. The Deschutes watershed supports two distinct populations, one in the Warm Springs River and the other in Shitike Creek (Kostow 1995).

### **a. Summer Chinook**

Summer chinook are not recognized by ODFW, though their historical and current presence has been the subject of discussions (e.g. Jonasson and Lindsay 1988; Beaty 1996). Historically, the Deschutes River probably did support a summer run of chinook salmon. Currently, chinook salmon migrate through the Deschutes River each month from April through October. There are some chinook that migrate during the summer period, however, the peaks in migration occur in May (spring run) and late September to early October (fall run).

Evidence for a historical summer run of chinook salmon comes primarily from the timing of migration of Deschutes River Fish through the lower mainstem of the Columbia River and in the Deschutes River. Fish passing Bonneville Dam in June and July are considered part of the summer run of chinook salmon. In tagging programs carried out between 1947-65, eight chinook salmon tagged at Bonneville Dam by the Oregon Fish Commission and Washington Department of Fisheries between June 13 and July 22 were subsequently recovered in the Deschutes Basin. Three of the recoveries were in the Metolius River (Jonasson and Lindsay 1988).

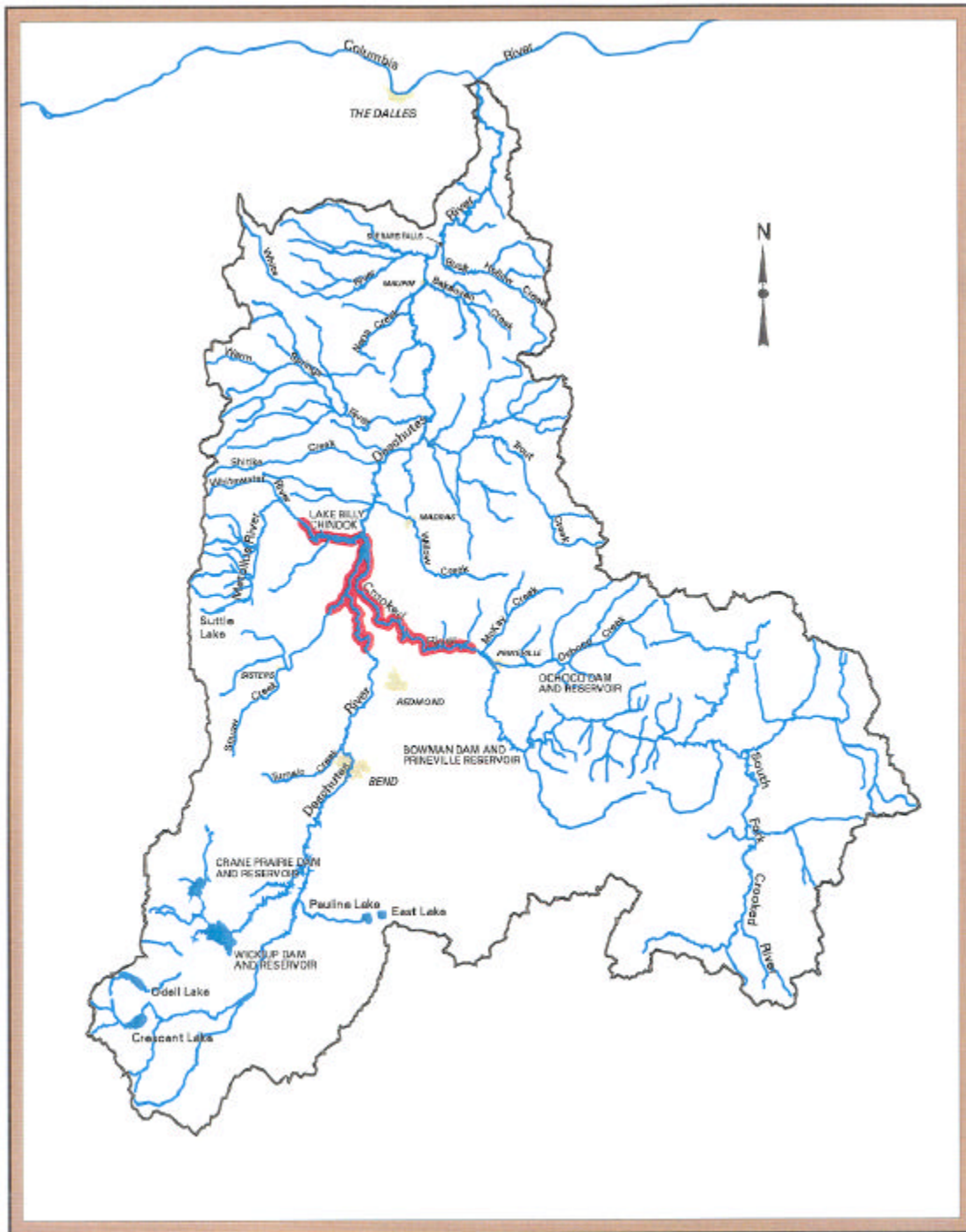
Historically, most of the salmon that migrated in the spring and summer through the Deschutes River spawned above the Pelton Round Butte Project. Some of those fish also spawned in the lower tributaries (Figure III-25, III-26 and III-27). Most fall chinook spawned below the dams. This means that the summer and fall runs of chinook could have been spatially segregated. After passage was stopped at Pelton Dam, summer and fall chinook were forced to spawn in the same area and at the same time immediately below the Pelton Reregulating Dam. The spatial/temporal overlap in summer and fall chinook spawning broke down reproductive isolation and caused Jonasson and Lindsay (1988) to conclude the summer run no longer exists, i.e., the Deschutes River currently supports only spring and fall runs.

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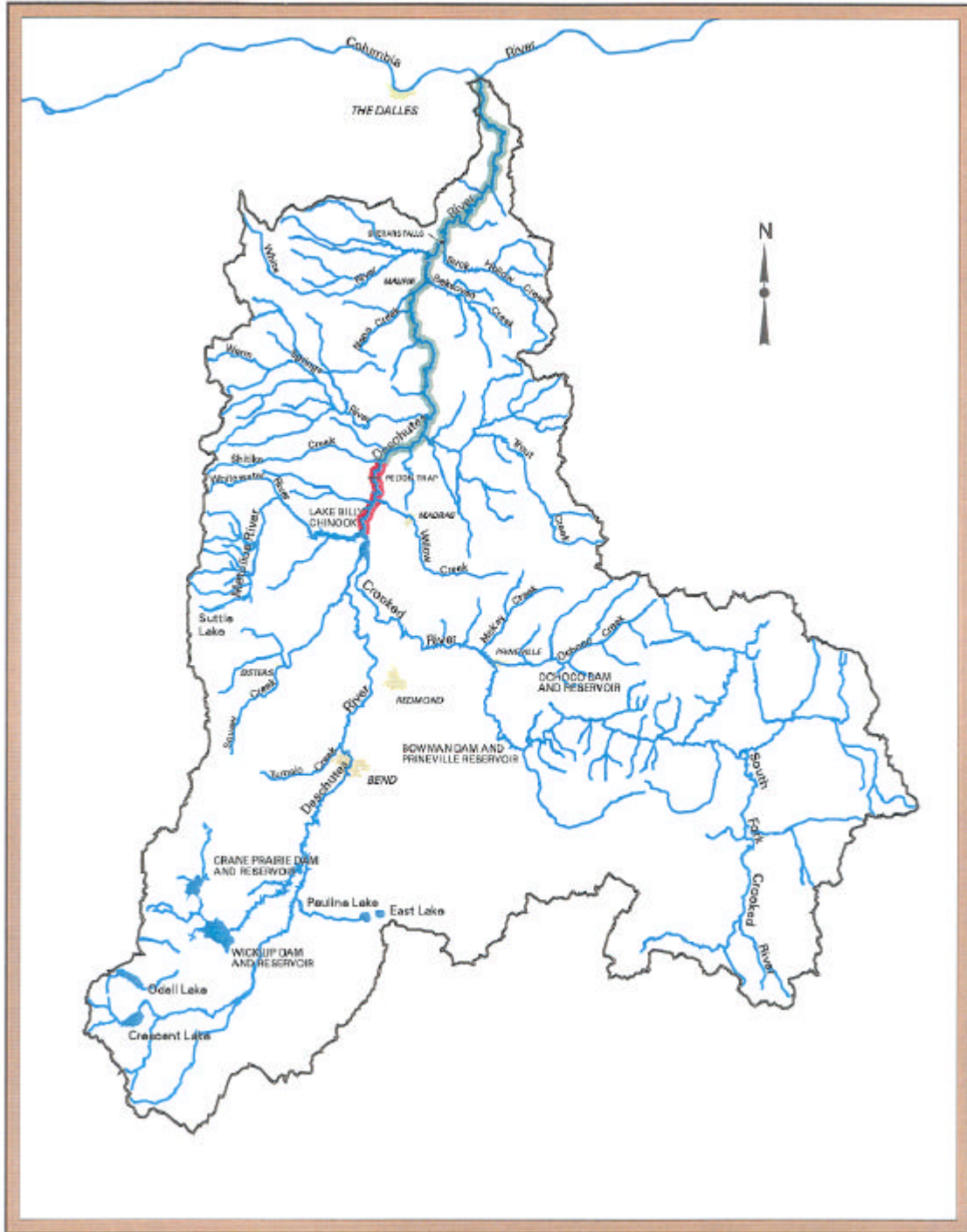
<sup>5</sup> The mid-Columbia GCG addresses populations on the Oregon side of the Columbia River.

Given the interest in restoration of anadromous salmonids above Pelton Round Butte Dams (e.g. Ratliff et al.1996), pronouncements regarding the death of the summer run of chinook salmon may be premature. Although there does not appear to be a separate group of chinook salmon with summer run timing that has maintained its reproductive isolation, renewed access to appropriate habitat above the dams could be followed by a re-emergence of the summer run phenotype.

Pacific salmon introduced into new habitat have shown they can develop new phenotypes in a relatively short time period (Healey and Prince 1995). In less than a century after the introduction of chinook salmon to New Zealand, the introduced stock developed phenotypes that diverged from the donor stock (Quinn and Unwin 1993). The introduction of fall chinook into tributaries of the Great Lakes in the 1970s resulted in at least one instance of the emergence of a spring spawning phenotype (Kwain and Thomas 1984). This latter example suggests a real possibility for the re-emergence of a summer run in the Deschutes River following renewal of passage past the dams. Reintroduction of the current summer/fall run chinook salmon to the appropriate habitat above the dams could allow the summer run phenotype to re-emerge. Beaty (1996) suggested referring to a summer/fall chinook salmon in the Deschutes River, instead of fall chinook to indicate the potential for re-establishing separate summer and fall runs. We believe Beaty's optimism is justified, however, for this report we use the single name, fall run to indicate fish other than spring chinook.



**Figure III-25.** Approximate historical spawning distribution of summer chinook in the Deschutes River.



**Figure III-26.** Approximate historical and current distribution of fall chinook in the Deschutes Basin.

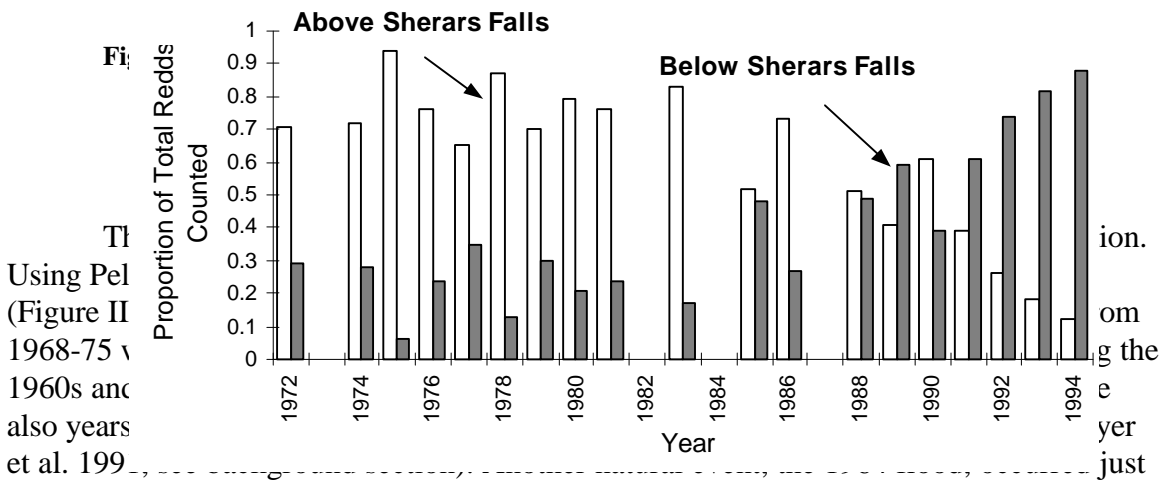


## b. Fall Chinook

### 1) Distribution

Fall chinook likely did not migrate past the site of Pelton Dam before it was constructed (Nehlsen 1995). It's possible that low summer flows blocked migration of fall chinook at Sherars Falls prior to 1940 when a fish ladder was built. However, beaver depletion and irrigation withdrawals impaired watershed function early in this century, possibly changing summer flows and making passage over Sherars Falls more difficult. The historical distribution of fall chinook was probably close to its current distribution possibly extending slightly above Pelton Dam (Figure III-26).

