10.0 SCREENING LEVEL DETERMINATION OF CHEMICAL CONTAMINANTS IN FISH TISSUE IN SELECTED PROJECT RESERVOIRS

10.1 DESCRIPTION AND PURPOSE

Past activities in and around Lake Ewauna and other locations in Keno reservoir suggest that sediments in the reservoir may be contaminated with agricultural chemical residue, polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), and trace metals including mercury. While it is unknown whether the Klamath Hydroelectric Project has contributed to the potential sources of sediment contaminants, it is possible that accumulation of potentially contaminated sediments in Project reservoirs has resulted in conditions conducive to bioaccumulation of such contaminants.

Both Oregon[1] and California[2] have water quality standards concerning bioaccumulation of toxic substances. Therefore, the water quality agencies of both states requested that studies be done to determine whether bioaccumulation of potentially toxic contaminants was occurring. The purpose of this study was to determine if edible fish in the Project reservoirs contain unacceptably high residues of potentially toxic contaminants.

10.2 OBJECTIVE

This study is intended to be a Tier I (screening level) study of the Project reservoirs. The primary aim of the study was to identify whether certain fish species are bioaccumulating toxic substances at levels that may adversely affect public health or wildlife via fish consumption, or be harmful to aquatic life (based on existing quality criteria/guidelines for the protection of human health, wildlife, and aquatic life). Locations were sampled where fishing is practiced, including areas where various types of fishing are conducted routinely (e.g., from a pier, from shore, or from private and commercial boats), thereby exposing a significant number of people to potentially adverse health effects. Target species included commonly consumed species that are dominant in the catch and have high bioaccumulation potential. Composites of fillets of these target fish above legal size were analyzed for levels of potentially toxic contaminants.

10.3 RELICENSING RELEVANCE AND USE IN DECISIONMAKING

The study has indirect relevance to relicensing in that it will provide useful information to the water quality agencies considering Section 401 certification. The results of the study will help guide the development of PM&E measures. In addition, the results will be useful to regulatory agencies during development of TMDLs for the Lower Klamath River basin.

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[1] Oregon Administrative Rules 340-011-0965(2)(p)(A).

[2] North Coast Regional Water Quality Control Board, 1994. Water Quality Control Plan for the North Coast Region, as amended.

10.4 METHODS AND GEOGRAPHIC SCOPE

10.4.1 Geographic Scope

Fish samples will be collected from various locations in each of the Project reservoirs: Keno (including Lake Ewauna area), J.C. Boyle, Copco, and Iron Gate. Samples will also be collected from Klamath Lake to be used as a reference for background conditions.

10.4.2 Methods

The methods used for sample collection, handling, and analysis have been developed with input from toxicologists from ODEQ, and CDFG based on chemicals known to be used on USBR's Klamath Irrigation Project.[3] They follow guidance documents issued by the EPA.[4] Tissue samples were analyzed by the CDFG Fish and Wildlife Water Pollution Control Laboratory in Rancho Cordova.

Fish were collected and handled using proper techniques and protocols recommended by the CDFG water pollution control laboratory. Fish were collected during May 2003 using a variety of methods, including electroshocking, nets, and angling. Target species included the following:

- Largemouth bass (*Micropterus salmoides),* primary target species
- Bullhead (*Ictalurus spp.*), also primary target species in Keno reservoir only

Largemouth bass are the primary target species in all reservoirs. Also, bullhead are a primary target species in Keno reservoir. Fish used for analysis included the largest specimens of at least legal size customarily caught by recreational anglers or subsistence fishers. Fish for analysis were tagged, labeled, wrapped in aluminum foil, sealed in plastic, frozen immediately in the field, and shipped overnight to the laboratory for analysis. Length and weight were recorded for all fish used in the analysis.

Two composite samples comprising six fish each of the primary target species were analyzed for each reservoir. The tissue analyzed consisted of fillets with the skin on[5] for fish caught in both California and Oregon. Tissue composites were homogenized and analyzed for total lipids, pesticides, PCBs, and selected metals. Specific target compounds are listed in Tables 10.4-1 and 10.4-2. Metals analysis included arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc. The analytical results were compared to established screening values (EPA, 2000), as detailed in Tables 10.4-3, 10.4-4, and 10.4-5, to determine if there is cause for concern with regard to chemical contaminants.[6] Table 10.4-6 lists the agricultural chemicals used on the Klamath Irrigation Project in Oregon and in Siskiyou County, California.

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[3] Chemicals known to be used on the irrigated lands in the Klamath Irrigation Project are identified in Table 10.4-6.

[4] EPA 823-B-00-007, November 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories Volume 1: Fish Sampling and Analysis Third Edition. Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency, Washington, DC.

[5] EPA Guidance recommends using skin-on fillets. The State of California prefers skin-free fillets because of the great difficulty in obtaining uniform homogenates with skin-on fillets (Gassel, pers. comm.).

[6] Neither Oregon nor California has criteria for protection of wildlife related to fish tissue concentration of organic contaminants. Some tissue quality criteria and guidelines for the protection of wildlife from other jurisdictions are presented in Table 10.4-5.

The methods proposed are intended as a screening-level analysis of existing conditions. Should any proposed mitigation or enhancement measure or change in operations lead to significant disruption of sediments in the project reservoirs, additional studies of potentially toxic contaminants will be developed in cooperation with the relevant state agencies.

10.4.3 Relationship to Regulatory Requirements and Plans

This study helps PacifiCorp address regulatory requirements and planning objectives related to Project effects on water quality. The information derived from this study will help address FERC requirements (18 CFR 4.51 and 16.8) for information on water quality in the Project area and potential effects of Project operations on water quality.

Relicensing of the Project requires certifications from relevant agencies that the Project complies with requirements of Section 401 of the federal Clean Water Act. This study provides information to help assess potential Project effects as they relate to water quality objectives and standards promulgated by these agencies.

Together with other hydrology and water quality studies conducted by PacifiCorp, this study provides information to address compliance with management objectives from various resource agencies, tribes, and other stakeholders that relate to water quality, including the following:

- Federal Clean Water Act regulations
- State of Oregon Water Quality Management Plan for the Klamath Basin (Basin Plan)
- State of California Water Quality Control Plan for the North Coast Region (Basin Plan)
- Federal ESA regulations
- Tribal natural resources goals and objectives and cultural values
- Tribal water quality standards as promulgated
- USFS and BLM Aquatic Conservation Strategy objectives under the Northwest Forest Plan
- BLM Resource Management Plans
- USFS Land and Resource Management Plans
- ODFW Fish and Wildlife Habitat Mitigation Policy
- ODFW Klamath Basin Fish Management Plan
- CDFG management goals

This study's information also will help PacifiCorp develop protection, mitigation, and enhancement measures to meet the intention of the regulations and management objectives related to water quality.

Table 10.4-1. Organochlorine compounds analyzed and their minimum detection limits (MDL) and reporting limits (RL) in tissue.

	MDL (ng/g wet wt)	**RL (ng/g wet wt)**
Aldrin	0.26	1.0
Chlordane, cis	0.68	2.0
Chlordane, trans	0.40	2.0
Chlordene, alpha	0.26	1.0
Chlordene, gamma	0.25	1.0
Chlorpyrifos	0.81	2.0
Dacthal	0.58	2.0
DDD, o,p'	0.71	2.0
DDD, p,p'	0.84	2.0
DDE, o,p'	0.53	2.0
DDE, p,p'	0.56	2.0
DDMU, p,p'	1.1	3.0
DDT, o,p'	1.0	3.0
DDT, p,p'	2.0	5.0
Diazinon	6.4	20
Dichlorobenzophenone, p,p'	TBD	10
Dicofol (Kelthane)	NR	NR
Dieldrin	0.40	2.0
Endosulfan I	0.74	2.0
Endosulfan II	TBD	10
Endosulfan sulfate	TBD	10
Endrin	0.71	2.0
Ethion	1.9	6.0
HCH, alpha	0.36	1.0
HCH, beta	0.56	2.0
HCH, gamma	0.27	1.0
Heptachlor	0.51	2.0
Heptachlor epoxide	0.37	1.0
Hexachlorobenzene	0.10	0.3
Methoxychlor	1.3	5.0
Mirex	0.93	3.0
Nonachlor, cis	0.96	2.4
Nonachlor, trans	0.35	1.0
Oxadiazon	0.88	3.0
Oxychlordane	0.29	1.0
Parathion, ethyl	0.64	2.0

Table 10.4-1. Organochlorine compounds analyzed and their minimum detection limits (MDL) and reporting limits (RL) in tissue.

	MDL (ng/g wet wt)	**RL (ng/g wet wt)**
Parathion, methyl	1.2	4.0
Tetradifon (Tedion)	0.54	2.0
Toxaphene	To be determined	20

Source: EPA, 2001.
ng/g wet wt = nanograms per gram

Table 10.4-2. PCB congeners and Aroclor mixtures analyzed and their detection limits in tissue (ng/g wet wt).

NIST Congeners	
PCB Congener 8	PCB Congener 128
PCB Congener 18	PCB Congener 138
PCB Congener 28	PCB Congener 153
PCB Congener 44	PCB Congener 170
PCB Congener	PCB Congener 180
PCB Congener 66	PCB Congener 187
PCB Congener 87	PCB Congener 195
PCB Congener 101	PCB Congener 206
PCB Congener 105	PCB Congener 209
PCB Congener 118	
Additional Congeners	
PCB Congener 5	PCB Congener 137
PCB Congener 15	PCB Congener 149
PCB Congener 27	PCB Congener 151
PCB Congener 29	PCB Congener 156
PCB Congener 31	PCB Congener 157
PCB Congener 49	PCB Congener 158
PCB Congener 70	PCB Congener 174
PCB Congener 74	PCB Congener 177
PCB Congener 95	PCB Congener 183
PCB Congener 97	PCB Congener 189
PCB Congener 99	PCB Congener 194
PCB Congener 110	PCB Congener 201
PCB Congener 132	PCB Congener 203
All individual PCB Congener reporting limits are 0.2 ng/g wet weight.	
Aroclors	**Detection Limits ng/g wet wt.**
Aroclor 1248	25
Aroclor 1254	10
Aroclor 1260	10
Aroclor 5460 (polychlorinated terphenyl)	100

Source: EPA, 2000.

Table 10.4-3. Dose-response variables and recommended screening values (SVs) for target analytes - recreational fishers.[a]

Target analyte	Noncarcinogens RfD (mg/kg-d)	CarcinogensC SF $(mg/kg\text{-}d)^{-1}$	SV[b] (ppm)	
			Noncarcinogens[b]	Carcinogens[b] ($RL=10^{-5}$)
Metals				
Arsenic (inorganic)[c]	3×10^{-4}	1.5	1.2	0.026
Cadmium	1×10^{-3}	NA	4.0	-
Mercury (methylmercury)[d]	1×10^{-4}	NA	0.4	-
Selenium	5×10^{-3}	NA	20	-
Tributyltin[e]	3×10^{-4}	NA	1.2	-
Organochlorine Pesticides				
Total chlordane (sum of cis- and trans chlordane,cis- and trans-nonachlor, and oxychlordane)[f]	5×10^{-4}	0.35	2.0	0.114
Total DDT (sum of 4,4'- and 2,4'-isomers of DDT, DDE, and DDD)[g]	5×10^{-4}	0.34	2.0	0.117
Dicofol[h]	4×10^{-4}	Na[i]	1.6	2.5
Dieldrin	5×10^{-5}	16	0.2	2.50×10^{-3}
Endosulfan (I and II)[j]	6×10^{-3}	NA	24	-
Endrin	3×10^{-4}	NA	1.2	-
Heptachlor epoxide	1.3×10^{-5}	9.1	5.2×10^{-2}	4.39×10^{-3}
Hexachlorobenzene	8×10^{-4}	1.6	3.2	2.50×10^{-2}
Lindane (γ-hexachlorocyclohexane; g-HCH)[k]	3×10^{-4}	1.3	1.2	3.07×10^{-2}
Mirex	2×10^{-4}	Na[l]	0.8	-
Toxaphene[j,m]	2.5×10^{-4}	1.1	1.0	3.63×10^{-2}
Organophosphate Pesticides				
Chlorpyrifos[n]	3×10^{-4}	NA	1.2	-
Diazinon[o]	7×10^{-4}	NA	2.8	-
Disulfoton	4×10^{-5}	NA	0.16	-
Ethion	5×10^{-4}	NA	2.0	-
Terbufos[p]	2×10^{-5}	NA	0.08	-
Chlorophenoxy Herbicides				
Oxyfluorfen[q]	3×10^{-3}	7.32×10^{-2}	12	5.46×10^{-1}
PAHs[r]	NA	7.3	-	5.47×10^{-3}
PCBs				
Total PCBs[s]	2×10^{-5}	2.0	0.08	0.02
Dioxins/furans[t]	NA	1.56×10^{5}	-	2.56×10^{-7}

Table 10.4-3. Dose-response variables and recommended screening values (SVs) for target analytes - recreational fishers.[a]

Target analyte	Noncarcinogens RfD (mg/kg-d)	CarcinogensC SF $(mg/kg\text{-}d)^{-1}$	SV[b] (ppm)	
			Noncarcinogens[b]	Carcinogens[b] ($RL=10^{-5}$)

NA = Not available in EPA's Integrated Risk Information System (IRIS, 1999).
DDD = p,p'-dichlorodiphenyldichloroethane
DDT = p,p'-dichlorodiphenyltrichloroethane
DDE = p,p'-dichlorodiphenlydichloroethylene
PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl
RfD = Oral reference dose (mg/kg-d)
CSF = Cancer slope factor $(mg/kg\text{-}d)^{-1}$

[a] Based on fish consumption rate of 17.5 g/d, 70kg body weight and, for carcinogens, 10^{-5} risk level and 70-year lifetime. Unless otherwise noted, values listed are the most current oral RfDs and CSF in EPA's IRIS database (IRIS, 1999).

[b] The shaded screening value (SV) is the recommended SV for each target analyte. The SVs listed may be below analytical detection limits achievable for some of the target analytes. See Table 1 and 2 **??** for detection limits.

[c] Total inorganic arsenic rather than total arsenic should be determined.

[d] Because most mercury in fish and shellfish tissue is present primarily as methylmercury and because of the relatively high cost of analyzing for methylmercury, it is recommended that total mercury be analyzed and the conservative assumption be made that all mercury is present as methylmercury. This approach is deemed to be most protective of human health and most cost-effective. The National Academy of Sciences conducted an independent assessment of the RfD for methylmercury. They concluded that "On the basis of its evaluation, the committee's consensus is that the value of EPA's current RfD for methylmercury, 0.1Fg/kg per day, is a scientifically justifiable level for the protection of human health."

[e] The RfD value listed is for tributyltin oxide.

[f] The RfD and CSF values listed are derived from studies using technical-grade chlordane for the *cis*- and *trans*-chlordane isomers or the major chlordane metabolite, oxychlordane, or for the chlordane impurities *cis*- and *trans*-nonachlor. It is recommended that total chlordane be determined by summing the concentrations of *cis*- and *trans*-chlordane, *cis*- and *trans*-nonachlor, and oxychlordane.

[g] The RfD value listed is for DDT. The CSF value (0.34) is for total DDT sum of DDT, DDE and DDD); the CSF value for DDD is 0.24. It is recommended that the total concentration of DDT include the 2,4'- and 4,4'-isomers of DDT and its metabolites, DDE and DDD.

[h] The RfD value is from Office of Pesticide Programs Reregistration Eligibility Decision (RED) for Dicofol.

[i] The CSF for dicofol was withdrawn from IRIS pending further review by the CRAVE Agency Work Group.

[j] The RfD value listed is from the Office of Pesticide Program's Reference Dose Tracking Report.

[k] IRIS (1999) has not provided a CSF for lindane. The CSF value listed for lindane was calculated from the water quality criteria (0.063 mg/L).

[l] No CSF or cancer classification is available for mirex. This compound is undergoing further review by the CRAVE Agency Work Group.

[m] The RfD value has been agreed upon by the Office of Pesticide Programs and the Office of Water.

[n] Because of the potential for adverse neurological developmental effects from chlorpyrifos, EPA recommends the use of a Population Adjusted Dose (PAD) of 3×10^{-5} for infants, children under the age of 6 years, and women ages 13 to 50 years.

[o] The RfD value is from a memorandum dated April 1, 1998, Diazinon:-Report of the Hazard Identification Assessment Review Committee. HED Doc. No. 012558.

[p] The RfD value listed is from a memorandum dated September 25, 1997; Terbufos-FQPA Requirement- Report of the Hazard Idenification Review.

Table 10.4-3. Dose-response variables and recommended screening values (SVs) for target analytes - recreational fishers.[a]

Target analyte	Noncarcinogens RfD (mg/kg-d)	CarcinogensC SF $(mg/kg\text{-}d)^{-1}$	SV[b] (ppm)	
			Noncarcinogens[b]	Carcinogens[b] $(RL=10^{-5})$

[q] The CSF value is from the Office of Pesticide Programs List of Chemicals Evaluated for Carcinogenic Potential.

[r] The CSF value listed is for benzo[*a*]pyrene. Values for other PAHs are not currently available. It is recommended that tissue samples be analyzed for benzo[*a*]pyrene and 14 other PAHs, and that the order-of-magnitude relative potencies given for these PAHs be used to calculate a potency equivalency concentration (PEC) for each sample.

[s] Total PCBs may be determined as the sum of congeners or Aroclors. The RfD is based on Aroclor 1254 and should be applied to total PCBs. The CSF is based on a carcinogenicity assessment of Aroclors 1260, 1254, 1242, and 1016. The CSF presented is the upperbound slope factor for food chain exposure. The central estimate is 1.0.

[t] The CSF value listed is for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). It is recommended that the 17 2,3,7,8-substituted tetra- through octa-chlorinated dibenzo-*p*-dioxins and dibenzofurans and the 12 dioxin-like PCBs be determined and a toxicity-weighted total concentration be calculated for each sample, using the method for estimating toxicity equivalency concentrations (TEQs).

Source: EPA (2000).

Table 10.4-4. Dose-response variables and recommended screening values (SVs) for target analytes - subsistence fishers.[a]

Target analyte	Noncarcinogens RfD (mg/kg-d)	Carcinogens CSF $(mg/kg\text{-}d)^{-1}$	SV[b] (ppm)	
			Noncarcinogens[b]	Carcinogens[b] $(RL=10^{-5})$
Metals				
Arsenic (inorganic)[c]	3×10^{-4}	1.5	0.147	3.27×10^{-3}
Cadmium	1×10^{-3}	NA	0.491	-
Mercury (methylmercury)[d]	1×10^{-4}	NA	0.049	-
Selenium	5×10^{-3}	NA	2.457	-
Tributyltin[e]	3×10^{-4}	NA	0.147	-
Organochlorine Pesticides				
Total chlordane (sum of cis- and trans chlordane,cis- and trans-nonachlor, and oxychlordane)[f]	5×10^{-4}	0.35	0.245	1.40×10^{-2}
Total DDT (sum of 4,4'- and 2,4'-isomers of DDT, DDE, and DDD)[g]	5×10^{-4}	0.34	0.245	1.44×10^{-2}
Dicofol[h]	4×10^{-4}	NA[i]	0.196	-
Dieldrin	5×10^{-5}	16	0.024	3.07×10^{-4}
Endosulfan (I and II)[j]	6×10^{-3}	NA	2.949	-
Endrin	3×10^{4}	NA	0.147	-
Heptachlor epoxide	1.3×10^{-5}	9.1	6.39×10^{-3}	5.40×10^{-4}
Hexachlorobenzene	8×10^{-4}	1.6	0.393	3.07×10^{-3}
Lindane (γ-hexachlorocyclohexane; g-HCH)[k]	3×10^{-4}	1.3	0.147	3.78×10^{-3}
Mirex	2×10^{-4}	NA[l]	0.098	-

Table 10.4-4. Dose-response variables and recommended screening values (SVs) for target analytes - subsistence fishers.[a]

Target analyte	**Noncarcinogens RfD (mg/kg-d)**	**Carcinogens CSF $(mg/kg\text{-}d)^{-1}$**	**SV[b] (ppm)**	
			Noncarcinogens[b]	**Carcinogens[b] (RL=10^{-5})**
Toxaphene[j,m]	2.5×10^{-4}	1.1	0.122	4.46×10^{-3}
Organophosphate Pesticides				
Chlorpyrifos[n]	3×10^{-4}	NA	0.147	-
Diazinon[o]	7×10^{-4}	NA	0.344	-
Disulfoton	4×10^{-5}	NA	0.019	-
Ethion	5×10^{-4}	NA	0.245	-
Terbufos[p]	2×10^{-5}	NA	0.009	-
Chlorophenoxy Herbicides				
Oxyfluorfen[q]	3×10^{-3}	7.32×10^{-2}	1.474	6.71×10^{-2}
PAHs[r]	NA	7.3	-	6.73×10^{-4}
PCBs				
Total PCBs[s]	2×10^{-5}	2.0	9.83×10^{-3}	2.45×10^{-3}

NA = Not available in EPA's Integrated Risk Information System (IRIS, 1999).
DDD = p,p'-dichlorodiphenyldichloroethane
DDT = p,p'-dichlorodiphenyltrichloroethane
DDE = p,p'-dichlorodiphenlydichloroethylene
PAH = Polycyclic aromatic hydrocarbon
PCB = Polychlorinated biphenyl
RfD = Oral reference dose (mg/kg-d)
CSF = Cancer slope factor $(mg/kg\text{-}d)^{-1}$

[a] Based on fish consumption rate of 17.5 g/d, 70kg body weight and, for carcinogens, 10^{-5} risk level and 70-yr lifetime. Unless otherwise noted, values listed are the most current oral RfDs and CSF in EPA's IRIS database.

[b] The shaded screening value (SV) is the recommended SV for each target analyte. The screening values listed may be below analytical detection limits achievable for some of the target analytes. Please see Tables 1 and 2 for detection limits.

[c] Total inorganic arsenic rather than total arsenic should be determined.

[d] Because most mercury in fish and shellfish tissue is present primarily as methylmercury and because of the relatively high cost of analyzing for methylmercury, it is recommended that total mercury be analyzed and the conservative assumption be made that all mercury is present as methylmercury. This approach is deemed to be most protective of human health and most cost-effective. The National Academy of Sciences conducted an independent assessment of the RfD for methylmercury. They concluded that "On the basis of its evaluation, the committee's consensus is that the value of EPA's current RfD for methylmercury, 0.1Fg/kg per day, is a scientifically justifiable level for the protection of human health".

[e] The RfD value listed is for tributyltin oxide.

