Agenda Item G.3
Situation Summary
March 2007

IDENTIFICATION OF STOCKS NOT MEETING CONSERVATION OBJECTIVES

Overfishing Concern

Each year, exclusive of stocks listed under the Endangered Species Act (ESA), the Salmon Technical Team (STT) must identify any of the natural salmon stocks with conservation objectives in Table 3-1 of the Salmon Fishery Management Plan (FMP) that have failed to meet their conservation objective in each of the past three years. For any stock so identified that does not meet the exception criteria, an Overfishing Concern is triggered. An Overfishing Concern requires the Council direct the STT and Habitat Committee (HC) to work with State and Tribal fishery managers to complete an assessment of the cause of the conservation shortfalls and provide recommendations to the Council for stock recovery (Agenda Item G.3.a, Attachment 1). Based on those recommendations, the Council must take actions within one year of an identified concern to prevent overfishing and begin rebuilding the stock.

In the case of natural stocks which have failed to achieve their conservation objective in each of the past three years, but are exceptions under the Salmon FMP overfishing criteria, the STT, HC, and Council should: (1) confirm that harvest impacts in Council fisheries continue to be less than five percent, (2) identify the probable cause of the current stock depression, (3) continue to monitor the status of the stocks, and (4) advocate measures to improve stock productivity.

Table G3_Att_2 (Agenda Item G.3.a, Attachment 2) has been extracted from the STT's Preseason Report I. It indicates that one stock subject to the Overfishing Criteria has failed to achieve its conservation objective in each of the three most recent years, Klamath River fall Chinook. Queets River spring/summer Chinook have not met their conservation objectives in the most recent four years assessed (2003, 2004, 2005 and 2006), and Quillayute spring/summer Chinook have not met their conservation objective in the most recent three years assessed (2004, 2005, and 2006). However, these latter two stocks are exceptions under the Salmon FMP Overfishing Concern criteria by virtue of historical harvest impacts of less than five percent in Council-managed ocean salmon fisheries.

Because the Klamath River fall Chinook (KRFC) stock is not an exception to the FMP Overfishing Criteria, and they did not meet the conservation objective for the third consecutive year in 2006, an Overfishing Concern has been triggered. KRFC are projected to meet the 35,000 adult natural spawner floor conservation objective in 2007. Absent any additional fishing in 2007, the forecast is for a natural spawning escapement of 73,400 adults in 2007.

Conservation Alert

The Salmon FMP states that any stock projected to fall short of its conservation objective triggers a Conservation Alert. If the stock in question has not met its conservation objective in the previous two years, the Council shall request the pertinent State and Tribal managers to complete a formal assessment of the primary factors leading to the shortfalls and report their conclusions and recommendations to the Council no later than the March meeting prior to the next salmon season.

In 2006, KRFC triggered a Conservation Alert, and because the stock had not met its conservation objective the previous two years, a formal assessment was required. The states of Oregon and California, the Yurok and Hoopa Valley Tribes, and the Council's HC were given the task of developing the assessment, which was to document the reasons for KRFC failing to meet its conservation objectives (Agenda Item G.3.a, Attachment 3). The habitat related portion of this report can serve as the essential fish habitat review component of the overfishing review report required when an Overfishing Concern is triggered.

Council Action:

1. **Identify naturally spawning stocks failing to meet their conservation objectives (exclusive of stocks listed under the ESA).**
2. **Provide direction to comply with the actions required by the Council's Overfishing Concern procedures in the Salmon FMP.**
   a. **For stocks that are exceptions (Queets and Quillayute spring/summer Chinook) to the Overfishing Concerns, these actions involve confirming continued low impacts by Council fisheries, identifying the probable cause of the depression, monitoring the status of the stocks, and advocating measures to improve stock productivity.**
   b. **For stocks that are not exceptions (Klamath fall Chinook), these actions include directing the STT and HC to work with relevant State and Tribal agencies to complete an assessment of the stock within one year to appraise fishing impacts, estimation errors, EFH status, and other factors, and assess the overall significance of the stock depression with regard to achieving maximum sustainable yield on a continuing basis. The assessment will include any recommendations to end overfishing and rebuild the stock, and identify criteria to determine when the stock has been rebuilt.**
3. **Review Agenda Item G.3.a, Attachment 3 and provide further guidance on completion, as necessary.**

Reference Materials:

1. Agenda Item G.3.a, Attachment 1: Excerpt from the Salmon FMP – § 3.2.3 Overfishing Concern.
2. Agenda Item G.3.a, Attachment 2: Table G3_Att_2.
3. Agenda Item G.3.a, Attachment 3: Draft Report on Factors Affecting the Low Abundance of Klamath Naturally Spawning Fall Chinook Salmon in 2004 and 2005.

Agenda Order:

a. Agenda Item Overview — Chuck Tracy
b. Agency and Tribal Comments
c. Reports and Comments of Advisory Bodies
d. Public Comment
e. **Council Action:** Direct Necessary Actions Required by the Salmon Fishery Management Plan

PFMC
02/20/07

3.2.3 Overfishing Concern

> *"For a fishery that is overfished, any fishery management plan, amendment, or proposed regulations . . . for such fishery shall–(A) specify a time period for ending overfishing and rebuilding the fishery that shall–(i) be as short as possible, taking into account the status and biology of any overfished stocks of fish, the needs of the fishing communities, recommendations by international organizations in which the United States participates, and the interaction of the overfished stock within the marine ecosystem; and (ii) not exceed 10 years, except in cases where the biology of the stock of fish, other environmental conditions, or management measures under an international agreement in which the United States participates dictate otherwise. . .."*
>
> *Magnuson-Stevens Act, § 304(e)(4)*

The Magnuson-Stevens Act requires overfishing be ended and stocks rebuilt in as short a period as possible and, depending on other factors, no longer than ten years. For healthy salmon stocks which may experience a sudden reduction in production and/or spawner escapement, the limitation on fishing impacts provided by the Council's MSY or MSY proxy conservation objectives provide a stock rebuilding plan that should be effective within a single salmon generation (two years for pinks, three years for coho, and three to five years for chinook). However, additional actions may be necessary to prevent overfishing of stocks suffering from chronic depression due to fishery impacts outside Council authority, or from habitat degradation or long-term environmental fluctuations. Such stocks may meet the criteria invoking the Council's overfishing concern.

3.2.3.1 Criteria

The Council's criteria for an overfishing concern are met if, in three consecutive years, the postseason estimates indicate a natural stock has fallen short of its conservation objective (MSY, MSP, or spawner floor as noted for some harvest rate objectives) in Table 3-1. It is possible that this situation could represent normal variation, as has been seen in the past for several previously referenced salmon stocks which were reviewed under the Council's former overfishing definition. However, the occurrence of three consecutive years of reduced stock size or spawner escapements, depending on the magnitude of the short-fall, could signal the beginning of a critical downward trend (e.g., Oregon coastal coho) which may result in fishing that jeopardizes the capacity of the stock to produce MSY over the long term if appropriate actions are not taken to ensure the automatic rebuilding feature of the conservation objectives is achieved.

3.2.3.2 Assessment

When an overfishing concern is triggered, the Council will direct its STT to work with state and tribal fishery managers to complete an assessment of the stock within one year (generally, between April and the March Council meeting of the following year). The assessment will appraise the actual level and source of fishing impacts on the stock, consider if excessive fishing has been inadvertently allowed by estimation errors or other factors, identify any other pertinent factors leading to the overfishing concern, and assess the overall significance of the present stock depression with regard to achieving MSY on a continuing basis.

Depending on its findings, the STT will recommend any needed adjustments to annual management measures to assure the conservation objective is met, or recommend adjustments to the conservation objective which may more closely reflect the MSY or ensure rebuilding to that level. Within the constraints presented by the biology of the stock, variations in environmental conditions, and the needs of the fishing communities, the STT recommendations should identify actions that will recover the stock in as short a time as possible, preferably within ten years or less, and provide criteria for identifying stock recovery and the end of the overfishing concern. The STT recommendations should cover harvest management, potential enhancement activities, hatchery practices, and any needed research. The STT may identify the need for special programs or analyses by experts outside the Council advisors to assure the long-term recovery of the salmon population in question. Due to a lack of data for some stocks, environmental variation, economic and social impacts, and habitat losses or problems beyond the control or management authority of the Council, it is likely that recovery of depressed stocks in some cases could take much longer than ten years.

In addition to the STT assessment, the Council will direct its Habitat Committee (HC) to work with federal, state, local, and tribal habitat experts to review the status of the essential fish habitat affecting this stock and, as appropriate, provide recommendations to the Council for restoration and enhancement measures within a suitable time frame.

3.2.3.3 Council Action

Following its review of the STT report, the Council will specify the actions that will comprise its immediate response for ensuring that the stock's conservation objective is met or a rebuilding plan is properly implemented and any inadvertent excessive fishing within Council jurisdiction is ended. The Council's rebuilding plan will establish the criteria that identify recovery of the stock and the end of the overfishing concern. In some cases, it may become necessary to modify the existing conservation objective/rebuilding plan to respond to habitat or other long-term changes. Even if fishing is not the primary factor in the depression of the stock or stock complex, the Council must act to limit the exploitation rate of fisheries within its jurisdiction so as not to limit recovery of the stock or fisheries, or as is necessary to comply with ESA consultation standards. In cases where no action within Council authority can be identified which has a reasonable expectation of providing benefits to the stock unit in question, the Council will identify the actions required by other entities to recover the depressed stock. Upon review of the report from the HC, the Council will take actions to promote any needed restitution of the identified habitat problems.

For those fishery management actions within Council authority and expertise, the Council may change analytical or procedural methodologies to improve the accuracy of estimates for abundance, harvest impacts, and MSY escapement levels, and/or reduce ocean harvest impacts when shown to be effective in stock recovery. For those causes beyond Council control or expertise, the Council may make recommendations to those entities which have the authority and expertise to change preseason prediction methodology, improve habitat, modify enhancement activities, and re-evaluate management and conservation objectives for potential modification through the appropriate Council process.