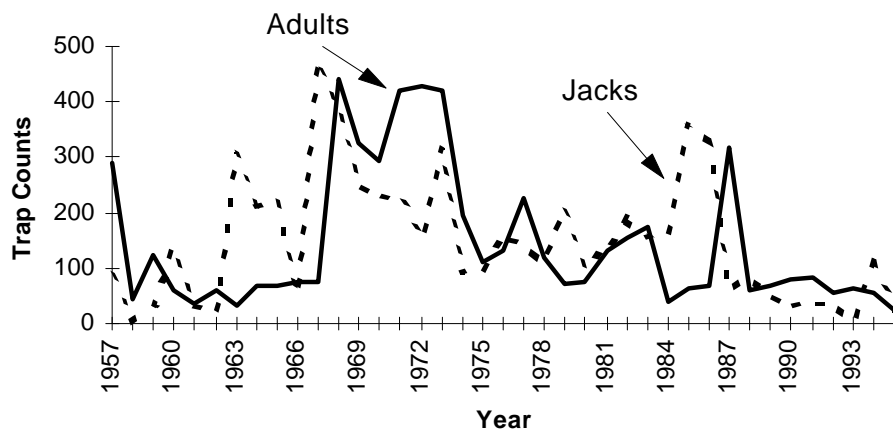
Since construction of the Pelton Round Butte Project, fall chinook have spawned throughout the lower Deschutes River from the mouth to the Pelton Reregulating Dam (RM 100 or RK 161). Prior to 1989, most of the spawning was concentrated in the upper river. From 1972 to 1988, 46% of the redds counted were located in the upper 6 miles (9.65 km) of the river between Dry Creek and the Pelton Reregulating Dam (Jonasson and Lindsay 1988). Fifty-five percent of the spawning gravel for fall chinook salmon was found in the 3 mile (4.83 km) stretch of the mainstem above Shitike Creek (Huntington 1985 cited in Jonasson and Lindsay 1988). Since the early 1980s, the proportion of fall chinook redds in the upper river above Sherars Falls has declined (Figure III-28). The distribution is now reversed. Most of the fall chinook redds are found below Sherars Falls (Beaty 1996).



before the increase in abundance in 1967. The flood may have improved the quality of spawning gravel.

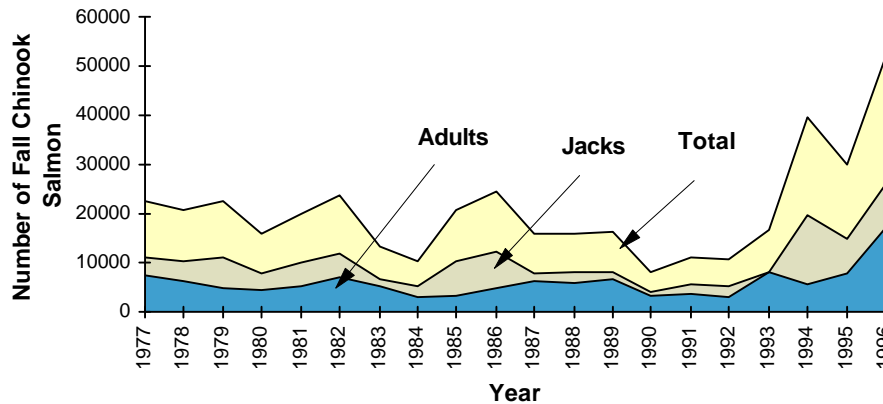
**Figure III-29.** Number of jack and adult fall chinook salmon at the Pelton Trap 1957-95. (Source: Beaty 1996)

## 2) Abundance



A 1903 survey of the Deschutes River found chinook salmon less abundant than steelhead (VanDusen 1903). However, the accuracy of the survey cannot be determined. Their finding may have been an artifact of high harvest rates in the lower Columbia and Deschutes rivers. High harvest rates in the late 19<sup>th</sup> and early 20<sup>th</sup> centuries might explain depressed spring and summer chinook stocks, but not fall chinook. Fishermen considered fall chinook inferior and targeted almost exclusively the spring and summer runs which were considered prime for canning purposes and for which they received a higher price (DeLoach 1939; Craig and Hacker 1940). After the turn of the century, the fishery shifted to fall chinook as the spring and summer runs went into decline (Lichatowich and Mobrand 1995).

The abundance of fall chinook salmon in the Deschutes River below Pelton Round Butte Dams has been monitored since 1977 (Figure III-30). Abundance of fall chinook has been variable with a period of decline between 1986 and 1993 followed by a significant increase in 1994, 1995 and 1996. Beaty (1996) analyzed the available information and could not conclusively identify a cause for the trough in production from 1986 to 1993 or for the shift in spawning distribution above and below Sherars Falls. He did develop several plausible hypotheses which should be prioritized and given further evaluation.



**Figure III-30.** Total run of fall chinook salmon in the Deschutes River 1977-96. (Source, Beaty 1996 and Personal communication, Jim Newton, ODFW)

### 3) Life History

The recovery in various salmon fisheries of coded wire tagged fall chinook from the Deschutes River suggest that they migrate through the lower Columbia River from late August to early October. The migration of fall chinook salmon past Sherars Falls peaks in September and October. There is probably some overlap between early arriving fall chinook and late migrating spring chinook during June and July (Jonasson and Lindsay 1988). In addition, some of the fish migrating in that period might include members of a relict population of summer chinook.

Mature fall chinook returning to the river range from age 2 to 6. When they migrated from the river as juveniles the majority were age 0 fish with a few migrating to sea as yearlings (Table III-6). Fall chinook spawn in the Deschutes River from September through December with a peak in November (Jonasson and Lindsay 1988).

Fall chinook emerge from the gravel from February through April and they generally rear in the areas where their parents spawned. The juveniles migrate from the river in May through July, however, some smolts are observed in the Deschutes River until mid-November. It would be difficult to determine whether those late migrating fish are from the spring or fall run. Juveniles whose parents spawned in the lower Deschutes River migrate to sea first; followed by juveniles from spawning areas in the upper reaches of the lower mainstem (Jonasson and Lindsay 1988).

**Table III-6.** Average percentage of age classes of adult fall chinook entering the Deschutes River from 1975 to 1980. (Source: Jonasson and Lindsay 1988).

Age Class <sup>a/</sup>	Percentage
2 <sub>1</sub>	34.0
3 <sub>1</sub>	28.9
3 <sub>2</sub>	1.3
4 <sub>1</sub>	29.5
4 <sub>2</sub>	1.6
5 <sub>1</sub>	3.7
5 <sub>2</sub>	0.9
6 <sub>1</sub>	0.1

<sup>a/</sup> Age is designated by a two digit symbol. The superscript t indicates the age at spawning and the subscript indicates the year of life the juvenile fall chinook went to sea. 4<sub>1</sub> would denote a fish that spawned in its fourth year of life and went to sea during its first year.

### **c. Spring Chinook**

#### **1) Distribution**

Spring chinook were once widely distributed in the Deschutes Basin: Crooked River, the upper mainstem, Squaw Creek, Metolius River, Shitike Creek and Warm Springs River (Figure III-28). Some spring chinook may have spawned in the mainstem between Pelton Dam and Squaw Creek.

In 1903, Oregon’s Master Fish Warden, described the Crooked River as a, “*sluggish stream used nearly entirely for irrigation purposes during the summer months of the year*” (VanDusen 1903 p. 16). He was looking for potential hatchery sites and the Crooked River was not an appealing prospect. By the time VanDusen made his survey, the first diversion of water from Crooked River was already 37 years old. Intensive grazing had already destroyed riparian vegetation and caused severe downcutting of stream channels in parts of the basin. The chronology of that degradation in Camp Creek was described by Buckley (1992).

Nehlsen (1995) reported several sightings of spring chinook in the Crooked River, however, there were no actual spring chinook spawning surveys conducted in the basin. We may never know for sure if the Crooked River sustained a viable population of spring chinook. However, the early descriptions of the undisturbed habitat, the presence of large numbers of beaver, and several reports of spring chinook or salmon in the basin establish a firm basis for assuming the existence of a native Crooked River stock of spring chinook. It is extinct today (Figure III-27). The weir observed by Ogden in 1826 is evidence that the number of fish in the Crooked River was sufficient to justify the effort to build the fish catching device. Some of those fish may have been spring chinook.

Habitat degradation resulting from the depletion of beaver, grazing and the development of irrigation reduced the productivity of spring chinook in the Crooked River early in this century. Construction of the Cove power Plant in 1910, probably blocked the migration of anadromous salmonids during periods of low flow. Bowman Dam (1961) located at RM 70 (RK 112.6) completely cut off the upper river to anadromous salmonids (Nehlsen. 1995). The Pelton Round Butte Project blocked access to the lower Crooked River in 1968.

The spawning distribution of spring chinook in the upper Deschutes River prior to the first surveys in 1951 is not known. Adult spring chinook trapped at Steelhead Falls indicate that the upper Deschutes River, up to that point, was probably used for spawning. The first spawning surveys in 1951 found spring chinook salmon spawning in the lower reaches of Squaw Creek. Before it was dewatered by irrigation, spring chinook may have spawned up to the forest boundary. A small number of spring chinook spawned in Squaw Creek in most years from 1951 to 1968 (Nehlsen 1995).

Because of its high quality, spring-fed water, the upper Metolius River supported a run of spring chinook salmon until passage of anadromous salmonids was terminated at Pelton Dam.

In the lower river, below the Pelton Reregulating Dam, spring chinook spawn in Shitike Creek and the Warm Springs River. Today, most of the spawning in Shitike Creek takes place in the lower reaches of the stream. A water intake dam, which was removed in 1983, limited access to the lower 7.15 miles (11.5 km) of the creek (Fritsch 1995). In the Warm Springs River, most of the wild spring chinook salmon (76%) spawn in the mainstem, above the hatchery. The remaining fish spawn in Beaver and Mill creeks (Lindsay et al. 1989).

## 2) Abundance

Crooked River was naturally warmer than the other spawning areas in the upper basin: Metolius River and Squaw Creek. Under pristine conditions, the stream temperatures in Crooked River were probably within the tolerance of spring chinook salmon in most years. Warm temperatures and faster growth of the juveniles in Crooked River could have produced a spring chinook population largely composed of the ocean-type life history.

Chinook salmon are usually characterized as exhibiting two juvenile life history patterns—stream or ocean type (Gilbert 1913; Healey 1991). Juvenile chinook following the stream type life history migrate to sea in their second year of life, whereas juveniles following the ocean type life history migrate in their first year, usually a few months after emerging from the gravel. Spring chinook salmon returning to the Deschutes River today are nearly all (99%) stream type fish (Lindsay et al. 1989). However, life history type in chinook salmon is not determined by race (spring, summer, fall), although a life history

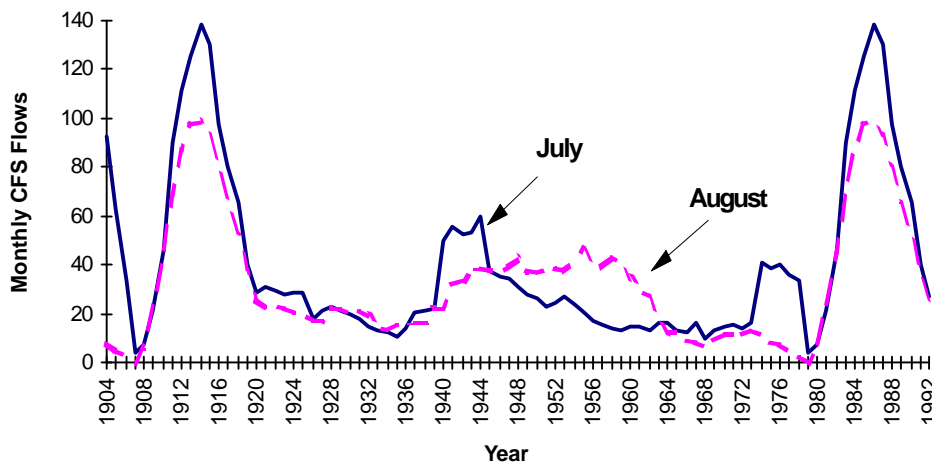
type may be more closely associated with a specific race. For example, fall chinook generally follow the ocean type life history. In wild chinook salmon populations, the propensity to migrate during their first year (ocean type) or in the spring of their second year (stream type) is a function of growth opportunity, which is determined by photoperiod at emergence and normal stream temperature (Taylor 1991). Responsiveness to photoperiod may be under Mendelian genetic control; experimental crosses suggest that the ocean type life history is dominant (Clarke et al. 1992). In streams flowing through arid areas of the Cascade rain shadow, such as the Crooked River, warm water for rearing and early emergence could have provided sufficient growth opportunity to produce the ocean type life history in spring chinook. In Oregon, the highly productive spring chinook population in the Rogue River is largely ocean type fish (90%) (Cramer and McPherson 1981).

Juvenile chinook salmon tend to exhibit a nearly continuous downstream migration, with the larger fish migrating earliest (Rich 1920; Nicholas and Hankin 1989). As the larger juveniles migrate downstream they “release” habitat in the upstream rearing area for the remaining smaller fish. Chinook salmon appear to have incorporated in their life history a natural grading system. Under this scenario spring chinook habitat has a spatial and temporal component (Mobrand et al. 1997). The net effect is greatly expanded capacity and productivity of the habitat.

The ocean type life history in spring chinook is heavily impacted by irrigation withdrawals. Spring chinook spawn higher in the watershed often above irrigation diversions. So the ocean type juveniles which are moving downstream during the summer, must migrate past the diversions, usually during the peak irrigation season. Irrigation diversions were largely unscreened prior to 1930. Juveniles entering the unscreened diversions were killed by the millions in some streams (Lichatowich and Mobrand 1995). Juveniles that managed to reach the lower reaches of tributary streams often found inadequate flows and elevated temperatures. The decline of spring and summer chinook salmon in the Yakima River from an annual run of about 300,000 fish to about 1,000 to 2,000 fish by 1930 was attributed to mortality at irrigation diversions and elevated temperatures in the lower river, both of which eliminated the ocean type life history (Lichatowich and Mobrand 1995). If it produced an ocean type, spring chinook life history, the Crooked River could have been a major producer of spring chinook salmon prior to Euroamerican settlement.

Even after the early grazing destroyed the riparian vegetation and if irrigation diversions were killing juvenile salmon, Crooked River might have been capable of producing large runs of spring chinook from time to time in response to natural environmental fluctuations. Anecdotal evidence of this comes from the Umatilla River, another warm river flowing through the steppe and steppe-shrub ecological zone in Oregon. By 1904, observers noted that irrigation combined with naturally low summer flows dried up the lower Umatilla River and prevented juvenile salmon from migrating out of the stream during the summer (Pacific Fishermen 1904). However, Van Cleve and Ting (1960) reported that in 1914 there was a large run of spring and fall chinook salmon into the Umatilla River. “Indians and white people ‘caught thousands and thousands of salmon from spring to fall’.” High summer flows in the Umatilla River between 1910 and 1917 (Figure III-31) could have permitted a re-expression of the ocean type life history (summer migrants) and a large increase in the run such as the one observed in 1914. After 1914, dams in the lower Umatilla River extirpated spring chinook in that basin.