[f] The RfD and CSF values listed are derived from studies using technical-grade chlordane for the *cis*- and *trans*-chlordane isomers or the major chlordane metabolite, oxychlordane, or for the chlordane

Table 10.4-4. Dose-response variables and recommended screening values (SVs) for target analytes - subsistence fishers.[a]

Target analyte	Noncarcinogens RfD (mg/kg-d)	Carcinogens CSF $(mg/kg\text{-}d)^{-1}$	SV[b] (ppm)	
			Noncarcinogens[b]	Carcinogens[b] $(RL=10^{-5})$

impurities *cis*- and *trans*-nonachlor. It is recommended that total chlordane be determined by summing the concentrations of *cis*- and *trans*-chlordane, *cis*- and *trans*-nonachlor, and oxychlordane.

g The RfD value listed is for DDT. The CSF value (0.34) is for total DDT sum of DDT, DDE and DDD); the CSF value for DDD is 0.24. It is recommended that the total concentration of DDT include the 2,4'- and 4,4'-isomers of DDT and its metabolites, DDE and DDD.

h The RfD value is from Office of Pesticide Programs Reregistration Eligibility Decision (RED) for Dicofol.

i The CSF for dicofol was withdrawn from IRIS pending further review by the CRAVE Agency Work Group.

j The RfD value listed is from the Office of Pesticide Program's Reference Dose Tracking Report.

k IRIS (1999) has not provided a CSF for lindane. The CSF value listed for lindane was calculated from the water quality criteria (0.063 mg/L).

l No CSF or cancer classification is available for mirex. This compound is undergoing further review by the CRAVE Agency Work Group.

m The RfD value has been agreed upon by the Office of Pesticide Programs and the Office of Water.

n Because of the potential for adverse neurological developmental effects from chlorpyrifos, EPA recommends the use of a Population Adjusted Dose (PAD) of 3×10^{-5} for infants, children under the age of 6 years, and women ages 13 to 50 years.

o The RfD value is from a memorandum dated April 1, 1998, Diazinon:-Report of the Hazard Identification Assessment Review Committee. HED Doc. No. 012558.

p The RfD value listed is from a memorandum dated September 25, 1997; Terbufos-FQPA Requirement-Report of the Hazard Idenification Review.

q The CSF value is from the Office of Pesticide Programs List of Chemicals Evaluated for Carcinogenic Potential.

r The CSF value listed is for benzo[*a*]pyrene. Values for other PAHs are not currently available in IRIS. It is recommended that tissue samples be analyzed for benzo[*a*]pyrene and 14 other PAHs, and that the order-of-magnitude relative potencies given for these PAHs be used to calculate a potency equivalency concentration (PEC) for each sample.

s Total PCBs may be determined as the sum of congeners or Aroclors. The RfD is based on Aroclor 1254 and should be applied to total PCBs. The CSF is based on a carcinogenicity assessment of Aroclors 1260, 1254, 1242, and 1016. The CSF presented is the upperbound slope factor for food chain exposure. The central estimate is 1.0.

t The CSF value listed is for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). It is recommended that the 17 2,3,7,8-substituted tetra- through octa-chlorinated dibenzo-*p*-dioxins and dibenzofurans and the 12 dioxin-like PCBs be determined and a toxicity-weighted total concentration be calculated for each

Table 10.4-4. Dose-response variables and recommended screening values (SVs) for target analytes - subsistence fishers.[a]

Target analyte	Noncarcinogens RfD (mg/kg-d)	Carcinogens CSF $(mg/kg-d)^{-1}$	SV[b] (ppm)	
			Noncarcinogens[b]	Carcinogens[b] $(RL=10^{-5})$

sample, using the method for estimating toxicity equivalency concentrations (TEQs).

Source: EPA (2000).

Table 10.4-5. A summary of the available tissue quality criteria and guidelines for the protection of wildlife.

Chemical Name	Guideline	Units	Application	Jurisdiction	Reference
Aldrin/Dieldrin	0.12	µg/g	Non-carcinogenic final fish flesh criteria for piscivorous wildlife	New York	Newell et al. 1987
	0.022	µg/g	1 in 100 cancer risk criteria for piscivorous wildlife	New York	Newell et al. 1987
Chlordane	0.37	µg/g	1 in 100 cancer risk criteria for piscivorous wildlife	New York	Newell et al. 1987
	0.5	µg/g	Non-carcinogenic final fish flesh criteria for piscivorous wildlife	New York	Newell et al. 1987
DDTs, Total	0.2	µg/g	Non-carcinogenic final fish flesh criteria for piscivorous wildlife	New York	Newell et al. 1987
	0.27	µg/g	1 in 100 cancer risk criteria for piscivorous wildlife	New York	Newell et al. 1987
	1	µg/g	Whole fish, wet weight basis, for protection of fish consuming birds	Ontario	Environment Ontario 1984
Hexachlorobenzene	0.2	µg/g	1 in 100 cancer risk criteria for piscivorous wildlife	New York	Newell et al. 1987
	0.33	µg/g	Non-carcinogenic final fish flesh criteria for piscivorous wildlife	New York	Newell et al. 1987
Hexachlorocyclo-hexane (all isomers)	0.1	µg/g	Non-carcinogenic final fish flesh criteria for piscivorous wildlife	New York	Newell et al. 1987
	0.51	µg/g	1 in 100 cancer risk criteria for piscivorous wildlife	New York	Newell et al. 1987
Mirex	0.33	µg/g	Non-carcinogenic final fish flesh criteria for piscivorous wildlife	New York	Newell et al. 1987
	0.37	µg/g	1 in 100 cancer risk criteria for piscivorous wildlife	New York	Newell et al. 1987
PCBs, Total	0.11	µg/g	1 in 100 cancer risk criteria for piscivorous wildlife	New York	Newell et al. 1987
	0.11	µg/g	Non-carcinogenic final fish flesh criteria for piscivorous wildlife	New York	Newell et al. 1987
	0.1	µg/g	Maximum concentration	British Columbia	BCMOELP 1994
Pentachlorophenol	2	µg/g	Non-carcinogenic final fish flesh criteria for piscivorous wildlife	New York	Newell et al. 1987

Table 10.4-5. A summary of the available tissue quality criteria and guidelines for the protection of wildlife.

Chemical Name	Guideline	Units	Application	Jurisdiction	Reference
Selenium (total)	3	μg/g	Maximum criterion	British Columbia	BCMOELP 1994
T4CDD, 2,3,7,8-	0.000002	μg/g	1 in 100 cancer risk criteria for piscivorous wildlife	New York	Newell et al. 1987
	0.000003	μg/g	Non-carcinogenic final fish flesh criteria for piscivorous wildlife	New York	Newell et al. 1987
Tetrachlorophenol, 2,3,4,6-	0.67	μg/g	Non-carcinogenic final fish flesh criteria for piscivorous wildlife	New York	Newell et al. 1987

Table 10.4-6. Agricultural chemicals used on the Klamath Irrigation Project in Oregon and Siskiyou County, California.

2,4-D, Dimethylamine Salt	Lambda Cyhalothrin
2,4-D, Isooctyl Ester	Lauric Acid
Acephate	Malathion
Alcohols, C4-C12, Normal	Maleic Hydrazide, Potassium Salt
Alkyl Polyethylene Glycol Ether	Mancozeb
Alkyl Polyoxy Alkylene Ether	Manganese Sulfate
Alkylaryl Polyoxyethylene Ether	Manzate
Alpha-Alkyl-Omega-Hydroxypoly (Oxyethylene)	Mcp
Aluminum Phosphide	Mcpa
Atrazine	Mcpa, Dimethylamine Salt
Azadirachtin	Mefenoxam
Chloropicrin	Metam-Sodium
Disulfoton	Methamidophos
Glyphosate, Isopropylamine Salt	Methoxychlor
Oxyfluorfen	Methyl Bromide
Phosphatidylcholine	Methyl Bromide
Triclopyr, Triethylamine Salt	Methyl Parathion
2,4-D, 2-Ethylhexyl Ester	Methyl Silicone Resins
2,4-D, Butoxyethanol Ester	Methyl Soyate
2,4-D, Dimethylamine Salt	Metribuzin
2,4-D, Isooctyl Ester 1	Metribuzin
2,6,8-Trimethyl-4-Nonanol	Mh 30
4(2,4-Db), Dimethylamine Salt	Mocap
Alkyl Polyethylene Glycol Ether	Monitor
Alkyl Polyoxy Alkylene Ether	Myclobutanil
Alkylamine, Alkyl Derived From Coconut Oil Fatty	N,N-Bis-(2-(Omega-Hydroxypoly(Oxyethylene) Ethyl)
Alkylaryl Polyoxyethylene Ether	Nonyl Phenoxy Poly (Ethylene Oxy) Ethanol
Alpha-Alkyl (C12-C15) Omega-Hydroxy Poly (Oxyethylene)	Norflurazon
Aluminum Phosphide	Octyl Phenoxy Poly Ethoxy Ethanol
Ammonium Propionate	Oleic Acid, Methyl Ester
Ammonium Sulfate	Oxamyl
Atrazine, Other Related	Oxyethylene
Azoxystrobin	Oxyfluorfen
Benomyl	Para-Nonylphenyl Polyoxyethylene
Borax	Paraquat
Bromoxynil Octanoate	Paraquat Dichloride
Captan	Parathion
Carbofuran	Pendimethalin
Chloropicrin	Permethrin

Table 10.4-6. Agricultural chemicals used on the Klamath Irrigation Project in Oregon and Siskiyou County, California.

Chlorothalonil	Petroleum Hydrocarbons
Chlorpropham	Petroleum Oil, Paraffin Based
Chlorpyrifos	Phosphatidylcholine
Chlorthal-Dimethyl	Phosphoric Acid
Citric Acid	Polyacrylamide Polymer
Clethodim	Polyacrylic Polymer
Clopyralid, Monoethanolamine Salt	Polyalkene Oxide Modified Heptamethyl Trisiloxane
Coconut Diethanolamide	Polyalkyleneoxide Modified Polydimethyl-Siloxane
Compounded Silicone	Poly-I-Para-Menthene
Copper Hydroxide	Polymerized Acrylic Acid
Cyfluthrin	Polyoxyethylene Dinonyl Phenol
Cymoxanil	Polyram
Dicamba, Dimethylamine Salt	Pounce
Diglycolamine Salt Of 3,6-Dichloro-O-Anisic Acid	Propargite
Dihydrogen Phosphate Ester	Propionic Acid 1
Dimethoate	Propylene Glycol
Dimethyl Poly Siloxane	Pymetrozine
Diphacinone	Ridomil
Diquat Dibromide	Rimsulfuron
Disulfoton	Sencor
Diuron	Sethoxydim
Esfenvalerate	Sevin
Ethoxylated Alkyl Phosphate Esters	Simazine
Fluazifop-P-Butyl	Sodium Salt
Fosetyl-Al	Strychnine
Free Fatty Acids And/Or Amine Salts	Sulfometuron Methyl
Glyphosate, Isopropylamine Salt	Systox
Heptamethyltrisiloxane Ethoxylated (8 Eo)	Tall Oil Acids
Hexazinone	Telone
Imazamethabenz	Temik
Imazapyr, Isopropylamine Salt	Triclopyr, Butoxyethyl Ester
Imazethapyr	Trifluralin 220.0000 3 133.00 A
Iprodione	Undecyl Polyoxyethylene
Isopropyl Alcohol	Velpar
	Zinc Sulfate

Sources: California Department of Pesticide Reporting; Sorenson and Schwarzbach, 1991; Dileanis et al. 1996; Johnson et al. 1968.

10.5 TECHNICAL WORK GROUP COLLABORATION

PacifiCorp has worked with stakeholders to establish a more collaborative process for planning and conducting studies needed to support Project relicensing documentation. As part of this collaborative process, Water Quality Work Group was formed and has met approximately monthly to plan and discuss water quality studies and results, including this study.

10.6 RESULTS AND DISCUSSION

10.6.1 Results of Spring 2003 Sampling

The sampling and analysis screening level determination of chemical contaminants in fish tissue in selected project reservoirs (based on the approach described in Section 10.4.2 was not completed in time for inclusion in this FTR. Results of this sampling and analysis, when available from the CDFG Fish and Wildlife Water Polluton Control Laboratory, will be presented and discussed in a separate final study report.

11.0 INVESTIGATION OF KLAMATH RIVER FRESHWATER BIVALVES IN THE J.C. BOYLE PEAKING REACH AND DOWNSTREAM OF IRON GATE DAM

11.1 DESCRIPTION AND PURPOSE

Concerns have been raised that the Klamath Hydroelectric Project operations and current conditions in the Klamath River may be affecting populations and distribution of freshwater bivalves. Little information is known about the current status, distribution, and relative abundance of these species in the Klamath River. Freshwater bivalves play a key role in watershed health through the filtration process as they feed (Helfrich et al., 1997). Bivalves are able to incorporate toxins and metals into their tissue and shell structure, thus acting as a filter for environmental contaminants. Being long-lived, up to 140 years (Bauer, 1987), and sensitive to pollution, these species provide a good indicator of overall health of the aquatic ecosystem in which they reside.

Freshwater bivalves are fed upon by insects, fish, birds, and mammals (Watters, 1998). Indigenous peoples also ate freshwater bivalves and used their shells as trade items (Helfrich et al. 1997). Historical use of bivalves by the tribes of the Klamath River basin has not been specifically identified by the Traditional Cultural Property/Ethnographic Study performed by PacifiCorp in consultation with the tribes. It would be expected that some historical use of these mollusk species by tribes of the Klamath basin did occur, but the importance of species and overall level of historical use are unknown.

11.2 OBJECTIVES

The goal of this freshwater bivalve investigation is to better understand the relative abundance, diversity, distribution, and population characteristics of bivalves in the J.C. Boyle peaking reach and the peaking reach of the Klamath River from Iron Gate dam to the confluence with the Shasta River (PacifiCorp, 2003b). Information collected during this study complements a previous study that generalized the distribution of bivalves in the California section of the Klamath River (Taylor, 1981). The results of this bivalve study provide baseline information that may assist in the development of PM&E measures for freshwater bivalves within the Project area.

11.3 RELICENSING RELEVANCE AND USE IN DECISIONMAKING

The results of this study will provide baseline information to assist in the development of PM&E measures. Measures may be incorporated that take into consideration areas that are found to contain substantial bivalve communities. Protection of this resource will be beneficial to water quality and general ecosystem health.

11.4 METHODS AND GEOGRAPHIC SCOPE

11.4.1 Study Areas

The geographic scope of the focused bivalve survey included the Keno reach, the J.C. Boyle peaking reach, and the Klamath River between Iron Gate dam and the Shasta River confluence

(PacifiCorp, 2003b) (Table 11.4-1). The Keno reach was added to the study area based on ODFW observations of large bivalves in this area (PacifiCorp, 2003b).

Table 11.4-1. Project area reaches referred to in this bivalve section.

Reach	Origin and Terminus (RM)
Link River Reach	Link River dam (RM 253.7) to Keno reservoir (RM 253.1)
Keno Reservoir	RM 253.1 to Keno dam (RM 233)
Keno Reach	RM 233 to head of J.C. Boyle reservoir (RM 228)
J.C. Boyle Reservoir	RM 228 to J.C. Boyle dam (RM 224.7)
J.C. Boyle Bypass Reach	RM 224.7 to J.C. Boyle powerhouse (RM 220.4)
J.C. Boyle Peaking Reach	RM 220.4 to head of Copco No. 1 reservoir (RM 204)
Copco No. 1 Reservoir	RM 204 to Copco No. 1 dam (RM 198.6)
Copco No. 2 Reservoir	RM 198.6 to Copco No. 2 dam (RM 198.3)
Copco Reach	RM 198.3 to head of Iron Gate reservoir (RM 196.8)
Fall Creek	Approximately RM 196
Iron Gate Reservoir	RM 196.8 to Iron Gate dam (RM 190.1)
Klamath River below Iron Gate Dam	RM 190.1 to Shasta River confluence (RM 176.7)

Brief descriptions of these sampled riverine reaches are provided in the following subsections.

11.4.1.1 Keno Reach

The Keno reach of the Klamath River mainstem originates at Keno dam (impounds Keno reservoir in Oregon) and terminates at the head of J.C. Boyle reservoir (also in Oregon). Flow within the 5-mile Keno reach is comparable to Keno reservoir inflow as a result of low reservoir storage capacity (i.e., inflow and outflow hydrographs are similar). In this reach, the river is steep and fast, and water quality is comparable to that within the reservoir, where nearly hypereutrophic conditions exist. High levels of nutrients and reservoir algae enter the river at the head of the Keno reach.

11.4.1.2 J.C. Boyle Peaking Reach

The J.C. Boyle peaking reach of the Klamath River mainstem originates at the J.C. Boyle powerhouse (Oregon) and terminates at the head of Copco Lake. The powerhouse is operated on a demand schedule (peaking mode) when flows in the mainstem are less than about 3,000 cfs, generally in all seasons other than spring. Daily instream flows within this approximately 16-mile reach are highly variable. Water quality within the J.C. Boyle peaking reach also varies with flow variability. During nonpeaking periods, water quality is similar to the higher quality groundwater from the upstream J.C. Boyle bypass reach. Conversely, during peaking periods, water quality in the peaking reach is mostly determined by lower quality water bypassed to the powerhouse from J.C. Boyle reservoir. Because of the short retention time of the reservoirs, this water quality is generally indicative of upper Klamath River basin conditions.

11.4.1.3 Klamath River below Iron Gate Dam

This reach originates at Iron Gate dam and terminates (by definition) at the confluence of the Shasta River. The constant power generation mode of Iron Gate dam provides stable flows to this approximately 13-mile reach of the Klamath River mainstem. Spills in the winter and spring months may occur when river flow exceeds the powerhouse hydraulic capacity of 1,735 cfs. Water quality within this reach is similar to that within Iron Gate reservoir.

11.4.1.4 Other Areas

In addition to the focused bivalve survey work within the reaches noted above, bivalves were collected incidentally in fall 2002 and spring 2003 during routine macroinvertebrate bioassessment sampling in both reservoir (Keno, J.C. Boyle, Iron Gate, and Copco) and riverine habitats (mainstem Klamath River and Fall Creek). This section reports the results of all three surveys.

11.4.2 Literature Review and Personal Contacts

There is no published information that specifically addresses the distribution and abundance of freshwater bivalves within the Project area. General references on the subject include the following:

- Freshwater mollusks of California: a distributional checklist (Taylor, 1981)
- Aquatic mollusk fauna in PacifiCorp's Project area (PacifiCorp, 2003c)
- The freshwater mussels of California (Bonnot, 1951)
- The larger freshwater clams of California, Oregon, and Washington (Ingram, 1948)

These references and several others (specifically, Frest and Johannes, 1998; 2000) were reviewed to summarize the previously described distribution of freshwater bivalves in and near the Project area.

Terrence Frest of Deixis Consultants was contacted by CH2M HILL biologist Earl Byron in June 2003 (Frest, pers. comm.) to discuss potential sample station locations within the Project area. Dr. Frest's comments and the reports noted above are summarized below.

11.4.3 Field Methods – Focused Surveys

This study focused on large (generally, 2 to 4 inches) bivalve species of the family Unionidae, which in California includes the genera *Anodonta*[1] (floaters), *Gonidea* (ridgemussel), and *Margaritifera* (pearlmussel)(PacifiCorp, 2000b). Sample sites (stations) within the three noted Project area reaches were established in early September 2003, based on the presence of apparently suitable habitat. Suitable habitat was determined by review of the detailed Scope of Work for this project (PacifiCorp, 2000b), review of available literature, personal contact with authorities on the subject (Frest, pers. comm, 2003), and professional judgment of the biologists conducting this study. In general, suitable habitat included those areas with benthic substrates

[1] *Gonidea angulata* is the only species within the genus *Gonidea* monospecific genus), and this species is therefore commonly referred to in this section by its generic name only. In contrast, several species of *Anodonta* exist in California, necessitating the use of the full genus-species nomenclature in this section. Where "*Anodonta*" appears without reference to a species, it should be interpreted as *A. oregonensis*.

finer than gravels (i.e., coarse sands to silts). Exceptionally swift water areas were not sampled because of safety concerns, and sampling was therefore restricted to lentic and lower-velocity areas (usually stream margins).

The size of the Project area and access considerations limited ability to evaluate all habitat areas within the noted reaches. Project area maps and documents were reviewed to preliminarily identify potentially suitable habitat areas and access points (e.g., Shaw, 2003). Accessible areas of suitable habitat were first inspected for the presence of empty shells (valves) on the riverbank or in the nearshore water. Empty shells are commonly indicative of small mammal (e.g., muskrat, river otter) predation (Convey et al.1989) and the presence of nearby bivalve beds. At locations where empty shells were observed, biologists used buckets with Plexiglas panels to view the nearshore bottom sediments to depths of 2 to 3 feet, depending on water visibility. Nearshore habitats were examined using snorkeling gear if water depth exceeded 3 feet.

If large bivalves were found using either method, the “bed” was characterized in terms of its size and species composition, referencing the methods of Strayer and Smith (2003). Several methods were used to characterize these mussel beds. For large, dense beds, composition and abundance were determined by observations within randomly located 0.25-m quadrats. For smaller and/or less-dense beds, bed margins were located and all bivalves located within the bed were identified and enumerated through intensive searches.

Regardless of the method used, bivalves were collected, measured, and returned to their bed locations as soon as possible. Voucher material (both empty valves and living specimens) was collected and sent to Terrence Frest of Deixis Consultants in Seattle, Washington, for authoritative identification. Sample stations were mapped using a global positioning system (GPS). Pictures were taken at several of the stations sampled.

11.4.4 Field Methods – Macroinvertebrate (Incidental) Surveys

As noted previously, freshwater bivalves were also collected during sampling efforts targeting aquatic insects. Methodologies for macroinvertebrate sampling are presented in Section 8.0 (fall 2002) and Section 12.0 (spring 2003) of this document. In general, macroinvertebrates (including small bivalve mollusks) were collected using kicknets for riverine habitats and bucket dredges for reservoir habitats. Reservoirs were sampled only during fall 2002 while riverine sites were sampled during both periods.

11.5 RELATIONSHIP TO REGULATORY REQUIREMENTS AND PLANS

This study helps PacifiCorp address regulatory requirements and planning objectives related to water quality effects on macroinvertebrates. The information derived from this study helps address FERC requirements (18 CFR 4.51 and 16.8) and the potential effects of Project operations for information on water quality and fish and wildlife in the Project area.

11.6 TECHNICAL WORK GROUP COLLABORATION

PacifiCorp has worked with stakeholders to establish a more collaborative process for planning and conducting studies needed to support Project relicensing documentation. As part of this collaborative process, a Water Quality Work Group was formed and has met approximately monthly to plan and discuss water quality studies and results, including this study.

11.7 RESULTS

11.7.1 Review of Existing Information on Aquatic Mollusk Fauna

This section provides a review of existing data and information on aquatic mollusk fauna in the Project area. For the purposes of this review, all sites in affected reaches, or spring runs adjacent to the affected reaches, were included. These areas do not consistently fall within the FERC Project boundary and are substantially more encompassing in geographic scope. This review covers a portion of Upper Klamath Lake near the Link River dam, Link River, Keno reach (includes Lake Ewauna), J.C. Boyle reach (peaking and bypass), and Fall Creek.

11.7.1.1 Regional Overview

The Klamath River basin is a highly diverse region for freshwater mollusk species. Aquatic mollusks may be found in lotic and lentic habitats, with springs containing the most diversity and endemism of species. The Upper Klamath River drainage, not all of which is in the Project area, contains 73 mollusk species. Much of this diversity can be attributed to the continuance of Upper Klamath Lake as a Great Basin pluvial lake (Frest and Johannes, 1998; Frest and Johannes, 2002). To add to the evolutionary complexity of this ancient lake system, it is thought that a connection to the Columbia River basin, the Sacramento River system, and the Rogue/Umpqua basin existed sometime in the past (Frest and Johannes, 1998; Frest and Johannes, 2000). Aquatic mollusk species in the Klamath River basin are a mix of both coastal and Great Basin fauna (Frest and Johannes, 1998). The eruption of Mount Mazama and the corresponding ash falls reduced the area's diversity, although some mollusk fauna survived the incident (Frest and Johannes, 1998; Frest and Johannes, 2002).

11.7.1.2 Project Area Mollusk Fauna

Based on the literature review, 37 species of aquatic mollusks have been identified in or adjacent to the Project area (Frest and Johannes, 1998; Taylor, 1981). Species are found to transition through the available habitats, with obvious differences in species composition among the reaches. Highly diverse and endemic populations are associated with springs and are found adjacent to lotic habitat (spring runs), in the river in the form of seeps (riverine), or as large groundwater accretions within lentic habitats. Endemism occurs in the genera *Fluminicola, Juga, Lyogyrus, Pyrgulopsis, Vorticifex, Lanx,* and *Carinifex* (Frest and Johannes, 1998). Less disturbed tributary systems and their associated springs, such as Fall Creek and Jenny Creek in the mid-Klamath River basin, contain a high number (six) of endemic species from the genera *Juga* (Frest and Johannes, 2000).