3.2.3.4 End of Overfishing Concern

The criteria for determining the end of an overfishing concern will be included as a part of any rebuilding plan adopted by the Council. Additionally, an overfishing concern will be ended if the STT stock analysis provides a clear finding that the Council's ability to affect the overall trend in the stock abundance through harvest restrictions is virtually nil under the "exceptions" criteria below for natural stocks.

TABLE G3_Att_2. Achievement of conservation objectives for natural stocks listed in Table 3-1 of the Pacific Coast Salmon Plan. Bolded numbers indicate a failure to meet the conservation objective. Stocks listed under the Endangered Species Act are not included. (Page 1 of 2)

Stock and Conservation Objective (thousands of spawners; spawners per mile; impact or replacement rate)	**Observed or Projected Conservation Achievement** (postseason estimates of thousands of spawners or spawners per mile; preseason or postseason impact or replacement rate)									**Overfishing Criteria**		
CHINOOK	1999	2000	2001	2002	2003	2004	2005	2006[a/]	2007[b/]	Alert[c/]	Concern[d/]	Exception[e/]
Sacramento River Fall 122.0 - 180.0 adult spawners	395.9	416.8	546.1	775.5	521.6	283.6	394.0	270.2	331.2	No	No	No
Klamath River Fall - < 66%-67% avg. spawner reduction rate but no less than 35.0 adult natural spawners annually	**18.5**	82.7	77.8	65.6	87.6	**24.1**	**26.8**	**30.4**	65.3	No	**Yes**	No
Southern, Central and Northern Oregon Coast Spring and Fall No less than 60 adult spawners/mile[f/]	124.0	85.0	203.0	268.0	297.0	211.0	118.0	81.0	>60	No	No	No
Upper Columbia River Bright Fall 43.5 adults over McNary Dam Council area base period impacts <4%	78.4	66.4	110.5	141.7	180.0	170.6	135.5	90.9	>43.5	No	No	Exp. Rate
Columbia River Summer Chinook 80.0 to 90.0 adults over Bonneville Dam Council area base period impacts <2%	**26.2**	**30.6**	**76.2**	127.4	114.8	NA	NA	NA	NA	NA	NA	NA
In 2004 state and tribal co-managers changed the stock definition from Chinook passing Bonneville Dam after May 31 to Chinook passing Bonneville Dam after June 14, and the goal changed to 29,000 at the river mouth	**20.1**	**22.3**	53.2	96.3	83.0	67.1	61.2	57.2	>29.0	No	No	Exp. Rate
Grays Harbor Fall - 14.6 adult spawners (MSP)	**10.4**	**9.3**	**9.5**	**11.3**	19.4	29.3	19.2	NA[g/]	NA[g/]	No	No	Exp. Rate
Grays Harbor Spring - 1.4 adult spawners	1.3	2.9	2.9	2.6	1.9	5.0	2.1	2.4	NA[g/]	No	No	Exp. Rate
Queets Fall - no less than 2.5 adult spawners (MSY)	**1.9**	3.6	2.9	1.9	5.0	3.5	3.1	NA[g/]	NA[g/]	No	No	Exp. Rate
Queets Spring/Summer - no less than 0.7 adult spawners	**0.4**	**0.3**	**0.6**	0.7	**0.2**	**0.6**	**0.3**	**0.3**	NA[g/]	Limited[e/]	No	Exp. Rate
Hoh Fall - no less than 1.2 adult spawners (MSY)	1.9	1.7	2.6	4.4	1.6	3.2	4.2	1.3	NA[g/]	No	No	Exp. Rate
Hoh Spring/Summer - no less than 0.9 adult spawners	0.9	0.5	1.2	2.5	1.2	1.8	1.2	0.9	NA[g/]	No	No	Exp. Rate
Quillayute Fall - no less than 3.0 adult spawners (MSY)	3.3	3.7	5.1	6.1	7.4	3.8	6.4	6.3	NA[g/]	No	No	Exp. Rate
Quillayute Spring/Summer - 1.2 adult spawners (MSY)	**0.7**	**1.0**	1.2	**1.0**	1.2	**1.1**	**0.9**	**0.6**	NA[g/]	Limited[e/]	No	Exp. Rate

TABLE G3_Att_ 2. Achievement of conservation objectives for natural stocks listed in Table 3-1 of the Pacific Coast Salmon Plan. Bolded numbers indicate a failure to meet the conservation objective. Stocks listed under the Endangered Species Act are not included. (Page 2 of 2)

Stock and Conservation Objective (thousands of spawners; spawners per mile; impact or replacement rate)	**Observed or Projected Conservation Achievement** (postseason estimates of thousands of spawners or spawners per mile; preseason or postseason impact or replacement rate)									**Overfishing Criteria**		
COHO	1999	2000	2001	2002	2003	2004	2005	2006[a/]	2007[b/]	Alert[c/]	Concern[d/]	Exception[e/]
Oregon Coast (OCN) - Total exploitation rate set annually; 15% in 2006, 20% in 2007.	9%	7%	NA	NA	NA	NA	NA	6.8%	6.2%	No	No	No
Grays Harbor - 35.4 adult spawners (MSP)	**33.3**	38.1	79.1	108.0	83.9	60.7	44.1	NA	>35.4	No	No	No
Queets - 5.8 to 14.5 adult spawners (MSY range) Includes supplemental adults	**5.3**	8.6	24.9	13.7	8.6	8.7	6.5	NA	>5.8	No	No	No
Hoh - 2.0 to 5.0 adult spawners (MSY range)	4.6	6.8	10.8	9.0	6.3	4.7	4.7	2.0	>2.0	No	No	No
Quillayute Fall - 6.3 to 15.8 adult spawners (MSY range)	9.4	13.3	18.9	23.0	14.8	13.4	11.5	**5.0**	>6.3	No	No	No
Western Strait of Juan de Fuca - 11.9 adult spawners	**8.0**	16.9	34.3	20.6	12.4	12.0	>11.9	>11.9	>11.9	No	No	No
Eastern Strait of Juan de Fuca - 0.95 adult spawners	1.4	2.1	2.6	2.5	2.9	8.50	>0.95	>0.95	>0.95	No	No	No
Hood Canal - 21.5 adult spawners (MSP)	**16.6**	27.3	94.7	69.3	170.3	146.1	38.1	>21.5	>21.5	No	No	No
Skagit - 30.0 adult spawners (MSP)	**27.3**	62.9	87.0	56.0	69.2	139.2	34.7	>30.0	>30.0	No	No	No
Stillaguamish - 17.0 adult spawners (MSP)	**7.0**	28.3	73.6	27.3	45.7	59.2	25.8	>17.0	>17.0	No	No	No
Snohomish - 70.0 adult spawners (MSP)	**61.3**	94.2	261.8	161.6	182.7	252.8	109.0	>70.0	>70.0	No	No	No

a/ Preliminary data.

b/ Preliminary approximations based on preseason abundance projections and last year's regulations or season structures.

c/ Conservation Alert - triggered during the annual preseason process if a natural stock or stock complex, listed in Table 3-1 of the salmon FMP, is projected to fall short of its conservation objective (MSY, MSY proxy, MSP, or floor in the case of some harvest rate objectives [e.g., 35,000 natural Klamath River fall Chinook spawners]).

Actions for Stocks that are not Exceptions - The Council will close salmon fisheries within its jurisdiction which impact the stocks, except in the case of Washington coastal and Puget Sound salmon stocks and fisheries managed under U.S. District Court orders. In these cases, the Council may allow fisheries which meet annual spawner targets developed through relevant U.S. v. Washington, Hoh v. Baldrige, and subsequent U.S. District Court ordered processes and plans, that may vary from the MSY or MSP conservation objectives. For all natural stocks that meet the conservation alert criteria, the Council will notify pertinent fishery and habitat managers, advising that the stock may be temporarily depressed or approaching an overfishing concern (depending on its recent conservation status), and request state and tribal fishery managers identify the probable causes, if known. If the stock has not met its conservation objective in the previous two years, the Council will request state and tribal managers to do a formal assessment of the primary factors leading to the shortfalls and report to the Council no later than the March meeting prior to the next salmon season.

d/ Overfishing concern - triggered if, in three consecutive years, the postseason estimates indicate a natural stock, listed in Table 3-1 of the salmon FMP, has fallen short of its conservation objective (MSY, MSP, or spawner floor as noted for some harvest rate objectives).

Actions required for Stocks that are not Exceptions - Within one year, the STT to recommend and the Council to adopt management measures to end the overfishing concern and recover the stock in as short a time as possible, preferably within ten years or less. The HC to provide recommendations for habitat restoration and enhancement measures within a suitable time frame.

e/ Exception -application of the conservation alert and overfishing criteria and subsequent Council actions do not apply for (1) hatchery stocks, (2) natural stocks with a cumulative adult equivalent exploitation rate of less than 5% in ocean fisheries under Council jurisdiction during the FRAM base periods, and (3) stocks listed under the ESA.

Conservation Alert and Overfishing Concern Actions for Natural Stocks that are Exceptions (those with exploitation rates limited to less than 5% in base period Council-area ocean fisheries) - Use the expertise of STT and HC to confirm negligible impacts of proposed Council fisheries, identify factors which have led to the decline or low abundance (e.g., fishery impacts outside Council jurisdiction, or degradation or loss of essential fish habitat) and monitor abundance trends and total harvest impact levels. Council action will focus on advocating measures to improve stock productivity, such as reduced interceptions in non-Council managed fisheries, and improvements in spawning and rearing habitat, fish passage, flows, and other factors affecting overall stock survival.

f/ Based on the sum of south/local and north migrating spawners per mile weighted by the total number of miles surveyed for each of the two components (2.2 miles for south/local and 7.5 miles for northern stocks).

g/ Preseason forecasts are not available for Washington coastal Chinook stocks.