**Figure III-31.** Five-year running average of July and August flows in Umatilla River, near Umatilla, Oregon, 1904-92. (Source: U. S. Geological Survey Station Number 14033500)

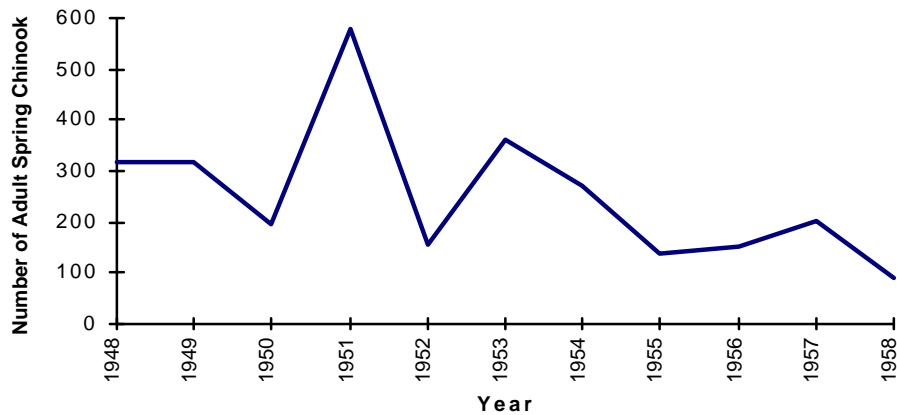


the time of the first survey in 1951, only a remnant population remained. Between the first survey in 1951 through the last in 1960, the number of spring chinook observed in Squaw Creek declined from 14 to 0 fish (Nehlsen 1995). Apparently spring chinook in Squaw Creek had been eliminated from the upper basin by mortality at irrigation diversions before the first survey was undertaken.

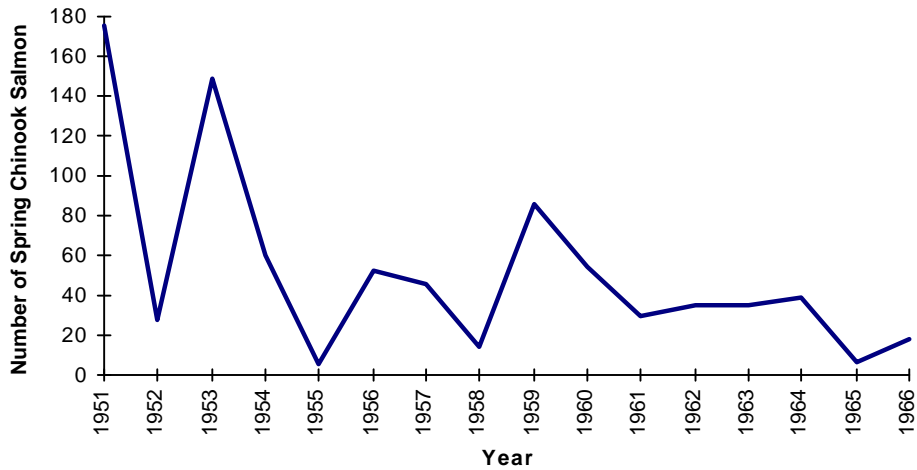
At the time the first surveys of anadromous salmonids were carried out in the Deschutes River, the Metolius River supported the largest run of spring chinook into the upper basin. That is not surprising since the Metolius River was disturbed less than the

other subbasins by Euroamerican development. Early reports indicated that the spring chinook run into the Metolius River was large (Davidson 1953); as late as 1949, it was estimated to be 2,000 fish (a 1949 document [author unknown] describing stream surveys conducted in 1949-- obtained from Mark Fritsch, CTWSRO). However, about the time that estimate was made, the Metolius River was raked and hatchery program initiated. The number of spring chinook captured at the rack never exceeded 600 fish (Wallis 1960) (Figure III-32). Spawning ground counts showed a steady decline in the Metolius River from 1953 until 1966 (Figure III-33). All migration past Pelton Dam was terminated in 1968.

Abundance of spring chinook in the Deschutes River below Pelton Dam was not estimated before 1969. The principal production areas are the Warm Springs River and Shitike Creek. In 1949, a survey of the Deschutes River estimated that 1,500 to 2,500 spring chinook spawned in the entire lower Deschutes River below the area of the future Pelton Reregulating Dam (a 1949 document [author unknown] describing stream surveys conducted in 1949; obtained from Mark Fritsch, CTWSRO).

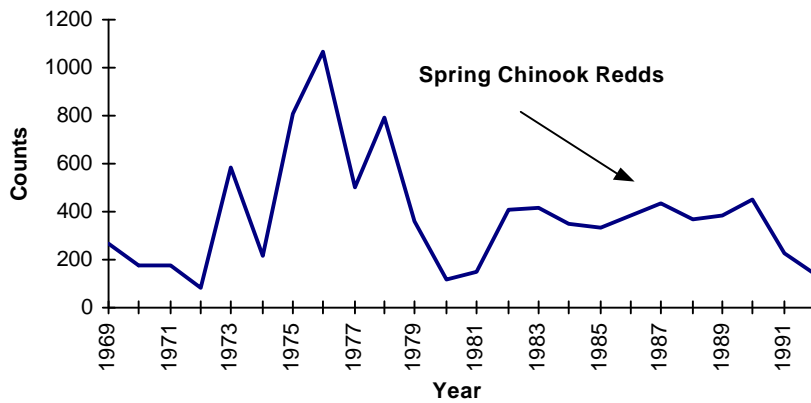


**Figure III-32.** Number of adult spring chinook counted at the Metolius Hatchery rack, 1948-58. (Source: Wallis 1960).

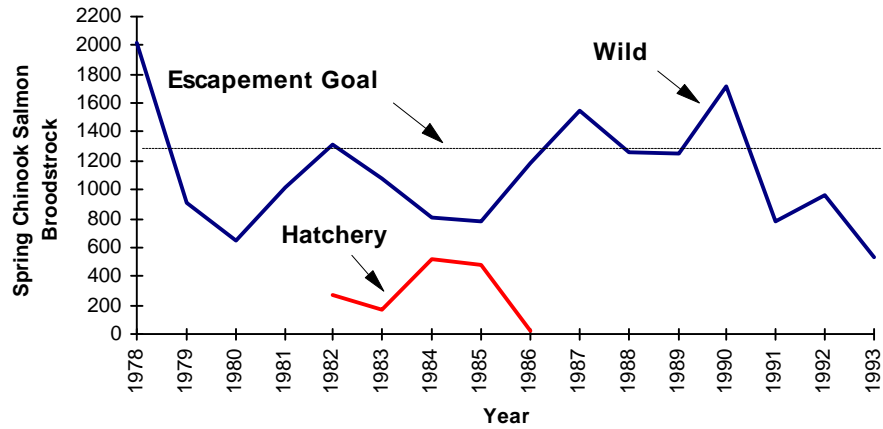


**Figure III-33.** Number of spring chinook salmon observed in spawning surveys of the Metolius River and its tributaries, 1951-66. (Source: Nehlsen 1995)

Since surveys were initiated in 1969, the total number of spring chinook redds counted in the Warm Springs River has varied from a low of 87 in 1972 to 1,066 in 1976 (Figure III-34). An escapement goal of 1,300 fish for the Warm Springs River was derived from a Ricker spawner-recruit model. In the 16-year period, 1978 to 1993, the escapements of wild spring chinook above the hatchery exceeded 1,000 fish 9 times. If hatchery fish passed above the weir are added to the total escapement, 1,000 or more spring chinook spawned in the Warm Springs above the hatchery in 11 out of the 16 years (Olson et al. 1995) (Figure III-35).



**Figure III-34.** Total number of spring chinook redds counted in the Warm Springs River, 1969-92. Counts from 1969-76 do not include index areas below Warm Springs National Fish Hatchery. (Source: Fritsch 1995)



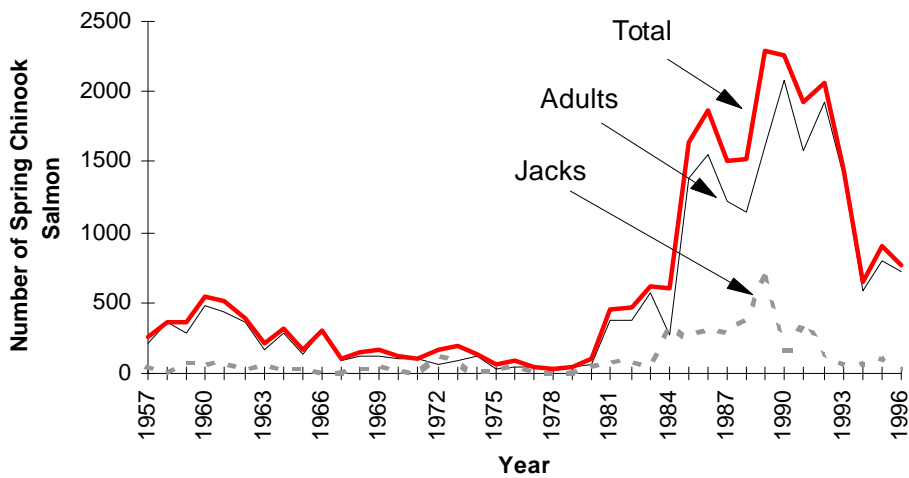
**Figure III-35.** Number of hatchery and wild spring chinook salmon allowed to pass the hatchery weir and spawn in the Warm Springs River, 1978-93. (Source: Olson et al. 1995).

A few spring chinook spawn in Shitike Creek and the number of redds in the index area (lower 6 miles [9.65 km] of the river) has varied from 2 in 1979 to 16 in 1982.

Round Butte Hatchery releases spring chinook below Pelton Dam as mitigation for spring chinook that originally spawned in the Deschutes and Metolius rivers above the hydro Project.

Spring chinook salmon have been captured at the Pelton Trap since 1957 (Figure III-36). Changes in hatchery practices including the use of more natural juvenile rearing conditions in the Pelton fish ladder have led to increases in adult returns in recent years (Lindsay et al. 1989).

**Figure III-36.** Adults, jacks and total spring chinook salmon captured in the Pelton



Trap, 1957-96. (Source: Lindsay et al. 1989; D. Ratliff, Portland General Electric Company, unpublished data)

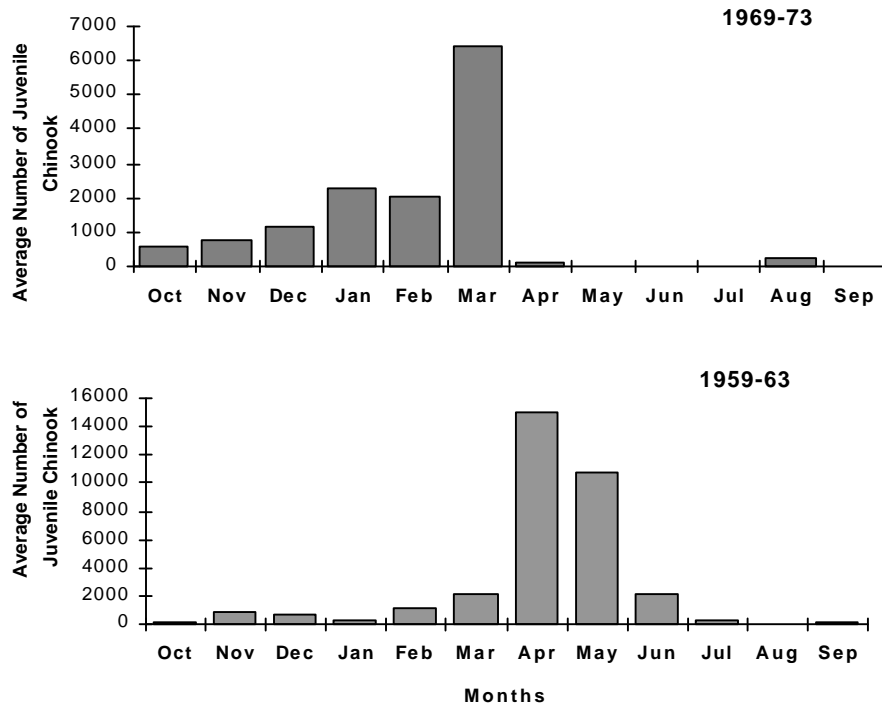
### 3) Life History

Nothing is known about the life history of spring chinook salmon in the Crooked River. However, as mentioned earlier, the warm water in the Crooked River would have created conditions suitable for the ocean type life history. Most of the juvenile spring chinook salmon from the Crooked River probably went to sea in their first year (ocean type). In streams with enhanced growth opportunity, a large proportion or majority of the population migrate to sea in their first year. For example, in the Rogue River (Cramer and McPherson 1981) and the Klamath River (Snyder 1931) the majority of the spring chinook salmon followed the ocean type life history. Even in the Situk River, Alaska most juvenile chinook salmon follow the ocean type life history (Johnson et al. 1992). The Situk River is above 56°N, which is the theoretical northern limit of the ocean type life history (Taylor 1990). Unusual growth opportunity enhanced by water flowing out of Situk Lake, created the ocean type life history outside its normal range.

The Metolius River, fed by springs which maintain a uniform temperature, could have produced unique life histories in spring chinook salmon. The unique winter-run, life history of chinook salmon found in the Sacramento River was a product of unique environments in tributaries fed largely by constant temperature springs (Slater 1963). The presence of an unusual life history pattern in the Metolius River was not detected in the limited monitoring that was carried out before passage at Pelton Dam was terminated.