Several species have been identified as being in need of some form of protective status. These include *Fluminicola* n. sp. 1, *Fluminicola* n. sp. 3, *Gonidea angulata, Lanx klamathensis, Lyogyrus* n. sp. 3, *Margaritifera falcata, Pisidium ultramontanum, Prygulopsis* n. sp. 1, *Pyrgulopsis archimedis,* and *Vorticifex klamathensis klamathensis.* Very little information is known about the overall status of many of the aquatic mollusk species that are found within the Project area. Overall populations are thought to be declining as a result of habitat degradation and overall loss of suitable habitat.

Most aquatic mollusk species are sensitive to environmental disturbances. Some have been identified as "cold water biota" and include the following that are found within the Project area: *Valvata hummeralis, Pyrgulopsis* sp., *Lyogyrus* sp., *Fluminicola* sp., *Stagnicola montanensis, Lanx* sp., *Helisoma newberryi, Vorticifex* sp., *Pisidium ultramontanum,* and *Pisidium punctatum* (Frest and Johannes, 1998). Distribution of cold water biota aquatic mollusk species in the Klamath River basin is limited to areas with unpolluted, cold, clear, flowing water. These species are intolerant of impoundments, slack water, herbicides, pesticides, nitrates or phosphates, high turbidity , unstable substrates, and frequent water surface fluctuations. Loss of host species for the larval life stage may also be detrimental to some aquatic mollusk species.

11.7.1.3 Historical Distribution of Freshwater Bivalves in the Project Area

Distribution of aquatic mollusks in the Klamath River basin has been obtained from sampling conducted by T.J. Frest and J. Johannes from 1995 to 1998 and from earlier work by D.W. Taylor (1981) in California. PacificCorp (2003c) summarized the known distribution of freshwater bivalves within the Project area. Eight freshwater bivalve taxa (some not identified to species level) have been reported from, or potentially occur within, the Project area. One of these is formally recognized as sensitive by federal and state resource agencies. Table 11.7-1 lists these eight taxa and summarizes their reported distributions in the Project area.

Protective status is identified where applicable. Locations have been separated into reaches and by two main habitat types: running waters (riverine) and springs (spring runs). Site identification numbers are available from the work performed by Frest and Johannes (1998, 2000). Taylor's work (1981) is presented in less detail and is based only on presence within the basin, with no site specificity identified. California occurrences of aquatic mollusk species from the California/Oregon stateline to the confluence of the Shasta River have been included in this report.

Brief descriptions of the eight taxa follows. The descriptions are taken from PacifiCorp (2003b), with additional authoritative references cited in text. They include probable locations of occurrence and current protective status, if applicable.

Table 11.7-1. Freshwater bivalves occurring or potentially occurring in PacifiCorp's Project area.

Species	Common Name	Protective Status [1]	Distribution in Project Area (Source)
Anodonta oregonensis	Oregon floater	None.	Klamath River, both Oregon and California (Ingram, 1948); Lower Klamath River below Shasta River (Taylor, 1981).
Gonidea angulata	Western ridgemussel	None. Frest and Johannes (1998) recommended land management agency "sensitive" status.	Klamath River, about 1 mile north of Shasta River (Ingram, 1948); Lower Klamath River above Shasta River (Taylor, 1981).
Margaritifera falcata	Western pearlshell	None. Frest & Johannes (1998) recommended land management agency "sensitive" status.	Klamath River (Ingram, 1948); Lower Klamath River (Taylor, 1981).
Pisidium punctatum	Perforated peaclam	None.	Klamath River drainage, in tributaries of Lower Klamath Lake to Shasta River (Taylor, 1981).
Pisidium ultramontanum	Montane peaclam	FSC, FSS, ONHP List 1, CNDDB S1. Frest & Johannes (1998) recommended federal and state (Oregon, California) endangered status.	Klamath River above Shasta River (Taylor, 1981).
Pisidium variabile	Triangular peaclam	None.	J.C. Boyle Reach (PacifiCorp, 2003b).
Sphaerium patella	Rocky Mountain fingernailclam	None.	Shasta River and adjacent Klamath River (Taylor, 1981).
Sphaerium sp.	Unidentified fingernailclam	NA	Link River and Fall Creek drainage (Frest and Johannes, 2000).

Sources: Frest and Johannes, 1998, 2000; Taylor, 1981).

[1] Protective Status codes: FSC = federal species of concern; FSS = USDA Forest Service sensitive; ONHP (2003) List 1 = threatened or endangered throughout its range; ONHP List 3 = review taxon; California Natural Diversity Database (CNDDB) (2003) S1 = extremely endangered in known range.

Anodonta oregonensis (Oregon Floater)

The Oregon floater is a large unionid mussel found associated with mud and sand substrates of lakes and larger, slow-moving rivers. However, it also may be found associated with gravel substrates. This species differs from the California floater (*A. californiense*) in possessing a somewhat thicker, more elongated shell. Taylor (1981) and Ingram (1948) reported this species from nonspecific locations in the Klamath River.

Status: The Oregon floater is not formally recognized as sensitive by any resource agency or organization.

Gonidea angulata (Western Ridgemussel)

This large, stout-shelled species is typically found in firm mud substrate to coarse benthic materials of lotic systems, but it may also be found in reservoirs with substantial flow. Similar to *Anodonta* spp. described previously, this species relies on unknown fish hosts during its larval glochidial stage of development. Although considered slightly more tolerant to pollution than other unionids, this species nevertheless is not found in highly polluted areas. Western ridgemussels are reported by Frest and Johannes (1998) as occurring in the Williamson River and Lost River drainages of the Klamath River basin. Taylor (1981) lists this species as occurring in the California section of the Klamath River upstream of the Shasta River confluence. Ingram (1948) notes a more precise location of occurrence: Klamath River, 1 mile north of the Shasta River confluence (approximately RM 178).

Status: The western ridgemussel is not formally recognized as sensitive by any resource agency or organization. However, this species is on the "Watch List" of Frest and Johannes (1998). Watch List taxa are those not thought to be in imminent danger of extinction, but recommended to be considered as sensitive by land managers.

Margaritifera falcata (Western Pearlshell)

This large unionid is found in coarse substrates of small to medium-sized rivers in fast, clear, cold waters. This species relies on chinook salmon, rainbow trout, brown trout, brook trout, speckled dace, Lahontan redside, and Tahoe sucker as fish hosts during its larval glochidial stage (Clarke, 1981). Distribution in the Upper Klamath River basin includes the lower Williamson and Sprague rivers. This species is recognized as occurring in the California section of the Klamath River, including the Smith River (Taylor, 1981).

Status: The western pearlshell is not formally recognized as sensitive by any resource agency or organization. However, this species is on the Watch List of Frest and Johannes (1998).

Pisidium ultramontanum (Montane Peaclam)

This small clam species prefers sand and gravel substrates of streams, lakes, or ponds that are spring-influenced. Frest and Johannes (1998) note this species within the Upper Klamath Lake and Lower Klamath Lake regions but report no records from the Project area specifically. Taylor (1981) describes this species in California as once occurring, but now extinct, in the Tule Lake, Pit River, and Lost River drainages. Recent occurrences of the montane peaclam have been noted in the Pit River system (Frest and Johannes, 1998), thus refuting Taylor's (1981) extinction designation for this drainage. This species is thought to occur in the California section of the Klamath River downstream to the confluence of the Shasta River (see Table 11.7-1). CH2M HILL (2003) reported suspected montane peaclams from two Project area reaches: the J.C. Boyle peaking reach and the peaking reach of the Klamath River between Iron Gate dam and the Shasta River.

Status: This species is considered by the USFWS to be a Species of Special Concern (CDFG, 2003a), by the USFS as a Sensitive Species (CDFG, 2003a), by the Oregon Natural Heritage Program (ONHP, 2003) as threatened or endangered throughout its range (List 1), and by the CDFG (2003a) as extremely endangered in its known range. Frest and Johannes (1998) recommended federal and state (Oregon and California) endangered status for the montane peaclam.

Pisidium variabile (Triangular Peaclam)

This species is common in the Klamath system, preferring perennial water bodies, including springs. This species was found in the Project area in spring-run areas of the J.C. Boyle peaking reach (Frest and Johannes, 1998). Occurrences of this species in the mainstem Klamath River, including the California section, should be expected owing to its widespread distribution (Taylor, 1981).

Status: The triangular peaclam is not formally recognized as sensitive by any resource agency or organization.

Pisidium punctatum (Perforated Peaclam)

The perforated peaclam prefers low-gradient rivers and large spring runs. Surveys performed in the Upper Klamath basin only found this species in Upper Klamath Lake (Frest and Johannes, 1998). No other occurrences of this species in the Oregon section of the Klamath River have been documented. Taylor (1981) identifies this species as present in the California section of the Klamath River downstream to the Shasta River confluence.

Status: The perforated peaclam is not formally recognized as sensitive by any resource agency or organization.

Sphaerium patella (Rocky Mountain Fingernailclam)

Unidentified fingernailclams (*Sphaerium* sp./spp.) have been documented in Upper Klamath Lake, Link River, and Fall Creek (Frest and Johannes, 1998, 2000). *Sphaerium patella*, the Rocky Mountain fingernailclam, is found in the California section of the Klamath River to the Shasta River confluence (Taylor, 1981).

Status: The Rocky Mountain fingernailclam is not formally recognized as sensitive by any resource agency or organization.

Additional species that may be encountered that were not identified in previous studies include *Pisidium insigne* (tiny peaclam), *P. casertanum* (ubiquitous peaclam), *P.idahoense* (giant northern peaclam), *P*. n. sp. 1 (Modoc peaclam), *Sphaerium simile* (pill clam), *S. striatinum* (striated fingernailclam), *S. raymondi* (lake fingernailclam), and *Corbicula fluminea* (asiatic clam) (Frest, pers. comm., 2003).

11.7.2 <u>Large Bivalve Field Surveys – Summer 2003</u>

Focused field surveys for large bivalves were conducted September 2-6, 2003, within the three Project area reaches noted above. Eight sampling stations were established among the three Project area reaches, with two stations located in the Keno reach, one station in the J.C. Boyle peaking reach, and five stations in the reach between Iron Gate dam and the Shasta River (Table 11.7-2). Locating areas of suitable bivalve habitat within the J.C. Boyle peaking reach proved exceptionally difficult because of the abundance of boulder substrate and scarcity of finer soils in this reach. Thus, a single sampling station was established in the peaking reach. Differences in habitats among reaches and sampling stations are discussed later (sections 22.7.2.1 through 11.7.2.10).

Two unionid mussel species were observed in the three Project area reaches investigated: the Oregon floater (*Anodonta oregonensis*) and the western ridgemussel (*Gonidea angulata*). Table 11.7-2 lists the station locations and summarizes the habitat descriptions at each of the eight sampled stations. Dr. Frest's identification of voucher material collected (both live and dead) is provided in Appendix 11A to this document.

Anodonta oregonensis was found at both stations in the Keno reach and at three of five sampled stations in the reach between Iron Gate dam and the Shasta River, but it was most abundant at Keno reach station KR-1 and station FFR-1 in the reach between Iron Gate dam and the Shasta River (Table 11.7-2). *Gonidea angulata* was found at one of two sampled stations in the Keno reach, at the single J.C. Boyle peaking reach station, and at four of five sampled stations in the reach between Iron Gate dam and the Shasta River. This species was most abundant at Keno reach station KR-2, but it was most expansively distributed at stations FR-1 and FR-3 in the reach between Iron Gate dam and the Shasta River.

The distribution and abundance of these unionid mussels at each of the eight established sampling stations are discussed in the following text.

11.7.2.1 Keno Reach: Station KR-1 (RM 233)

Keno reach station KR-1 is located immediately below Keno dam, within a tule rush (*Schoenoplectus acutus* var. *occidentalis*, formerly within genus *Scirpus*) and broadleaf cattail (*Typha latifolia*) thicket on the west margin of the Klamath River. Water velocity at this station was barely perceptible, and water depth ranged from 1 to 1.5 feet. Bottom substrate consisted of fine sand to silt soils (sometimes anaerobic) among the roots and rhizomes of the tule rushes and cattails. The water at this station was nutrient-rich, and visibility was limited to several inches by suspended microalgae. Therefore, search efforts at this station were entirely tactile.

Seventy-nine Oregon floaters were found within a relatively small clearing (approximately 5.4 m^2) among the tule/cattail thicket (mean abundance = 14.6/m^2). Project biologists intensively collected all *Anodonta* present in this area. Density in this bed ranged from zero to 20/m^2, as determined by 15 randomly placed 0.25-m by 0.25-m (0.25-m^2) quadrats sampled prior to the intensive bed-wide collection. No other bivalve species were found at this station.

Table 11.7-2. Bivalve species observed at sampled stations in September 2003.

River Reach (RM)	Station ID	Station Location (RM)	Species Observed	Habitat Characteristics/Comments
Keno Reach (RM 233-228)	KR-1	RM 233	*Anodonta oregonensis*	Soft sediments associated with bulrush and cattail patch just below Keno dam. Low velocity water, depth 1.5 feet. *Anodonta* semiburied. No other species noted.
	KR-2	RM 228	*Gonidea angulata* and *A. oregonensis*	Coarse sand with silt associated with bulrush patch in mid-channel, just above J.C. Boyle reservoir. Generally, smaller *Gonidea* than other sites; mostly to completely buried. Low velocity water. Water depth 1.5 feet. *Gonidea* dominant species, though few *Anodonta* noted.
J.C. Boyle Peaking Reach (RM 220.4-204)	PR-1	RM 205.2	*G. angulata*	Coarse sand in pool below rock chute. Water depths vary, depending on release flows, from 2.5 to 5 feet. Low velocity. No associated vegetation. *Gonidea* mostly to totally buried. No other species noted.
Reach between Iron Gate Dam and the Shasta River (RM 190.2-176.7)	FFR-1	RM 189.8	*A. oregonensis*	Cobble substrate (perhaps artificially placed?) downriver of Iron Gate fish hatchery bridge over Klamath River. Slow water velocity in countercurrent noted. Water depth 3 to 4 feet. Unidentified hydrophyte associate (pondweed?). No other species noted.
	FFR-2	RM 185.6	*G. angulata* and *A. oregonensis*	Coarse sand substrate between cobbles and boulders. Just upstream of footbridge at Klamath River County Estates. Swift water. No associated vegetation. Water depth to 2.5 feet. *Gonidea* dominant species, though few *Anodonta* noted.
	FFR-3	RM 180.6	*G. angulata* and *A. oregonensis*	Coarse to fine sand substrate between cobbles in slow-moving section of water (depth to 2 feet.). Unionid. hydrophyte associate (same as IG-1 and IG-4). *Gonidea* dominant species, though few *Anodonta* noted.
	FFR-4	RM 179.3	*G. angulata*	Coarse to fine sand with some silt substrate just upstream of I-5 bridge over Klamath River. Moderate water velocity. *Gonidea* mostly to totally buried in approximately 1.5 feet of water. Unionid. hydrophyte associate (same as FFR-1, above). No other species noted.
	FFR-5	RM178.6	*G. angulata*	Coarse sand substrate between cobbles. Just downstream of I-5 rest area. Swift water, 1to 15 feet deep. No associated vegetation. No other species noted.

The length-frequency distribution of the 79 *Anodonta* collected at station KR-1 is shown in Figure 11.7-1. Small, and presumably young, *Anodonta* were poorly represented at station KR-1. Most individuals (approximately 70 percent) sampled were about 90 mm in greatest dimension (hereafter referred to as "length"). Measured *Anodonta* at station KR-1 ranged from 52 to 126 mm in length. Two age cohorts may be represented in the sampled population, with modal lengths centered at approximately 75 mm and 100 mm, respectively.

Overall, the population of *Anodonta oregonensis* at station KR-1 is area-restricted and apparently confined to the clearings among tules and cattails. It is, however, locally dense. Searches in nearby areas produced no bivalves of any species.

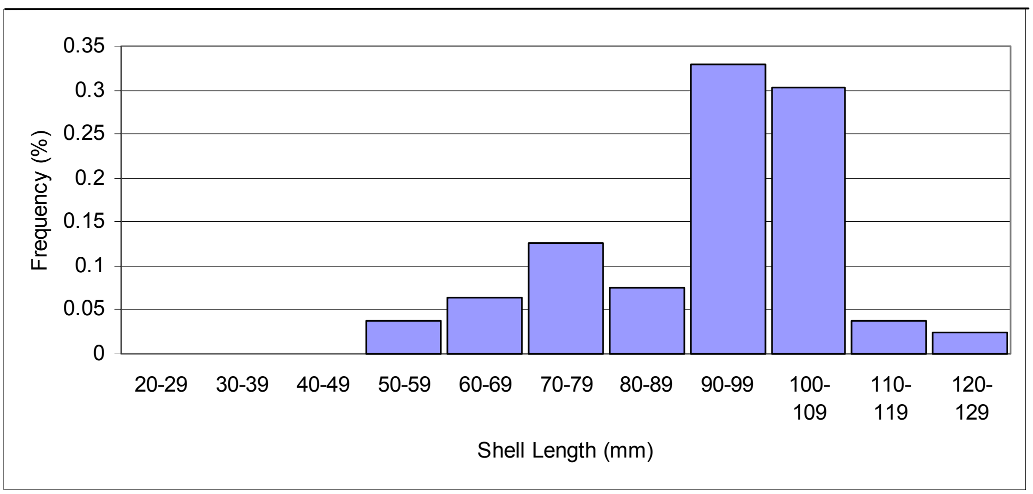

Figure 11.7-1. Size frequency of *Anodonta oregonensis* (n=79), Keno reach station KR-1, September 5, 2003.

11.7.2.2 Keno Reach, Station: KR-2 (RM 228)

Keno reach station KR-2 is located at the lowest extent of the Klamath River immediately above the backwatering effect of J.C. Boyle reservoir, near the south margin of a tule rush "island."

Water velocity at this station was moderate (less than 1fps). Water depth ranged from 1 to 1.5 feet. Bottom substrate consisted of fine sand to medium sand. Water visibility at this station was somewhat limited (to 1 foot) because of suspended microalgae, and search efforts at this station were therefore tactile.

Thirty-five *Anodonta oregonensis* and six *Gonidea* were found in an approximately 1-m^2 bed located at the margin of a tule rush thicket, with many of the observed mussels buried in fine sand to a depth of 4 to 5 inches. Opportunistic searches in nearby areas upriver and downriver produced no mussels. Similarly, searches near the root structures of the tules inside the island thicket produced no mussels. This population therefore appeared isolated. Similar to methods at station KR-1, all mussels were collected within the defined (and apparently area-restricted) bed.

The length-frequency distribution of the 35 *Anodonta* samples collected at station KR-2 is shown in Figure 11.7-2. *Anodonta* at this station were considerably smaller than those sampled at the upriver station KR-1, with only a single mussel exceeding 90 mm in length (samples ranged from 37 to 93 mm). No clear separation of age cohorts is evident in the unimodal length frequency distribution (Figure 11.7-2).

The six *Gonidea*, collected with the previously noted *Anodonta*, were 43, 49, 51, 60, 64, and 84 mm in length, respectively. Both species were sympatric (i.e., co-occurring), and no conclusions regarding habitat partitioning can be made at this location.

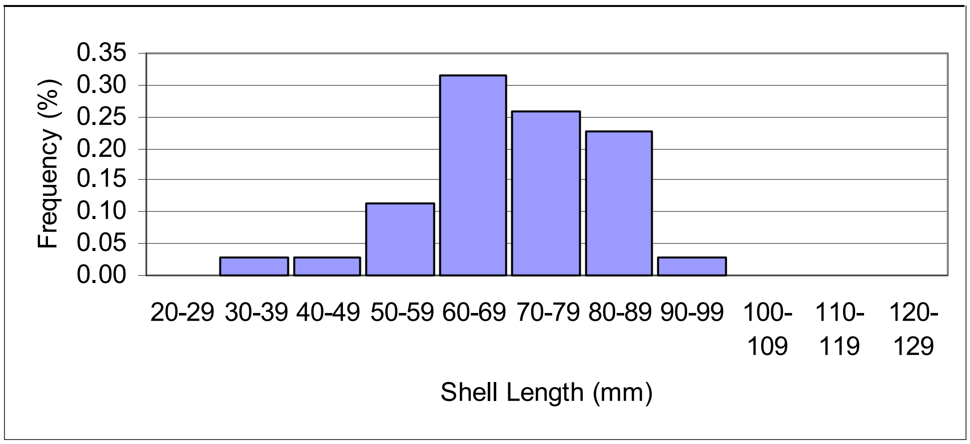

Figure 11.7-2. Size frequency of *Anodonta oregonenis* (n=35), Keno reach station KR-2, September 5, 2003.

11.7.2.3 J.C. Boyle Peaking Reach: Station PR-1 (RM 205.2)

J.C. Boyle peaking reach station PR-1 is located approximately 500 feet upriver from the Miller Ranch property, within a pool habitat feature on the southern branch of a braided portion of the Klamath River. No macrovegetation was present at this site. Water velocity, depth, and visibility at this station were variable, depending on the release schedule from J.C. Boyle reservoir. During the course of sampling this station, on the morning of September 6, 2003, water conditions changed from approximately 2.5 feet deep, less than 0.5 fps, and 4 to 8 feet of visibility during the nongeneration period, to approximately 5 feet deep, 1.5 fps, and less than 1.5-foot visibility as a result of the start of the daily peaking cycle. Bottom substrate consisted of medium sand. Snorkel surveys were conducted at this station because of excessive water depth.

Sixteen *Gonidea* were found within a fairly small (9 m^2) area (mean abundance = 1.8/m^2) constrained and defined as a pool below a large mid-channel boulder that dissipated streamflow energy. *Gonidea* were mostly or entirely buried in the sandy substrate, with some found beneath small cobbles buried to a depth of 4 inches. As with stations KR-1 and KR-2, all mussels found within the bed area were gathered as a means of estimating bed density and size-frequency distribution. Five additional *Gonidea* were found in scattered habitats near, but outside of, the defined 9-m^2 search area. No other bivalve species were found at this station.

The bimodal length-frequency distribution of 21 *Gonidea* collected at station PR-1 is shown in Figure 11.7-3. Two age cohorts may be represented at this station, with mean lengths centered at 55 mm and 85 mm, respectively. Measured specimens ranged from 37 to 100 mm length.

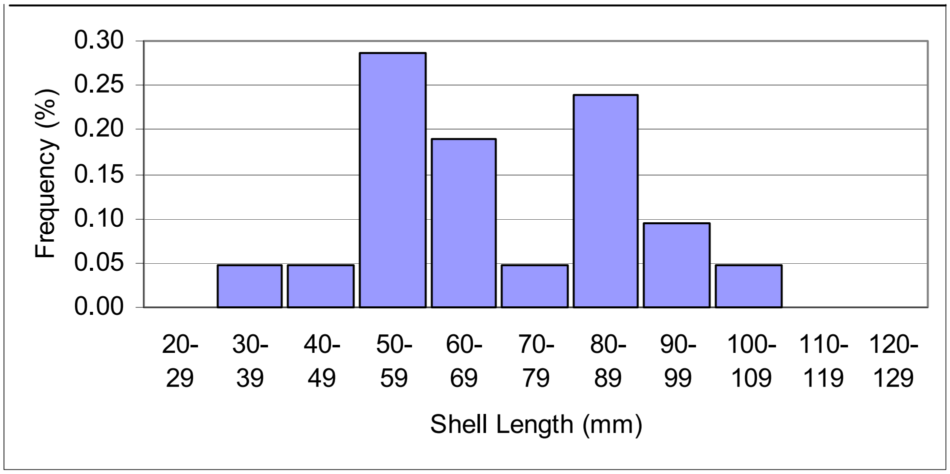

Figure 11.7-3. Size frequency of Gonidea angulata (n=21), peaking reach station PR-1, September 6, 2003.