Agenda Item G.3.a
Attachment 3
March 2007

Draft Report

Factors Affecting the Low Abundance of Klamath Naturally-Spawning Fall Chinook Salmon in 2004 and 2005

February 14, 2007
Prepared by the Pacific Fishery Management Council Habitat Committee in cooperation with the States of Oregon and California and the Yurok Tribe

TABLE OF CONTENTS

Introduction

The Council's fishery management plan (FMP) for salmon states that when a Conservation Alert concern is triggered, the Council must request state and tribal fishery managers to complete an assessment of the reasons for the shortfall within one year. In 2006, the Council directed its Habitat Committee (HC) to work with state and tribal habitat experts to review the status of the essential fish habitat affecting this stock and, as appropriate, provide recommendations to the Council for restoration and enhancement measures within a suitable time frame. This report is a result of these efforts.

Because Klamath River fall Chinook have failed to meet their escapement goal of 35,000 natural spawners for three consecutive years, the Council's criteria for an overfishing concern has been met. The salmon FMP states that "When an overfishing concern is triggered, the Council will direct its STT to work with state and tribal fishery managers to complete an assessment of the stock within one year... The assessment will appraise the actual level and source of fishing impacts on the stock, consider if excessive fishing has been inadvertently allowed by estimation errors or other factors, identify any other pertinent factors leading to the overfishing concern, and assess the overall significance of the present stock depression with regard to achieving MSY on a continuing basis…" (p. 3-4, 3-5). This preliminary report is intended to contribute to such a report developed by the STT during the coming year. As such, this report focuses primarily on habitat factors related to stock declines, rather than harvest and hatchery implications, which will be discussed in the STT's subsequent report.

It should be noted that this report discusses habitat impacts throughout the Klamath basin, including areas above Iron Gate dam that are currently inaccessible to fall Chinook. The authors felt that it was important to describe habitat impacts in this larger context. This particularly important now, when the benefits and drawbacks of dam removal are being considered by PacifiCorp, the operator of the dams, and the Federal Energy Regulatory Commission, which is currently in the process of relicensing the dams.

1.1 Current status of stock

Klamath River fall Chinook returns typically consist of age-2 to age-5 fish. The escapements that failed to meet the 35,000 natural spawning escapement objective during 2004, 2005, and 2006 primarily consisted of fish from the 2000-2002 brood years. The 2006 inriver run—primarily comprised of fish from brood years 2002-2004—was also projected to be substantially below the 35,000 spawning escapement objective, trigging a conservation alert.

2 Fishing

[This section has not been developed. Include: harvest management objectives; stock recruitment analysis; 66% spawner reduction rate; 35,000 natural spawning escapement floor; Amendment 15; possible effects of fishing; overfishing in parent years; overescapement in parent years; overfishing; harvest rates; technical infrastructure; F1 generation (hatchery fish counted as spawners); other issues]

3 Habitat

3.1 Historical perspective

3.1.1 Early impacts

Habitat for Chinook salmon in the Klamath River Basin has been seriously impacted over the past century and a half, beginning with gold dredging in the 1800s. Subsequent impacts from dam building and operation, grazing, agriculture, mining, wildfires, water diversion, timber harvest, floods, urbanization, and road construction have diminished the productive capacity of the stream and river habitat. As a result, the fisheries resources of the Klamath River have undergone a major decline during the past century, leading to the listing of Coho salmon under the Federal and California Endangered Species Acts and the curtailment of fisheries along the Pacific Coast from Cape Falcon, Oregon, to Monterey, California to protect Chinook originating in the Klamath Basin (PFMC 2004).

3.1.2 Current conditions

Since the early 1980s, the depleted status of Klamath River Basin fall Chinook stocks has constrained management of ocean fisheries from Northern Oregon to south of San Francisco during some years. To protect these stocks, on many occasions the Council has had to reduce the harvest of salmon in otherwise relatively healthy mixed-stock fisheries where Klamath salmon occur (PFMC 2002). In April 2006, the Council adopted the most restrictive salmon season in history, severely restricting fisheries south of Cape Falcon in order to address the depressed status of Klamath fall Chinook. This has led to significant economic consequences in many coastal communities. Compared to 2005 (which was also not a good year for salmon fisheries), coastwide income from the fisheries was reduced about 64% for commercial fisheries, and 29% for recreational fisheries.

3.2 Dams and their effects

3.2.1 General Dam Operations

Dams in the Klamath Basin include several on the upper mainstem of the Klamath River, as well as major dams on tributaries such as the Trinity and Shasta Rivers. These will be discussed in more detail below.

Although anadromous fish stocks fluctuate naturally, factors associated with hydropower operations in the Klamath Basin, including lack of fish passage and water quality impacts, have had a consistent and increasingly detrimental impact on Klamath River salmon. The Klamath Hydroelectric Project has a direct impact on the essential fish habitat (EFH) of coho and Chinook salmon. EFH includes the water quantity and quality conditions necessary for successful migration and holding, spawning, egg-to-fry survival, fry rearing, smolt migration, and estuarine rearing of juvenile coho and Chinook salmon (PFMC 2002).

All anadromous species in the Klamath River Basin have declined significantly in the years since initiation of the Klamath Hydroelectric Project. The Council believes the operations of the full complex of dams in the Klamath River basin can be a primary limiting factor for anadromous salmonid abundance (PFMC 2006).

The effects of the Klamath Hydroelectric Project and its operations are discussed in further detail below.

3.2.2 Mainstem Dams

The Klamath Hydroelectric Project consists of six dams within the mainstem Klamath River (Fig. 1), including:

- Iron Gate Dam (river mile 190, constructed 1962)
- Copco 2 (river mile 198, constructed 1925)
- Copco 1 (river mile 199, constructed 1918)
- JC Boyle (river mile 225, constructed 1958)
- Keno (river mile 233, constructed 1967)
- Link River (river mile 254, constructed 1921). This dam is only linked to the Klamath project by its East and West generation facilities (Federal Energy Regulatory Commission 2006; FERC 2006).

All of these dams, except the Link River dam (which is owned by the U.S. Bureau of Reclamation), are owned and operated by PacifiCorp. PacifiCorp also owns the Fall Creek Dam, on a tributary of the Klamath River above Iron Gate Dam upstream of the current range for anadromous fish.

The Klamath Project is currently undergoing a relicensing process. PacifiCorp has filed an application for relicensing with the Federal Energy Regulatory Commission (FERC), as the previous 50-year license expired during 2006. A final environmental impact statement (EIS) from FERC regarding the requested license is scheduled to be released during 2007. Currently the Project is operating under the authority of an annual license that was issued during the spring of 2006..

3.2.2.1 Lack of fish passage

The Klamath Project prevents access to more than 400 miles of migration, spawning, and rearing habitat for salmon, steelhead, and Pacific lamprey above Iron Gate Dam.

Iron Gate, Copco 2, and Copco 1 dams have no upstream or downstream fish passage facilities (FERC 2006). J.C. Boyle and Keno have upstream fish passage facilities, but downstream fish passage facilities at J.C. Boyle are ineffective, and entrainment and mortality has been documented with numerous fish salvages in the power canal. Downstream fish passage at Keno Dam is conducted through the dam's spill gates or fish ladder, auxiliary water supply, and sluice conduit; these fish are subjected to mechanical or hydraulic-caused injury and mortality. Link River Dam, at the northeast end of the Project, has a newly completed ladder that provides

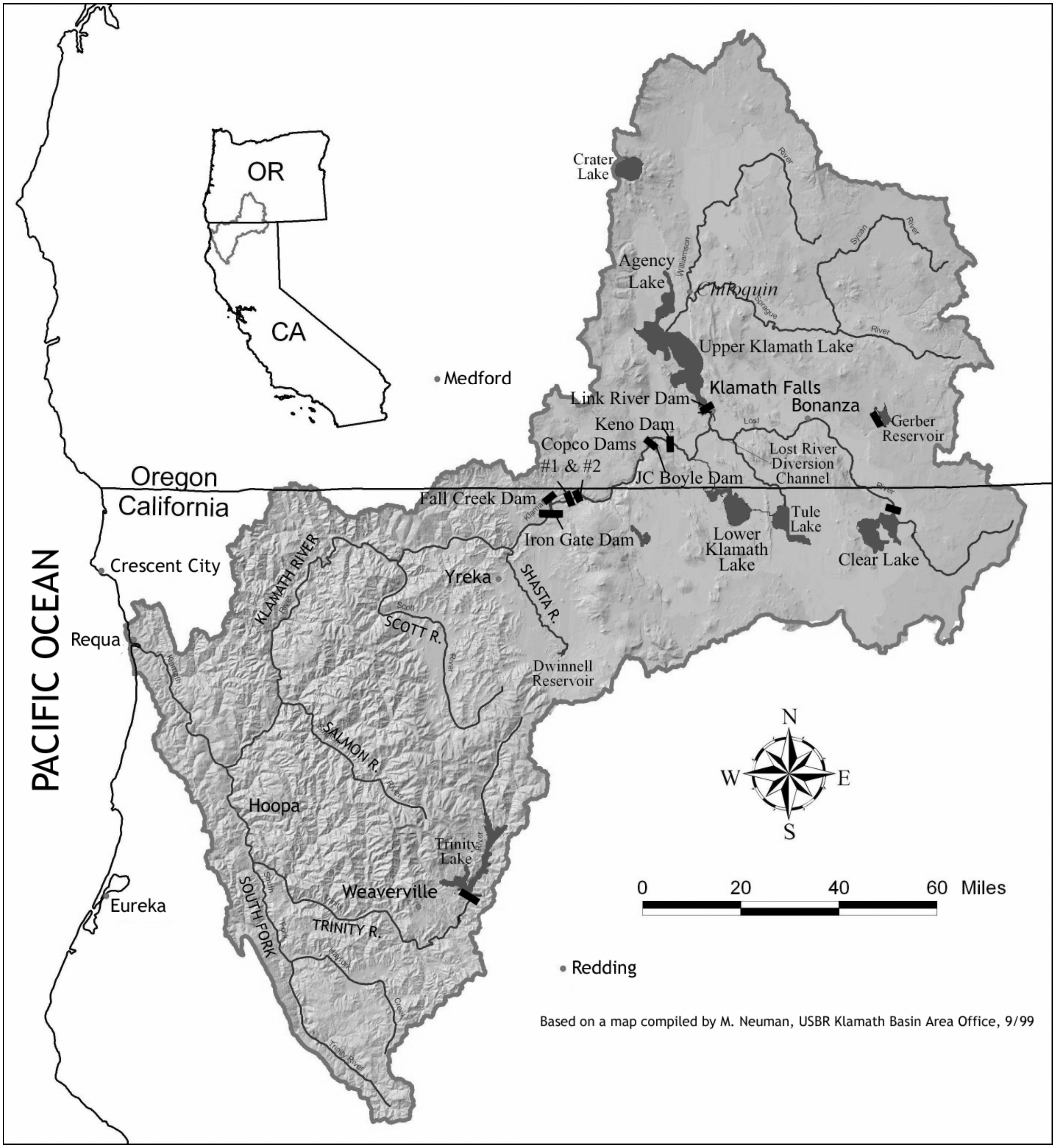

Fig. 1 The Klamath River Basin

passage for native fish including salmonids and suckers listed under the Endangered Species Act (ESA).