Juvenile chinook salmon migrating from the Metolius River into Lake Simtustus were captured in scoop traps in 1960 and 1961 (Newton 1973). The juveniles entered Lake Simtustus in late March and early April and their migration peaked in April and May at Pelton Dam.

The migration of juvenile chinook salmon was also monitored at Pelton Dam from 1959 to 1973. The migration of juvenile chinook salmon underwent an apparent shift in timing after completion of Round Butte Dam in 1964 (Figure III-37). Prior to 1964, migration peaked in April and May, however, after 1964, migration peaked in March. The reservoirs appeared to select against the later migrating juveniles, however, there is no indication as to what the selection factor was (predation, for example). Nehlsen (1995) cited a personal communication from George Eicher that no subyearling juvenile chinook were observed migrating past the Pelton Dam during the project evaluations. However, juveniles were migrating in nearly every month of the year from 1959 to 1965 (Newton 1973 Table 14) which strongly suggests that some subyearling juveniles were migrating downstream in the years immediately following the construction of Pelton Dam. Subyearling migrants may have been moving directly to the ocean or they may have been moving to the lower river to rear followed by migration to sea as yearlings the following spring.



**Figure III-37.** Average number of juvenile chinook salmon captured in the Pelton migrant trap, 1959-63 and 1969-73. (Source: Newton 1973)

The migration of chinook juveniles from the Warm Springs River has been monitored since 1976. The juveniles move downstream throughout much of the year, but exhibit strong peaks in spring and fall (February through May and September through December). The spring migration is composed primarily of yearlings with a few subyearlings. The fall migration is entirely subyearlings. The subyearling migrants in both the spring and fall periods, over-winter in the Deschutes or Columbia mainstems before migrating to sea as yearlings. A very small percentage of the juveniles (1%) migrate to sea as subyearlings (Lindsay et al. 1989). The subyearling chinook salmon that migrate in fall show a survival advantage over juvenile that remain in the Warm Springs River over-winter and migrate to sea in the spring (Lindsay et al. 1989). The fall migrants over-winter in the mainstem Deschutes or Columbia rivers, and apparently habitat conditions in those areas are better than winter habitat in the Warm Springs River. The specific, favorable habitat attribute has not been identified and it is not known if the survival advantage is consistent from year to year.

Adult spring chinook from the Warm Springs River exhibit a narrow age distribution. About 80% of the returning adults from 1977 to 1985 were age 4 and about 15% were age 5, the remaining were age 3 (Lindsay et al. 1989). A data set covering 17 years collected by CTWSRO showed 77% age 4, 18% age 5 and 0.05% age 3 (Personal communication, Colleen Fagan, CTWSRO).

#### **d. Genetics**

The largest allozyme database available for an Oregon salmonid exists for chinook salmon (Kostow 1995) because the examination of allozyme variation in fall chinook salmon has been used since the 1970s to determine stock composition in mixed stock fisheries (Bartley and Gall 1990; Bartley et al. 1990; Schreck et al. 1986; Utter et al. 1989; Utter et al. 1995; Utter et al. 1987). Previously such work was referred to as genetic stock identification; however, more recently, it has been called mixed stock analysis (Utter and Ryman 1993).

Kostow (1995) recognizes spring and fall races of chinook salmon in the Deschutes Basin, but not summer chinook, in spite of a pulse of adult chinook salmon that enter the Deschutes River in July. In the Columbia River, summer and fall chinook are closely related, while in the Snake River, the summer run is more closely related to spring chinook. Additional examination of the genetic and life history attributes of the early returning (July) fall chinook in the Deschutes might further resolve whether this group is a remnant of the summer run or an early fall run of chinook.

Kostow (1995) lists the Deschutes River spring chinook as part of the mid-Columbia GCG. Presently, the mid-Columbia GCG includes two Deschutes River populations (Warm Springs River and Shitike Creek) and four John Day River populations (north fork, middle fork, Granite Creek and the upper mainstem). Nevertheless, clear allozyme differences exist between the Deschutes and John Day spring chinook populations (Marshall 1993). Due to the small samples sizes analyzed (Marshall in Kostow 1995), further study may indicate that separation of the Deschutes and John Day spring chinook populations is warranted. Differences or similarities between the Warm Springs and Shitike Creek populations in the Deschutes subbasin were not discussed in the Kostow report, so it was not possible for us to assess the genetic structure of spring chinook populations within the Deschutes drainage or to make inferences about historic metapopulation structure. The Kostow report notes the extinction of the Metolius River and Squaw Creek spring chinook populations, but makes no mention of spring chinook stocks in the Crooked River. As noted above in our report, the Crooked River stock, which may have contributed substantially to historic spring chinook production from the Deschutes system, was probably extirpated prior to any systematic inventory of salmonids in the Deschutes Basin.

The Deschutes fall chinook, which is presently confined to a single isolated population in the mainstem Deschutes River, appears unique compared to other Columbia Basin tributary fall chinook populations. Based on allozyme analysis (Marshall 1993) it does not cluster with any other Oregon populations, but is most similar to fall chinook populations in the Hanford Reach and the Yakima River. Other Oregon fall chinook populations tend to be similar to one another and less similar to the Hanford Reach fall chinook (Kostow 1995). Historically, the Deschutes fall chinook population was probably

part of a regional group of populations that included the now extinct populations from the John Day, Umatilla and Walla Walla rivers.

There has never been a hatchery program for fall chinook in the Deschutes and very few hatchery strays from other basins have been found in spawning surveys (Kostow 1995). Because of this and the extinction of all other closely related fall chinook populations in the adjacent region (John Day, Umatilla and Walla Walla rivers), the Deschutes fall chinook population is an important genetic resource. The Deschutes population of fall chinook could play a key role in the restoration of fall chinook populations in the mid-Columbia tributaries. Key elements in selection of an appropriate stock in most restoration programs are the ecological similarity and geographic proximity of the donor stock to the extirpated stock. Restoration programs for fall chinook in the John Day, Umatilla and Walla Walla rivers should place high value on the Deschutes fall chinook as a donor stock.

### **3. Sockeye/Kokanee Salmon**

ODFW identified four populations of sockeye/kokanee salmon in the Deschutes GCG (Kostow 1995). One of the four populations is anadromous and it has been suggested that it spawns in the Deschutes River below Pelton Dam (Kostow 1995). Based on several years of experience and observation, fish managers have never documented the existence of this anadromous population and they question its existence (Personal communication, Jim Newtown, ODFW and Collene Fagan, CTWSRO). Although the Link Creek/Suttle Lake and Metolius River/Lake Billy Chinook populations are both in the Metolius Basin they are physically separated and their isolation has probably caused them to diverge. The remaining population is from Odell Lake (Kostow 1995).

The origin of the two populations in the Metolius Basin is uncertain. In 1959, Rulifson (1959) concluded there were no surviving natural runs of sockeye salmon into any Oregon streams, although historically the Deschutes and Grande Ronde basins did support natural populations. A hatchery located on Spring Creek in the upper Metolius River imported sockeye eggs, primarily from Leavenworth Hatchery (Washington State) beginning in 1947. Eggs were imported for at least the next twelve years (Wallis 1960). If the natural run was extinct by 1959, the current populations might be a mixture of imported stocks. On the other hand, there is the possibility that the transfers did not persist and the existing kokanee populations were derived from a small number of native sockeye that were overlooked in the earlier surveys. The size of the run in the 1950s may have been too small to be detected and was therefore believed to be extinct.

#### **a. Distribution**

Historically, sockeye salmon migrated through the Deschutes and Metolius rivers into Lake Creek through Suttle Lake to Link Creek where they spawned. The juveniles

reared in Suttle Lake. The anadromous form of sockeye could not migrate upstream past Pelton Dam after passage was terminated in 1968 (Nehlsen 1995; Fies et al. 1996b).

Kokanee migrate from Lake Billy Chinook to the upper reaches of the Metolius River and into several tributaries to spawn. The kokanee that migrate into the Metolius River account for the majority of the spawners, however, a few kokanee also spawn in Crooked River below Opal Springs, the upper Deschutes River and other small tributaries (Stuart et al. 1996). Three sites in the Metolius River at RM 30, 36, and 37 (RK 48.3, 57.9 and 59.5) appear to be important spawning areas. Two tributaries, Heising Spring and Spring Creek are important tributary spawning areas (Schulz and Thiesfeld 1996).

### **b. Abundance**

The early reports of sockeye salmon in the Metolius River give varying accounts of their abundance (Nehlsen 1995). One could draw almost any conclusion about the abundance of sockeye salmon from the mixture of observations presented in Nehlsen's monograph. After Pelton Dam was constructed, the counts of sockeye salmon ranged from about 30 to 332 fish. Most of these were artificially propagated, however, a few (2 to 35) wild sockeye salmon also migrated past Pelton Dam (Nehlsen 1995).

The population of kokanee in Lake Billy Chinook apparently was derived from natural reproduction. Prior to 1968, the fishery in Lake Billy Chinook was dominated by rainbow trout. In 1964 and 1965, kokanee comprised less than 1% of the fish captured in trapping operations (Mullarkey 1967). However, in 1968, a dramatic shift took place. Kokanee dominated the harvest, but that was two years before the first hatchery kokanee were planted into the reservoir (Herrig 1969). Today kokanee are the most abundant species in the reservoir and their abundance may reach 300,000 fish (estimates derived from trawling) to nearly a million fish (estimate derived from acoustic sampling) (Thiesfeld 1997).

Spawning surveys in the Metolius River monitored 11 mainstem and 15 tributary sites for spawning kokanee from Lake Billy Chinook in 1994 and 1995. The total count of spawners from all survey sites was 7,633 fish in 1994 and 1,629 fish in 1995 (Schulz and Thiesfeld 1996). These were not complete counts of all spawners. The spawning run from Suttle Lake into Link Creek numbers in the hundreds (Kostow 1995).

### **c. Life History**

Kokanee from Lake Billy Chinook spawn in the Metolius River from early September to mid-November (Schulz and Thiesfeld 1996). The spawning migration begins in July when the kokanee concentrate in the Metolius arm of Lake Billy Chinook. They migrate to the spawning areas in the Metolius River during late August and September (Stuart et al. 1996). The downstream migration of juvenile kokanee occurs through late winter and some age-0 kokanee are captured in the reservoir as early as January.

Shortly after emerging from the gravel, most juvenile sockeye salmon migrate from the spawning areas to a nursery lake for their freshwater rearing. A riverine rearing life history for juvenile sockeye salmon is unusual, but not unheard of (Brugner 1991). Kokanee may retain the smoltification cycle of their anadromous counterparts (Foote et al. 1994) and, therefore, be capable of migrating to sea and switching to the anadromous life history. This supports the theory that the small sockeye run below Pelton Dam is derived from kokanee “leaking” out of the reservoirs.

### **d. Genetics**

The primary genetics work on sockeye and kokanee in the Deschutes system has been done by the University of Idaho Aquaculture Research Institute (Matt Powell and Rick Williams, unpublished data). They have presently examined mitochondrial DNA (mtDNA) variation in over 1,400 sockeye and kokanee specimens throughout the Columbia River Basin and British Columbia. Powell and Williams examined 17 adult specimens (not determined whether they were “sockeye” or “kokanee”) that returned to the Pelton Fish Trap over a two year period. They identified five mitochondrial DNA haplotypes in the 17 specimens. Three haplotypes occurred most frequently in the adult specimens. Two of these, H-7 and H-18 are ubiquitous in sockeye and kokanee populations throughout the Columbia River basin and British Columbia. The third haplotype, H-9, does not have a widespread geographic distribution, but is prevalent in samples from the Stanley Basin, Idaho. One haplotype, H-20, was unique among the 1,400 specimens we have examined to this point. It’s uniqueness was due to a unique restriction site, rather than to a unique combination of restriction patterns among different restriction enzymes. The former has more evolutionary significance than the latter; but unfortunately provides little insight into the relationship between adults returning to the Pelton Trap and upstream kokanee populations.

Powell and Williams also examined kokanee populations from the Metolius River at two locations, Wizard Falls (N= 53 specimens) and the Gorge Campground (N= 38 specimens). Five haplotypes were observed in the two kokanee samples, however, 2 of the 5 haplotypes were not observed in the 17 adult samples. One haplotype, oddly enough has been observed only in kokanee from Petit Lake in the Stanley Basin in Idaho.

Although the Deschutes adult sample and the two Metolius kokanee samples shared many common mtDNA haplotypes, frequencies of the various haplotypes were quite different. If the adult specimens were returning adults from kokanee passed through the Pelton Round Butte Project, one would expect the mtDNA haplotype frequencies of the adult sample group to reflect the haplotype frequencies of the upstream kokanee populations. Because the haplotype frequencies of the two groups differ more than could be attributed to the small number of adults sampled, there appears little support for the idea that the adult specimens were derived from downstream drift of kokanee from the Metolius system. Increased samples sizes for the adult specimens would help clarify this question, as would additional kokanee samples from Link Creek and Suttle Lake in the upper Metolius.

In examining mtDNA variation in sockeye and kokanee throughout the Columbia River Basin and southern British Columbia, Powell and Williams did not find clearly defined geographic structure. This is in marked contrast to studies of mtDNA variation in sockeye from British Columbia northwards through Alaska and across the northern and western Pacific Rim (Altukhov and Salmenkova 1991; Wood 1995; Wood et al. 1994). Similar patterns of geographic structuring of mtDNA (and other genetic markers) is typically the rule, rather than the exception for salmonid species, including chinook salmon (Utter et al. 1995), bull trout (Williams et al. 1997b) and cutthroat trout (Shiozawa and Evans 1995). Powell and Williams concluded that the typical pattern of geographical genetic structure had been strongly compromised for Columbia Basin *O. nerka* populations by the common and widespread transfer of kokanee stocks, many of non-native origin (i.e., out-of-basin transfers). Unfortunately, many of the transfers were successful and have left molecular traces of their various origins in the subsequent population. Thus, past fisheries management practices have severely compromised our ability to use molecular genetic tools for the historical reconstruction of sockeye and kokanee populations in the Columbia Basin in general and perhaps in the Deschutes, although this is uncertain without samples from Suttle Lake.