The population of *Gonidea* at station PR-1 appears area-restricted and confined to the noted pool feature. Extensive snorkel sampling both up- and downriver did not reveal additional populations or individuals (see section 11.7.2.4).

11.7.2.4 J.C. Boyle Peaking Reach: Other Areas Examined

Several other areas were examined within the peaking reach in an attempt to locate a population, or even individuals, of large mussel species. Macroinvertebrate sampling stations BF4V (RM 209.1) and BF4C (RM 209) were examined on September 4, 2003. Station BF4V was characterized by swift, clear water and substrates of boulder, rock, and cobble. Dominant habitats included high-gradient and low-gradient riffles. Station BF4C was characterized by smaller cobbles than station BF4V and a dominant fast-water glide habitat with clear water. While empty valves of *Gonidea* were found in the shallow zones of both sites (as determined using viewer-buckets), no live animals were located, and sampling stations were not established.

Macroinvertebrate sampling station BFS-a (RM 208.5) was examined on September 4, 2003. This area consisted of a low-gradient riffle with large boulder substrate. No mussel presence (either vacant valves or living specimens) was evident, and a sampling station was not established.

Two areas near Miller Ranch were examined on September 4, 2003. The first area was located immediately upstream of the Miller Ranch at approximate RM 205.2 on the northern channel of the Klamath River in an area where the river branches. This area was examined in response to the recommendation of Thomas Payne and Associates (TPA) biologists who, the previous day, saw mussels near this location during their fish survey work. After about 2 hours of diving in an approximately 500-m stretch of the Klamath River at this area, no living mussels (few *Gonidea* valves evident) were found, and a station was not established.[2] The second area was near RM 204, just downriver from the old Spannaus Ranch. This area was characterized as a slow-water glide with large boulder substrate. No evidence of mussels was found, and a station was not established.

11.7.2.5 Reach between Iron Gate Dam and the Shasta River: Station: FFR-1 (RM 189.8)

Station FFR-1 is located below Iron Gate dam, immediately downriver of the bridge crossing to Iron Gate fish hatchery. The presence of *Anodonta oregonensis* at this location was suggested by the abundance of vacant and broken shells (apparent midden area for muskrat or river otter) on the northern river bank.

Water velocity at this station was moderate (less than 1 to 2 fps). Water depth ranged from 2 to 4 feet. Bottom substrate consisted of medium and fine sand channels among rocky cobbles. Water visibility was fair to poor, ranging from 1 to 3 feet. Water depth prevented tactile or viewer bucket surveys, and the area was therefore investigated via snorkel surveys. An abundant aquatic plant (somewhat filamentous) obscured the bottom over much of the sampled area.

Thirty-seven *Anodonta oregonensis* were found in an approximately 18.7-m^2 (mean abundance = ~2/m^2) intensively searched area near the shore. Water velocity in the mid-channel area and safety concerns limited ability to search more extensively. Therefore, this survey did not define the limits of the sampled bed. No other bivalve species were found.

The length-frequency distribution of 41 *Anodonta* collected (three were collected from outside the defined area) at station FFR-1 is shown in Figure 11.7-4. *Anodonta* at this station ranged from 56 to 96 mm in length, with a single modal size at approximately 80 mm. *Anodonta* at this station were intermediate in size compared to those observed at Keno reach stations KR-1 and KR-2 (Figures 11.7-1 and 11.7-2, respectively).

[2] Sampling station PR-1 was established less than 500 m from this area. *Gonidea* were found to occupy the southern channel of the braided river, and not the northern channel examined. It is unlikely that station PR-1 is the area that the TPA biologists noted based on their description of the bed they had apparently observed.

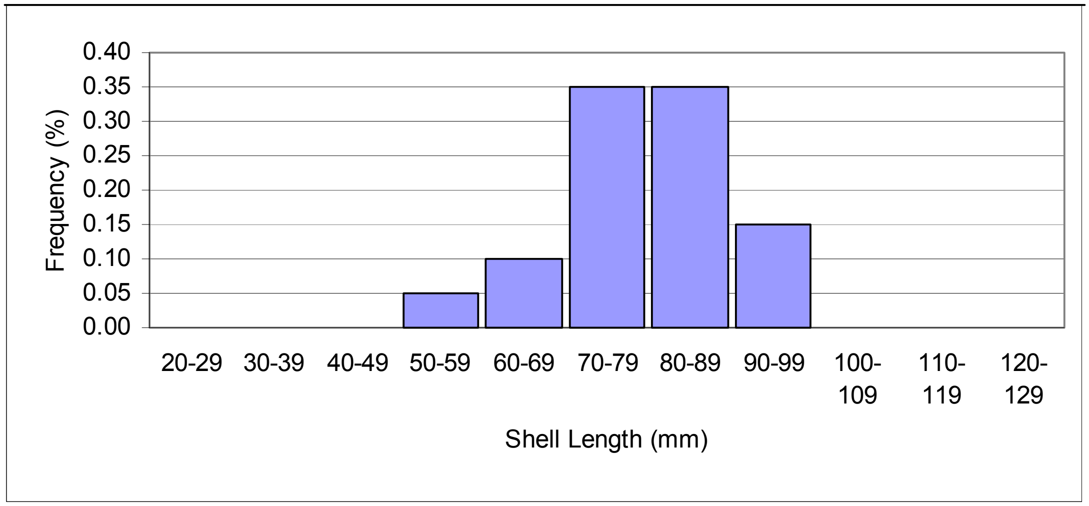

Figure 11.7-4. Size frequency of *Anodonta oregonensis* (n=40), peaking reach station FFR-1, September 3, 2003.

11.7.2.6 Reach between Iron Gate Dam and the Shasta River: Station FFR-2 (RM 185.6)

Station FFR-2 is located upriver of the footbridge at the Klamath River Country Estates near the north bank of the Klamath River. Here again, valves near the shoreline suggested the presence of living animals.

Water velocity at this station was moderate to swift (less than 2 to 3 fps), and the dominant instream habitat would be classified as a swift run or glide. Water depth ranged from 1 to 2.5 feet, and therefore the area was searched with viewer buckets. Bottom substrate consisted of baseball-sized cobbles with gravels and coarse sand. Water visibility was fair to poor, ranging from 1 to 2.5 feet. Aquatic vegetation was scarce to lacking.

Twenty *Gonidea* and four *Anodonta oregonensis* were found in an approximately 37.5-m^2 (mean *Gonidea* abundance = ~0.5/m^2) intensively searched area near the shore. Opportunistic searching outside of this sampled area did not produce any bivalves, and this area may therefore be considered a defined bed. It is not, however, as firmly defined and constrained as beds noted at other stations (e.g., KR-1). It appeared that most *Gonidea* were distributed within a fairly narrow (~2 m) band that paralleled the shoreline.[3]

The length-frequency distribution of 20 *Gonidea* collected at station FFR-2 is shown in Figure 11.7-5. The size range of *Gonidea* at this station was similar to that of station FFR-1, with lengths ranging from 57 to 96 mm and a possible cohort mean near 85 mm. The sample size of 20 individuals is too low to draw conclusions regarding additional cohorts, but the size distributions at stations FFR-1 and FFR-2 appear similar.

[3] It is important to restate here that deep, swift areas of the river were not surveyed due to safety concerns. As such, bivalves may have been more widely distributed within the Project area than reported herein.

The four *Anodonta* observed at station FFR-2 were 66, 70, 72, and 77 mm in length, respectively. This species was found occupying the slower, finer substrate areas near the river margin, in contrast to *Gonidea*, which were found in the higher velocity areas.

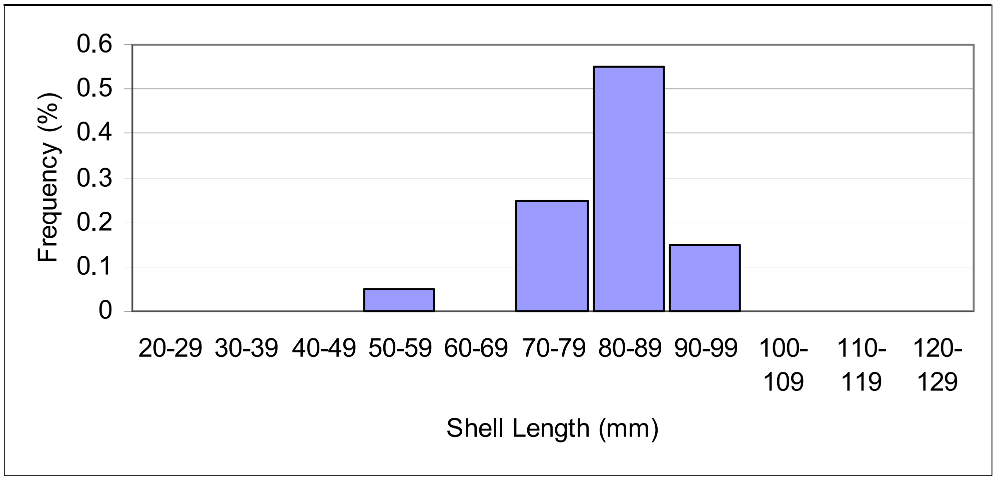

Figure 11.7-5. Size frequency of *Gonidea angulata* (n=20), peaking reach station FFR-2, September 3, 2003.

11.7.2.7 Reach between Iron Gate Dam and the Shasta River: Station FFR-3 (RM 180.6)

Station FFR-3 is located near the east bank of the Klamath River just downriver of a historic house at Osburger Gulch.

The aquatic habitat at this station is characterized as a slow velocity (~0.5 fps) run or glide, with abundant instream vegetation similar to that observed at station FFR-1. Water depth ranged from 1 to 2 feet. Bottom substrate consisted of fine sands with a substantial silt component and scattered cobbles. Water visibility was fair (to 2 feet), allowing the use of viewer buckets. Minimal water depths allowed intensive tactile searches.

A total of 142 *Gonidea* and four *Anodonta oregonensis* were found within an approximately 21 m^2 (mean *Gonidea* abundance = 6.8/m^2) intensively searched area near the shore. The boundaries of a defined bed were not determined, and bivalves were undoubtedly distributed far more broadly in this area. Twelve *Gonidea* were found within a single, randomly placed 0.25-m^2 quadrat, demonstrating the exceptional density of this species at this station.

The length-frequency distribution of 60 of 142 *Gonidea* observed at station FFR-3 (partial sample histogram only) is shown in Figure 11.7-6. Measured *Gonidea* at this station ranged from 53 to 100 mm in length, with a single peak mean evident at approximately 75 mm. The four *Anodonta* samples at this station measured 58, 58, 65, and 79 mm in length, respectively.

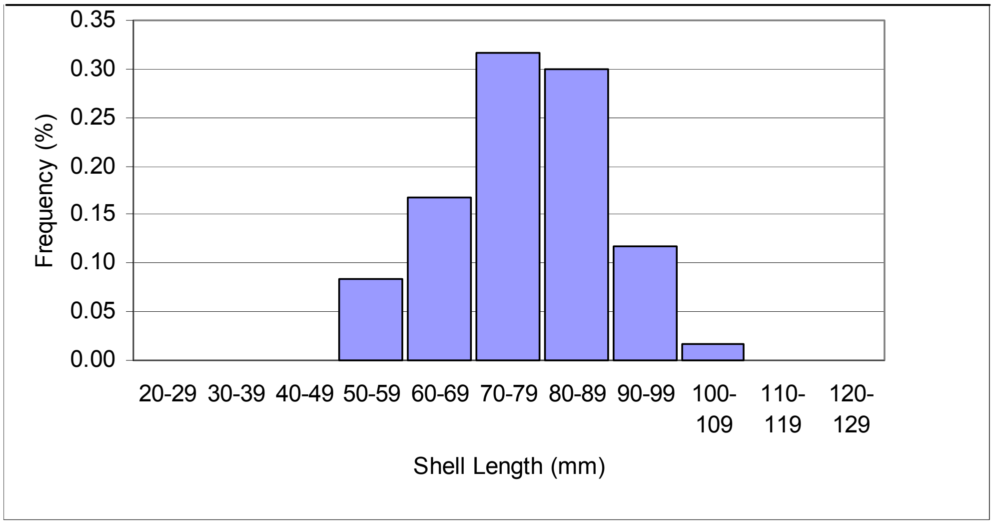

Figure 11.7-6. Size frequency of *Gonidea angulata* (n=60), peaking reach station FFR-3, September 3, 2003.

11.7.2.8 Reach between Iron Gate Dam and the Shasta River: Station FFR-4 (RM 179.3)

Station FFR-4 is located near the east bank of the Klamath River approximately 100 m upriver of the Interstate 5 overpass near RM 179.

The aquatic habitat at this station may be characterized as a low to moderate velocity (~1.5 fps) run, transitioning to a low-gradient riffle immediately downriver. Water depth ranged from 1 to 2.5 feet. Bottom substrate consisted of medium and fine sands with a silt fraction among scattered cobbles and gravels. Water visibility was fair (to 2.5 feet), but aquatic vegetation hampered use of viewer buckets. Therefore, searching at this station was entirely tactile.

The sampled area measured 5.8 m wide by 57.8 m long (~ 335 m^2 total), paralleling the shoreline in the noted depth contour. Sixty-two *Gonidea* were found in 15 randomly placed 0.25-m^2 quadrats. The estimated abundance of *Gonidea* in this defined area is therefore 5,538 individuals, with an estimated mean abundance of approximately 16.5/m^2. Counts per sampled quadrat ranged from zero to 18, with many of the animals buried on top of one another to depths of 6 inches.

This area was the largest occupied habitat sampled in the September 2003 survey effort, and it may harbor more mussels than any other station sampled. This bed also may have extended considerably farther upriver. No other bivalve species were observed at this location.

The size distribution for the 62 collected *Gonidea* is presented in Figure 11.7-7. Lengths ranged from 21 to 103 mm. No definitive cohort break was evident, but most animals were 70 to 90 mm in length.

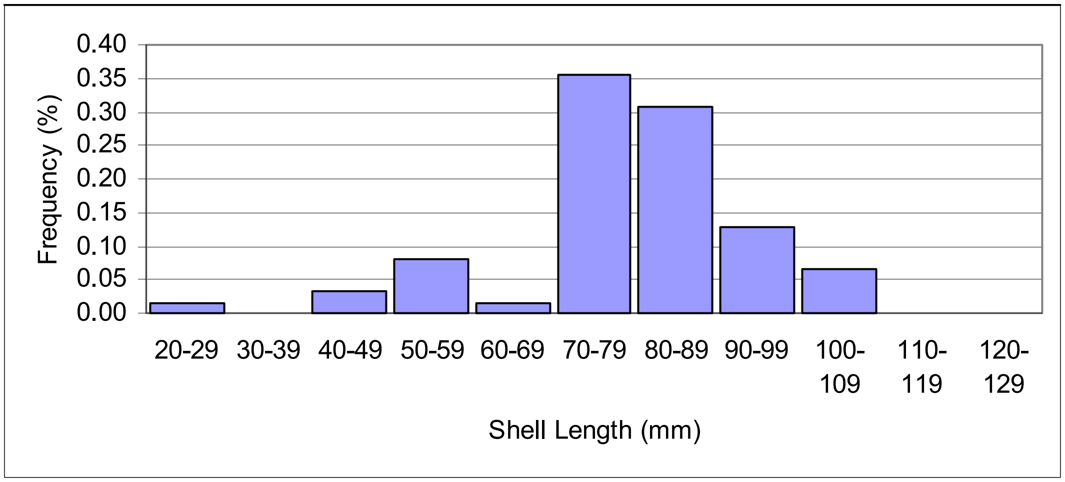

Figure 11.7-7. Size frequency of *Gonidea angulata* (n=62), peaking reach station FFR-4, September 2, 2003.

11.7.2.9 Reach between Iron Gate Dam and the Shasta River: Station FFR-5 (RM 178.6)

Station FFR-5 is located just downriver of the Collier rest area on Interstate 5, near the east bank of the Klamath River. This station was examined on the recommendation of T. Frest (pers. comm., 2003).

The aquatic habitat at this station is very similar to that of station FFR-2, consisting of a moderate to swift (to ~2.5 fps) run, with very little instream vegetation. Water depth ranged from 1 to 1.5 feet. Substrates consisted of coarse sand patches interspersed with cobbles and gravels. Water clarity was fair, ranging from 2 to 4 feet (lateral visibility). Aquatic vegetation was not present to any notable extent.

Eleven randomly placed 0.25-m^2 quadrats were sampled in an approximately 12-m^2 region and 41 *Gonidea* were found, for an estimated abundance of approximately 179 individuals at the station (mean abundance = 14.9/m^2). Counts within quadrats ranged from zero to 14 individuals. This bed, in contrast to station FFR-4, appeared constrained, as opportunistic searches up- and downriver did not yield additional bivalves.

The size distributions for 36 of the 41 *Gonidea* observed at this station are presented in Figure 11.7-8. Lengths ranged from 47 to 94 mm, with most individuals clustered in the single mode of 70 to 79 mm.

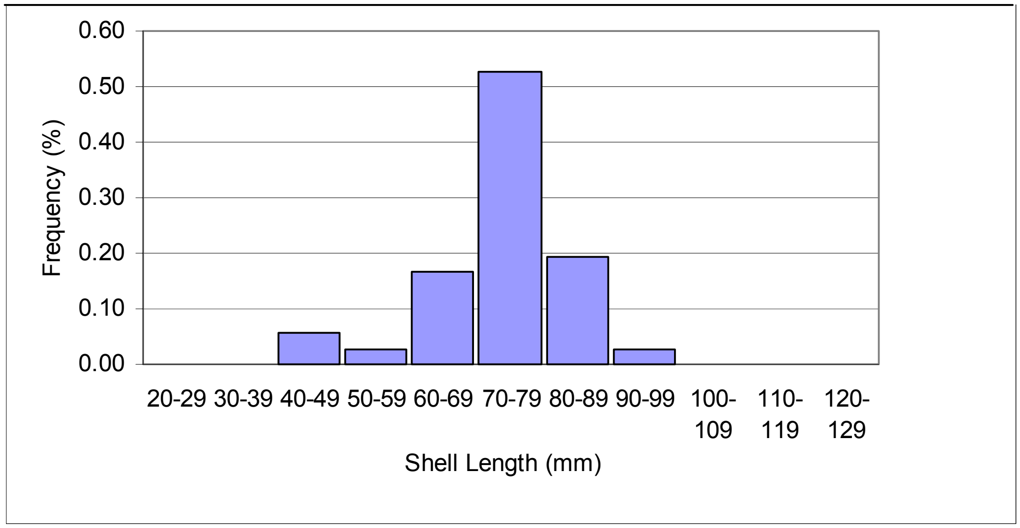

Figure 11.7-8. Size frequency of *Gonidea angulata* (n=36), peaking reach station FFR-5, September 3, 2003.

11.7.2.10 Reach between Iron Gate Dam and the Shasta River: Other Areas Examined

Two other sites within the reach between Iron Gate dam and the Shasta River were inspected for the presence of large bivalves. Water velocity at the area below the Ager Road bridge crossing of the Klamath River (RM 184.2, macroinvertebrate station KR3C) was sufficiently slow to harbor mussels, but no evidence of occupation, including vacant shells, was found.

Viewer-bucket searching at macroinvertebrate station KR4A (RM 182.2) produced several live *Gonidea* and a few empty valves of *Anodonta oregonensis*. No station was established at this location because sufficient numbers of living animals could not be found. Bivalve habitat at this location was marginal at best, and the dominant substrate (cobbles) resembled that within the J.C. Boyle peaking reach.

11.7.3 Field Surveys – Fall 2002 and Spring 2003 Macroinvertebrate Studies

Table 11.7-3 lists freshwater bivalves collected during the fall 2002 and spring 2003 macro-invertebrate sampling effort (see Sections 8.0 and 12.0 of this report for further details on methods and locations).

Samples from riverine reaches contained several species of freshwater bivalves, some of which were notably abundant. Tiny peaclams (*Pisidium insigne*) and ubiquitous peaclams (*P. casertanum*) were found abundantly at several stations within Fall Creek. Ubiquitous peaclams, grooved fingernailclams (*Sphaerium simile*), and montane peaclams (*P. ultramontanum*) were found at several stations within the J.C. Boyle peaking reach. This latter species was also found at peaking reach station KR2. Pond fingernailclams (*S. securis*) were found only at Keno reach station KEKR in the spring 2003 survey.

Table 11.7-3. Bivalve species observed at macroinvertebrate stations in fall 2002 and spring 2003.[1]

Species	Station[2] (no. per square meter) by Reach									
	Reach below Iron Gate Dam	**Iron Gate Reservoir**	**Fall Creek**	**Copco Reach**	**Copco Reservoir**	**Peaking Reach**	**Bypass Reach**	**J.C. Boyle Reservoir**	**Keno Reach**	**Keno Reservoir**
Musculium lacustre (= *M. raymondi*)			none		CR-007 (4) CR-008 (9)			JCB005 (3)		KN003 (4)
Pisidium spp.						BF4 (7)	BB1 (12)		KDB (24)	
Pisidium casertanum	**KR-3 (1)**		FCB-1 (152) FCB-2 (124) FCB-3 (31)	CB1 (1)		BF1 (27) BF3 (6) BF4-V (9)	**BB3 (19)**			
Pisidium insigne			FCA-1 (20), FCB-3 (10) FCF-1 (3) FCF-2 (5)							
Pisidium ultramontanum	KR-2 (6)					BF1 (11) BF3 (6) **BF3 (7)** **BF5 (3)**				
Pisidium variabile	**KR-1 (1)**				CR-007 (2) CR-008 (9)	**BF4 (4)** **BF5 (3)**		JCB005 (9)	**KDB (21)**	
Sphaerium securis									**LEKR (3)**	
Sphaerium simile		IG010 (3)				BF3 (6)		JCB005[3] (9) JCB005[4] (6)		KN003[3] (34) KN003[4] (6)
Anodonta californiensis (?)								JCB005 (9)		

[1] Spring 2003 samples shown in bold type.
[2] Station nomenclature follows macroinvertebrate stations noted in Chapter 8.0 of this document.
[3] Sampled with dredge.
[4] Sampled with drag net.

Lake fingernailclams and triangular peaclams (*P. variabile*) were found in the Copco, J.C. Boyle, and Keno reservoirs, with the latter species also found in Iron Gate reservoir. California floater (*Anodonta californiensis*), a large unionid mussel, was potentially collected during net sampling in J.C. Boyle reservoir. Material was not kept, however, and the identification is based on a discussion between T. Frest and CH2M HILL biologists (Frest, pers. comm., 2003).

11.8 DISCUSSION

The distribution of large bivalves within the study area is patchy and is strongly related to the patchy distribution of suitable habitat. Low-energy areas where sediments accumulate and where hydrology is consistent were most suitable for *Anodonta oregonensis*. While these types of habitats also supported *Gonidea angulata*, this latter species appeared to prefer faster waters and, consequently, coarser substrates such as medium and coarse sands.

Both species could be exceptionally dense where found. Commonly, *Gonidea* were found buried to depths of 6 inches, oftentimes atop one another. Perhaps intergravel flow in the faster-moving water areas provided enough oxygen to support animals that had no apparent connection to the water column. *Gonidea* were always buried at least 80 percent, with only the tops of shells evident. In contrast, *Anodonta* were sometimes found lying atop the bottom substrate. Others were buried slightly, but never to the extent that the *Gonidea* were buried.

Mussel predation was evident in the project area, with most middens containing *Anodonta* rather than *Gonidea*. Here also, swifter water may render predation on *Gonidea* more difficult than predation on *Anodonta*. It was assumed that predation on mussels in the Project area was primarily due to aquatic mammals—namely river otter and/or muskrat—but such predation was not observed directly. Convey et al. (1989) and Hanson et al. (1989) reported that muskrats selectively preyed on larger northern floaters (*Anodonta grandis simpsoniana*) in a lake in central Alberta, Canada, and that this predation had a substantial affect on both the size-distribution and the overall biomass of the prey species. No attempt was made in the present study to characterize the extent or effect of predation on large mussels within the Project area.