In addition, power canal diversions result in inadequate flow in stretches of the Klamath River below J.C. Boyle dam and Copco 1, and hydroelectric operations cause substantial diurnal flow fluctuations below power houses and dams. Such fluctuations are the result of efforts to maximize power generation to meet demand at peak times, and will be discussed in further detail below. Flows also fluctuate below the non-hydropower Keno Dam to facilitate peaking at J.C. Boyle and other downstream peaking facilities.

The Long Range Plan for the Klamath River Basin Conservation Area Fishery Restoration Program clearly identifies the lack of passage through and beyond the Klamath project area as a significant limitation on the Klamath River anadromous fish resource (KRBFTF and William M.Kier Associates 1991).

3.2.2.2 Unreachable habitat

As noted above, lack of fish passage at the Klamath Project facilities blocks access to more than 400 miles of anadromous fish habitat. Just within the Project reach, suitable anadromous fish habitat has been documented in 28 miles of mainstem river, 12 miles of perennial tributaries, and 18 miles of intermittent tributaries, for a total estimate of 58 miles of habitat (ALJ 2006). The project also blocks access to over 350 miles of habitat above Keno dam, including tributaries of Upper Klamath Lake where historically, steelhead and Chinook salmon (both spring and fall-run) were abundant (ALJ 2006 pp. 12, 24). Reintroducing anadromous fish above the current barrier of Iron Gate Dam is a key component of Klamath River Basin restoration. Significant resources are now being directed toward improving potential habitat in the Upper Klamath Basin above Upper Klamath Lake (PFMC 2006).

3.2.2.3 Impoundment Effects

A total of 41.7 miles of riverine channel has been inundated by Project reservoirs (9.1 miles for Iron Gate reservoir, 4.4 miles for Copco reservoirs; 3.7 miles for J.C. Boyle reservoir; and 23 miles for Keno reservoir) (PacifiCorp 2004). Project alterations include impounding waters at five dam sites, use of storage for peaking, diverting the majority of flows from bypassed Project reaches, and rapidly fluctuating flow rates due to ramping. These effects are discussed below.

3.2.2.3.1 Alteration of the natural hydrologic regime

The ecological structure and functioning of aquatic, wetland, and riparian ecosystems depends largely on the hydrologic regime. The Klamath Hydroelectric Project has significantly altered the natural hydrologic pattern of the Klamath River within the project reaches and downstream. Even though Klamath fall Chinook cannot migrate above Iron Gate dam, alterations in the hydrologic regime above the dam affect the ecosystem as a whole. Poff and Ward (1989) found that intra-annual variation in hydrologic conditions plays an essential role in species dynamics within such communities through influences on reproductive success, natural disturbance, and biotic interactions. Modifications of hydrologic regimes can indirectly alter the composition, structure, and functioning of aquatic, riparian, and wetland ecosystems (Stanford and Ward 1979). For example, project reservoir environments now favor mostly non-native species and impair native species (Moyle 2002). Non-native species compete with and prey on native species, limiting the productive potential of native fish populations in Project reservoirs.

Numerous studies demonstrate that departure from the natural flow regime leads to significant reductions in the functioning of river ecosystems (Poff, et al. 1997). To avoid this, significant components of the natural variability of river flow must be retained. Flows in the J.C. Boyle and Copco bypassed reaches have been severely altered from the natural flow regime. Most of the aquatic habitat that was present before the Project was constructed is now gone.

3.2.2.3.2 Reduced flood flows

Klamath Project reservoirs are relatively small, and are not operated for flood control. Though reservoirs allow high flows to pass, their magnitude is often decreased, especially in bypass reaches. For instance, the peak flow magnitude in the J.C. Boyle bypass reach is usually reduced by approximately 3000 cfs on events ranging from 5000-8000 cfs of total inflow (FERC 2006). This reduction in flood flows has resulted in changes in the distribution and species of riparian vegetation due to changes in the availability of sediments. For example, most riparian vegetation in the J.C. Boyle bypass and peaking reaches is dominated by reed canary grass, a highly invasive species that outcompetes native riparian species and survives well in excessively coarse substrate.

Reduced flows in the J.C. Boyle bypassed reach have also resulted in channel constriction, elimination of native riparian vegetation such as willows, and development of an island (PacifiCorp 2004). During construction of the road and power canal in the J.C. Boyle bypass reach, significant amounts of material were deposited within the right bank of the river. Riparian vegetation has been reduced by the deposits, aquatic habitats have been damaged, and fish passage constricted in some places.

Extremely reduced flows in the Copco No. 2 bypass reach have resulted in a significant degree of riparian encroachment into the active channel, a significantly reduced channel, and reduction in aquatic habitat availability (PacifiCorp 2004).

3.2.2.3.3 Effects of Hydroelectric Peaking Operations

Hydroelectric peaking operations are used to maximize hydroelectric revenues by maximizing power generation when demand is greatest. Storage at J. C. Boyle and Copco reservoirs is used to manipulate flows through the powerhouses to a constant, elevated level during the afternoon and early evening, and to minimum levels at night and in the morning. Such operations at the J.C. Boyle Powerhouse result in large, artificial, daily fluctuations in flows in the J. C. Boyle peaking reach. Flows exiting the Copco Powerhouse enter Iron Gate Reservoir directly, avoiding river reach flow fluctuations.

Such large flow fluctuations result in high mortalities of many aquatic populations from physiological stress, wash-out during high flows, and stranding during rapid dewatering (Cushman 1985; Petts 1984). Frequent dewatering can result in massive mortality of bottom-dwelling organisms and subsequent severe reductions in biological productivity (Weisberg, et al. 1990). Frequent flow fluctuations severely impair the rearing and refuge functions of shallow shoreline or backwater areas for small fish species or young life stages of larger fish (Bain, et al.

1988; Stanford 1994). Specific effects on the J.C. Boyle peaking reach and the Keno reach have been documented, including the stranding and mortality of hundreds of fish and tens of thousands of aquatic insects, and subsequent reduced productivity and survival of native trout populations (see ODFW 2006 for specific studies and references; Tinniswood and Smith 2003).

3.2.2.3.3.1 Effects of Large Flow Fluctuations in the Peaking Reaches

Comparison of the Keno, J.C. Boyle bypass, and J.C. Boyle peaking reaches provides an indication of the impacts of the large flow fluctuations caused by Klamath Project peaking operations. Although the Oregon Department of Fish and Wildlife (ODFW) supports restoration of anadromous fish species to historic habitat and is preparing a Reintroduction Plan, ODFW's current Fish Management Plan for the basin (ODFW 1997) identifies the primary objective for these Klamath River reaches as management of the native redband/rainbow trout. Creel census information from Toman (1983) show that numbers of trout in the J.C. Boyle bypass and peaking reaches were slightly less than in the Keno reach, and the size of fish was significantly larger in the Keno reach. PacifiCorp's studies (PacifiCorp 2005b) also showed that trout are significantly larger in the Keno reach. Further analysis indicates that the larger size of trout in the Keno reach is due to greater numbers of older fish and higher growth rates in older fish (Addley 2005). Trout growth in the bypassed reach is impaired by the removal of most of the flows from that reach, and growth in the peaking reach is impaired by the adverse effects of artificial flow fluctuations.

3.2.2.3.3.2 Abundance of Macroinvertebrates

Artificial flow fluctuations create a varial zone on the streambed that experiences alternating wetting and drying. A PacifiCorp analysis estimated that peaking operations reduce the wetted perimeter of the peaking reach by 10 to 25 percent (PacifiCorp 2005b). The extreme fluctuations in the varial zone significantly reduce the biomass of algae and macroinvertebrates. PacifiCorp found a distinctly lower abundance and diversity of macroinvertebrates in the varial zone of the peaking reach than in adjacent constantly wetted sites (Addley 2005). This effect greatly reduces food availability to fish in the peaking reach, leading to smaller size fish than those found in the Keno Reach (Addley 2005).

Macroinvertebrate drift density, a measure of food availability to trout, was measured in the three reaches (Addley 2005). Drift density was high in the Keno reach and low in the J. C. Boyle bypassed and peaking reaches. The Keno reach receives high amounts of nutrients that support primary and secondary production, yielding high macroinvertebrate densities. The J.C. Boyle bypassed reach receives few nutrients because the flows received from upstream are very low and the spring accretions are low in nutrients, yielding low rates of primary and secondary production. The J.C. Boyle peaking reach receives high amounts of nutrients from upstream (the hydroelectric flows are returned to this reach), but the effects of peaking on the varial zone reduce the ability of this reach to assimilate nutrients, limiting primary and secondary production.

As part of its relicensing, PacifiCorp prepared a Bioenergetics Report (Addley 2005) that analyzed the impacts of hydroelectric peaking on trout growth by comparing growth in different reaches of the Klamath River and by comparing growth with macroinvertebrate prey densities. The analysis indicates that the higher drift density of invertebrate prey likely is responsible for some of the higher growth rates in the Keno reach, and suggests that trout may be switching to more abundant or higher energy prey and/or migrating and modifying their temperature regime in later growth stages.