#### **4. Bull Trout**

Bull trout *Salvelinus confluentus*, a recently described species (Cavender 1978; Haas and McPhail 1991), are an inland char distributed primarily throughout the Intermountain West from northern California, where they are thought to be extirpated (Moyle and Williams 1990; Williams et al. 1989), to the upper Yukon and MacKenzie drainages in Canada. Bull trout are largely peripatric and occasionally sympatric with the coastally distributed Dolly Varden *S. malma*. Bull trout numbers have declined dramatically throughout much of its range due to habitat degradation, blockage of spawning migrations by construction of dams, misguided fisheries management practices including eradication efforts, and the introduction of non-native salmonids. Lake trout *S. namaycush*, brown trout *Salmo trutta*, and rainbow trout *O. mykiss* are thought to have replaced bull trout populations through competitive displacement (Boag 1987; Donald and Alger 1993; Nelson 1965); whereas, brook trout *S. fontinalis* can adversely affect bull

trout populations through competitive displacement as well as extensive hybridization (Ferguson 1990; Leary et al. 1983; Leary et al. 1985a; Leary et al. 1985b; Markle 1992).

Bull trout have been listed as a threatened species throughout most of the intermountain west and Pacific Northwest. That decision has been overturned, and they are now proposed for listing in part of their range; for example, the Columbia River and Klamath Basin populations are listed as threatened. Management agencies are interested not only in preserving remaining bull trout populations, but also in elucidating basic life history information, and determining the extent and structure of residual genetic variation. Such information can lead to rational management plans that preserve existing ecological and genetic diversity (Allendorf and Leary 1988; Meffe and Vrijenhoek 1988; Quattro and Vrijenhoek 1989; Stuart et al. 1997; Wayne 1992). Buchanan et al. (1997) listed six bull trout populations and their status in the Deschutes Basin. These same six populations were also identified by Ratliff and Howell (1992). The upper Deschutes and Crescent Lake populations are probably extinct. The Metolius population is at low risk. Shitike and Warm Springs populations are considered moderate risk and the Odell Lake populations at high risk of extinction (Buchanan et al. 1997).

#### **a. Distribution**

In the Columbia River Basin, bull trout occur primarily east of the Cascade Mountain crest into the upper Columbia and Snake River drainages. In the Deschutes Basin, bull trout were historically distributed throughout most of the basin including, the Metolius drainage, Crescent Lake and Crescent Creek, Odell Lake and Odell Creek, Davis Lake, the upper Deschutes River (above the present Lake Billy Chinook), several lower Deschutes River tributaries, and the Crooked River upstream of Prineville (ODFW 1994). A number of separate populations may have existed. In the Deschutes, bull trout above Big Falls, RM 132 (RK 212), were isolated from populations in the lower river (Ratliff et al. 1996).

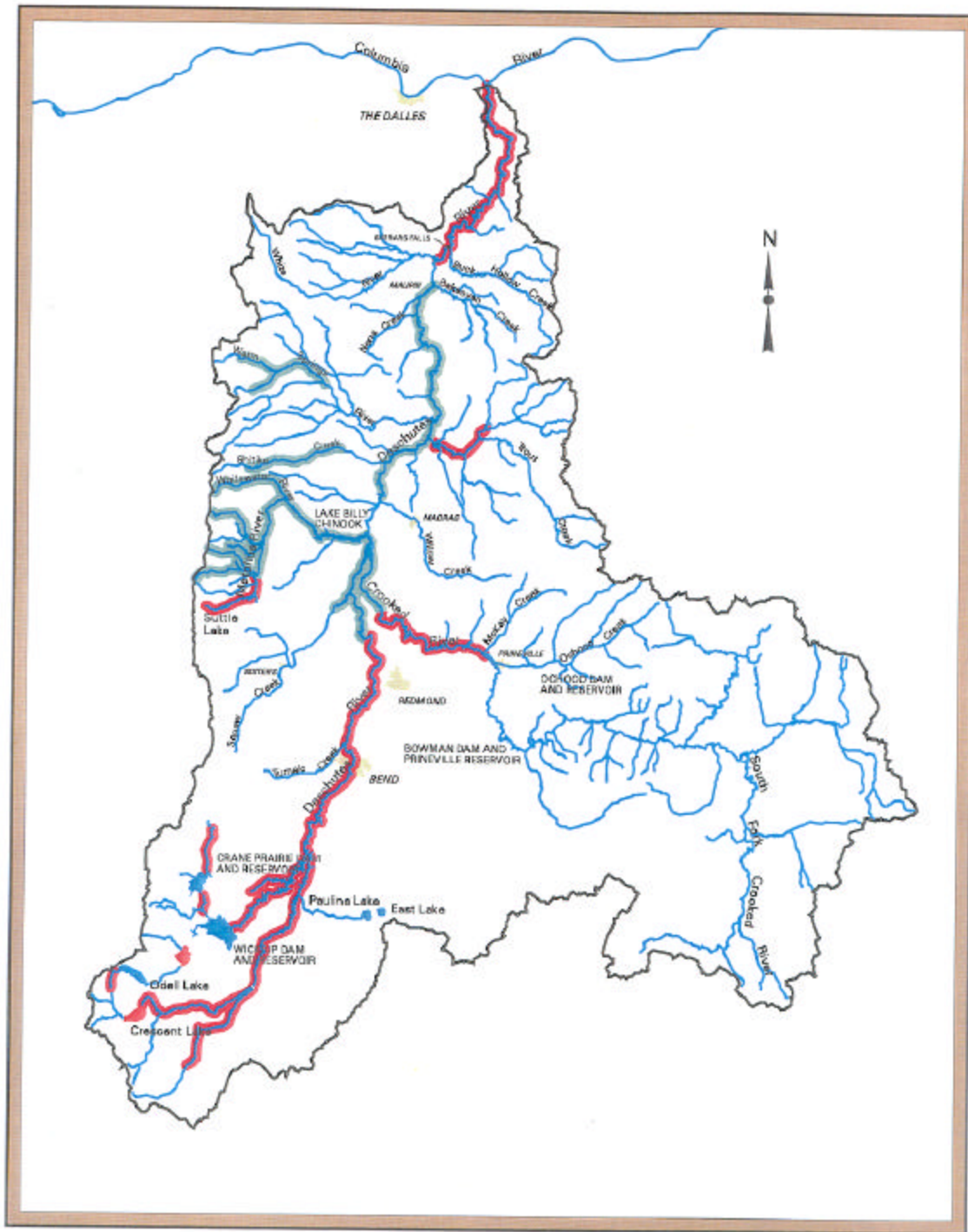
Presently, bull trout are found in the Metolius River and its tributaries, Lake Billy Chinook, Lake Simtustus, in the Deschutes River from Lake Billy Chinook up to Steelhead Falls, and the Crooked River up to Opal Springs. Numbers are greatest in the Metolius River and Lake Billy Chinook. Bull trout are also found in the lower Deschutes and two of its tributaries, Shitike Creek and the Warm Springs River (Ratliff et al. 1996) (Figure III-38). Abundance of bull trout below Pelton Reregulating Dam appears to be low. The status of bull trout in Shitike Creek was recently downgraded from low risk to moderate risk because of the presence of brook trout and low spawner counts (Buchanan et al. 1997).

Historical surveys indicate that the current abundance of bull trout is the highest in 40-50 years and the Metolius-Lake Billy Chinook population

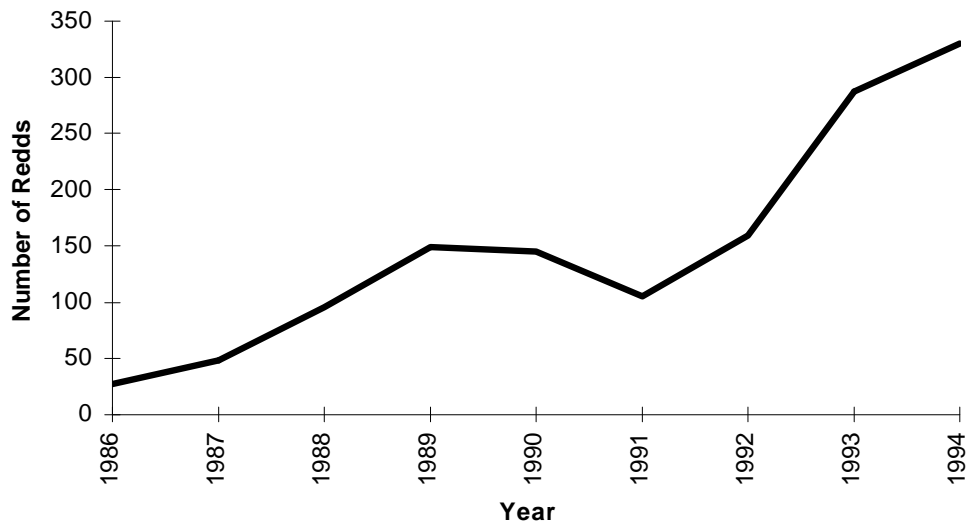
may be one of the most robust bull trout populations in the Columbia Basin. ODFW has instituted restrictive regulations requiring catch-and-release on wild trout (including bull trout) in the Metolius River and reductions in bag limits to one fish over 24" in length and size restrictions for bull trout harvest in Lake Billy Chinook (Thiesfeld et al. 1995; Ratliff et al. 1997; Stuart et al. 1997). The CTWSRO also instituted restrictive angling regulations including a no fishing sanctuary in the lower Metolius River to protect staging adults (Personal communication, Colleen Fagan, CTWSRO). As a result of angler education and the restrictive angling regulations, bull trout abundance in Lake Billy Chinook and the Metolius River appears to be increasing (Riehle et al. 1997). Several indices support this observation including an increase in redd counts in the Metolius system from 27 redds in 1986 to 330 redds in 1994 (Figure III-39). Redd count data for 1995 and 1996 show a decrease (Personal communication, Colleen Fagan, CTWSRO).

#### **b. Abundance**

Historical abundance of bull trout has been difficult to estimate in the Deschutes Basin; however, ODFW has compiled old files, reports, personal interviews and local historical publications (ODFW 1994). The historical analysis suggests that bull trout populations in the early 1940s were more abundant than today, while populations in the 1950s were similar to the present. Bull trout abundance in the early 1990s, is better than anytime since the late 1950s. Juvenile fish densities are similar to those observed in the Flathead River (Fraley and Shepard 1989) and the Pend Orielle River (Pratt 1985).



**Figure III-38.** Approximate historical spawning distribution of bull trout in the Deschutes River. (Source: Buchanan et al. 1997)



**Figure III-39.** The number of bull trout redds observed in the Metolius Basin. (Source: Riehle et al. 1997; Buchanan et al. 1997; ODFW 1994)

The recovery of bull trout abundance in the Metolius system and Lake Billy Chinook, coupled with the large size of some bull trout in Lake Billy Chinook (>10 kg), has resulted in increased angler effort (around 140,000 annual angler hours in the early 1990s) (ODFW 1994). In 1993 and 1994, the bull trout population was estimated to be 818 and 1,895 fish respectively. These were Peterson population estimates (Ratliff et al. 1996). Riehle et al. (1997) estimated the adult population at about 600 fish based on data from the early 1990s.

Clearly the restrictive fishing regulations in the Lake Billy Chinook and Metolius system have had a positive effect on bull trout abundance. It will be important to monitor bull trout abundance (adult and juvenile) in years to come, as the population appears to be steadily increasing. At some point, one would assume that either spawning habitat, juvenile rearing habitat or prey availability will become limiting. A cautionary note is appropriate, however, as a key component to the bull trout's recent increased abundance is likely the availability of prey species, such as kokanee in Lake Billy Chinook. Variation in the abundance of kokanee would likely affect bull trout abundance.

### c. Life History

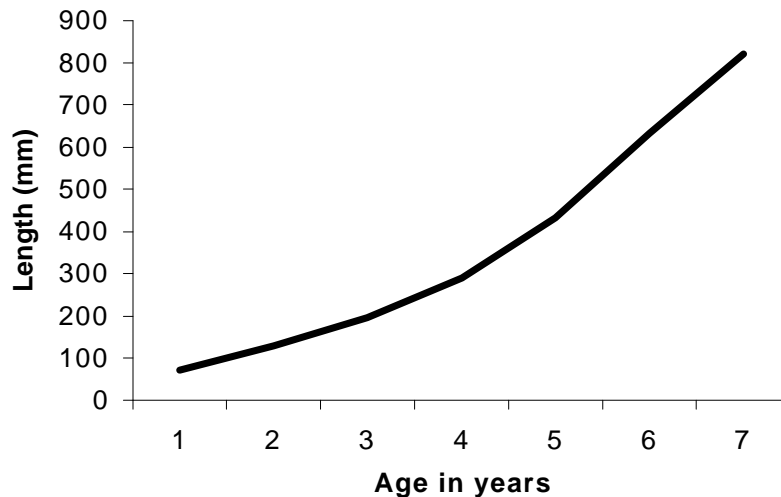
Bull trout, like other char species, have multiple life history forms with complex age structure, behavior, and maturation schedules (Rieman and McIntyre 1993; Rieman and McIntyre 1995; Rieman and McIntyre 1996). Resident and migratory (both fluvial and adfluvial) forms exist throughout the range. Resident populations typically occur in small

headwater streams where they spend their entire life cycle (Goetz 1989). Juveniles of migratory forms rear in tributary streams for several years before migrating downstream into larger rivers (fluvial form) or lakes (adfluvial form) (Shepard et al. 1984). Sexually mature adults migrate back into the tributaries to spawn from August through November. Spawning is associated with falling water temperatures between 32.9°F and 48.2°F (5°C and 9°C).