No published age-at-length information was found for *Gonidea* or *Anodonta oregonensis* in the Klamath River. Frest (Appendix 11A) noted that *Gonidea* material sent to him for identification (unmeasured, but approximately 70 to 105 mm length) ranged from 10 to 50+ years in age. Similarly, *Anodonta oregonensis* material sent to him (also unmeasured, but up to approximately 90 mm in length) ranged from 8 to 20 years old. Hanson et al. (1988) reported that northern floaters in Narrow Lake, Canada, were approximately 50 mm at age 5, 55 mm at age 6, and 60 to 70 mm at ages 7 to 10. Cohort recruitment was not readily apparent at any sampled station, as small animals less than 50 mm in length were uncommon to rare.

Based on the September 2003 observations within accessible portions of the Project area, it is unlikely that the J.C. Boyle peaking reach supports broadly distributed populations of large unionid bivalves. This may be due to the high gradient nature of this reach and the subsequent dominance of tightly packed larger substrates (large and small boulders, cobbles). In contrast, selected microhabitats within the Keno reach and the Klamath River between Iron Gate dam and the Shasta River appear to support locally extensive populations of both *Anodonta oregonensis* and *Gonidea angulata*. Of the two, the latter appears more broadly distributed, possibly reflecting the relative abundance of preferred habitat (faster water, coarser substrate) and relative scarcity of slower, nutrient enriched habitats (e.g., nearly eutrophic lakes).

12.0 SPRING 2003 MACROINVERTEBRATE MONITORING

12.1 DESCRIPTION AND PURPOSE

The purpose of this study was to conduct a bioassessment of macroinvertebrates in the Project area during spring 2003.[1] This bioassessment was conducted as a follow-up to a bioassessment of macroinvertebrates in the Project area during fall 2002 (see Section 8.0 of this document). Thorough bioassessments of stream macroinvertebrate populations in northern temperate latitudes normally require both spring and fall assessments in order to capture the full species diversity of the site (Harrington and Born, 2000; EPA, 1998).

The information from both the fall 2002 and spring 2003 assessments provides information to (1) assess the potential relationship of macroinvertebrate community composition to water quality conditions, (2) assess the presence of designated Species of Concern,[2] (3) determine the quality of the macroinvertebrate assemblage as a food source for fish and wildlife, and (4) identify susceptibility of macroinvertebrate taxa to flow changes. The comparisons between fall 2002 and spring 2003 results help to assess seasonal differences in the presence and composition of macroinvertebrate taxa, as well as potential effects on these taxa from seasonal differences in flow and water quality conditions.

12.2 OBJECTIVES

The objectives and key questions addressed by this study, together with the previous fall 2002 macroinvertebrate study (see Section 8.0), are as follows:

1. Characterize macroinvertebrate presence and community composition in waters affected by the Project.
2. Do waters affected by the Project support healthy and diverse residential macroinvertebrate communities?
3. Develop a baseline of existing macroinvertebrate community conditions in the event monitoring of macroinvertebrates becomes a postlicensing monitoring requirement.
4. Is macroinvertebrate community composition related to water quality conditions? If so, how is it related?
5. Are designated Species of Concern present?
6. Support subsequent assessment (together with other resources studies) of the quality of the macroinvertebrate assemblage as a food source for fish and wildlife, and to identify susceptibility of macroinvertebrate taxa to flow changes.
7. Support subsequent assessment (together with other studies and during license application preparation) of the Project's potential effects on water quality and fish and wildlife resources, and possible measures to protect, enhance, and mitigate where necessary.

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[1] Sampling occurred over several days during April and May, 2003.

[2] USFWS has designated the following macroinvertebrate Species of Concern that could occur in the Project area: *Apatania (=Radema) tavala* (Cascades apatanian caddisfly), *Homoplectra schuhi* (Schuh's homoplectran caddisfly), *Rhyacophila mosana* (Bilobed rhyacophilan caddisfly).

12.3 RELICENSING RELEVANCE AND USE IN DECISIONMAKING

The results of this study assist the assessment of current water quality conditions in waters affected by Project facilities and operations. Relicensing of the Project requires Section 401 certifications from relevant agencies that the Project complies with requirements of the federal Clean Water Act. Information from this study is used to document water quality conditions and potential Project effects as they relate to water quality objectives and standards promulgated by these agencies for maintenance and protection of biological integrity.[3]

Relicensing of the Project also requires PacifiCorp to assess water quality effects as they relate to other resources issues. For example, water quality is important to supporting healthy and diverse macroinvertebrate communities, which in turn are important as a food resource for fish and wildlife species. Therefore, the tasks described in this section contribute information (together with other resources studies) for the assessment of fish and wildlife resources as well as water quality conditions.

12.4 METHODS AND GEOGRAPHIC SCOPE

12.4.1 Study Areas

The spring 2003 sampling was conducted in the following areas of the Klamath River in the Project vicinity: (1) Keno dam to J.C. Boyle reservoir (Keno reach), (2) J.C. Boyle dam to J.C. Boyle powerhouse (J.C. Boyle bypass reach), (3) J.C. Boyle powerhouse to Copco No. 1 reservoir (J.C. Boyle peaking reach), and (4) Iron Gate dam to the confluence with the Shasta River. Details on the number of sampling sites in each of these sections are discussed below.

12.4.2 Macroinvertebrate Sampling Protocols

As was done during the fall 2002 macroinvertebrate sampling, the California Stream Bioassessment Procedure was used for the spring 2003 sampling. The CSBP protocols have been adapted from the USEPA Rapid Bioassessment Protocols by the California Department of Fish and Game Aquatic Bioassessment Laboratory (CDFG, 1999a). The CSBP is a standardized protocol for assessing biological and physical/habitat conditions of wadeable streams in California (CDFG, 1999a). ODEQ indicated that use of the CSBP protocols would be acceptable.[4]

PacifiCorp used CSBP protocol guidance for various facets of sample collection and analysis, including the following (see CDFG, 1999a for details):

- Field and laboratory procedures
- Procedures for selecting sampling locations
- Concurrent water quality measurements
- Concurrent physical/habitat quality measurements
- Methodology for developing and analyzing data

[3] For example, the State of Oregon's water quality standards include a Biological Criteria standard that stipulates that "waters…shall be of sufficient quality to support aquatic species without detrimental changes to resident biological communities."

[4] Use of the CSBP protocols was indicated as acceptable in a letter dated March 19, 2002, from Paul DeVito (ODEQ) to Todd Olson (PacifiCorp).

12.4.3 CSBP Macroinvertebrate Sampling Procedure

The CSBP sampling procedure was used to assess macroinvertebrate communities in the river reach areas of the Klamath River in the vicinity of the Project, as listed above. Specific sampling locations are described below. In accordance with CSBP methods, sampling was focused in riffle habitats within specific reaches in each river area. Riffle habitats are considered to contain the most diverse and productive macroinvertebrate assemblages, and therefore provide the most sensitive areas for assessing potential effects. Three riffles were randomly selected in each specific reach for sample collection. Starting with the downstream riffle, a measuring tape was placed along the bank of the entire riffle. From all meter increments along the tape in the upper third of the riffle, a single meter mark was randomly chosen. Sampling occurred along a transect across the channel at the chosen meter mark.

Collection of macroinvertebrates was obtained at three locations along the transect using a D-shaped kicknet (0.5-mm mesh), sampling a 1- by 2-foot portion of substrate upstream of the kicknet to a depth of approximately 4 to 6 inches. In locations dominated by boulder or bedrock and where sampling of substrate to a depth of approximately 4 to 6 inches was not possible, an alternative technique was used. The alternative technique involved sampling a 1- by 2-foot area of boulder or bedrock surface by gently brushing or scraping surface material into the kicknet until the surface was “cleansed.” The three locations were selected to represent, as much as possible, the substrate and structural composition along the transect.

A consistent sampling effort of approximately 1 to 3 minutes occurred at each of the three locations. The three collections at each location along the transect were combined to form a single composite sample. The contents of the kicknet were placed in a 0.5-mm mesh sieve to remove large twigs, leaves, and rocks. The remaining sample was then placed in a plastic jar and preserved with 95 percent ethanol. The above steps were repeated for the next two randomly chosen transects within the riffle.

The CSBP protocol (CDFG, 1999a) also was used by PacifiCorp to obtain concurrent physical/ habitat measurements and field measurements of water quality parameters (temperature, pH, conductivity, and DO). EPA’s physical/habitat scoring criteria were used to measure the physical habitat quality of the sampling sites. Physical habitat characteristics that were measured included riffle length and width, water depth and velocity, percent canopy cover, substrate composition and embeddedness, and percent gradient.

12.4.4 Sampling Locations

The number of reaches, transects, and samples for the spring 2003 study are summarized in Table 12.4-1.

Table 12.4-1 Planned number of reaches, transects, and samples for spring 2003 macroinvertebrate study.

Area	Reaches[1]	Transects[2]	Samples[3]	State	
				OR	CA
Keno Dam to J.C. Boyle Reservoir	2	6	6	√	
J.C. Boyle Bypass Reach	3	9	9	√	
J.C. Boyle Peaking Reach	6	18	18	√	√
Klamath River Between Iron Gate Dam and the Shasta River	6	18	18		√
Total	**17**	**51**	**51**		

[1] Reaches are defined as a stretch of stream that contains at least five riffles within the same stream order and relative gradient. Reach estimates for each area were derived from a review of topographic maps and aerial photographs and from initial field reconnaissance.

[2] Per CSBP protocols, a sampling transect is placed in each of three randomly chosen riffles in each reach (in the upper third of the riffle).

[3] Per CSBP protocols, one sample is obtained at each sampling transect. The sample is a composite of kicknet collections from three areas along each transect.

This planned sampling effort is reduced from the more comprehensive study conducted in fall 2002. In discussions with the Water Quality Work Group, it was determined that the spring 2003 sampling could focus on key river reaches of most concern in the Project area, and that the proposed number of reaches and samples is sufficient for comparison with fall 2002 results to assess potential seasonal differences in macroinvertebrate community composition.

The specific reaches that were sampled in each of the four river areas are:

1. Keno dam to J.C. Boyle reservoir

   - Upper reach from dam (RM 233.4) to RM 230
   - Lower reach from RM 230 to reservoir (RM 228.3)

2. J.C. Boyle bypass reach

   - Upper reach from dam (RM 224.7) to RM 224 (above springs)
   - Middle reach (RM 224 to RM 222.5)
   - Lower reach from RM 222.5 to powerhouse (RM 220.4) (below springs)

3. J.C. Boyle peaking reach

   - Reach 1, from powerhouse (RM 220.4) to RM 218.5
   - Reach 2, from RM 218.5 to RM 215.5 (near Caldera rapids)
   - Reach 3, from RM 215.5 to RM 211.8
   - Reach 4, from RM 211.8 to RM 208.8 (near Hessig Ranch)
   - Reach 5, from RM 208.8 to RM 206.8 (near Beswick)
   - Reach 6, from RM 206.8 to RM 204 (Copco No. 1 reservoir)

4. Klamath River between Iron Gate dam and the Shasta River

- Reach 1, from dam (RM 190) to RM 188.3
- Reach 2, from RM 188.3 to RM 186.1
- Reach 3, from RM 186.1 to RM 183.2
- Reach 4, from RM 183.2 (near Hornbrook) to RM 179.5
- Reach 5, from RM 179.5 to RM 177.9 (I-5 rest area)
- Reach 6, from RM 177.9 to RM 176.7 (Shasta River confluence)

In addition to the 51 samples obtained from the 17 reaches listed in Table 12.4-1, triplicate samples were analyzed at 10 percent of the reaches at ODEQ's request, resulting in the analysis of 59 samples.

12.4.5 Sampling Schedule

Sampling occurred during May 2003.

12.4.6 Laboratory Analysis

Macroinvertebrate samples were sent to a qualified laboratory for professional sample processing and identification of organisms to a standard level of taxonomy, usually to genus and/or species level. Each sample was processed in the laboratory to obtain a subsample of 300 organisms that were then identified to the standardized level recommended by the California Bioassessment Laboratories Network (CAMLnet)[5] using appropriate taxonomic keys and QA/QC procedures. For each sample, the laboratory reported the taxonomic list of organisms and the number of organisms within each taxon. Sample QA/QC and validation procedures followed CSBP protocols (see CDFG, 1999a, for details), including 20 percent taxonomic subsampling.

12.4.7 Data Development and Analysis

The CSBP and CLBP data analysis procedures were based on a multimetric approach to bioassessment data analysis. The taxonomic list and numbers of organisms reported for each sample were used to generate a table of sample values and means for several biological metrics in four categories: richness measures, composition measures, tolerance/intolerance measures, and functional feeding groups. The final choice of metrics and procedures used to compare sites was done in consultation with the California State Water Resources Control Board and ODEQ. The metrics were related to water quality and habitat conditions to determine correlation and probable causation.

12.4.8 Geographic Scope

The collection of macroinvertebrate samples occurred in 17 mainstem river reaches along the Klamath River from Keno dam (RM 233.4) to the mouth of the Shasta River (RM 176.7) (Table 12.4-1).

[5] CAMLnet is an organization that provides technical assistance to, and ensures consistent efforts from, analytical laboratories in California.

12.5 RELATIONSHIP TO REGULATORY REQUIREMENTS AND PLANS

This study helps PacifiCorp address regulatory requirements and planning objectives related to water quality effects on macroinvertebrates. The information derived from this study helps address FERC requirements (18 CFR 4.51 and 16.8) for information on water quality and fish and wildlife in the Project area and the potential effects of Project operations on water quality and fish and wildlife.

Relicensing of the Project requires certifications from relevant agencies that the Project complies with requirements of Section 401 of the federal Clean Water Act. This study provides information to assess potential Project effects as they relate to water quality objectives and standards promulgated by these agencies.

Together with other hydrology and water quality studies conducted by PacifiCorp, this study provides information to address compliance with management objectives from various resource agencies, tribes, and other stakeholders that relate to water quality and fish and wildlife, including:

- Federal Clean Water Act regulations
- State of California Water Quality Control Plan for the North Coast Region (Basin Plan)
- State of Oregon Water Quality Basin Plan for the Klamath River
- Tribal natural resources goals and objectives and cultural values, including tribal water quality standards as promulgated
- USFS and BLM Aquatic Conservation Strategy objectives under the Northwest Forest Plan
- BLM Resource Management Plans
- USFS Land and Resource Management Plans
- ODFW Fish and Wildlife Habitat Mitigation Policy
- ODFW Klamath Basin Fish Management Plan
- CDFG management goals

This study's information also helps PacifiCorp and stakeholders to develop PM&E measures to meet the intention of the regulations and management objectives related to water quality and fish and wildlife.

12.6 TECHNICAL WORK GROUP COLLABORATION

PacifiCorp has worked with stakeholders to establish a more collaborative process for planning and conducting studies needed to support Project relicensing documentation. As part of this collaborative process, a Water Quality Work Group was formed and meets approximately monthly to plan and discuss water quality studies and results, including this macroinvertebrate study.

12.7 RESULTS

12.7.1 Physical Habitat

The physical habitat of the reaches pertinent to the determination of macroinvertebrate diversity and abundance includes substrate, riparian conditions, channel disturbance, flow, and water quality. Flow and water quality constituents were measured at the time of sampling and represent instantaneous values only (rather than long-term or seasonal average conditions). Substrate, riparian, and channel conditions were characterized thoroughly in the fall of 2002, and similarities among reaches were reported in Section 8.0. Results of that analysis, as they pertain to the spring 2003 reaches, are summarized in Table 12.7-1.

Table 12.7-1. Statistical similarities among reaches, as grouped using cluster analysis (SAS, 2002).

Physical Habitat Groupings	
Substrate Composition and Embeddedness	**Riparian and Channel Conditions**
Bypass/Peaking/Keno	Keno/Bypass
Peaking/Lower Klamath	Bypass/Peaking
	Peaking/Lower Klamath

(Sources: SAS, 2002; see also Section 8.0 of this document.)

The cluster analysis results indicated that substrate and riparian conditions similarities are grouped by geographically adjacent reaches. Keno reach sites grouped more with the bypass area, while the sites on the lower Klamath River below Iron Gate dam grouped with the peaking reach rather than with more upstream locations. Statistically significant differences in physical habitat conditions were limited to the J.C. Boyle bypass reach having better channel flow and riffle frequency than the J.C. Boyle peaking reach and Keno reach, respectively. Better channel alteration and riparian vegetation conditions were found in the J.C. Boyle peaking reach, relative to the lower Klamath River, below Iron Gate dam (see fall 2002 results, Section 8.0). The substrate analysis indicates gradually changing substrate conditions moving downstream through the study area, with few significant differences among reaches. Comparisons between the J.C. Boyle bypass and peaking reaches did not reveal significant differences related to embeddedness or sediment deposition.

Point sample water quality measurements were collected at the time of macroinvertebrate collections at a frequency of once per reach. Results are presented in Figure 12.7-1. The results are indicative of conditions only at the time of sampling and do not represent daily or seasonal average conditions. As such, they are only weakly indicative of differences among locations. Nevertheless, the results suggest generally good water quality conditions at the time of the spring macroinvertebrate sampling. Water temperatures ranged from 12° to a little over 16°C. DO was always above 8 mg/L and specific conductnace and pH were indicative of these naturally basic and mineral-rich waters. The only possible Project-related impact was the increase in temperature and associated decrease in DO in the first few peaking sites compared to the lower J.C. Boyle bypass sites. The initial peaking sites directly receive reservoir (upper basin) water and were approximately 2° to 4°C warmer than sites immediately upstream (Figure 12.7-1). This may be an artifact of warmer, upper basin water entering at the head of these reaches.

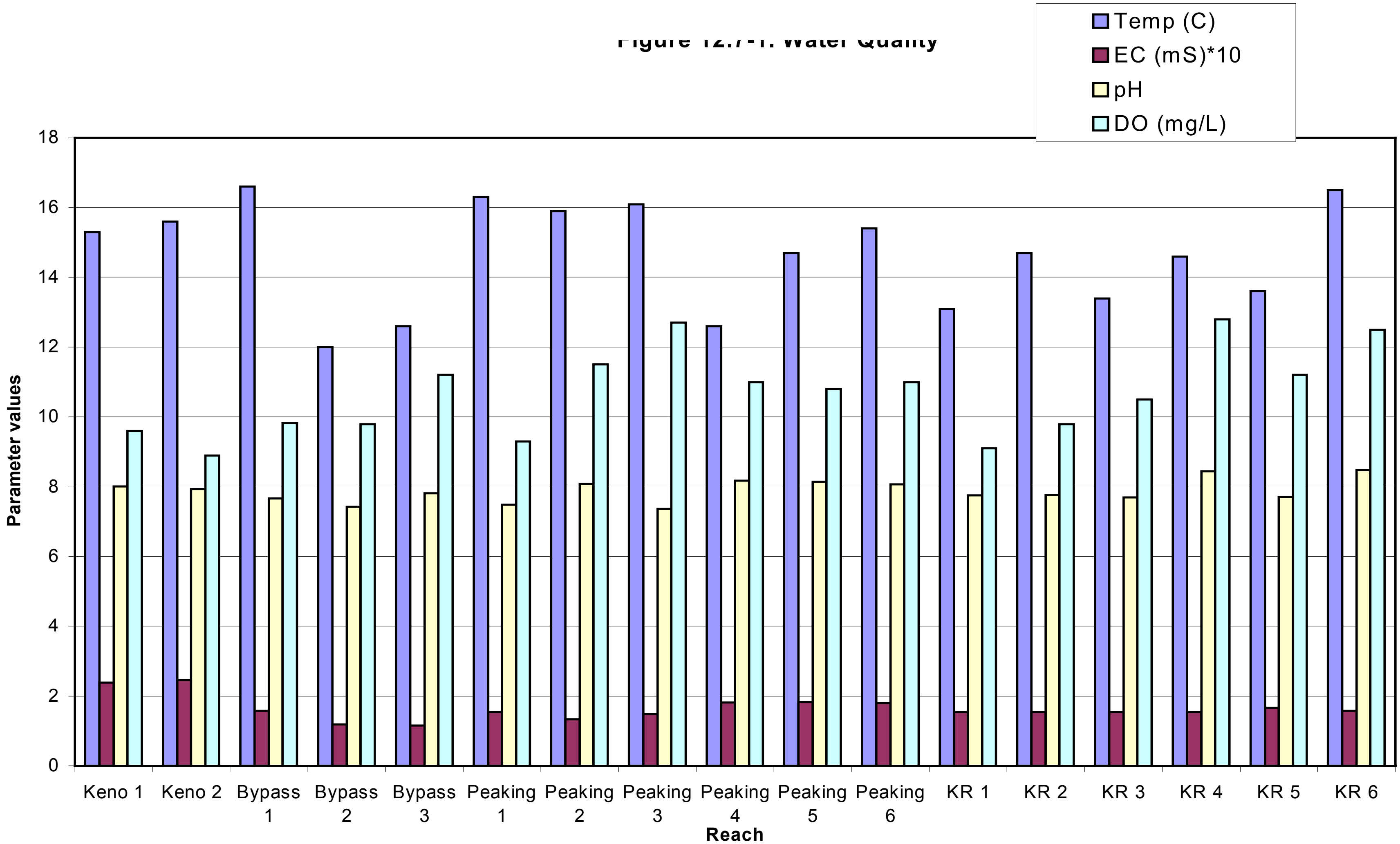

Figure 12.7-1. Water quality measurements (temperature, specific conductance, pH, and DO in Project reaches.

12.7.2 Macroinvertebrate Communities

Macroinvertebrate sampling results are presented in Appendix 12A as raw counts by site (Table 12A-1), mollusc taxa results (Table 12A-2), and all metrics by site (Table 12A-3). In addition, sampling locations were grouped by macroinvertebrate metric results using cluster analysis and compared statistically among reaches (similar to the fall 2002 results; see Section 8.0).

The standard metrics used to group macroinvertebrate count data listed in Table 12.7-2, along with an indication of the direction of change of each metric, may be used to indicate environmental conditions.

Table 12.7-2. Standard list of benthic macroinvertebrate metrics used in this analysis.

Metrics	Metrics
Total abundance, H	Total taxa richness, H
EPT taxa richness, H	EPT index, H
Sensitive EPT index, H	Shannon diversity (log e), H
Total ephemeroptera taxa, H	Total plecoptera taxa, H
Total trichoptera taxa, H	Tolerant taxa richness, L
Long-lived taxa %, H	Long-lived taxa richness, H
Tolerant taxa %, L	Intolerant taxa %, H
Hydropsychidae %, L	Baetidae %, L
Dominant taxa %, L	Collectors %, L
Filterers %, L	Scrapers (grazers) %, variable
Predators %, variable	Shredders %, H
Collector-filterer abundance, L	Collector-gatherer abundance, L
Predator taxa richness, H	Scraper abundance, variable
Scraper taxa richness, variable	Hilsenhoff Biotic Index (HBI score), L

Note: H or L = Better conditions that are represented by either Higher (H) or Lower (L) score (varying among metrics); H or L indicates the direction of the better, less impaired conditions. Variable = uncertain relationship between metric score and environmental conditions (CSBP, 2002).

Cluster analyses by major metric types revealed slightly variable results, depending on the class of metrics examined. The variability in functional feeding groups showed similarities between the Keno reach, J.C. Boyle bypass, and Lower Klamath River; the J.C. Boyle bypass and peaking reaches; and the J.C. Boyle peaking reach and the Lower Klamath River (Figure 12.7-2).