3.2.2.3.3.3 Water Quality

The large flow fluctuations associated with peaking hydropower operations limit the assimilative capacity of the river to remove hypereutrophic (excessively nutrient-rich) components of the water entering the system. In addition, highly variable flow regimes limit the success of benthic algae due to repeated drying and rewetting (PacifiCorp 2005c). Benthic algae are responsible for the removal of nutrients from the water column through assimilation. Without peaking operations, the Project reaches would provide stronger assimilation and removal of nutrients (PacifiCorp 2005c).

Peaking operations also affect temperatures, as will be discussed in Section 3.2.2.4.

3.2.2.3.3.4 Fish Stranding

Currently, fish stranding is not an issue in the area reachable by Klamath River fall Chinook. However, with a variety of proposals for the Klamath project currently under discussion, it is worth noting that hydropower peaking can cause significant salmonid losses due to stranding (Anglin, *et al.* 2005) and is likely causing stranding mortality of fry and juvenile fish in the J.C. Boyle peaking reach. The most common habitat types in the J.C. Boyle peaking reach are shallow rapids, riffles, and runs. Channels with an abundance of shallow habitat are more likely to have larger areas exposed during downramping (when water levels drop), where fish could become separated from the main river flow due to declines in stage (Hunter 1992). Recently, a stranding survey (Dunsmoor 2006b) indicated significant stranding-related fishery losses, especially during the first peaking event of the season. Later peaking events in the same season do not show the same dramatic effect, and rising water levels after the first downramping event (possibly combined with removals by predators and scavengers) sweep away the evidence (Dunsmoor 2006b).

Actually observing stranded fish can be quite difficult. The magnitude of fish stranding can be significantly underestimated using only observation techniques. Being in “the right place at the right time” can result in widely different estimates of stranding. This variability is documented in a technical memo provided by Mr. Larry Dunsmoor to the Klamath Tribe earlier this year (Dunsmoor 2006a). The memo summarizes a four-day stranding survey performed in early July 2006 at the start of the annual peaking cycles at J.C. Boyle powerhouse. In contrast to the few fish found by PacifiCorp during earlier field surveys, Mr. Dunsmoor found hundreds of dead and dying juvenile and larval fish, crayfish and macroinvertebrates on the first day of observation. Two days later, during a repeat survey, the number of stranded organisms observed in the same areas was estimated to be an order of magnitude less, illustrating the transient nature of stranded organisms in a natural setting.

The impacts of large flow fluctuations on aquatic resources were considered in depth as part of the trial-type hearing on the PacifiCorp project (Docket No. 2006-NMFS-0001) brought under the Energy Policy Act of 2005. This hearing generated multiple findings of fact. Several of the findings of the Administrative Law Judge (ALJ 2006) on peaking impacts are quoted below (pp. 45-46):

- "Peaking is the most widely documented source of fish stranding."
- "Peaking fluctuations can result in severe cumulative impacts to fish populations."
- "PacifiCorp's peaking operations cause high mortality to fish and other aquatic organisms through stranding."
- "The severe loss of fish and other aquatic life on July 2006 is directly attributable to PacifiCorp's peaking operations."
- "Peaking operations that cause high mortality likely only happen a few times a year, following the first peaking event after several months of steady flow."
- "Project peaking operations kill, through stranding, large numbers of young fish and aquatic invertebrates that are the primary prey food for trout."

The Administrative Law Judge also ruled on the issue of downstream displacement of fish (p. 46):

- "Few fry have been captured in the Oregon section of the peaking reach, the section of the peaking reach with the highest ramp rates."
- "PacifiCorp's mark-recapture studies did not mark or recapture any fry in the Oregon peaking reach, the area of peaking reach where peaking effects would be most pronounced."

Concerning bioenergetics, macroinvertebrates, and growth rates, the Administrative Law Judge found the following (pp. 47-48):

- "Flow fluctuations from peaking operations increase energetic demands on salmonids, decreasing energy available for overall health, growth, and reproduction."
- "Larger fish operate closer to the energetic margin, so energetic costs of peaking would be expected to reveal themselves in larger fish."
- "Peaking operations reduce the production of sessile organisms, like macroinvertebrates, by ten ('10') percent to twenty-five ('25') percent."
- "Macroinvertebrate drift rates, a measure of food availability for trout, in the non-peaking Keno reach were five to six times greater than in the peaking reach. Fluctuations in the peaking reach are undoubtedly a contributing factor to the lower macroinvertebrate drift rates."
- "[Compared to other areas with no peaking,] [a]verage trout size has decrease[d] since Project operations began. For trout residing below J.C. Boyle dam, the average length has decreased from about twelve inches (30 cm) in 1961, shortly after the J.C. Boyle facility was completed, to about seven inches (18 cm) in 1990. "
- "Most rivers in the Pacific Northwest do not naturally experience a ramp rate in excess of two inches per hour, except during or immediately after events such as an intense storm or flood event."

3.2.2.4 Changes to water temperature

Changes in water temperature due to reservoir impoundments are well documented (Crisp 1977; Jaske and Goebel 1967; Sylvester 1963). Reservoirs reduce annual and daily fluctuations in temperature and delay the warming and cooling periods by acting as thermal sinks. Bartholow (2005) modeled the effect of hypothetical removal of the Klamath hydroelectric dams on thermal characteristics of the Klamath River downstream of Iron Gate Dam. They found that dam removal would "restore the timing of the river's seasonal thermal signature by shifting it approximately 18 days earlier in the year, resulting in river temperatures that more rapidly track ambient air temperatures." With dam removal, water temperatures would be cooler in the fall and winter (when temperatures are cooling) and warmer in spring and early summer (when temperatures are warming); these thermal regimes are more similar to conditions under which anadromous fish evolved.

As part of its relicensing, PacifiCorp (PacifiCorp 2005a) modeled thermal lag conditions caused by Project reservoirs to assess temperature differences between existing conditions and hypothetically, without project conditions. Model results show that river reaches cool and heat relatively quickly without the reservoir volumes (assuming no reservoirs). Most of the alternatives modeled showed that under existing conditions, water temperatures are cooler in the spring and warmer in the late summer and fall than they would be without the dams. The Project dams appear to warm water temperatures by 1° to 5° C during the months of August through November, and to cool water temperatures by 1° to 3° C during the months of February through June (PacifiCorp 2005a).

Temperatures are critical for salmonids on the Klamath River. In the spring months of March through May, juvenile salmonids need temperatures above 10° to 13° C for optimal growth (EPA 2003). The Project significantly delays the onset of these temperatures (PacifiCorp 2005a) and likely slows juvenile salmonid growth. Juvenile disease risk is elevated at 14° to 17° C and is high at 18° to 20° C (EPA 2003). By slowing juvenile growth rates, juvenile outmigration is likely delayed, subjecting juvenile Chinook to higher temperatures and increased disease risk.

During summer months, high water temperatures in the mainstem Klamath River downstream of Iron Gate Dam are commonly cited as a cause of decline of anadromous fish runs in the Klamath River (Bartholow 1995; Campbell, et al. 2001). Temperatures commonly reach levels that are lethal to salmonids, and temperatures in the mainstem Klamath River "get higher with a greater frequency, and stay higher for a longer time, than waters in adjacent coastal anadromous streams" (Bartholow 1995). Spring Chinook, steelhead, and coho over-summer in the Klamath River as juveniles, making them especially vulnerable to these elevated temperatures. Salmonid juveniles have been shown to use cool water areas to get by during these warm time periods, but these areas are limited on the Klamath River; (Belchik 1997; Berman and Quinn 1991; Sutton, et al. 2004).

Project dams likely exacerbate the effects of high water temperatures on salmonid juveniles because while they decrease maximum temperatures in June and July, they also elevate minimum temperatures at that time and slow the cooling of both daily maximum and minimum temperatures in August and September (PacifiCorp 2005a). As stated earlier, juvenile disease risk is high at 18° to 20°C and temperatures are lethal above 23°C. The elevation of minimum daily temperatures in June and July is likely to impact fish by removing the effectiveness of important thermal refugial areas (NRC 2004). Indeed, juvenile fish die-offs in the Klamath River are not uncommon. Mortality of over 240,000 juvenile Chinook salmon in the Trinity and Klamath rivers was associated with water temperatures in excess of 20°C in June, July, and August (Williamson and Foott 1998).

Adult salmonids entering the river to spawn are likely impacted by the temperature effects of Project dams. Spring-run Chinook salmon enter the river in May and June and fall-run Chinook enter in August and September. Upstream migration appears to be delayed when temperatures equal or exceed 22°C, at which point adult Chinook seek out and reside in thermal refuges or stay in the estuary where temperatures are much cooler (Strange 2005). Thermal tolerances for adults are similar to those for juveniles identified above (EPA 2003). Therefore, the elevation of minimum daily temperatures in June and July caused by Project dams likely impacts Chinook trying to hold in thermal refugia, and may lead to premature mortality. The elevation of water temperatures in August and September due to Project dams likely postpones spawning migration, leading to delayed spawning and egg development and subsequent reduced survival. In addition, elevated water temperatures in August and September increase adult mortality by causing salmonids to crowd in poor quality habitat (Matthews and Berg 1997; Schreck and Li 1991). Such conditions are known to lead to outbreaks of diseases such as Flexibacter colunmaris (Holt, et al. 1975; Wakabayashi 1991), and Ichthyophthirius multifiliis (Bodensteiner, et al. 2000). Such an outbreak resulted in over 30,000 adult Chinook deaths in the Klamath River during September of 2002 (CDFG 2004; USFWS 2003a; USFWS 2003b).

It is worth noting that all reaches of the Klamath River, including Project reservoirs and riverine reaches, are listed for 303(d) violations for temperature, as they were during the brood years of 2000 and 2002 (the Klamath River was first listed in 1990). All Project reservoirs are listed for other water quality violations in addition to temperature. These include, but are not limited to, dissolved oxygen, toxic ammonia, pH, and chlorophyll-a. Nutrient assimilation occurs in free-flowing reaches of the Klamath River. Because of the water quality impacts caused by Project reservoirs, nutrient assimilation from Upper Klamath Lake releases is delayed many miles downstream of the hydroelectric Project than would normally have occurred upstream in the absence of the Project reservoirs.