In the Metolius system, bull trout presently exhibit primarily an adfluvial life history. Although scale information and tag recaptures suggest that some fish have a fluvial life history (Personal communication, Michael Riehle, USDA Forest Service). Historically, a fluvial life history predominated; however the formation of Lake Billy Chinook with completion of the Pelton Round Butte Project, shifted the population to an adfluvial life history. It is uncertain if a strictly fluvial life history remains extant. Bull trout spawn in Jack, Canyon, Roaring, Heising, Candle, and Jefferson creeks (Ratliff 1992; Riehle et al. 1997), as well as in a spring in the upper meadows of Whitewater River (Thiesfeld et al. 1996). Bull trout also spawn in the Metolius River from Jack Creek to Canyon Creek. Adult bull trout reside in Lake Billy Chinook, as well as in the Metolius River mainstem above Lake Billy Chinook. Adult bull trout implanted with radio transmitters in Lake Billy Chinook, remained near the mouth of the Metolius river until mid-July when they initiated upstream migration (Thiesfeld et al. 1996). Most fish moved quickly through the Metolius to the mouth of the intended spawning streams. From that point, movement into the tributary stream, spawning, and movement back into the mainstem Metolius occurred within one month. Bull trout moving into the Whitewater system, which lacks the cold water springs of Jack, Canyon, Candle, and Jefferson creeks, entered the Whitewater system earlier and migrated upstream faster than bull trout entering the spring-fed creeks (Thiesfeld et al. 1996). After spawning, most adult bull trout migrated back to Lake Billy Chinook by December.

Juvenile bull trout (age 0 and 1, <3.9 inches or <100 mm in length) were found primarily in the coldest (<48.2°F or <9°C) spring-fed tributaries in the Metolius system (Jack, Candle, Jefferson, Canyon, and Roaring creeks), but were not observed in the Deschutes River, Squaw Creek, or Alder Springs (Ratliff 1992). Larger and older bull trout were found in the Metolius River, upper Canyon Creek, Brush Creek (age 2-4) and Lake Billy Chinook and occasionally encountered by anglers in the Deschutes River, Squaw Creek, or Alder Springs. The streams where bull trout spawn are only slightly cooler (~35.6°F or ~2°C) than Spring Creek and Abbot Creek (Metolius tributary streams); however this difference may account for their absence in those streams.

Most juveniles disperse from their rearing streams during May or June of their second or third years. Bull trout enter Lake Billy Chinook during their third or fourth year based on scale analysis (Pratt 1991) and trap net catch at the head of the Metolius Arm. Based on tag recoveries, bull trout annual growth in the river was 3.03 inches (77 mm), whereas annual growth in Lake Billy Chinook was 6.6 inches (167 mm). Growth of bull trout in the reservoir appeared to be rapid due to the forage provided by kokanee, particularly so for age 5 and older bull trout (Figure III-40) (Riehle et al. 1997).



**Figure III-40.** Age and length of bull trout in the Metolius River. (Source: Pratt 1991)

#### **d. Genetics**

There is limited genetic analysis of Deschutes Basin bull trout populations. Leary et al. (1993) and Williams et al. (1997b) examined allozyme and mitochondrial DNA variation respectively in Klamath River and Columbia River bull trout populations. Their work showed that populations typically had low genetic variation, but that differences occurred between populations such that overall genetic diversity existed at the species level. In both studies, most populations came from either the Klamath River or from the upper Columbia (John Day River and upstream) and the Snake River. One population in both studies came from Jack Creek, a Metolius River tributary in the Deschutes Basin

Williams et al. (1997b) defined three evolutionary groups of bull trout: one including populations from the Klamath River Basin, one from the lower Columbia River, and a third from the upper Columbia (John Day and upstream). The lower Columbia group included the Jack Creek population and another from the Lewis River. The three groups differed from one another by approximately 1.0–1.5% sequence divergence, a level

of divergence associated with subspecific distinctions in rainbow trout and cutthroat trout. Additional genetic analysis of mitochondrial DNA variation among bull trout from the Lower Deschutes populations in Shitike Creek and the Warm Springs River, along with the populations from the lower Crooked River and the upper Deschutes River near Steelhead Falls, would provide insight into the distinctiveness and relationship of these populations to each other, including potential metapopulation structure.

A recent analysis by Spruell and Allendorf (1997) examined genetic variation in nuclear microsatellite DNA variation among forty-four Oregon bull trout populations including specimens from Jack Creek, Jefferson Creek and the Whitewater River in the Metolius system and from Shitike Creek and the Warm Springs River in the lower Deschutes system. Microsatellite DNA variation is similar to allozyme variation, and therefore, should provide insights into population relationships and metapopulation structure for Deschutes Basin bull trout.

Spruell and Allendorf (1997) found clear genetic divergence between bull trout populations in the lower Deschutes Basin and those in the Metolius system above the Pelton Round Butte Project. They speculated that the genetic divergence may accurately reflect historic differences between upper and lower Deschutes Basin bull trout populations, or they could be attributable to the closure of the Pelton Round Butte Dams and the elimination of gene flow between upper and lower river populations. Isolation of the two groups coupled with sharp reductions in population size might have allowed genetic drift and selection to account for the differences observed between the upper and lower river bull trout populations. We believe however, that it is more likely that the divergence described by Spruell and Allendorf (1997) accurately reflects historical differences between upper and lower Deschutes Basin bull trout populations.

The Spruell and Allendorf (1997) report did not discuss Deschutes Basin bull trout populations in detail, as the study was primarily designed to address potential ESU-level organization in bull trout populations throughout Oregon. Nevertheless, their data may contain sufficient definition to address population differences between the two lower river populations (Warm Springs and Shitike Creek) and among the Metolius populations (Jack Creek, Jefferson Creek and the Whitewater River). ODFW (1994) noting that little exchange of tagged fish occurred between Jacks and Jefferson creeks, speculated that populations in the two creeks might be genetically distinct. Again, Spruell and Allendorf (1997) data may be able to address this point.

## **CHAPTER IV. CONCEPTUAL FOUNDATION**

As defined in Chapter I, a conceptual foundation is a set of scientific theories, principles and assumptions, which in aggregate describe how a salmonid producing ecosystem functions. The preceding four chapters were essentially the conceptual

foundation. They contain all the key elements, the raw material needed for a conceptual foundation. However, the specific elements of the conceptual foundation were buried in the extensive narrative, which also provided the supporting context and rationale. The purpose of this chapter then is to draw out and crystallize the elements of a conceptual foundation and present them in a set of summary statements. This chapter is derived from and must be consistent with the rest of the report.

The consistency requirement extends beyond this report and the Deschutes Subbasin. The conceptual foundation for a specific subbasin must be in concordance with the conceptual foundations for the more inclusive levels in the geographical hierarchy. In the Columbia Basin, the conceptual foundations for the Deschutes River, the subregion that includes the Deschutes River, and the Columbia Basin should all be in concordance. So a first step in the development of a conceptual foundation for the Deschutes River is the identification, review and evaluation of the conceptual foundations for the subregion and basin.

In Chapter I we stated that conceptual foundations are rarely explicitly stated in fishery restoration programs. Fortunately in the Columbia Basin, there have been two attempts to articulate a conceptual foundation at the basin level: The Independent Scientific Group's report, "Return to the River" (ISG 1996); and the Northwest Power Planning Council's report, "An Integrated Framework for Fish and Wildlife Management in the Columbia River Basin" (NPPC 1997). In both of these examples, there is an existing foundation (Tables IV-1 and IV-2) compared with a description of a proposed conceptual foundation (Tables IV-3 and IV-4). In both reports, the current conceptual foundation was inferred from existing programs; none of the management agencies have explicitly described the conceptual basis of their programs.

**Table IV-1.** Existing watershed level conceptual foundation for salmon and steelhead management in the Columbia Basin, taken from Return to the River. (Source: ISG 1996)

<b>Existing watershed level conceptual foundation from Return to the River.</b>	
1.	The number of adults is a simple positive response to the number of smolts produced. Technology can circumvent natural ecological processes.
2.	Salmon and steelhead production can be increased by focusing management primarily on in-river components of the Columbia River.
3.	Management actions will not compromise environmental attributes which form the basis for production of salmonids.
4.	It is desirable and possible to circumvent ecological processes and simplify and control the production of native fishes.

**Table IV-2.** Existing watershed level conceptual foundation for salmon and steelhead management in the Columbia Basin described by Northwest Power Planning Council. (Source: NPPC 1997)

<b>Existing watershed level conceptual foundation for salmon and steelhead from NPPC.</b>	
1.	The ecosystem is a machine which is fixed, describable and predictable. Decline in production can be rectified by adding more fish to the system.
2.	Species production can be controlled by human action.
3.	System constraints that simplify the ecosystem have no important effect on biological productivity.

4.	Technological solutions can replace natural production lost through human actions.
5.	Mainstem Columbia (with the exception of Hanford) is not important habitat for salmonids except as simple migrational corridors.
6.	Introduction of non-native species will have allowable impacts on native species.
7.	Actions to restore one specie will not impact other species or populations.

**Table IV-3.** A proposed alternative conceptual foundation for the management of Columbia River salmon and steelhead taken from Return to the River. (Source: ISG 1996)

<b>Proposed alternative conceptual foundation for Columbia River from Return to the River.</b>	
1.	The Columbia River is a natural, cultural system. Restoration must consider the whole ecosystem, natural as well as cultural.
2.	Salmonid productivity requires a network of complex interconnected habitats which are created, altered and maintained by natural physical processes in freshwater, estuary and ocean.
3.	Life history, genetic diversity and metapopulation organization are ways the salmon adapt to their habitat. Diversity is how the salmon cope with environmental variation.

**Table IV-4.** A proposed alternative conceptual foundation for the management of Columbia River salmon and steelhead described by Northwest Power Planning Council. (Source: NPPC 1987)

<b>Proposed alternative conceptual foundation for Columbia River salmon and steelhead from NPPC.</b>	
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1. Environmental variability is a natural part of the ecosystem causing long- and short-term fluctuations in production.
2. Biological diversity of salmon is a response to environmental variability.
3. Population structures develop in response to spatial and temporal variation in the ecosystem.
4. Goals can be achieved by assuring suitable ecosystems attributes.
5. Species assemblages and abundance reflect ecosystem conditions.
6. Suitable ecosystem conditions can be achieved by managing human impacts and allowing natural process to restructure habitat.
7. Needs of multiple, coevolved species can be met by suitable ecosystem conditions.
8. Technology should be used to develop suitable ecosystem conditions rather than replace them.

The existing basin-level conceptual foundations described in ISG (1996) and NPPC (1997) (Tables IV-1 and IV-2) share many similar attributes, and likewise, the two proposed, alternative conceptual foundations are similar (Tables IV-3 and IV-4), however, there are major differences between the current and proposed conceptual foundations in both reports. The existing conceptual foundation is based on the fundamental assumption that it is possible and desirable to circumvent ecological processes in order to simplify and control production. It is assumed this can be done through the application of technology (ISG 1996; NRC 1996). It also assumes that once simplification and control are achieved it will result in a level of production at least equivalent to or exceeding the historical (e.g. OFGC 1919; Ebel 1977; Lichatowich et al. 1996).

To state as a fundamental principle that resource management programs rely on the use of technology today, in this modern age, seems to be stating the obvious and it could be argued that it does not add anything of value to our understanding. We cannot escape the use of technology. It is a necessary and vital part of our everyday lives including natural resource management. The reason for explicitly including a reference to technology in the existing conceptual foundation is not to contrast it with a resource management program that is free of technology. Rather, the purpose is to set up a comparison between current uses of technology and the underlying assumptions of that use and contrast that to an alternative where the use of technology is guided by a different set of assumptions. Under the alternative conceptual foundation, the highest priority for the use of technology is to support or nurture natural ecological processes rather than replace them.

The existing basin level conceptual foundation (Tables IV-1 and IV-2) assumes technology is an adequate or superior substitute for natural ecological processes (ISG 1996) and that technology can solve problems created by poor stewardship or extensive development and use of water resources. Closely tied to the belief that technology can substitute for natural, ecological processes is the use of the machine as a model for natural ecosystems (Table IV-2). The idea that nature operates like a machine has a long history (Botkin 1990), however, it was refined and incorporated into ecosystem ecology following World War II (Golley 1993). The machine implies equilibrium points determined by fixed laws governing a few critical variables, which can be measured and manipulated. This leads to the belief that the future states of managed ecosystems can, not only be controlled, but predicted. In ecosystems producing Pacific salmon, it also leads to the belief that equilibrium states in altered systems can be reestablished simply by manipulating numbers of fish—adding smolts to the system will result in a linear or at least predictable response in terms of the number of adults. This has led to a search for fixed laws with few significant variables. For example, fixed rules for operating hatcheries (e.g. standard size and time of release); a single fixed flow survival relationship for the mainstem Columbia River that will optimize survival of all smolts regardless of their life history; and the belief that supplementing a stream's natural production with hatchery reared fish will boost natural production even in basins where habitat is severely degraded. The latter treats the ecosystem as a machine with a broken part and supplementation as a substitute part that can replace the relationship between the fish and its habitat in a healthy stream.

The assumptions underlying the current conceptual framework (Tables IV-1 and IV-2) are not unique to Pacific salmon management. For example, Finlayson (1994) listed six assumptions that underlie the management of Canada's northern cod stocks:

1. The universe is mechanistic and deterministic and its workings are governed by a few fundamental and unvarying laws.
2. The marine ecosystem and its sub-systems (in this case, commercially valuable fish stocks) are fundamentally robust. That is they are relatively insensitive to small perturbations and tend to vary around natural dynamic equilibrium states.
3. These natural equilibrium states are dominated (or can be described and represented) by relatively few significant variables. In this case, they are fecundity, recruitment, natural mortality and fishing mortality.
4. These variables are knowable and their effects on the stocks are simple, continuous, and can be realistically modeled by equation with a small number of parameters. Therefore they are predictable.