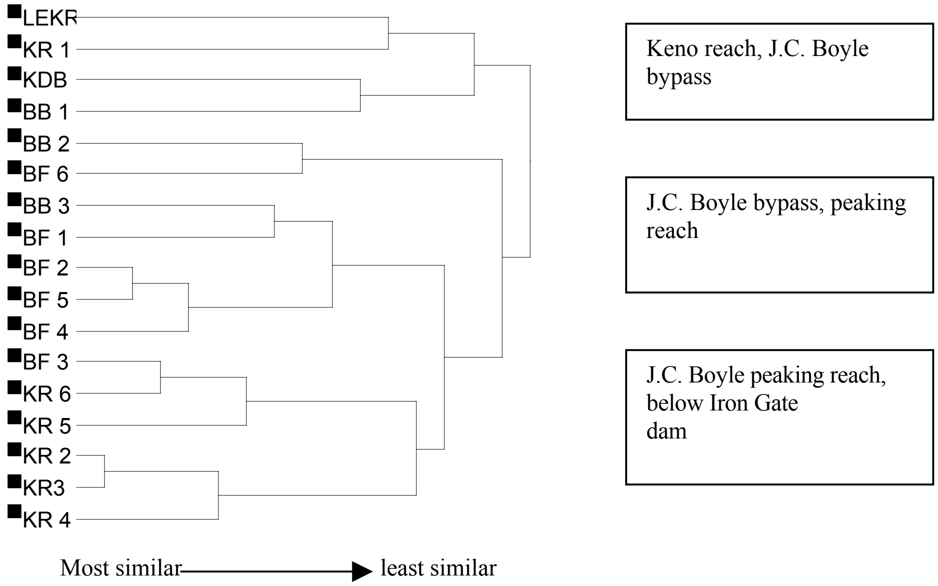

Figure 12.7-2. Hierarchical clustering of reaches based on functional feeding groups, spring 2003.

Biotic index metrics (e.g., HBI, EPT, sensitive EPT, Shannon diversity) showed slightly different groupings among sites. Keno reach and J.C. Boyle bypass reach showed similarities, and the J.C. Boyle peaking reach and Lower Klamath River sites constituted another cluster based on these metrics (Figure 12.7-3).

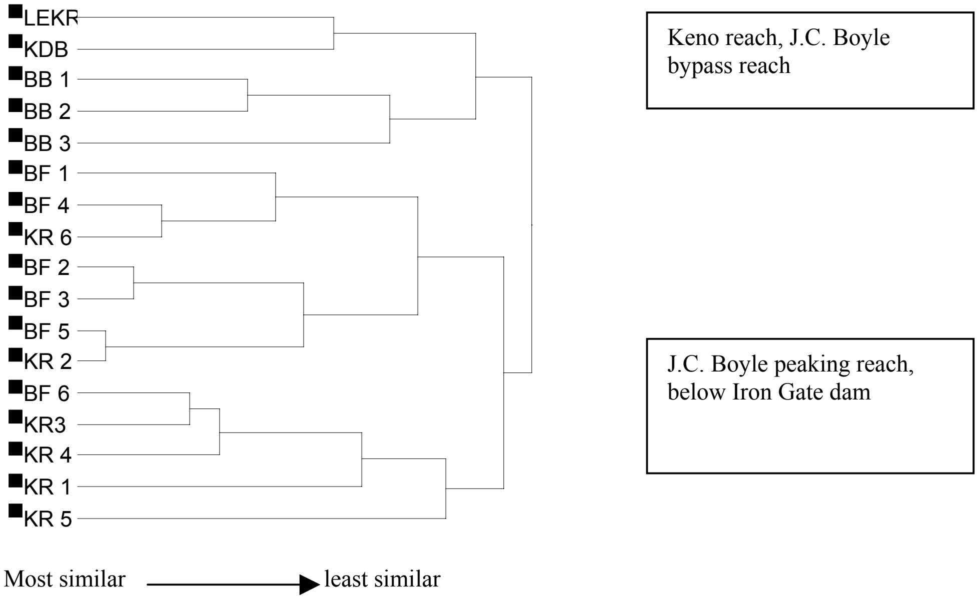

Figure 12.7-3. Hierarchical clustering of reaches based on biotic indices, spring 2003.

Taxa richness metrics produced similar clusters by reach of the Keno and the J.C. Boyle bypass reaches, and the J.C. Boyle upper peaking sites with reaches below Iron Gate. In addition, the Lower Klamath River sites constituted a third grouping (Figure 12.7-4).

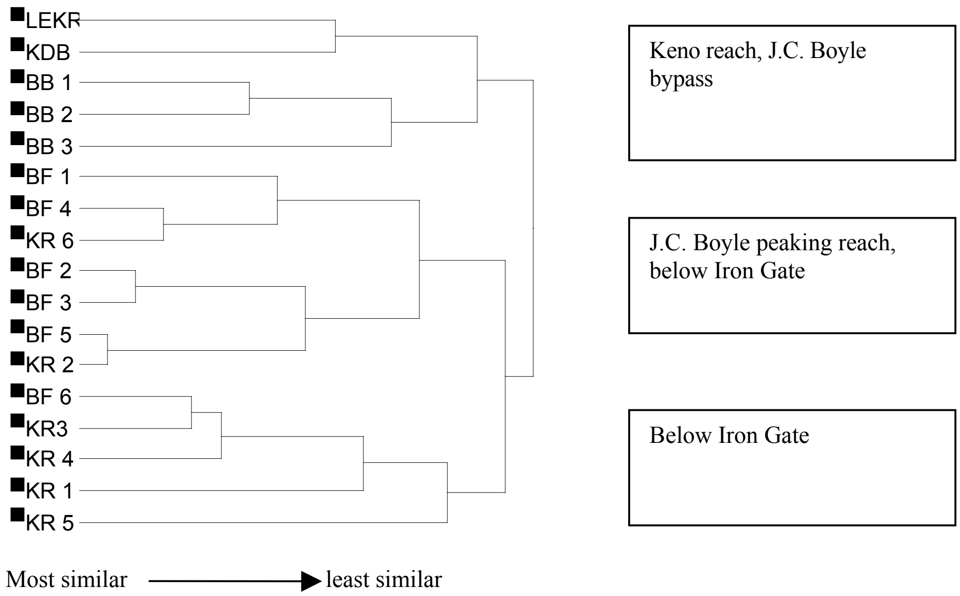

Figure 12.7-4. Hierarchical clustering of reaches based on taxa richness indices, spring 2003.

In general, the station cluster results indicate a similarity between the J.C. Boyle bypass and peaking reach communities (for every metric grouping) and longitudinal similarities. The Keno reach clusters with the J.C. Boyle bypass and the sites below Iron Gate tend to be similar to the J.C. Boyle peaking reach. Statistical similarities among macroinvertebrate metrics by reach are shown in Table 12.7-3.

Table 12.7-3.Comparison of significant differences in macroinvertebrate metrics by reach.

J.C. Boyle Peaking Reach to Bypass	**Keno Reach to J.C. Boyle Bypass**	**J.C. Boyle Peaking Reach to Klamath below Iron Gate Dam**
Taxa richness (P)	Tolerant taxa % (BB)	Intolerant taxa % (P)
EPT taxa richness (P)	Shannon diversity (K)	Baetidae % (P)
Sensitive EPT index (P)	Collector-filterer % (BB)	Predator % (Unk)
Tolerant taxa % (BB)	Scraper abundance (Unk)	Predator taxa (Unk)
Intolerant taxa % (P)	Predator % (Unk)	Sensitive EPT index (P)
Long lived taxa % (BB)		
Dominant taxa % (P)		
Shannon diversity (P)		
Scraper taxa (Unk)		
Scraper abundance (Unk)		

Note: Abbreviations for stations with less impaired condition are shown. All relationships are significantly different, P< 0.05, ANOVA.

The results indicate general similarities in macroinvertebrate communities that are closely linked along the length of the river. Only a few metrics showed statistically significant differences for the Keno reach/J.C. Boyle bypass comparison or the J.C. Boyle peaking reach/Lower Klamath River sites comparison. These general results are similar to those from the fall 2002 survey.

The greatest number of statistically significant differences in metric results by reach were found for the J.C. Boyle peaking reach compared to the J.C. Boyle bypass reach, immediately upstream. However, results were somewhat split. Most major taxa metrics showed improved conditions in the peaking reach (EPT, sensitive EPT, diversity), but certain groups of taxa (long-lived and tolerant groups) showed enhanced conditions in the bypass reach.

Several taxa, although showing statistically different results between reaches, were not obviously related to improved or degraded conditions (i.e., scraper abundance) (Table 12.7-3). As an example, periphyton algae growth, as required to support the scraper guild, is heavily influenced by sunlight exposure. Steep canyons, such as in the J.C. Boyle peaking reach, may be expected to vary greatly from site to site in the conditions favorable to scrapers, regardless of flow or water quality considerations.

The metrics show general similarities in longitudinal pattern to the results from the fall 2002 sampling of the mainstem Klamath River sites, although the absolute values of the metrics were seasonally variable. For instance, although overall density estimates were lower in the spring, taxa richness was essentially unchanged, seasonally (Figures 12.7-5 and 12.7-6). However, several metrics showed reach-specific differences or overall study area differences between the seasonal sampling events (Figures 12.7-7, -8, -9, and -10). For example, the results indicate an apparent seasonal change in the distribution of feeding guilds, possibly indicating changes in food type and availability. The generally better water quality in the spring months in the river below Iron Gate is reflected in the seasonal change to greater overall EPT taxa richness (Figure 12.7-7 and 12.7-8). Another line of evidence for altered spring water quality was the shift in the macroinvertebrate community to a lower percentage of filterers in the peaking reach and river below Iron Gate (Figure 12.7-9a, b). One indicator of improved conditions in the J.C. Boyle peaking reach in the spring samples was the reduced percentage of dominant species compared to the fall samples (Figure 12.7-10).

Statistical comparisons of metrics by reach between the fall and spring samples indicated changes in overall species composition along with generally improved water quality conditions during the spring period. The results of fall/spring comparisons are summarized in Table 12.7-4. The J.C. Boyle peaking reach and area below Iron Gate dam registered the most change in macroinvertebrate community structure between the two seasons. Significant differences (Table 12.7-4) were driven by changed community structure between the seasons, mostly in terms of the relative decrease in filterer and increase in collector-gatherer taxa in the spring (i.e., Figures 12.7a, b).

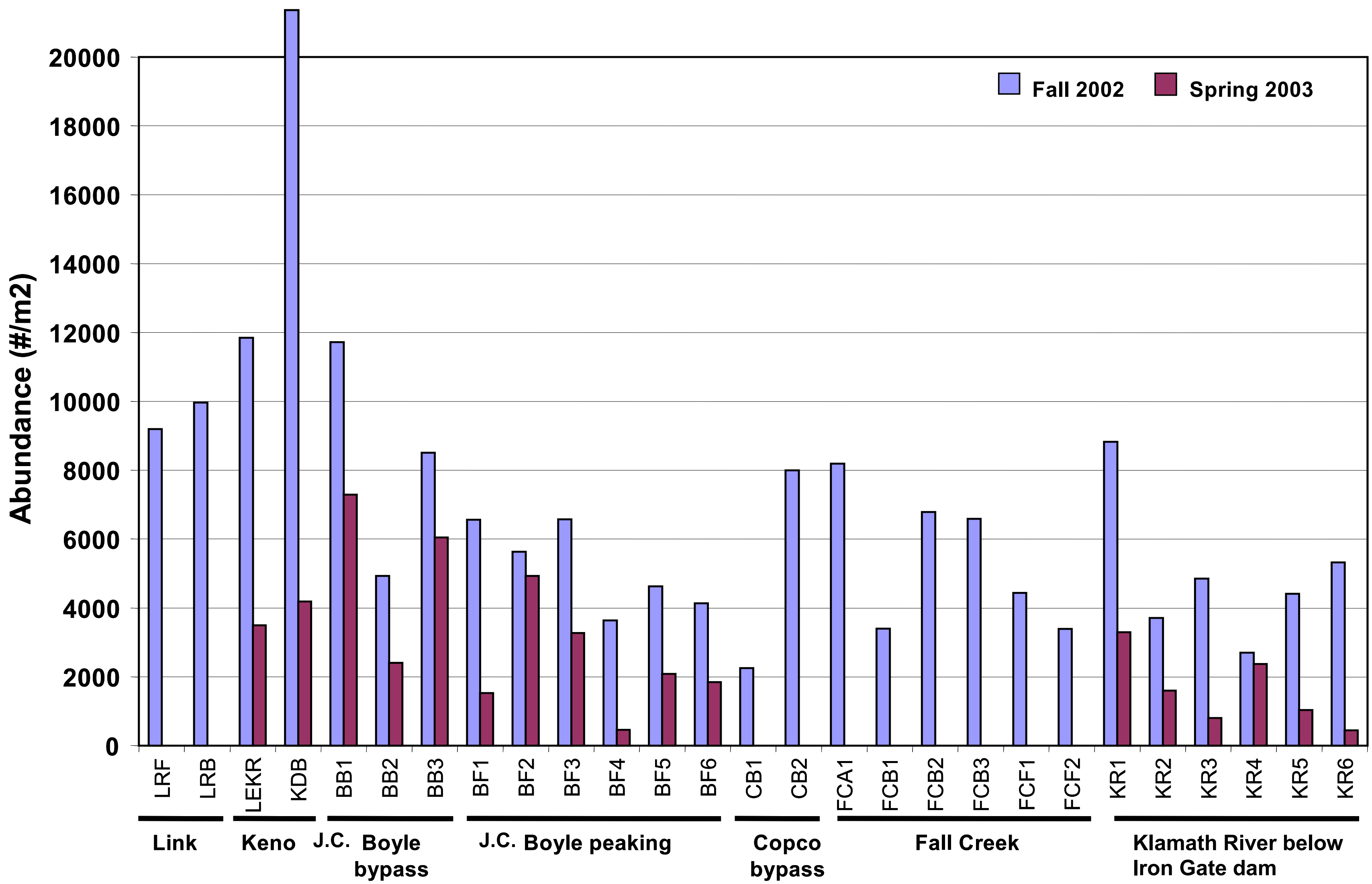

Figure 12.7-5. Total invertebrate density.

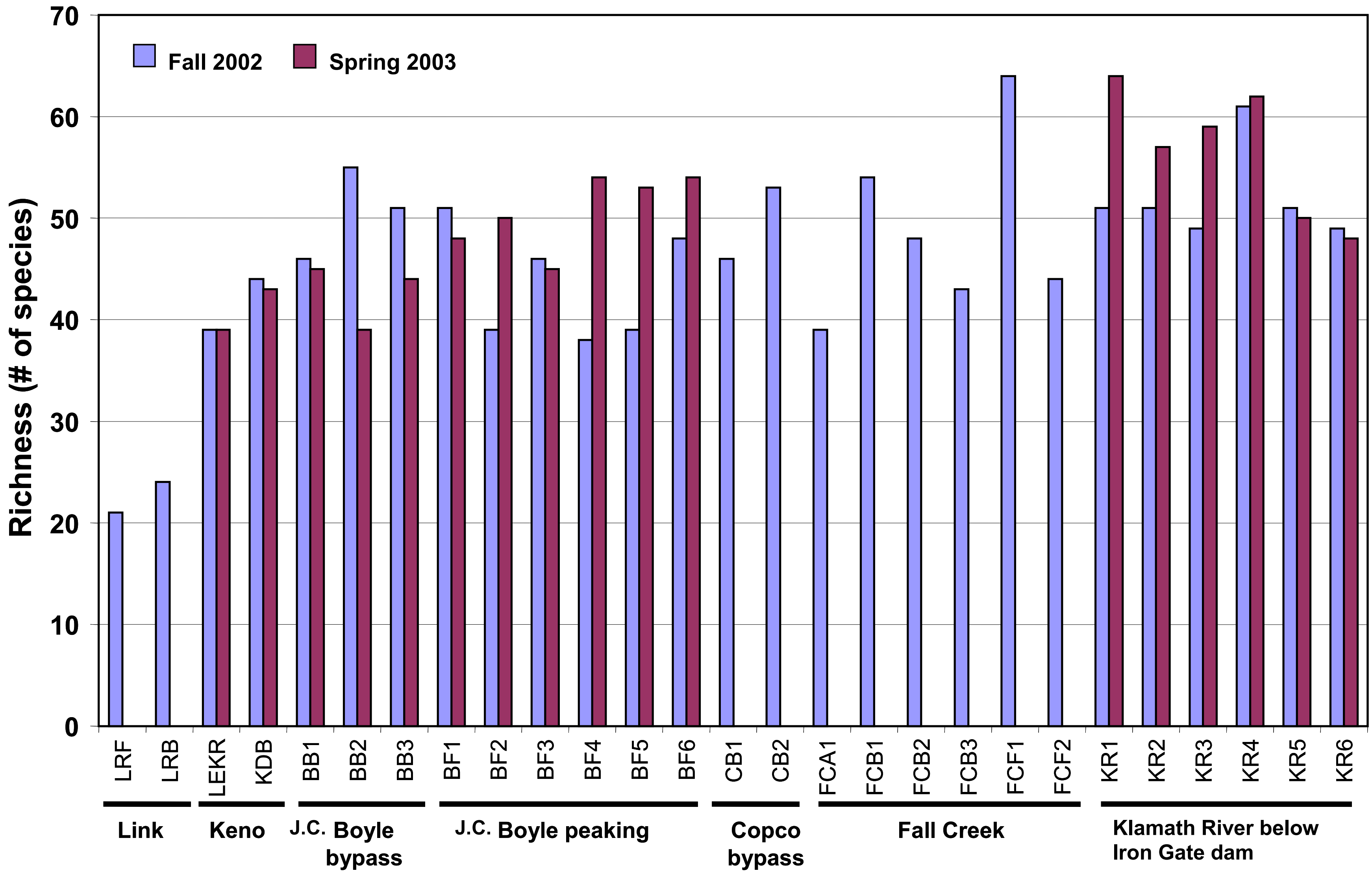

Figure 12.7-6. Taxa richness.

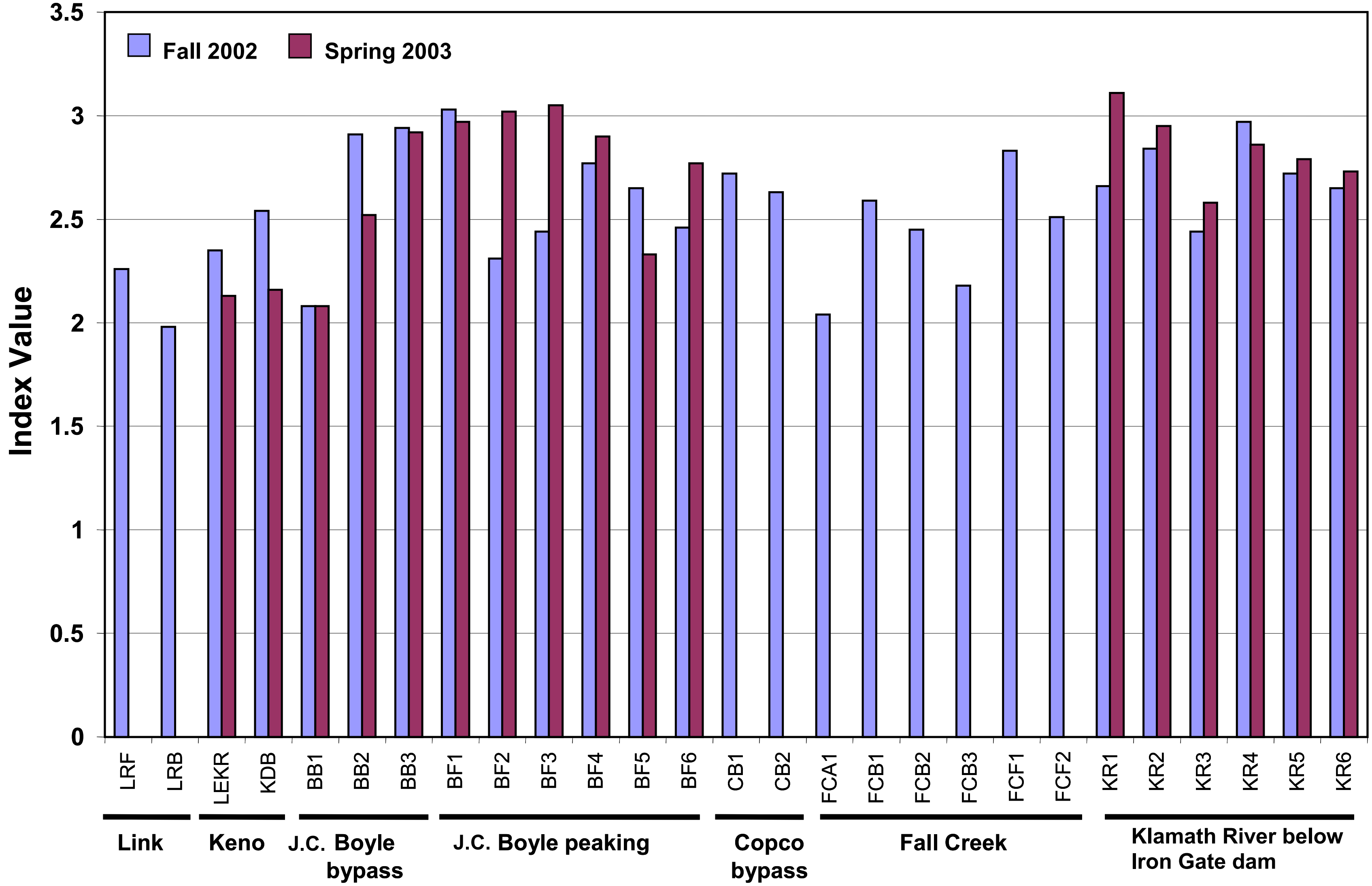

Figure 12.7-7. Shannon diversity index.

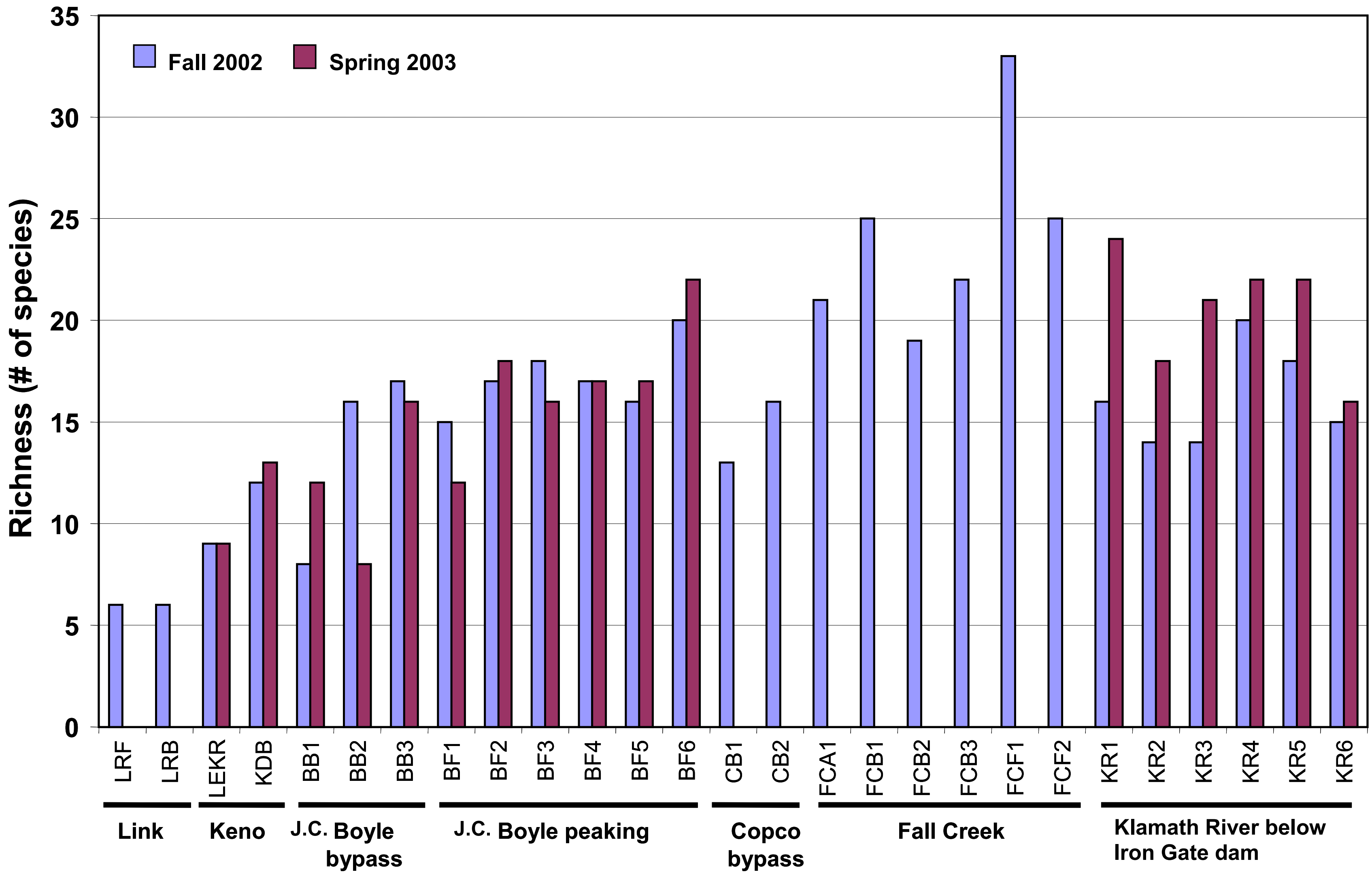

Figure 12.7-8. EPT richness.