3.2.2.5 Changes to dissolved oxygen

Water quality data shows that Klamath Project reservoirs negatively affect quality parameters by slowing and storing water. For example, although there is no dewatered reach or withdrawal for hydropower at the Keno Dam, the presence of the dam for regulating flows slows water through the entire reach from Lake Ewauna to below Keno Dam, increasing retention time and solar exposure and thereby contributing to water quality problems. Water quality conditions in the Keno Reservoir are typically within acceptable limits from October to June for native fish, including suckers and salmonids. However, water quality in Keno Reservoir is not within dissolved oxygen (DO) criteria for suckers or trout from July through September in most years. The Keno Reservoir experiences widespread persistent anoxia annually during warm summer months. During most years, Klamath Reservoir has a DO less than 6 mg/l and water temperatures greater than 20ºC. These impacts extend downstream during many years.

3.2.2.6 Changes to nutrient loads

Past studies have shown that the reservoirs do not trap or generate nutrients (Campbell 1999; EPA 1978). However, a recent nutrient budget analysis of Copco and Iron Gate reservoirs demonstrates that both reservoirs act as a source of nitrogen and phosphorus periodically, especially during the critical period of July through September (Kann 2005). Peaking and bypass operations inhibit the Klamath River's capacity to assimilate nutrients within the Project area (PacifiCorp 2005). Asarian and Kann (2006) found the free flowing river below Iron Gate has substantial assimilative capacity, and this same assimilative capacity would exist in other parts of the hydroelectric project if dams are removed.

3.2.2.7 Toxic Algae Blooms

The reservoirs of the Klamath Project have created large areas with ideal conditions for the development of toxic blue green algae blooms. Sampling in 2004, 2005 and 2006 demonstrated widespread and high abundance of toxic blooms in Copco and Iron Gate reservoirs from July-October, exceeding World Health Organization guidelines of both cell density and toxin by 10 to over 1000 times (Kann 2006). Blooms of Microcystis aeruginosa, a blue green alga (cyanobacteria), have recently been reported in Iron Gate and Copco Reservoirs (Kann 2005; Kann 2006; QVIC 2005). The Yurok tribe also found microcystin in adult steelhead that had only been in the river a short time.

M. aeruginosa is a microscopic organism that is found naturally at low concentrations in lakes and streams. Occasionally, it forms a harmful bloom, a dense aggregation of cells that float on the water surface. This species forms a toxin (microcystin) that is a strong hepatotoxin, causing liver disease in fish (Anderson, *et al.* 1993; Carmichael 1988), and promoting tumors (Carmichael 1995).

M. aeruginosa is commonly found in water bodies that are eutrophic (high in nutrients) and hypereutrophic (overly nutrient-rich) (Watanabe, et al. 1996). Excessive nutrients, poor water flow (stagnant conditions), and alterations of lake conditions such as land clearing, agricultural development, and water management have been associated with cyanobacteria blooms (Hallegraeff 1993). Research on the lower Neuse River of North Carolina indicated that blooms of M. aeruginosa were triggered by high levels of nutrients and periods of low flows and decreased turbulence (Paerl 1987).

M. aeruginosa may naturally exist in small concentrations along the margins of the Klamath River, but it would likely be far less abundant if the reservoirs were restored to free-flowing river reaches. In its Final License Application PacifiCorp states that "the risk of blue-green algae blooms in the Project area is less under the without-dams scenarios" (PC 2005, AR-2). Monitoring for the presence of M. aeruginosa and its effects on Klamath River biota are needed.

3.2.2.8 Disease

Significant juvenile Chinook and coho salmon fish kills and disease-related incidents occurred in the Klamath Basin every year from 2000-2004. An unprecedented and disastrous kill of adult anadromous salmonids occurred in the lower Klamath River in September, 2002 resulting in a conservatively estimated loss of more than 30,000 returning adult salmon, according to the U.S. Fish and Wildlife Service (a California Department of Fish and Game analysis indicated that the loss may have been more than double that number (CDFG 2004). Most of the mortalities were fall Chinook salmon, although hundreds of coho salmon and steelhead trout were also killed.

In 2002, ocean and inriver fisheries were managed to allow a fall Chinook spawning escapement to the Klamath basin of 57,000 adults, of which 35,000 were expected to spawn in natural areas and the rest at Iron Gate and Trinity River hatcheries. Actual returns were much greater, which likely resulted in the crowded conditions that contributed to the spread of disease. Actual natural spawning escapement in 2002 was over 65,000 adults, and therefore the 2002 adult fish kill may have had a minimal effect on the 2005 and 2006 shortfall.

Outmigrating juvenile Chinook and steelhead within the Lower Klamath River Basin experience significant mortality from infectious disease, with recent estimates of disease-related infection rates in downstream migrants as high as 90 percent (Foott, personal communication). The primary pathogens implicated in this mortality are the myxozoan parasites Ceratomyxa shasta and Parvicapsulum minibicornis (Foott, et al. 1999; Foott, et al. 2002; Foott, et al. 2003; Williamson and Foott 1998).

The life cycles of these parasites are complex and require development in both a vertebrate and invertebrate host. For C. shasta, the invertebrate host is the freshwater polychaete Manayunkia speciosa (Bartholomew, et al. 1997). Fish become infected by contact with actinospores that are produced within Manayunkia. Following fish mortality, myxospores are released into the water where they are then taken up by the polychaete. The invertebrate host for Parvicapsulum minibicornis has not yet been identified, but new information suggests that its host may also be Manayunkia (Hendrickson, personal communication).

Little is known of the life history, ecology, and distribution of Manayunkia. Within the Klamath River, Manayunkia has been collected from several locations above and below Iron Gate Dam, often in association with mats of the filamentous green alga Cladophora (Stocking and Bartholomew 2004). The polychaete inhabits a tube built of fine organic and/or inorganic particles, and its distribution may be restricted to locations where these particle sizes are readily available.

Researchers at Oregon State University are considering a hypothesis that algae buildup on substrate in the Klamath River contributes to increasing habitat suitable for the polychaete worm that is the alternate host for C. shasta (Stocking and Bartholomew 2004). Increases in such habitat can increase production of the polychaete and subsequently the number of myxozoan spores in the water column that may infect fish. In addition to high nutrient levels, reductions in the magnitude and extent of peak flows resulting from hydroelectric operations has likely increased the amount of stable habitat for the polychaetes downstream of the Project (McKinney, et al. 1999).

3.2.2.9 Gravel depletion

Native species in the Klamath River evolved under the seasonal variability of an unregulated river, with a freely moving sediment bedload. However, the Project’s dams have been collecting and storing sediments for decades, while reaches below the dams have been deprived and scoured of gravel and finer sediments. PacifiCorp (2004) reported that the Project impacts alluvial features (and therefore potential salmonid spawning material) from Iron Gate Dam to the confluence with Cottonwood Creek.

Lack of gravel and sediment recruitment to reaches below Project dams has led to a coarsening of the sediments and loss of gravel. This, combined with lack of seasonal flows, has led to a loss of channel structure and complexity, loss of alluvial features, and decreased productivity of fish habitat. Salmonids are dependent on the gravel sediments for spawning that are normally maintained by flood events, and riparian vegetation is important for providing stream edge habitats for juvenile rearing. It is possible that reduced sediment recruitment and associated scour has altered the environment for the life cycle of disease pathogens (e.g. the polychaete worm (manayunkia) and its habitat, which is essential for C. Shasta).

In most Project reaches, the river bed is coarsened as smaller gravels are transported downstream without being replaced, and larger gravels and cobbles that are unsuitable for use by spawning fish dominate (Kondolf and Matthews 1993; PacifiCorp 2004). PacifiCorp states that the Project causes a deficit of sediment for transport between dams and below the Project. The sediment supply in the reach below J.C. Boyle Dam is especially limited. In addition, the Project may have significantly coarsened the channel bed from downstream of Iron Gate Dam to the confluence with Cottonwood Creek (PacifiCorp 2004).

3.2.2.10 Loss of ecosystem function

Anadromous fish play a key role in ecosystem function. They are an important source of energy and nutrients for subsequent generations of salmon and to maintain proper ecological function (Stockner 2003). When salmon return from the ocean to spawn, they bring vital nutrients with them to the watershed. In addition to elemental nutrients, salmon carcasses contain minerals, amino acids, proteins, fats, carbohydrates, and other biochemicals essential for living organisms (Wipfli, et al. 2003). The significance of these biochemicals and their availability to the food web may be more important than nitrogen, phosphorous, or other nutrients (Wipfli, et al. 2003). In the Klamath River above Iron Gate Dam, anadromous fish previously provided nutrient input from the marine environment that is no longer occurring due to this Project.

It is likely that marine-derived nutrients from salmon carcasses would have an important effect on the recovery of riparian ecosystems in the Klamath River Basin and provide associated benefits to other species, including federally listed suckers and terrestrial wildlife. Decomposing carcasses provide a vital source of food and nutrients, not just for other fish species and wildlife, but for a host of organisms in the watershed vital to ecosystem health.

3.2.3 Major dams not on the mainstem

In addition to the mainstem Klamath Project dams, there are several dams not on the mainstem that affect salmonid abundance.

The Shasta River, with its stable, cool flows, was historically a highly productive producer of salmonids in the Klamath River system (NRC 2004). Currently, however, the Dwinell dam on the Shasta eliminates access to about 22% of habitat historically available to salmon and steelhead in the Shasta watershed (NRC 2004).

The Trinity River, the largest tributary of the Klamath Basin, was once a premier salmon producing river, with its fall Chinook supporting robust commercial, sport, and tribal fisheries and healthy coastal communities. However, since creation of the Trinity River Diversion in 1955 and subsequent operation of the Diverson in 1963, Trinity River fish stocks have steadily declined. This decline is primarily attributable to reductions in mainstem Trinity River stream flows and the resultant affect upon the geomorphology of the river. As part of the Diversion project, the Trinity and Lewiston River Dams were completed in 1961 and 1963, respectively. The dams cut off access to 109 miles of upstream anadromous fish habitat (NRC 2004). For many years following completion of Trinity Dam, approximately 90% of the water from above the dam was diverted to the Central Valley for agricultural and municipal purposes, as well as power production.