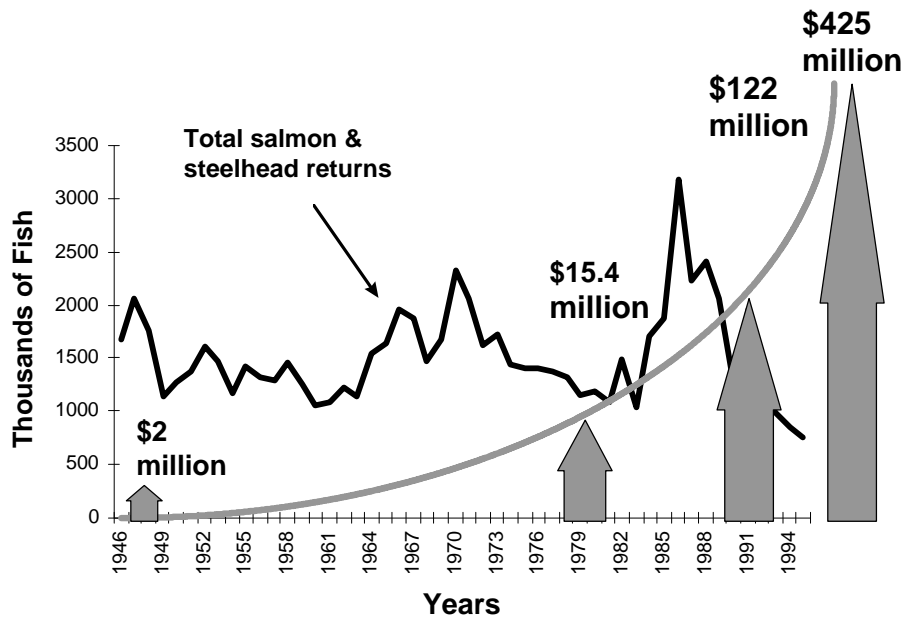
5. Science based management can manipulate some of these variables (primarily fishing mortality). It can monitor the others to effectively control the system to produce (within certain broad limits) equilibrium states in general harmony with human needs and desires.
6. Having rebuilt the stocks to the desired level, they could then be maintained at that level by relatively minor adjustments in the total allowable catch. Long-sought-for stability could be brought to the fishery and its industries (Finlayson 1994 p. 25).

The assumptions underlying the management of northern cod stocks on Canada's east coast are extraordinarily similar to those guiding the management of Pacific salmon. Both the northern cod and Pacific salmon (California, Oregon, Washington, and Idaho) are in depleted status. The conceptual foundations for both have failed to be useful in preventing depletion. The major difference between the conceptual foundations for Pacific salmon and northern cod is the greater reliance in salmon management on technology to circumvent freshwater ecological processes.

Overoptimistic faith in the ability of technology to overcome the effects of poor stewardship has been identified as a fundamental flaw in the management of National Forests (Hirt 1994; Langston 1995). Overconfidence in the ability of technology to circumvent ecological process can snare its practitioners in a conceptual/bureaucratic trap. The expectations created by new technology (supplementation vs conventional hatcheries, for example) becomes an excuse for a delay in addressing the root cause of the problem (over harvest and/or habitat degradation). When technology fails to deliver its promised results, it is not the technology that is questioned, but political leaders are blamed for not providing enough funds or funds on a timely schedule (Hirt 1994). At that point the trap has been sprung. The result is an escalating spiral of larger and larger costs that produce little or no tangible benefits. This scenario appears to fit the program to restore Columbia River salmon over the past 50 years (Figure IV-1).

Alternatives to the existing conceptual foundation at the basin level are shown in Tables IV-3 and IV-4. There is little difference between the two except in the level of descriptive detail, so they have been combined and will be treated here as a single set of assumptions (Table IV-5).

The alternative explicitly recognizes that the Columbia Basin is a natural-cultural ecosystem. It is composed of elements of the original evolving watershed and biological community. Superimposed on this are the anthropogenic changes such as dams and reservoirs, irrigation diversions, and the effects of grazing by non-native ungulates. Anthropogenic changes have set the basin on a new



**Figure IV-1.** Total adult salmon and steelhead returns to the Columbia River and the cost of the salmon restoration program. Initially the program expended \$2 million/year (Laythe 1950). From 1949 to 1981 the average annual cost was \$15.4 million/year and from 1982 to 1991 \$122 million/year (GAO 1992) and has reached \$425 million/year in recent years (NPPC 1994).

developmental trajectory (e.g. Frissell et al. 1996). This does not mean that anthropogenic and non-human elements in the ecosystem are separable and move on different developmental tracks. The natural and cultural parts of the ecosystem are coevolving, each adapting to the other while at the same time each is molding the other in a continuum of change (Norgarrd 1994). Over thousands of years, Native Americans and the Pacific salmon coevolved a sustainable relationship with salmon. In the Columbia Basin, the industrial economy of the Euroamericans has not demonstrated a sustainable relationship with the salmon. To coevolve a sustainable relationship with the salmon will require a new approach to the use of watersheds guided by a different vision of the natural-cultural system (Oregon Business Council 1997).

**Table IV-5.** Proposed alternative conceptual foundation (composite of Tables IV-3 and IV-4) for the Columbia Basin.

<b>Proposed alternative conceptual foundation for Columbia Basin</b> (composite of Tables IV-3 and IV-4)	
1.	The Columbia River is a natural-cultural system characterized by natural environmental variability and fluctuation in production. Salmon restoration and management must consider the whole ecosystem, natural as well as cultural, in the freshwater, estuary, and ocean. Suitable ecosystem attributes can be achieved by managing human interference in the natural habitat forming processes and by use of technology to support those processes. The use of technology to circumvent natural ecological processes should be avoided, if possible.
2.	Salmonid productivity requires a network of complex interconnected habitats, which are created, altered and maintained by natural physical processes in freshwater, estuary and ocean. Management and restoration goals depend on achieving suitable ecosystem attributes.
3.	Species diversity and the biotic community are a reflection of the ecosystem attributes. The coevolved assemblage of species share requirements for similar ecosystem attributes.
4.	Life history, genetic diversity and metapopulation organization are ways the salmon adapt to their habitat. Diversity and population structure are how salmon cope with spatial and temporal environmental variations. Such diversity promotes production and long-term persistence at the species level.

The existing conceptual framework, assumes the ecosystem is always moving toward a stable equilibrium and management activities are “experimental” manipulations of the machine-like functioning of the ecosystem. Everything is viewed as though it is in fact a series of experiments in a controlled environment; experiments designed to recapture the equilibrium. The alternative conceptual foundation treats human activities as having long-term coevolutionary consequences, and that management is in effect one-long continuous experiment (Lichatowich 1996) within which we must continually adjust our programs in an adaptive process. In the existing conceptual framework salmon managers ask, “*How can I manipulate the system to return to the desired stable equilibrium?*” For example, reduced levels of salmon production because of habitat loss in freshwater or because of reduced marine survival is addressed by increasing the number of smolts produced in hatcheries. In the alternative, salmon managers should ask, “*Which is the most desirable of the possible developmental trajectories for the natural and cultural elements of the ecosystem?*” Restoration of salmon and steelhead would emphasize the removal of constraints on life history diversity. This means restoration of a minimum level of habitat

complexity and connectivity and the maintenance of that habitat through natural ecological processes.

The alternative conceptual foundation treats the population in its environment as the basic management unit and the mapping of life history onto the habitat template (Healey and Prince 1995) as critical elements of management and restoration programs. Recovery programs should concentrate on recovery of phenotypic (e.g., life history) diversity in the restored habitat as opposed to predicting and controlling numbers of fish. When phenotypes and habitat are in synchrony, productivity will be maximized.

The alternative conceptual foundation recognizes linkages among parts of the salmon's extended ecosystem, such as the linkage between the ocean and freshwater. Fluctuations in ocean survival due to climate change will create severe depression in salmon production only if phenotypic diversity has been reduced by harvest, hatchery operations and habitat degradation in freshwater (ISG 1996).

The role of technology in the alternative conceptual foundation has also been modified. It is not used to circumvent natural ecological processes or habitat, but is used to support, restore and strengthen them. For example, supplementation is a valid use of technology to boost production in the alternative conceptual foundation only if it is preceded or accompanied by programs that have a high probability of removing the existing constraints on production, such as habitat degradation or overharvest. The scale of supplementation efforts might also be very different. The alternative conceptual foundation would emphasize the integration of artificial and natural production where as the current conceptual foundation would emphasize the maximal use of hatchery fish.

As discussed in Chapter I, the management goals and conceptual foundation together lead to appropriate strategies. Deciding what to do (strategies) must take into account what the program intends to achieve (goals) and the ecological condition necessary to achieve it (conceptual foundation) (Figure I-2). The conceptual foundation should have a major influence on the possible suite of strategies (Tables IV-6 and IV-7).

**Table IV-6.** Management strategies consistent with the alternative conceptual foundation. (Adapted from NPPC 1997).

<b>Management strategies consistent with alternative conceptual foundation</b>	
1.	Develop multi-species management strategies for co-occurring assemblages of anadromous and resident fish.
2.	Design and engineer systems that support natural ecological processes.

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|----|---|
| 3. | Promote the development of habitat complexity and connectivity in harmony with other uses of the river.   |
| 4. | Recognize natural characteristics of the river with regard to historically successful species, populations and life histories and design river use and management to take advantage of those characteristics. |

**Table IV-7.** Management strategies consistent with the current conceptual foundation. (Adapted from NPPC 1997)

<b>Management strategies consistent with current conceptual foundation</b>	
1.	Manage each species/population as a distinct separate unit in isolation from the species.
2.	Design and engineer alternatives to habitat and natural ecological processes. (Hatcheries, transportation, etc.)
3.	Manipulate biological attributes (run timing or smolt migration) to accommodate other river uses.
4.	Manipulate the system and simplify biological attributes (life history) under the assumption that there will be no negative impact on biological productivity.

A conceptual foundation for the subregion level in the Columbia Basin has yet to be formulated. However, Lichatowich and Moberand (1995) completed a review of the chinook salmon in the steppe and steppe-shrub vegetational zone (Franklin and Dyrness 1973) and described elements of a conceptual foundation for that subregion (Table IV-8). A large part of the Deschutes River watershed falls within the steppe and steppe-shrub subregion. The statements presented in Table IV-8 would apply to Crooked River and other eastside tributaries.

**Table IV-8.** Elements of a conceptual foundation for chinook salmon in the subregion bounded by the steppe and steppe-shrub vegetational zones. (Derived from Lichatowich and Moberand 1995)

<b>Elements of a conceptual foundation for</b>
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### **chinook salmon in subregion<sup>1</sup>**

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1. Historically, salmon and steelhead habitat in steppe and steppe-shrub subregion of the Columbia Basin approached marginal conditions. For chinook salmon habitat in the steppe-shrub are highly susceptible to alteration.
2. Loss of flow due to irrigation withdrawals greatly restricted natural habitat forming processes and reduced the resiliency of the ecosystem. Irrigation was probably the most important source of habitat degradation.
3. The destruction of riparian vegetation due to grazing combined with water diversion boosted water temperatures to levels that are lethal to salmonids, especially in the lower reaches of the rivers.
4. Growth opportunity and life history diversity were lost due to the thermal fragmentation and physical degradation of salmonid habitat.
5. Loss of specific life histories especially subyearling migrants, was a major factor in the depletion of chinook salmon in the steppe and steppe-shrub subregion.
6. The remaining isolated pockets of habitat in the headwaters of this subregion were probably not the most productive habitats in the watersheds historically.

<sup>1</sup> Statements would apply to Crooked River

For this report, we adopted the alternative conceptual foundation (Tables IV-3, IV-4, and IV-5). In the section that follows, the conceptual foundation specific to the Deschutes River will be developed and explained (Table IV-9). It should be reaffirmed here that this presentation of a conceptual foundation does not imply it is the only possible set of assumptions or principles that could guide management of the watershed. It is the set of assumptions and principles that we believe describes the functioning of the Deschutes River ecosystem relative to its native salmonids and it is the set we believe will be more useful in the management and restoration of native salmonids in the basin. Other sets of assumptions are possible, and conceptual foundations that differ from ours could be developed or they might be in use in the basin today. One of the purposes for articulating this conceptual foundation is to stimulate discussion, which can lead to revision and improvement. One point must be kept in mind while reviewing the statements that make up the subbasin level conceptual foundation. Everyone, who is interested in and has an opinion about the management of the Deschutes River or the restoration of anadromous salmonids in the basin, employs a conceptual foundation. If in your review of the conceptual foundation presented here, you find points you disagree with, make note of the disagreement, but more importantly legitimate your disagreement by stating your alternative to this conceptual foundation.

**Table V-9.** Conceptual Foundation for the management of native salmonids in the Deschutes Basin. The bold text are elements of the basinwide conceptual foundation taken from Table IV-5. Elements of the conceptual foundation for the Deschutes River follow each of the basinwide statements.

## Conceptual Foundation for the Deschutes Basin

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1. **The Columbia River is a natural-cultural system characterized by natural environmental variability and fluctuation in production. Salmon restoration, and management must consider the whole ecosystem, natural as well as cultural, in the freshwater, estuary, and ocean. Suitable ecosystem attributes can be achieved by managing human interference in the natural habitat forming processes and by use of technology to support those processes. The use of technology to circumvent natural ecological processes should be avoided, if possible.**

**1.a.** The Deschutes River is a coevolving natural—cultural system. Large stable production areas for native salmonids remain in the basin, however, the system’s developmental trajectory since Euroamerican settlement has generally been detrimental to native salmonids. Development since 1830 has not produced a balance in the natural and cultural elements of the ecosystem.

**Implication** — Natural and cultural elements of the Deschutes River must be considered in any management planning. Unless a balance between the needs and constraints of the natural and cultural components of the ecosystem is achieved, the performance of many of the native salmonid populations in the basin will decline.

**1.b.** Important environmental attributes have been influenced by human activity in the basin: Flow and temperature manipulation below Pelton and Prineville Dams, the diversion of water for irrigation and the destruction of riparian vegetation, especially in the Crooked River, the mainstem Deschutes above Pelton-Round Butte Dams and in the eastside tributaries have destroyed or degraded salmon and steelhead habitat.

**Implication** — Many of the changed attributes of salmon habitat are out of synch with the normal life histories of salmonids (flow in the Crooked River, for example) or are lethal for part of the year. The goal of Deschutes River management should be to restore attributes of salmonid habitat to as close to their natural historic range as possible.