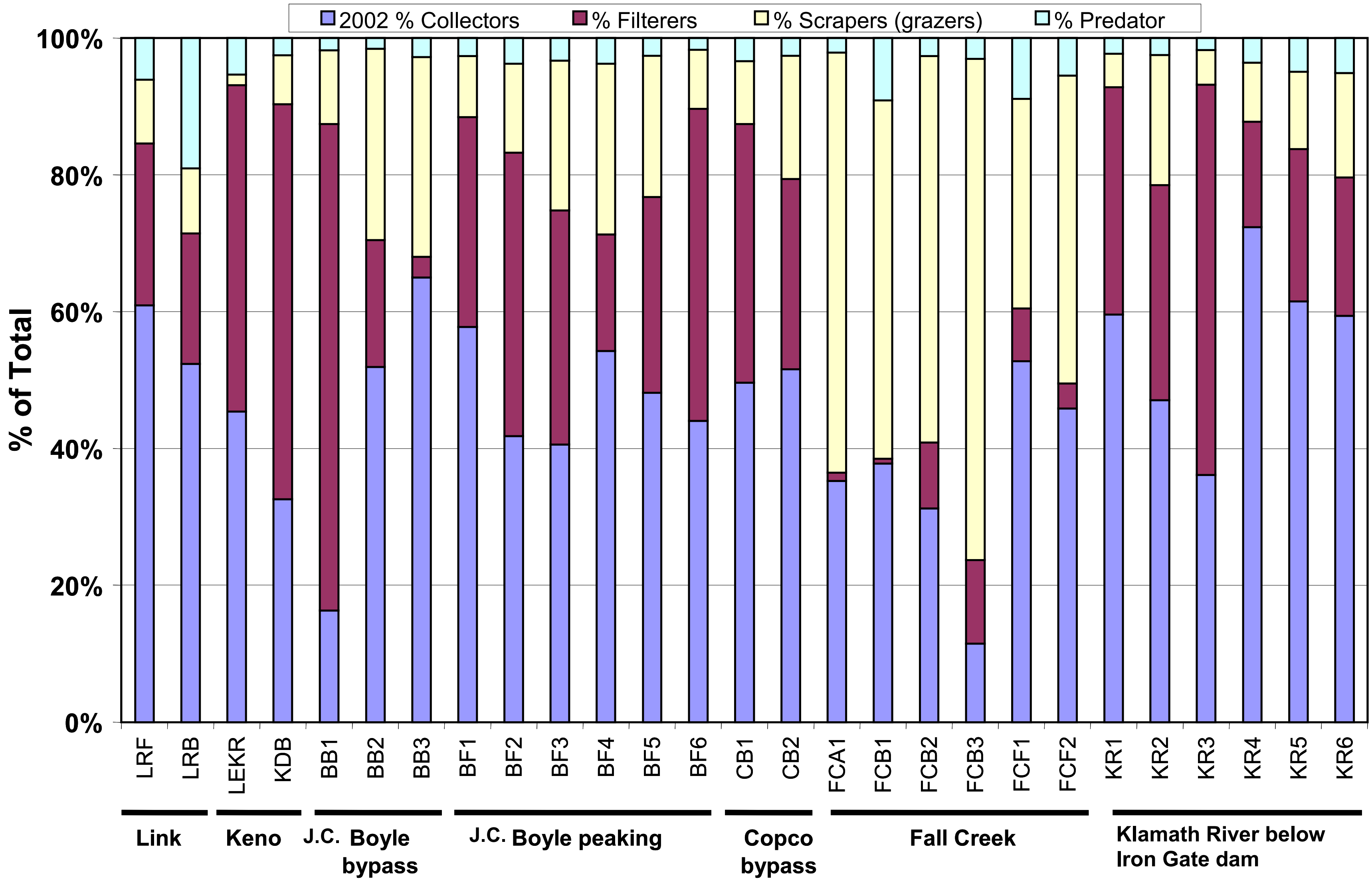

Figure 12.7-9(a). Functional feeding groups – fall 2002.

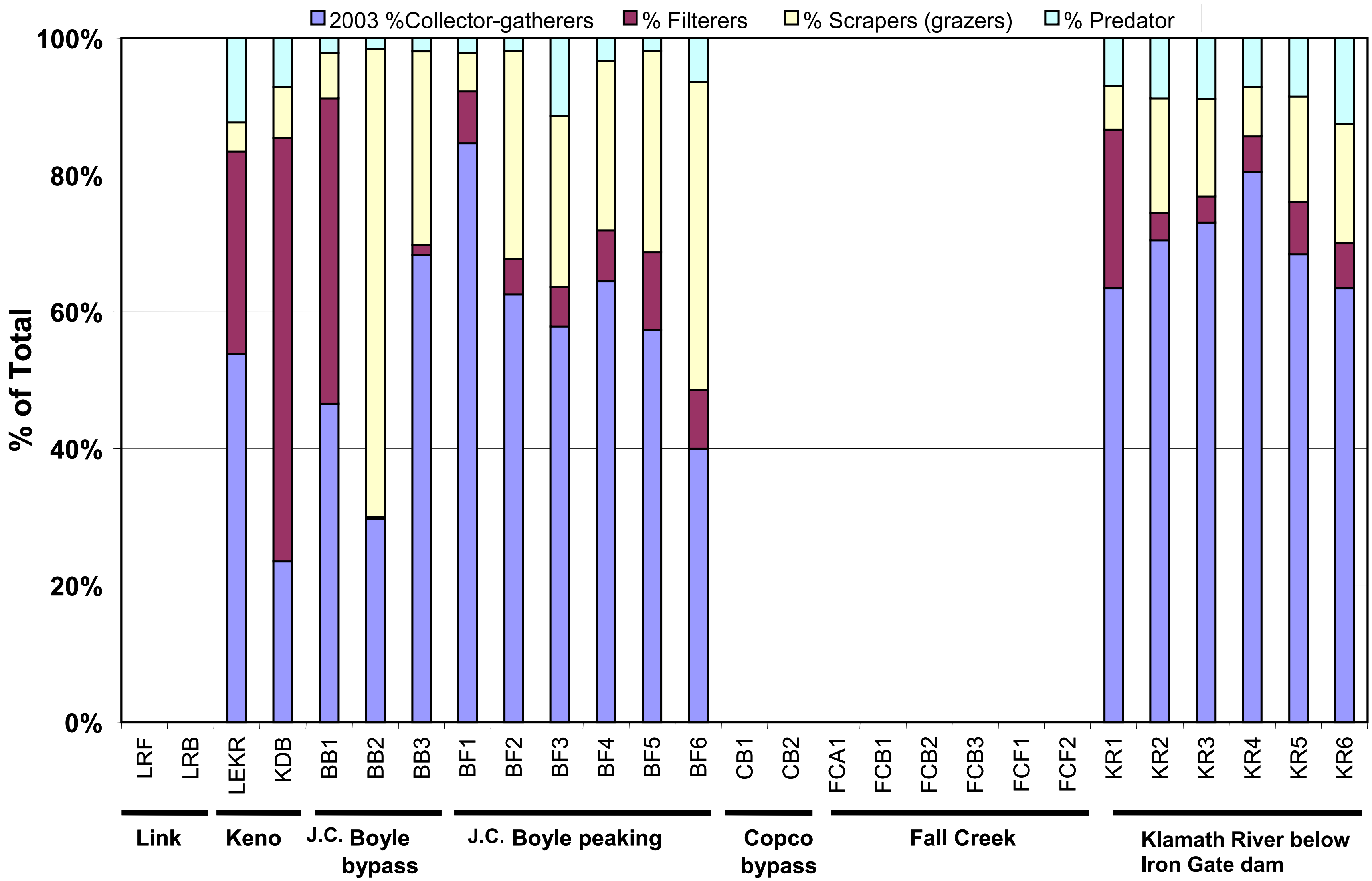

Figure 12.7-9(b). Functional feeding groups – spring 2003.

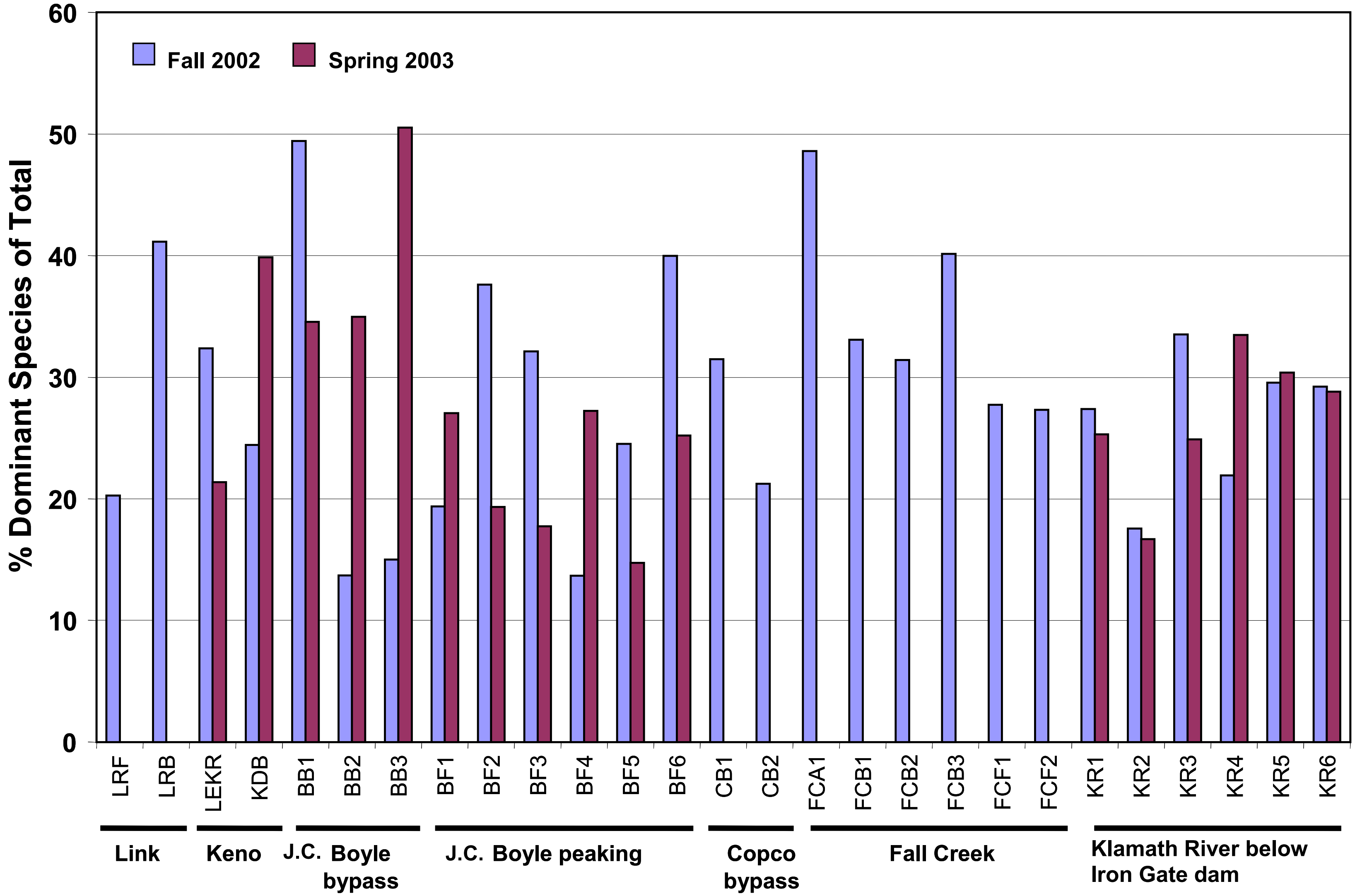

Figure 12.7-10. Dominant taxa (% of total taxa).

Table 12.7-4 Paired t-test comparisons of fall 2002 and spring 2003 macroinvertebrate metrics by reach.

	Reach			
Metric	**Keno**	**J.C. Boyle Bypass**	**J.C. Boyle Peaking**	**Below Iron Gate Dam**
Total Taxa Richness	S	NS	S	S
EPT Taxa Richness	NS	NS	NS	S
EPT Index	NS	NS	S	S
Sensitive EPT Index	NS	NS	S	S
HBI	NS	NS	NS	NS
Shannon	NS	NS	NS	NS
Tolerant Taxa, %	NS	NS	NS	NS
Intolerant taxa, %	NS	NS	S	S
Dominant taxa, %	NS	NS	NS	NS
Predators, %	NS	NS	NS	S
Baetidae, %	NS	NS	NS	S
Hydropsychidae, %	NS	S	S	S
Collector-filterer abundance	NS	NS	S	S
Collector-gatherer abundance	NS	NS	S	S

S = significantly different ($P < 0.05$).
NS = not statistically different.

The differences between seasons may indicate natural shifts in the macroinvertebrate community structure related to the variable life histories of the member species and to the changing food resources and water quality of the seasons. In general, the spring macroinvertebrate results, compared to the fall results indicate a shift toward better water quality. A greater percentage of EPT and sensitive EPT taxa were found in the spring, along with greater numbers of collector-gatherers and filterers in the peaking and most downstream reaches.

Seasonal differences as seen in the Keno and J.C. Boyle reaches are unlikely to be statistically different (e.g., as indicated in Table 12.7-4) because of the fewer numbers of sites in those two relatively short reaches (only two and three sites per reach, respectively). However, seasonal differences in most parameters in all major reaches are visible in the seasonal comparisons depicted in Figures 12.7-5 to 12.7-10 (including the Keno and J.C. Boyle bypass reaches).

Molluscs were sampled as part of the kicknet samples and were noted as "non-insects" in the bioassessment metrics. The bivalve molluscs, including larger species not sampled by kicknet, were separately reported in Section 11.0 of this document. A summary of all snail and clam species sampled as part of the spring 2003 kicknet sampling is reported in Appendix 12A (Tables 12A-2 through 12A-6).

As noted in the fall 2002 macroinvertebrate samples, several new or unnamed small mollusc species are evident in the Klamath River data set (Appendix Table 12A-2). Stations along the mainstem river were generally similar in species diversity and abundance of small mollusc species. As reported in Section 8.0, Fall Creek had a more diverse and abundant small mollusc community than did the mainstem Klamath River sites.

Dominant species in the spring dataset included *Baetis tricaudatus* in the J.C. Boyle bypass reach, the caddisfly (*Hydropsyche* sp.) in the J.C. Boyle bypass and peaking reaches, and the beetle *Optioservus* sp. in the bypass and upper peaking reaches. The blackfly (*Simulium* sp.) was dominant in the Keno reach and in the upper stations of the J.C. Boyle bypass and Lower Klamath River, below Iron Gate dam.

The small polychaete worm (*Manayunkia speciosa*) was found in low abundance in several of the kicknet samples. This is in contrast to observations during fall 2002 samples, when this Species of Concern was discovered only in extremely low abundance in drift samples. No drift samples were collected during the spring 2003 sampling event, and it is unknown whether the polychaete remained present in drift. Its presence was noted in kicknet samples primarily from the J.C. Boyle bypass and peaking reaches (Appendix Table 12A-1).

12.8 DISCUSSION

The macroinvertebrate communities of the riverine reaches revealed some basic differences among sites, most of which are attributable to expected differences associated with geographic variation and the longitudinal or elevation changes in riverine communities. The physical habitats along the river were variable in predictable ways, with fast water and boulder substrates predominating in the steep, J.C. Boyle canyon bypass and peaking reaches and a wider, even-flowing, cobble-bottomed river in the lower reaches below Iron Gate reservoir.

Existing conditions in the Project area are indicative of gradual, longitudinal change along the nearly 80 miles of river from southern Oregon through northern California that were considered in the scope of this study, punctuated by the influence of reservoirs on downstream stations. Physical habitats and flows all reflect these general, large-scale changes. Figures 8.7-1 and 8.7-2 illustrate these physical habitat and water quality changes throughout the various study reaches.

The stream macroinvertebrate communities do not strongly reflect these longitudinal changes in physical habitat (e.g., Figures 12.7-8 and 12.7-9). However, some differences were observed between peaking and bypass reaches and between geographically separate locations. Metrics showing elevation trends included taxa and EPT taxa richness, the percent dominant taxa, and the EPT index. The trends are indicative of generally improved downstream conditions.

J.C. Boyle peaking and bypass comparisons were somewhat more distinctive than was revealed in the fall 2002 results. Most spring 2003 results indicated improved conditions in the J.C. Boyle peaking reach compared with the bypass reach (Table 12.7-4). The uppermost bypass location, BB1, remains distinctive in exhibiting evidence for different and more degraded conditions than the other bypass locations.

In addition to developing baseline data on macroinvertebrates of the study area, it is possible to address some of the key objectives questions raised by the original objectives of this study, as answered by the cumulative fall and spring results.

1. Characterize macroinvertebrate presence and community composition in waters affected by the Project.

The macroinvertebrates have been characterized throughout the study area as part of both this spring 2003 report and the fall 2002 sampling and report. The diversity of sites provided an ability to characterize current conditions and to evaluate altered conditions as affected by the Project.

2. Do waters affected by the Project support healthy and diverse residential macroinvertebrate communities?

The variability in community macroinvertebrate communities is discussed above, including potential project impacts. The communities appear very comparable in overall taxa richness and abundance to those of other similar-sized river systems in the region (e.g., Clackamas and Willamette). The Klamath River's taxa richness is relatively higher for midges, non-insects, and other Diptera, while EPT richness is generally lower. There is no dramatic evidence of impairment to macroinvertebrate communities related to Project operations. The J.C. Boyle peaking reach is not degraded with respect to other reaches.

3. Develop a baseline of existing macroinvertebrate community conditions in the event monitoring of macroinvertebrates becomes a postlicensing monitoring requirement.

The fall 2002 and spring 2003 sampling provide an excellent base of knowledge for the beginning of long-term monitoring. The design of such a program can be facilitated by the analysis of results above. The results presented here provide a characterization throughout the study area, in bypass and peaking reaches, and in areas of more constant, regulated flows (below Iron Gate dam).

4. Is macroinvertebrate community composition related to water quality conditions? If so, how is it related?

Both the macroinvertebrate community and water quality demonstrate gradual, longitudinal changes along the full, Project-investigated extent of the river. However, stream macroinvertebrate communities do not appear to be strongly water-quality-related. In contrast, the invertebrate communities of the reservoirs apparently vary with substrate quality and the degree of eutrophication (fall sampling, see Section 8.0). The eutrophic conditions of Lake Ewauna are likely related to the degraded macroinvertebrate communities at that reservoir.

The lists of Oregon and California impaired water bodies show that the Klamath River is impaired for a variety of standard water quality conditions associated with nutrient enrichment and temperature. However, detrimental effects associated with nutrient enrichment (e.g., excessive algae growths, DO depletion) or high temperatures were not obvious during this study (e.g., see Figure 12.7-1).

5. Are designated Species of Concern present?

The three caddisfly Species of Concern were not found as part of these samples. However several new or little-described mollusc species were found, as well as the polychaete host species for an important salmonid disease (Appendix 12A, Tables 12A-1 and 12A-2).

6. Support subsequent assessment (together with other resources studies) of the quality of the macroinvertebrate assemblage as a food source for fish and wildlife, and to identify susceptibility of macroinvertebrate taxa to flow changes.

The overall abundance of macroinvertebrates gradually increased moving downstream through the Project study reaches (Figure 12.7-5). However, the indices of diversity and other metrics did not indicate dramatic effects of Project operations on the macroinvertebrate community. J.C. Boyle peaking area communities, compared to those of the J.C. Boyle bypass, indicate somewhat better conditions in the peaking reach. The station showing the most consistent evidence of degradation (e.g., higher percent dominant taxa, shifted feeding groups, low EPT index, lower diversity) was the most upstream J.C. Boyle bypass site (BB1).

7. Support subsequent assessment (together with other studies and during license application preparation) of the Project's potential effects on water quality and fish and wildlife resources, and possible PM&E measures where necessary.

The macroinvertebrate fauna are susceptible to drawdown and drying of habitats in varial zones. However, the general richness and abundance of the fauna throughout the system suggest adequate to good availability of macroinvertebrates as a food source for fish and wildlife.

13.0 ANALYSIS OF POTENTIAL KLAMATH HYDROELECTRIC PROJECT EFFECTS ON WATER QUALITY AESTHETICS

13.1 DESCRIPTION AND PURPOSE

The purpose of this study is to assess how water quality affects aesthetic conditions in the Project area and infer how the Project may contribute to these water-quality-related aesthetic conditions. Oregon has a specific aesthetics standard that states: "Aesthetic conditions offensive to the human senses of sight, taste, smell, or touch shall not be allowed" [OAR 340-041-0965(2)(l)]. California does not have a comparable specific aesthetics objective (standard). Both Oregon[1] and California[2] also have other water quality standards or objectives with aesthetics-related components, such as turbidity, color, tastes and odors, or suspended and settleable solids. This study is not intended to address these other standards or objectives, but the information gained from this study can be used to address aesthetics-related aspects of these other standards or objectives.

13.2 OBJECTIVES

The objectives addressed by this study are as follows:

1. Assess how water quality affects aesthetic conditions in the Project area and infer how the Project may contribute to these water-quality-related aesthetic conditions.

2. Assess whether water quality aesthetic conditions comply with state water quality standards or objectives concerning aesthetic conditions.

13.3 METHODS AND GEOGRAPHIC SCOPE

13.3.1.1 Summary of Existing Information

The first step of the analysis was to compile and summarize available data since 1980 related to water quality aesthetics in the Klamath River. The types of data included in this summary are:

- Turbidity
- Secchi disc
- Klamath Recreational Survey Water Quality Results

This information is attached in the technical memorandum titled Summary of Available Data Related to Water Quality Aesthetics (Appendix 13A). This document is organized to provide (1) brief discussions and summaries of each data type, and (2) attachments containing data tables and graphs of each data type.

13.3.1.2 Additional Data Collection

During March-October 2003, PacifiCorp conducted water quality monitoring within the Project area. Water quality samples were collected at nine river sites from Link River to the Klamath

[1]Oregon Administrative Rules 340-011-0965.