Following more than 17 years of studying the flows necessary to support healthy fish populations, a Record of Decision (ROD) regarding Trinity River flows was signed in December of 2000, allowing greater flows in the Trinity River. Now the various phases of the ROD (increased flow, mechanical restoration to improve geomorphic degradation caused by decades of decreased flow, gravel augmentation, and watershed restoration) are being implemented. Due to funding challenges, progress is slower than anticipated.

[This section not complete. Elaborate on benefits from ROD; which broods will benefit; connection to 2003 brood].

3.3 Federal Klamath Irrigation Project

The Federal Klamath Irrigation Project, operated by the U.S. Bureau of Reclamation, supplies irrigation water for local agriculture. The project irrigates over 200,000 acres on about 1,400 farms, and regulates flows to the Klamath River downstream.
[This section not complete.]

3.3.1 Private Off-Project Upper Basin water diversions

3.3.2 Shasta River water use

3.3.3 Scott River water use

3.3.4 Miscellaneous water diversions

3.4 Other inriver habitat impacts

Other inriver habitat impacts include effects of timber harvest practices (sedimentation, etc.); road building; mining, grazing, and channel alteration.

[This section not complete.]

3.5 Ocean conditions

[This section not complete.]

4 Hatcheries

[This section not complete.]

5 Cumulative effects

[This section not complete.]

6 Recommendations

Over the years, the Council has made a great number of recommendations for improving conditions in the Klamath Basin, through letters to the U.S. Bureau of Reclamation (BOR), U.S. Department of Interior, and FERC. These recommendations are summarized below:

6.1 Short-Term Recommendations

- **Reinitiate consultation** with National Marine Fisheries Service (NMFS) as soon as possible regarding the effects of water project operations on Chinook and coho salmon essential fish habitat (EFH). [This section needs updating after recent developments]
- **Ensure that Incidental Take Permits for the Shasta and Scott Rivers provide for adequate flows to sustain healthy fish populations**.
- **Fully implement the Trinity River Record of Decision**. Use of Trinity River water should only be considered for emergency conditions, as determined by basin fishery managers, and not as a holistic or permanent solution to inadequate Klamath Project releases to the Klamath River. The 146-mile anadromous reach of the Klamath River above the Trinity confluence that is not influenced by Trinity Project flow augmentation is very important as rearing and outmigration habitat for Chinook and coho salmon. CDFG has observed negative consequences from the highly unnatural pulsed flows from the Trinity to the lower Klamath River that have resulted in the premature upstream migration of fall Chinook to the upper Trinity River. The Council recommends that Trinity River water not be used in an unnatural fashion to mitigate for Klamath Project-induced low Klamath River flows. If additional water is necessary to augment Klamath River flows, then that water should not be taken from Trinity Record of Decision flow allocation, but from other sources.
- **Implement Hardy Phase II flow recommendations**.
- **Implement consistent/adequate (e.g. 25% CFM) coded wire tagging at Basin hatcheries**.
- **Support studies of juvenile survival and health and provide adequate funding for the Klamath monitoring programs.** Studies should be established and adequately funded to determine the rate of in-river juvenile mortality associated with these pathogens and to identify appropriate mitigating actions.

6.2 Long-Term Recommendations

- **Remove Iron Gate, Copco I, Copco II, and J.C. Boyle dams.** The Council has recommended that FERC order the decommissioning and removal of Iron Gate, Copco 1, Copco 2, and J.C. Boyle dams on the Klamath River, and that FERC proceed with the development of a decommissioning plan, in consultation with resource agencies, tribes, and other interested parties, that provides full restoration of habitat in and below the project dams and reservoirs. FERC should also consider including mitigation funds to restore future anadromous habitat above the project (PFMC 2006).

- **If four dams are not removed from the river, then fully implement the mandatory terms and conditions** regarding Section 18 and Section 4e of the Federal Power Act regarding fishways, river corridor conditions, and fish reintroduction. The Council believes that volitional anadromous fish passage should be included within Pacificorp's final license agreement, and that dam removal and/or project decommissioning should be examined in detail in an EIS. Trap and haul, as proposed by PacifiCorp and in the Draft EIS by FERC would not be adequate for several reasons (for examples see ODFW 2006). [This needs updating with recent developments.]
- **Return flows to a natural pattern.** In order to restore aquatic resources in bypassed reaches, including anadromous salmonids, it is necessary to return flows to a natural pattern. Flows in the bypassed reaches should optimize habitat availability, habitat quality (mostly temperature), and food availability. Increased flows in a pattern that mimics the natural flow regime would benefit salmonid productivity in the bypassed reaches. As part of the FERC relicensing process, governmental agencies have proposed minimum flow levels for the bypassed and peaking reaches that are more in line with natural flow regimes, along with a prescription to vary the flow as a percentage of inflow to restore variation (for instance see ODFW 2006). In addition, implement gravel restoration to restore channel habitat to more natural conditions than currently exist, particularly downstream from Iron Gate Dam.
- **Develop credible long-term solutions to water management problems within the Klamath Basin**. In light of protracted recurring droughts in the upper Klamath Basin, sufficient water supplies do not exist to fully support all resource needs. However, providing near-full irrigation deliveries at the expense of fishery resource water needs is short-sighted. The BOR should revisit the process used to allocate Project water in order to achieve a balanced allocation between irrigated lands and the river's fisheries, consisting of the full assemblage of anadromous fish both above and below the confluence of the Trinity River.

6.2.1 Recommended studies

[This section not completed]

6.2.2 Appendices/bibliography

Addley, R. C. B. Bradford and J. Ludlow. 2005. Klamath River Bioenergetics Report. Logan, UT: Institute for Natural Systems Engineering, Utah Water Research Lab, Utah State University.

ALJ (Administrative Law Judge). 9-28-2006. Decision in the Matter of Klamath Hydroelectric Project, Docket Number 2006-NMFS-0001, FERC Project Number 2082 and Attachment D, Rulings on Proposed Findings of Fact. Issued by Hon. Parlen L. McKenna.

Anderson, R. J., H. A. Luu, D. Z. X. Chen, C. F. B. Holmes, M. L. Kent, M. LeBlanc, F. J. R. Taylor, and D. E. Williams. 1993. Chemical and biological evidence links microcystins to salmon "netpen liver disease". *Toxicon* 31:1315-1323.

Anglin, D. R., Haeseker, S. L., Skalicky, J. J., Schaller, H., Tiffan, K. F., Hatten, J. R., Rondorf, D. W., Hoffarth, P., Nugent, J., Benner, D., and Yoshinaka, M. 2005. Effects of hydropower operations on spawning habitat, rearing habitat, and stranding/entrapment mortality of fall Chinook salmon in the Hanford Reach of the Columbia River.: Alaska Department of Fish and Game, Yakama Nation, Columbia River Inter-Tribal Fish Commission.

Asarian, E. and Kann, J. 2006. Klamath River Nitrogen Loading and Retention Dynamics, 1996-2004. Kier Associates Final Technical Report to the Yurok Tribe Environmental Program.: Klamath, CA.

Bain, M. B., J. T. Finn, and H. E. Brooke. 1988. Streamflow regulation and fish community structure. *Ecology* 69:382-392.

Bartholomew, J. L., M. J. Whipple, D. G. Stevens, and J. L. Fryer. 1997. The life cycle of *Ceratomyxa Shasta*, a myxosporean parasite of salmonids, requires a freshwater polychaete as an alternate host. *J. Parasitol* 83(5):859-868.

Bartholow, J. M. 1995. Review and analysis of Klamath River Basin water temperatures as a factor in the decline of anadromous salmonids with recommendations for mitigation. Fort Collins, CO: River Systems Management Section, Midcontinent Ecological Science Center: 1-54 in compilation of Phase I reports for the Klamath River Basin.

Bartholow, J. M., S. G. Campbell, and M. Flug. 2005. Predicting the thermal effects of dam removal on the Klamath River. *Environmental Management* 34(6):856-874.

Belchik, Michael. 1997. Summer Locations and Salmonid Use of Cool Water Areas in the Klamath River - Iron Gate Dam to Seiad Creek, 1996. Klamath, CA: Yurok Tribal Fisheries Program. Funded by : National Biological Service Cooperative Agreement.

Berman, C. H. and T. P. Quinn. 1991. Behavioral thermoregulation and homing by spring Chinook salmon, Oncorhynchus tshawytscha (Walbaum), in the Yakima River. *Journal of Fish Biology* 39:301-312.

Bodensteiner, L. R., R. J. Sheehan, P. S. Wills, A. M. Brandenburg, and W. M. Lewis. 2000. Flowing water: an effective treatment for ichthyophthiriasis. *Journal of Aquatic Animal Health* 12:209-219.

Campbell, S. G. 1999. Water quality and nutrient loading to the Klamath River from Keno, OR to Seiad Valley, CA during 1996-1997. Denver: University of Colorado.

Campbell, S. G., R. B. Hanna, M. Flug, and J. F. Scott. 2001. Modeling Klamath River system operations for quantity and quality. *Journal of Water Resources Planning and Management* 127:284-294.

Carmichael, W. W. 1995. Toxic Microcystis and the environment. In *Toxic Microcystis* Boca Raton, FL: CRC Press.

Carmichael, W. W. 1988. In *Handbook of Natural Toxins* Pages 121-147. New York: Marcel Dekker.

CDFG (California Department of Fish and Game). 2004. September 2002 Klamath River fish-kill: Final analysis of contributing factors and impacts.

Crisp, D. T. 1977. Some physical and chemical effects of the Cow Green (Upper Teesdale) impoundment. *Freshwater Biology* 7:109-120.

Cushman, R. M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. *North American Journal of Fisheries Management* 5:330-339.