**1.c.** The massive use of technology in the form of barging and artificial propagation of steelhead above McNary Dam is threatening the Deschutes River summer steelhead. Large numbers of stray steelhead from hatcheries outside the basin are probably spawning with wild native steelhead in the Deschutes River.

**Implication** — The persistence of native steelhead in the Deschutes River will be in jeopardy as long as the number of out-of-basin strays remains as high as it has in recent years. Round Butte Hatchery may be a genetic refuge for native steelhead in the basin, extra care should be taken when selecting broodstock. The upper Warm Springs River is also an important refuge for native steelhead, which should continue to be protected.

**2. Salmonid productivity requires a network of complex interconnected habitats which are created, altered and maintained by natural physical processes in freshwater, estuary and ocean. Management and restoration goals depend on achieving suitable ecosystem attributes.**

**2.a.** Unique geologic and hydrologic attributes combine to make the physical characteristics of salmon habitat in the Deschutes River below Pelton Dam highly stable.

**Implication** — The lower river is a large stable production area. A high degree of stability, if it has persisted for a long period of time (centuries), could have evolved a native fish community adapted to stability and therefore vulnerable to small environmental fluctuations. Land and water use practices in the basin should be monitored to prevent disruption in the normal historic range of flow and temperature in the lower mainstem.

**2.b.** The lower Deschutes mainstem from Pelton Dam to the confluence with White River is the center of production for native redband trout and summer steelhead. The center of fall chinook production is from Sherars Falls to the river's mouth.

**Implication** — This mainstem area is the obvious core for metapopulation structure of the above native salmonids in the lower Deschutes. The lower Deschutes at and below the three arms (Crooked, upper Deschutes and Metolius) was historically an important production area (core) in the basin.

Fall chinook may have always been composed of a single population in the mainstem Deschutes River. On the other hand, fall chinook from the Deschutes River might have been a satellite in a larger metapopulation whose core was the fall chinook that spawned in the mainstem Columbia above The Dalles prior to the construction of mainstem dams. Other possible satellite populations might have included the John Day and Umatilla which are extinct.

Historically, the eastside tributaries were the principal spawning areas for summer steelhead. That suggests the relation between the mainstem and tributaries was more complex than the core-satellite (mainstem-tributary) structure that appears to exist today. The tributaries may have historically been important sources of spring chinook.

**2.c.** Other important production centers in the basin are: the Warm Springs River (spring chinook, summer steelhead, bull trout and lamprey), Metolius River and Lake Billy Chinook (kokanee), the upper Deschutes River Lower Bridge to Lake Billy Chinook (redband trout), Lake Billy Chinook and Metolius River (bull trout), and the tailrace below Prineville Reservoir and headwater tributaries such as Ochoco Creek and the North Fork (redband trout).

**Implication** — All of these production centers are in some way the consequence of/or affected by altered, degraded or fragmented salmonid habitat in the basin. Data on the genetic structure of native salmonids in the Deschutes Basin are either lacking or are not now in a form that is amenable to analysis leading to the description of the historic and current metapopulation structure.

**3. Species diversity and the biotic community are a reflection of the ecosystem attributes. The coevolved assemblage of species share requirements for similar ecosystem attributes and those attributes can be estimated by intensive study of focal species.**

**3.a.** The redband trout (both resident and anadromous forms) is a focal species in the Deschutes River.

**Implication** — Mobrand et al. (1997) argue that ecosystem health can be examined through an analysis of capacity, performance and life history of keystone species in a basin. The assumption behind their argument is that an identification of ecosystem attributes necessary to support diverse life histories and contribute to the performance of the keystone species will also encompass the majority of the attributes necessary to achieve ecosystem health. However, such an approach must be taken with caution to avoid ignoring the needs or adversely impacting other species in the native fish assemblage. Attributes required for the entire native fish assemblage need to be considered. Redband trout are present in the Deschutes River in anadromous and resident forms and they have a ubiquitous distribution. They experience and respond to all the natural and anthropogenic environmental gradients in the basin. If a full Ecosystem Diagnosis and Treatment (Lestelle et al. 1996) analysis is implemented, the focal species should be the redband trout.

**3.b.** Long-term stocking of hatchery trout susceptible to *C. shasta* and the subsequent interbreeding between hatchery trout and native redbands in the Metolius River has reduced fitness in the native fish by lowering their susceptibility to the parasite. A remnant, genetically pure redband population exists in the lower Metolius River that could serve possibly as a source for restoration now that hatchery stocking has ceased.

**Implication** — Loss of productivity can occur through a change in habitat or through management practices that reduce the fitness of the population in habitat that is in most respects not degraded.

4. **Life history, genetic diversity and metapopulation organization are ways the salmon adapt to their habitat. Diversity and population structure are how salmon cope with spatial and temporal environmental variations. Such diversity promotes production and long-term persistence at the species level.**

**4.a.** Large springs in the lower Crooked River and middle Deschutes River partially offset the effects of irrigation withdrawals. However, even with the effect of the springs habitat is still altered from the historic. The constant flow and temperature of springs create islands of unique habitat in the upper Metolius River, lower Crooked River and Squaw Creek and the mainstem above Pelton and Round Butte Dams. Anadromous and resident salmonids utilizing those habitats now or in the future have the potential for developing unique life history patterns.

**Implication** — Any program to restore anadromous salmonids to the upper basin must be capable of detecting and monitoring new, locally adapted life histories if and when they occur in these unique habitats. This assumes that the springs will not be influenced by future ground water withdrawals in the basin.

**4.b.** The limited life history information available suggests there is still substantial diversity remaining in the basin's native salmonids.

**Implication** — Several studies have provided important information on life history of salmonids in the Deschutes River. Three recent studies have been designed to map life history onto the habitat template: The life history study of steelhead and rainbow in the lower mainstem and the Lake Billy Chinook kokanee and redband studies. The occurrence, source and value of life history diversity have received little specific attention. Developing a better understanding of life history-habitat relationship is critical to affecting management and restoration. Management and research should emphasize this area more.

What are the next steps? Even though this report is a final draft the conceptual foundation should be subject to the addition of new elements or revision of old elements when warranted by scientific information. As stated in the introduction of this report, the combination of goals and conceptual foundation leads to appropriate management and restoration strategies. So the next step should be the integration of goals and conceptual foundation to begin deriving alternative implementation strategies and research. The preliminary steps in this process should be undertaken by the fisheries technical subcommittee.

# CHAPTER V.

## RECOMMENDATIONS

The following recommendations if implemented would add to refine or expand the conceptual foundation for the basin.

**1. Research management and restoration efforts in the basin would benefit from an ecosystem perspective.**

In 1943 an investigative committee of the Washington State Senate recognized that salmon management in the Columbia Basin was impeded by fragmentation of efforts. They summarized their findings with the statement: “*We are hopelessly defeated in obtaining any solution to the Columbia River fisheries [declines] unless we simplify our administration over this resource*” (Columbia River Fisheries Interim Investigating Committee 1943, p. 7). The Deschutes Basin is a microcosm of the fragmentation problem in the Columbia Basin. Fishery related programs in the Deschutes Basin are carried out by several different state, federal, tribal and private organizations. Although there is a commendable amount of cooperation and coordination among these agencies and institutions, in our review of the scientific information, we saw areas where more is required.

The Washington State Senate report was concerned with the administration of fisheries programs. However, in recent years a new dimension has been added to the need for close coordination. Ecosystem management has focused attention on questions, problems and information at scales not considered in previous decades. The emergence of ecosystem perspective in fisheries management has created a technical, as well as administrative, need for closer coordination. In the Deschutes Basin, there is a need for an institution, committee, watershed council, or board that can identify ecosystem scale questions, organize programs to monitor ecosystem health, analyze information and report on fishery problems and solutions at the ecosystem level. This may be as simple as ensuring that data collected throughout the basin are reported in comparable units and are periodically compiled, reviewed and synthesized from an ecosystem perspective. If an ecosystem level institution were created, it could implement a full Ecosystem Diagnosis and Treatment program, as an aid to shifting emphasis to the whole system.

**2. There is a need to explicitly recognize the physical connection between the upper and lower basin.**

This recommendation is related to the first. The native salmonids in the Deschutes Basin are biologically separated by the Pelton Round Butte Project. Anadromous salmonids and fluvial trout and char no longer migrate freely past the dam sites. The size of the basin, the physical barrier presented by the dams and the lack of an ecosystem perspective (described above), have all contributed to a fragmented habitat in the basin. In our review, it was apparent that the various parts of the basin are managed without explicit concern for the downstream effects, the connections to other parts of the basin.

The lower river is a robust production center with a stable environment. However, we agree with the Lower Deschutes River Subbasin Management Plan that, "*The stream is the product of its watershed*" (ODFW and CTWSR 1990 p. 20). Although the upper and lower parts of the river may be biologically separated, they are still physically connected. From the standpoint of the physical attributes of the habitat, perhaps one of the more critical uncertainties is this: Are there thresholds of land and water usage and change in ecosystem function in the upper basin that can disrupt the stability of the lower river environment and lead to loss of capacity and performance of the native salmonids?

**3. Recognize that the Metolius and Crooked rivers are both examples of the vulnerability of some habitats in the basin to change.**

The Crooked and Metolius rivers were marginal salmonid habitats for two very different reasons. The Crooked River, flowing through hot and arid landscape, was a naturally warm stream capable of supporting salmonids. The loss of riparian vegetation and the diversion of water for irrigation destroyed salmonid habitat and pushed temperatures to lethal levels in many parts of the basin.

The Metolius River is fed by large springs at temperatures that are colder than optimum for salmonid growth. Habitat in the Metolius River has not undergone the same degree of alteration as the Crooked River. However, the marginally cold water combined

with added stress from poor hatchery practices have combined to reduce the production of redband trout in the basin.

Salmonid populations in marginal habitats are sometimes considered unimportant and relegated to a lower priority in management (e.g., Nickelson and Lawson 1997; PFMC 1997). However, an ecosystem perspective that includes the structure of salmonid populations and the mechanisms that lead to their persistence suggest that marginal populations should be elevated to a higher priority (Thompson 1965; Scudder 1989). One of the reasons marginal populations should be given higher priority is that they are invaluable for the maintenance of the genetic diversity of species (Scudder 1989). Because they are more vulnerable to land and water use practices and fishery management, marginal habitats should receive more attention from resource management agencies. In addition to the Crooked and Metolius rivers mentioned above, other marginal habitats include but are not limited to the eastside tributaries and the shorter westside tributaries. All marginal habitats need special management consideration.

**4. The relationship between life history diversity and habitat attributes needs additional attention.**

Although the life histories of native salmonids in the basin have been studied, the relationship between life history diversity and habitat attributes has received little attention. Redband trout populations in the lower mainstem within 10 miles (16.1 km) of each other have shown life history differences. If those differences are real, it's important to determine what environmental gradients or local habitat differences they are responding to. Studies of the Warm Springs population of spring chinook salmon have shown survival differences between juvenile life histories. What causes those differences and what are the implications for management are important questions. The mapping of life history onto the habitat template is a difficult task, but it is critical to effective management (Healey and Prince 1995). The study by Zimmerman and Reeves is a good start, but more will have to be done.

**5. Restoration programs should anticipate and monitor for the appearance of unique life history patterns.**

Large springs in the lower Crooked River, the mainstem Deschutes and in the Metolius River create uniquely stable environments. These areas may be the key points for early recolonization by anadromous salmonids if passage past Pelton and Round Butte Dams is reinstated. There is a strong possibility that anadromous salmonids that establish self-sustaining populations in those unique habitats will develop new life history patterns or at least life histories will diverge from the donor stock. Monitoring should be keyed to recognize the emergence of life history variants and management should be capable of acting adaptively to nurture them.

**6. Either analyze existing information or collect new genetic data to determine if the spring chinook populations in the lower river represent one or two genetic management units.**

Spring chinook populations from the Warm Springs and Shitike Creek should be examined using available allozyme data to assess the degree of distinctiveness or similarity from one another. If the data are available, Fisher's Exact Test (using the program GENEPOP) would quickly identify if the populations are genetically distinct. Alternatively, G-tests (log-likelihood contingency table analysis) would do the same thing. From a management perspective, it is important to know whether the Deschutes spring chinook populations represent one or two genetic management units. If data are not available for the assessment described above, then genetic analysis of the Warm Springs and Shitike Creek spring chinook populations should be a priority task.

**7. The Deschutes fall chinook population should be recognized and managed as a unique genetic resource that may function as an invaluable source population for rebuilding fall chinook populations in the adjacent John Day, Umatilla and Walla Walla rivers.**

**8. ODFW and CTWSR and other institutions such as National Marine Fisheries Service and Northwest Power Planning Council should immediately initiate research to assess the impact of out-of-basin strays on the Deschutes River summer steelhead.**

A working group has been formed to start addressing this problem.

**9. There is a need for additional comprehensive basinwide genetic studies on resident redband trout to: identify hybridized versus pure populations, identify geographic and genetic structure, and attempt to infer present and historic metapopulation structure.**

There is a specific need to genetically compare redband trout populations from the lower mainstems of Metolius, Squaw Creek, Deschutes and Crooked rivers. That study should use allozymes and mtDNA technology, as these techniques are proven, standardized enough for use between various laboratories, and previous comparative data exist on some of the specific populations of interest. This is being addressed in part through the Lake Billy Chinook redband trout study.

**10. Use existing data from Spruell et al. (1997) to compare upper basin (Metolius system) bull trout populations with lower Deschutes populations.**

In addition to the comparison between upper and lower river bull trout populations, test for differences between lower river populations and between populations within the Metolius system (G-tests or Fisher's Exact Test; see recommendations in Chinook section). This analysis will shed light on population relationships, potential management units, and historic metapopulation structure.

**11. Continue monitoring spawning distributions, life history attributes and population abundance of bull trout and test for correlation with kokanee abundance in Lake Billy Chinook.**

**12. Continue the work of the Metolius Bull Trout Working Group.**

The Metolius Bull Trout Working Group should review the recommendations in Buchanan et al. (1997) on pages 152-154 and implement those that are appropriate.

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