[2]North Coast Regional Water Quality Control Board, 1994. Water Quality Control Plan for the North Coast Region, as amended.

River below Iron Gate dam, and at J.C. Boyle, Copco, and Iron Gate reservoirs, for various constituents. These constituents include several that can affect aesthetics conditions, such as nutrients, chlorophyll *a*, turbidity, total suspended solids, and total volatile solids.

In addition, synoptic water quality surveys were conducted during a 4-day period twice during the summer, once in June and once in August at 12 sites in the Klamath River between Iron Gate dam and Martin's Ferry. These synoptic surveys are used to describe daily and hourly variation in various constituents, including nutrients, chlorophyll *a*, turbidity, total suspended solids, and total volatile solids. These data collection activities are described in Section 3.0 of this FTR.

13.3.1.3 Data Analysis and Modeling

The effect of water quality conditions on aesthetics and the relative Project contribution to these conditions are assessed in two primary steps. First, the existing recreational user survey information (Appendix 13A) is used to summarize responses to questions regarding perceptions of water quality conditions and effects on user experience. From this information, the specific factors that are contributing to the perceived water quality condition or effect are determined. It should be noted that water quality condition was only one of many factors that recreational users were asked about in the survey. In addition, the survey was not designed to correlate user responses on water quality conditions to specific, quantified water quality conditions at the time of the response. However, the survey is considered adequate to determine whether the user's experience was affected by water quality conditions and to identify factors causing the water quality conditions cited by users.

Second, for the factors identified in the first step, water quality modeling (described in Section 4.0 of this FTR) and water quality data trend analysis (based on data described in section 13.3.1.2 above) are used to draw inferences on potential Project effects on these factors. Because the model does not directly predict aesthetics, this is done primarily by using model results for parameters that are surrogates for the aesthetics factors identified in the first step (e.g., nutrients and algae). Modeling results for these parameters are compared for existing conditions and for hypothetical without-Project scenarios. The analysis of water quality data (e.g., turbidity, chlorophyll *a*, total suspended solids) consists primarily of nonparametric exploration of data trends, distributions, and site comparisons.

Some stakeholders requested that PacifiCorp also analyze whether changes have occurred in water quality aesthetics since wild and scenic designation in the early 1980s. PacifiCorp is examining available turbidity, algae (i.e., chlorophyll *a*), and Secchi disk data since 1980, together with flow data, to determine if there are any obvious trends in the data over that period. The data are being partitioned or adjusted to account for variation due to season or river discharge rate.

13.4 RELATIONSHIP TO REGULATORY REQUIREMENTS AND PLANS

This study helps PacifiCorp address regulatory requirements and planning objectives related to Project effects on water quality. The information derived from this study helps address FERC requirements (18 CFR 4.51 and 16.8) for information on water quality in the Project area and potential effects of Project operations on water quality.

Relicensing of the Project requires certifications from relevant agencies that the Project complies with requirements of Section 401 of the federal Clean Water Act. This study provides information to help assess potential Project effects as they relate to water quality objectives and standards promulgated by these agencies.

This study, together with other hydrology and water quality studies conducted by PacifiCorp, provides information that can be used as necessary to address water quality management objectives related to aesthetics from various resource agencies, tribes, and other stakeholders concerned with water quality, including the following:

- Federal Clean Water Act regulations
- State of Oregon Water Quality Management Plan for the Klamath Basin (Basin Plan)
- State of California Water Quality Control Plan for the North Coast Region (Basin Plan)
- Tribal natural resources goals and objectives and cultural values
- Tribal water quality standards as promulgated
- USFS and BLM Aquatic Conservation Strategy objectives under the Northwest Forest Plan

13.5 TECHNICAL WORK GROUP COLLABORATION

PacifiCorp worked with stakeholders to establish a more collaborative process for planning and conducting studies needed to support Project relicensing documentation. As part of this collaborative process, a Water Quality Work Group was formed and met approximately monthly to plan and discuss water quality studies and results, including this study.

13.6 RESULTS

The analysis of potential Project effects on water quality aesthetics using water quality modeling and water quality data trend analysis has not been completed (as of the date of preparation of this Water Resources FTR). PacifiCorp plans to complete this analysis by the end of April 2004. A summary of available data related to water quality aesthetics is provided in Appendix 13A, including the results of the Klamath Recreation User Survey (see Recreation Resources FTR) in which recreational users were asked whether water quality conditions affected their experiences on the Klamath River in the Klamath Hydroelectric Project area.

14.0 INFORMATION SOURCES

American Society of Civil Engineers (ASCE). 1975. Sedimentation Engineering, Vito A. Vanoni, ed. Prepared by the ASCE Task Committee for the Preparation of the Manual on Sedimentation of the Hydraulics Division. American Society of Civil Engineers, New York.

Ayres Associates. 1999. Geomorphic and Sediment Evaluation of the Klamath River, California, below Iron Gate Dam. Report to U.S. Fish and Wildlife Service by Ayres Associates, Fort Collins, Colorado.

Bagnold, R.A. 1980. An Empirical Correlation of Bedload Transport Rates in Flumes and Natural Rivers. Proceedings of the Royal Society 372A, pp. 453-473.

Baker, F.C. 1918. The Relation of Shellfish to Fish in Oneida Lake, New York. New York State College of Forestry at Syracuse University, Circular (21):11-34, 16 figures.

Balance Hydrologics, Inc. 1996. Initial Assessment of Pre- and Post-Klamath Project Hydrology on the Klamath River and Impacts on Instream Flows and Fishery Habitat. Report to the Yurok Tribe, by Balance Hydrologics, Berkeley, California.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protective Agency, Office of Water, Washington, D.C.

Bartholomew, J.L. 2001. Salmonid Ceratomyxosis. In: J. Thoesen, Ed., Suggested Procedures for the Detection and Identification of Certain Finfish and Shellfish Pathogens. Blue Book, 4th Edition. Fish Health Section, American Fisheries Society.

Bauer, G. 1987. Reproductive Strategy of the Freshwater Pearl Mussel *Margaritifera margaritifera*. Journal of Animal Ecology 56:691-704.

Belchik, Michael. 2003. Yurok Tribe. Conversation on September 10, 2003, at Aquatics Work Group Meeting in Ashland, Oregon.

Bonnot, P. 1951. The Fresh-water Mussels of California. California Department of Fish and Game 37(4):485-488.

Boyle, J.C. 1976. Fifty Years on the Klamath. Klocker Printer, Medford, Oregon.

British Columbia Ministry of Environment, Land, and Parks (BCMOELP). 1988. British Columbia approved water quality guidelines (Criteria): 1998 Edition. British Columbia Ministry of Environment, Land, and Parks. Environmental Protection Department. Water Management Branch. Victoria, British Columbia.

Brune, G.M. 1953. The Trap Efficiency of Reservoirs. Transactions of the American Geophysical Union 34:407-418.

Buer, K. 1981. Klamath and Shasta Rivers Spawning Gravel Study. California Department of Water Resources, Northern District.

California Department of Fish and Game (CDFG). 1999a. California Stream Bioassessment Procedure. Protocol Brief for Biological and Physical/Habitat Assessment in Wadeable Streams. California Department of Fish and Game, Water Pollution Laboratory, Aquatic Bioassessment Laboratory. Revision Date: May 1999.

California Department of Fish and Game (CDFG). 1999b. California Lentic Bioassessment Procedure. Protocol Brief for Biological Sampling Lakes and Reservoirs. California Department of Fish and Game, Water Pollution Laboratory, Aquatic Bioassessment Laboratory. Revision Date: July 1999.

California Department of Fish and Game (CDFG). 2003a. State and Federally Listed Endangered and Threatened Animals of California. California Natural Diversity Database. January 2003. Available: http://www.dfg.ca.gov/whdab/TEAnimals.pdf.

California Department of Fish and Game (CDFG). 2003b. Special animals. July 2003. Available: http://www.dfg.ca.gov/whdab/pdfs/spanimals.pdf

California Department of Pesticide Reporting. Available: www.cdpr.ca.gov/docs/pur/purmain.htm. Accessed December 30, 2002.

Cameron, Jason. 2003. U.S. Bureau of Reclamation. Personal communication.

CH2M HILL. 2003. Klamath Hydroelectric Relicensing. Macro-invertebrate Study – Field Maps. May 2003.

CH2M HILL and Dr. Scott Wells. 1996. Klamath River Total Maximum Daily Load Study: System Characterization Appendices. Prepared for Oregon Department of Environmental Quality. May 1996.

CH2M HILL. 1995. Water Quality Model of the Klamath River Between Link River and Keno Dam. Prepared for Oregon Department of Environmental Quality.

Chapra, S.C. 1997. Surface Water-Quality Modeling. McGraw-Hill, New York.

Chow, V.T. 1964. Handbook of Applied Hydrology. McGraw-Hill, New York.

City of Klamath Falls. 1986. Application for License, Salt Caves Hydroelectric Project, FERC Project No. 10199. Submitted to the Federal Energy Regulatory Commission by the City of Klamath Falls.

Clarke, A.H. 1981. The Freshwater Molluscs of Canada. National Museum of Natural History, National Museums of Canada.

Cole, T.M. and S.A. Wells. 2002. CE-QUAL-W2: A Two-Dimensional Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.1: User Manual. Instruction Report EL-2002-1. U.S. Army Engineering and Research Development Center, Vicksburg, Mississippi.

Convey, L.E., J.M. Hanson, and W.C. MacKay. 1989. Size-selective Predation on Unionid Clams by Muskrats. Journal of Wildlife Management 53(3):654-657.

de la Fuente, J. 2002. Personal communication.

de la Fuente, J., and P.A. Haessig. 1993. Salmon Sub-basin Sediment Analysis. Final report. Klamath National Forest, Yreka, California.

De Vito P. 2002. Oregon Department of Environmental Quality. Letter to Todd Olson, PacifiCorp, dated March 19, 2002.

Dileanis, P.D., S.E. Schwarzbach, J. Bennett, and others. 1996. Detailed Study of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Klamath Basin, California and Oregon, 1990-92. U.S. Geological Survey Water-Resource Investigations Report 95-4232. Sacramento, California.

Eilers, J.M. and C.P. Gubala. 2003. Bathymetry and Sediment Classification of the Klamath Hydropower Project Impoundments. Technical Report prepared for PacifiCorp by JC Headwaters, Inc. March 2003.

Eilers, J.M. and R. Raymond. 2003. Sediment Oxygen Demand and Nutrient Release from Sites in the Klamath Hydropower Project. Technical Report prepared for PacifiCorp by JC Headwaters Inc. March 17, 2003.

Environment Ontario. 1984. Water Management: Goals, Policies, Objectives, and Implementation Procedures of the Ministry of the Environment. Water Resources Branch, Toronto, Ontario.

Environmental Protection Agency (EPA). 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1: Fish Sampling and Analysis, Third Edition. EPA 823-B-00-007. United States Environmental Protection Agency, Office of Water, November 2000.

Fevold, K. and J. Vanderhoof. 2001. Freshwater Mussels Found in Bear and Cottage Lake Creeks during Habitat Assessments. King County Water and Land Resources Division, King County, Washington.

Frest, T.J. 2003. Malacologist, Deixis Consultants, Seattle, Washington. Telephone conversation on June 27, 2003, with Earl Byron, CH2M HILL.

Frest, T.J. and E.J. Johannes. 1995. Interior Columbia Basin Mollusk Species of Special Concern. Deixis Consultants, Seattle, Washington.

Frest, T.J. and E.J. Johannes. 1998. Freshwater Mollusks of the Upper Klamath Drainage, Oregon. Deixis Consultants, Seattle, Washington. Oregon Natural Heritage Program, Portland Oregon.

Frest, T.J. and E.J. Johannes. 2000. A Baseline Mollusk Survey of Southwestern Oregon, with Emphasis on the Rogue and Umpqua River Drainages. Deixis consultants, Seattle, Washington. Prepared for the Oregon Natural Heritage Program, Portland, Oregon. October 31, 2000.

Frest, T.J. and E.J. Johannes. 2002. Biogeography, Endemism, and Ecology of an Ancient Lake Mollusk Fauna: Upper Klamath Lake Drainage, South-Central Oregon. Presentation at Klamath Basin Symposium 2002, unpublished.

Gassel, Margie. California Office of Environmental Health Hazards Assessment. Personal communication.

Hanson, J.M., W.C. MacKay, and E.E. Prepas. 1988. The Effects of Water Depth and Density on the Growth of a Unionid Clam. Freshwater Biology 19:345-355.

Hanson, J.M., W.C. MacKay, and E.E. Prepas. 1989. Effect of Size-selective Predation by Muskrats (Ondatra zebithicus) on a Population of Unionid Clams (*Anodonta grandis simpsonianus*). Journal of Animal Ecology 58:5-28.

Hardy, T. and R.C. Addley. 2001. Evaluation of Interim Instream Flow Needs in the Klamath River, Phase II. Final Report prepared by the Utah State University Institute for Natural Systems Engineering for the U.S. Fish and Wildlife Service. December 2001.

Harrington, J. and M. Born. 2000. Measuring the Health of California Streams and Rivers: A Methods Manual for Water Resource Professionals, Citizen Monitors and Natural Resource Students. Sustainable Land Stewardship International Institute, Sacramento, California.

Hassan, M.A. and P. Ergenzinger. 2003. Use of Tracers in Fluvial Geomorphology (pp. 397-423). In G.M. Kondolf and H. Piégary, eds., Tools in Fluvial Geomorphology. John Wiley & Sons.

Helfrich, L.A., R.J. Neves, D.L. Weigman, R.M. Speenburgh, and B. Beaty. 1997. Help Save America's Pearly Mussel. Virginia Cooperative Extension, Virginia State University. Publication Number 420-014. November 1997.

Hynes, H.B.N. 2001. The Ecology of Running Waters, 3rd edition.

Ingram, W.M. 1948. The Larger Freshwater Clams of California, Oregon, and Washington. Journal of Entomolgoy and Zoology 40(4):72-92.

Johnson, D.M., R.R. Petersen, D.R. Lycan, J.W. Sweet, M.E. Neuhaus, and A.L Schaedel. 1985. Atlas of Oregon Lakes. Oregon State University Press, Corvallis.

Johnson, W.C. 1992. Dams and Riparian Forests: Case Study from the Upper Missouri River. Rivers 3:229-242.

Johnson, W.C., G.L. Muth, and P.G. Godsil. 1968. Klamath Basin Study: Pesticide Investigation. Federal Water Quality Administration, Pacific Southwest Region.

Kann, J. 2001. Compilation of Klamath Tribes Upper Klamath Water Quality Data, 1990-2001. Prepared for the Klamath Tribes Natural Resources Department and U.S. Bureau of Reclamation Cooperative Studies. May 3, 2001.

Kanz, Russ. 2001. State Water Resources Control Board. Letter to Todd Olson, PacifiCorp, dated March 23, 2001.

Karr, J.R. and E.W. Chu. 1999. Restoring Life in Running Waters—Better Biological Monitoring. Island Press, Covelo, California.

Kirchner, J.W., W.E. Dietrich, F. Iseya, and H. Ikeda. 1990. The Variability of Critical Shear Stress, Friction Angle, and Grain Protrusion in Water-worked Sediments. Sedimentology 37:649-672.

Kondolf, G.M. Assessing Salmonid Spawning Gravels. 2000a. Transactions of the American Fisheries Society 129:262-281.

Kondolf, G.M. 2000b. Some Suggested Guidelines for Geomorphic Aspects of Anadromous Salmonid Habitat Restoration. Restoration Ecology 8:48-56.

Kondolf, G.M. and W.V.G. Matthews. 1986. Transport of Tracer Gravels on a Coastal California River. Journal of Hydrology 85:265-280.

Kondolf, G.M. and W.V.G. Matthews. 1993. Management of Coarse Sediment in Regulated Rivers of California. University of California Water Resources Center, Riverside. Report No. 80. Available: http://elib.cs.berkeley.edu.

Ligon, F.K., W.E. Dietrich, and W.J. Trush. 1995. Downstream Ecological Effects of Dams: A Geomorphic Perspective. Bioscience 45(3):183-192.

McBain and Trush. 1995. River Channel Morphological and Sediment Changes in the Klamath Basin, Oregon and California: Summary of Available Geomorphic Data, Data Deficiencies, and Identification of Critical Geomorphic Issues. Report to the Technical Working Group, Klamath River Fisheries Task Force, by McBain and Trush, Arcata, California.

Merigliano, M.F. and P. Lesica. 1998. The Native Status of Read Canary Grass (*Phalaris arundinacea L*) in the Inland Northwest, USA. Natural Areas Journal 18(3):223-230.

Meyer-Peter, E. and R. Muller. 1948. Formulas for Bed-load Transport. Proceedings. 2d Meeting IAHR, Stockholm, pp. 39-64.

Milhous, R.T. 1982. Effect of Sediment Transport and Flow Regulation on the Ecology of Gravel-bed Rivers. In: Gravel Bed Rivers, R.D. Hey, J.C. Bathurst, and C.R. Thorne, eds. John Wiley & Sons, Chichester, pp. 819-841.

Montgomery, D.R. and J.M. Buffington. 1993. Channel Classification, Prediction of Response, and Assessment of Channel Condition. Report TFW-SH10-93-002. Prepared for the Committee of the Washington State Timber, Fish, and Wildlife Agreement.

Morris, G.L. and J. Fan. 1997. Reservoir Sedimentation Handbook. McGraw-Hill, New York.

Moyle, P.B. 1976. Inland Fishes of California. University of California Press, Berkeley.

Newell, A.J., D.W. Johnson, and L.K. Allen. 1987. Niagara River Biota Contamination Project: Fish Flesh Criteria for Piscivorous Wildlife. Technical Report 87-3. Division of Fish and Wildlife, Bureau of Environmental Protection, New York State Department for Environmental Conservation. New York, New York.

Oregon Department of Environmental Quality. 1995. Water Quality Model of the Klamath River between Link River and Keno Dam (DRAFT). Prepared by CH2M HILL and S. Wells. December 1995.

Oregon Department of Environmental Quality (ODEQ). 1998. Laboratory Field Sampling Reference Guide.

Oregon Department of Environmental Quality (ODEQ). 1999. Oregon Plan Water Quality Monitoring Guidebook.

Oregon Natural Heritage Program (ONHP). 2003. Rare, Threatened, and Endangered Plants and Animals of Oregon: Invertebrates. Available: http://oregonstate.edu/ornhic/inverts.html.

PacifiCorp. 2002. Explanation of Facilities and Operational Issues Associated with PacifiCorp's Klamath Hydroelectric Project. May 2002. Available: http://newwww.pacificorp.com/File/File17804.pdf.

PacifiCorp. 2003a. Draft License Application Klamath Hydroelectric Project (FERC Project No. 2082). Draft, dated June 2003.

PacifiCorp. 2003b. Investigation of Klamath River Freshwater Bivalves in the J.C. Boyle Peaking Reach and Downstream of Iron Gate Dam. Final Study Plan. April 2003.

PacifiCorp. 2003c. Aquatic Mollusk Fauna in PacifiCorp's Klamath Project Area. Prepared for Aquatic Working Group meeting, February 2003.

Parker, G. 1990. Surface-based Bedload Transport Relation for Gravel Rivers. Journal of Hydraulic Research 28(4):417-436.

Raymond, Richard. 2002. E&S Environmental Chemistry, Inc. Personal communication.

Reid, L.R. and T. Dunne. 1996. Rapid Evaluation of Sediment Budgets, p. 64. Catena Verlag, Reiskirchen, Germany.

Richter, B. 1999. Characterizing Hydrologic Regimes in Ecologically Meaningful Terms. Stream Notes, January 1999. Stream Systems Technology Center, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Richter, B.D., J.V. Baumgartner, J. Powell, and D.P. Braun. 1996. A Method for Assessing Hydrologic Alteration within Ecosystems. Conservation Biology 10:1163-1174.

Richter, B.D., J.V. Baumgartner, R. Wigington, and D.P. Braun. 1997. How Much Water Does a River Need? Freshwater Biology 37:231-249.

Rood, S.B. and J. M. Mahoney. 1990. Collapse of Riparian Poplar Forests Downstream from Dams in Western Prairies. Environmental Management 14:451.464.

Rosgen, D.L. 1994. A Classification of Natural Rivers. Catena 22:169-199.

SAS Institute (SAS). 2002. JMP Statistics and Graphics Guide.

Shaw, T. 2003. TR Payne & Associates habitat mapping data collected in 2002. Data file e-mailed to Chris Green, CH2M HILL, on August 28, 2003, by Tom Shaw, U.S. Fish and Wildlife Service fishery biologist, Arcata, California.

Sorenson, S. K. and S. E. Schwarzbach. 1991. Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Clamath Basin, California and Oregon, 1988-89. U.S. Geological Survey Water-Resource Investigations Report 90-4203. Sacramento, California.

Strayer, D.L. and D.R. Smith. 2003. A Guide to Sampling Freshwater Mussel Populations. American Fisheries Society Monograph 8. Bethesda, Maryland.

Stumm, W. and J.J. Morgan. 1981. Aquatic Chemistry. John Wiley & Sons. New York.

Taylor, D.W. 1981. Freshwater Mollusks of California: A Distributional Checklist. California Department of Fish and Game 67(3):140-163.

U.S. Army Corps of Engineers. Hydrologic Engineering Center. 1986. Water Quality for River-Reservoir Systems (WQRRS): Users Manual. Document CPD-8. December 1986.

U.S. Bureau of Reclamation (USBR). 2000. Klamath Project: Historic Operation. USBR Klamath Basin Area Office. November 2000.

U.S. Bureau of Reclamation (USBR). 2003. Klamath Project 2003 Operations Plan. April 10, 2003.

U.S. Department of Agriculture/U.S. Department of Interior. 1994. Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl.

U.S. Fish and Wildlife Service (USFWS). 2002. Biological Opinion Regarding the Effects of Operation of the U.S. Bureau of Reclamation's Proposed 10-Year Operation Plan for the Klamath Project and its Effect on the Endangered Lost River Sucker, Endangered Shortnose Sucker, Threatened Bald Eagle, and Proposed Critical Habitat for the Los River and Shortnose Suckers. Klamath Falls Fish and Wildlife Office. Klamath Falls, Oregon.

U.S. Forest Service. 1994. Endangered and Threatened Wildlife and Plants: Animal Candidate Review for Listing as Endangered or Threatened Species; Proposed Rule. Federal Register 56: 58982-59028.

U.S. Water Resources Council (WRC). 1982. Guidelines for Determining Flood Flow Frequencies. Bulletin 17B. March 1982.

Vannote, R.L., G.W. Marshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The River Continuum Concept. Canadian Journal of Aquatic Sciences 37:130-137.

Vanoni, V. 1975. Sedimentation Engineering. American Society of Civil Engineers, New York.

Watercourse Engineering Inc. 2003. Klamath River Water Quality 2000 Monitoring Program: Project Report. Prepared for the U.S. Bureau of Reclamation, Klamath Falls Area office. January 2003.

Watters, G.T. 1998. Freshwater mussel biology. Conchologists of America. Available at: http://coa.acnatsci.org/conchnet/uniobio.html. September 16, 1998.

Wetzel, R.G. 2001. Limnology: Lake and River Ecosystems, 3rd Edition. Academic Press, San Diego, California.

Wilcock, P.R., A.F. Barta, C.C. Shea, G.M. Kondolf, W.V.G. Matthews, and J. Pitlick. 1996. Observations of Flow and Sediment Entrainment on a Large Gravel-Bed River. Water Resources Research 32:2897-2909.

Williams, G.P. and M.G. Wolman. 1984. Downstream Effects of Dams on Alluvial Rivers. U.S. Geological Survey Professional Paper 1286.

Wolman, M.G. 1954. A Method of Sampling Coarse River-bed Material. Transactions of the American Geophysical Union 35 (6):951-956.