Dunsmoor, L. 2006a. Observations and Significance of Fish and Invertebrate Stranding During the first Few Major Peaking Cycles in 2006 Downstream of the J.C. Boyle Hydroelectric Project.: Technical Memo to the Klamath Tribes, 18 pp.

Dunsmoor, L. K. and C. W. Huntington. 3-29-2006b. Suitability of environmental conditions with Upper Klamath Lake and the migratory corridor downstream for use by anadromous salmonids.

EPA (U.S.Environmental Protection Agency). 1978. Report on Iron Gate Reservoir, Siskyou County, California.: EPA Region IX, with the cooperation of the California State Water Resources Control Board and the California National Guard.

EPA (U.S.Environmental Protection Agency). 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. Seattle, WA: Region 10 Office of Water.

Federal Energy Regulatory Commission. Draft Environmental Impact Statement for the Klamath Hydroelectric Project, Docket No. P-2082-027. 2006.

FERC (Federal Energy Regulatory Commission). 2006. Draft Environmental Impact Statement for the Klamath Hydroelectric Project, Docket No. P-2082-027.

Foott, J. S., Harmon, R., and Stone, R. 2003. Ceratomyxosis resistance in juvenile Chinook salmon and steelhead trout from the Klamath River. FY2002 Investigational Report. Anderson, CA: U.S. Fish and Wildlife Service, California-Nevada Fish Health Center.

Foott, J. S., Martinez, T., Harmon, K., True, K. C., McCasland, B., Glase, C., and Engle, R. 2002. Juvenile Chinook health monitoring in the Trinity River, Klamath River and estuary, June - August 2001. FY2001 Investigational Report. Anderson, CA: U.S. Fish and Wildlife Service, California-Nevada Fish Health Center.

Foott, J. S., Williamson, J. D., and True, K. C. 1999. Health, physiology, and migration characteristics of Iron Gate Hatcher Chinook, 1995 releases. FY95 Investigational Report. Anderson, CA: U.S. Fish and Wildlife Service, California-Nevada Fish Health Center.

Hallegraeff, G. M. 1993. A review of harmful algal blooms and their apparent global increase. *Phycologia* 32(2):79-99.

Holt, R. A., J. E. Sanders, J. L. Zinn, J. L. Fryer, and K. S. Pilcher. 1975. Relation of water temperature to *Flexibacter columnaris* infection in steelhead trout *(Salmo gairdneri)*, coho *(Oncorhynchus kisutch)* and Chinook *(O. tshawytscha)* salmon. *Journal of Water Resources Planning and Management* 32:1553-1559.

Hunter, Mark. 1992. Hydropower flow fluctuations and salmonids: A review of the biological effects, mechanical causes and options for mitigation. Washington: Washington Department of Fisheries.

Jaske, R. T. and J. B. Goebel. 1967. Effects of dam construction on temperatures of the Columbia River. *Journal of the American Waterworks Association* 59:435-942.

Kann, J. 2005. Toxic Cyanobacteria in Copco and Iron Gate Reservoirs. Technical Memorandum Prepared for the Karuk Tribe of California.

Kann, J. (Aquatic Ecosystem Sciences LLC). 2006. Partial seasonal summary of 2006 toxic Microcystis aeruginosa trends in Copco and Iron Gate reservoirs and the Klamath River, CA.: Technical Memorandum to the Karuk Tribe Department of Natural Resources.

Kondolf, G. M. and Matthews, W. V. G. 1993. Management of coarse sediment on regulated rivers. Davis, CA: University of California Water Resources Center.

KRBFTF and William M.Kier Associates (Klamath River Basin Fisheries Task Force). 1991. *Long Range Plan for the Klamath River Basin Conservation Area Fishery Restoration Program*. Yreka, CA: U.S. Fish and Wildlife Service.

Matthews, K. R. and N. H. Berg. 1997. Rainbow trout responses to water temperature and dissolved oxygen stress in two southern California stream pools. *Journal of Fish Biology* 50(1):50-67.

McKinney, T., R. S. Rogers, and W. R. Persons. 1999. Effects of Flow Reductions on Aquatic Biota of the Colorado River Below Glen Canyon Dam, Arizona. *North American Journal of Fisheries Management* 19:984-991.

Moyle, P. B. 2002. *Inland Fishes of California (Second Edition)*: University of California Press.

NRC. 2004. *Endangered and Threatened Fishes in the Klamath River Basin - Causes of Decline and Strategies for Recovery*. Washington, D.C.: U.S. Department of Interior and U.S. Department of Commerce.

ODFW (Oregon Department of Fish and Wildlife). 1997. Klamath River Basin, Oregon fish management plan. Portland, OR: ODFW Fish Division.

ODFW (Oregon Department of Fish and Wildlife State of Oregon Hydroelectric Application Review Team). 2006. Comments and recommended 10(j) terms and conditions. Comments on the FERC Notice of Ready for the Assessment for the Klamath Hydroelectric Project (FERC #2080-027).: State of Oregon.

PacifiCorp. 2004. Water Resources, final technical report for relicensing the Klamath Hydroelectric Project (FERC Project No. 2082).

PacifiCorp. 12-16-2005a. Ecosystem Diagnosis and Treatment (EDT) Analysis. Response to November 10, 2005, FERC AIR AR-2.

PacifiCorp. 8-16-2005b. Instream flow studies and analysis of effects on aquatic habitat and other flow dependent resources. Instream flow addendum report prepared in response to FERC AIR AR-5.

PacifiCorp. 2005c. Response to FERC AIR GN-2, Status Report, Klamath River Water Quality Modeling, Klamath Hydroelectric Project Study 1.3 (FERC Project No. 2082). Portland, OR.

Paerl, H. W. 1987. *Dynamics of Blue-Green Algal (Microcystis Aeruginosa) Blooms in the Lower Neuse River, North Carolina: Causative Factors and Potential Controls*. Morehead City, NC: Water Resources Research Institute of the University of North Carolina.

Petts, G. E. 1984. *Impounded Rivers: Perspectives for Ecological Management*. New York: John Wiley & Sons.

PFMC. 2002. Letter to U.S. Department of the Interior and Secretary of Commerce.

PFMC. 2004. Letter to Federal Energy Regulatory Commission.

PFMC. 2006. Letter to the Federal Energy Regulatory Commission.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The Natural Flow Regime: A paradigm for river conservation and restoration. *BioScience* 47:11:769-784.

Poff, N. L. and J. V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. *Canadian Journal of Fisheries and Aquatic Sciences* 46:1805-1818.

QVIC (Quarz Valley Indian Community). 2005. Memo from Chairman Peters to Magalie Salas of FERC regarding toxic algae pollution in Copco Reservoir. Fort Jones, CA.

Schreck, C. B. and H. W. Li. 1991. Performance capacity of fish: stress and water quality. *Aquaculture and Water Quality. Advances in World Aquaculture 3.*:21-29.

Stanford, J. A. 1994. Instream flows to assist the recovery of endangered fishes of the Upper Colorado River Basin. Washington, D.C.: US Department of the Interior, National Biological Survey. Biological Report #24.

Stanford, J. A. and J. V. Ward. 1979. *The Ecology of Regulated Streams*Vol. No. 33757. New York: Plenum Press.

Stocking, R. W. and Bartholomew, J. L. 2004. Assessing links between water quality, river health and Ceratomyxosis of salmonids in the Klamath River system.: Oregon State University, Department of Microbiology.

Stockner, John G. 2003. Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity. Pages 1-285 in Bethesda, Maryland: American Fisheries Society.

Strange, J. S. 2005. Adult Chinook migration in the Klamath River Basin: 2003 radio telemetry study final progress report.: Yurok Tribal Fisheries Program; School of Aquatic and Fishery Sciences - University of Washington.

Sutton, Ron, Deas, Mike, Faux, Russ, Corum, R. Alex, Soto, Toz L., Belchik, Michael, Holt, Jamie E., McCovey, Barry W., and Myers, Frankie J. 2004. Klamath River Thermal Refugia Study Summer 2003. Klamath Falls, OR: Klamath Area Office, Bureau of Reclamation.

Sylvester, R. O. 1963. Effects of Water Uses and Impoundments on Water Temperature. *Proceedings of the 12th Pacific Northwest Symposium on Water Pollution Research v.s. Public Health Service*, Corvallis, OR.

Tinniswood, W. R. and Smith, R. C. 2003. Native Trout Project. Fish Research Project SFR-162-R, Annual Progress Report. Portland, OR: Oregon Department of Fish and Wildlife.

Toman, J. V. 1983. Klamath River: summary of existing physical and biological parameters. Oregon Department of Fish and Wildlife Central Region Administrative Report No. 85-5.: Oregon Department of Fish and Wildlife.

USFWS (USDI Fish and Wildlife Service). 2003a. Klamath River fish die-off - September 2002 - Causative factors of mortality. Arcata, CA: USDI Fish and Wildlife Service.

USFWS (USDI Fish and Wildlife Service). 2003b. Klamath River fish die-off - September 2002 - Report on estimate of mortality. Arcata, CA: USDI Fish and Wildlife Service.

Wakabayashi, H. 1991. Effect of environmental conditions on the infectivity of Flexibacter columnaris to fish. *Journal of Fish Diseases* 14:279-290.

Watanabe, M. F., K. Harada, W. W. Carmichael, and H. Fujiki. 1996. *Toxic Microcystis*: CRD Press, Inc.

Weisberg, S. B., A. J. Janicki, J. Gerritsen, and H. T. Wilson. 1990. Enhancement of benthic macroinvertebrates by minimum flow from a hydroelectric dam. *Regulated Rivers: Research & Management* 5:265-277.

Williamson, J. D. and Foott, J. S. 1998. Diagnostic evaluation of moribund juvenile salmonids in the Trinity and Klamath Rivers (June-Sept 1998). Anderson, CA: USDI Fish and Wildlife Service, California-Nevada Fish Health Center.

Wipfli, Mark S., John P. Hudson, and John P. Caouette. 2003. Marine subsidies in freshwater ecosystems: Salmon carcasses increase the growth rates of stream-resident salmonids. *Transactions of the American Fisheries Society* 132:371-378.