RECOMMENDATIONS FOR STUDY OF THE DISTRIBUTION AND POPULATION DYNAMICS OF THE FRESHWATER POLYCHAETE, MANAYUNKIA SPECIOSA IN THE LOWER KLAMATH RIVER

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INTRODUCTION and JUSTIFICATION

Outmigrating juvenile fall Chinook (*Oncorhynchus tshawytscha)* within the Lower Klamath River Basin are experiencing significant mortality from infectious disease, with subsequent impacts on adult returns. The primary pathogens implicated in this mortality are the myxozoan parasites *Ceratomyxa shasta* and *Parvicapsulum minibicornis* (Nichols and Foott 2006).

The life cycles of the parasites are complex and require development in both a vertebrate and invertebrate host. For both *C. Shasta* and *P. minibicornis*, the invertebrate host has been identified as the freshwater polychaete *Manayunkia speciosa* (Bartholomew et al. 1997, Bartholomew et al. 2006). Fish become infected by contact with actinospores that are produced within *Manayunkia*. Following fish mortality, myxospores are released into the water where they are then taken up by the polychaete.

Little is known of the life history, ecology, and distribution of *M. speciosa*. Polychaetes are a diverse and abundant group of annelids that are almost exclusively marine (Pennak 1978). Very few species worldwide have colonized freshwaters, and those that have are, with few exceptions, restricted to lake, river, and spring habitats within 20 mi of the seacoast. *Manayunkia speciosa* was first described by Leidy in 1859 from the Schuylkill River in Pennsylvania. It has since been collected throughout North America, and may be widely distributed (Mackie and Qadri 1971). It is not known whether the current distribution of the polychaete reflects its native distribution, or is the result of unintentional transfers coincident with stocking of exotic warmwater fishes to waters of the west coast in the late 1800's. Within the Klamath River, *M. speciosa* has been collected from several locations above and below Iron Gate Dam, often in association with mats of the filamentous green alga *Cladophora* (Stocking and Bartholomew 2007). The polychaete inhabits a tube built of fine inorganic particles, and its microhabitat distribution may be restricted to locations where these particle sizes are readily available.

Because abundance, spatial distribution and habitat requirements of the polychaete ultimately influence the presence and severity of infection in salmonids, quantitative assessment of these elements is an important and critical step in designing and subsequently quantifying the effectiveness of potential management actions to reduce disease effects in the Klamath River and elsewhere.

In this report, we make some recommendations regarding the development of a research plan for monitoring the distribution and population dynamics of *M. speciosa* in the lower Klamath River (Iron Gate Dam to Klamath Glen), that are founded upon preliminary field sampling of its occurrence and habitat associations, as well as upon information obtained from culture of the animal in the laboratory. Field sampling occurred at varying dates from fall 2005 through fall 2006, with additional live samples collected for laboratory studies through summer 2007. Sampling locations between Iron Gate Dam and Weitchpec (near the confluence of the Trinity River) were largely determined by road access; samples obtained from Klamath Glen to the Trinity River confluence were jetboat-based. Appendix 1 describes sampling dates, sample locations and geographic coordinates, and polychaete presence or absence from each sample, and Appendix 2 provides a listing of macroinvertebrate taxa that we identified from our samples. This information will become important for assessment of non-target impacts as management strategies for disease control are implemented. Samples generally consisted of timed 30-second collections using a D-frame 250 µm mesh net from dominant habitats at each sampling location. Habitat types included coarse and fine sediments as well as beds of rooted vascular macrophytes and the filamentous green alga *Cladophora.* At each location, depth, velocity, and stream temperature were measured, the particle size and nature (e.g. extent of periphyton or macrophyte cover) of dominant substrate was visually assessed and recorded. Locations were georeferenced with a GPS unit. Some dredge samples were also collected using a petite ponar sampler, and some collections were made using artificial substrates specifically to test the efficiency of these as collection devices. Life history information obtained from our laboratory culture of the polycheate is described in the attached manuscript, which is being prepared for submission for publication within the peer-reviewed literature.

Recommendations

1. Monitoring Objectives

The design of a monitoring program is critically dependent on its objectives. While specification of monitoring objectives properly belongs with the funding entity and its stakeholders, lessons learned from our preliminary sampling allow us to suggest that some objectives will be more feasible to achieve than others. For example, because of the highly patchy distribution of the polycheate, a monitoring objective to estimate overall abundance of the polycheate within the river system would be unrealistic and could be achieved only at enormous expense. We suggest that a more limited objective to establish relative densities and recruitment rates of the polycheate at different locations along the river would be more appropriate. Inasmuch as management interest in the polycheate derives from an interest in reducing fish disease by severing the cycling of pathogens between fish and invertebrate hosts, it will be important to sample the polycheate population with sufficient precision and using standardized protocols such that an effect from management treatments (e.g. flow manipulation) can be detected. Among other things, this suggests a need to accumulate pre-treatment data of polycheate locations and densities prior to initiation of management treatments. Polychaete samples within the river to date are not sufficient as these were haphazardly collected and are not associated with variance estimates. We also suggest that it will be important to monitor the relative infection levels of the polycheate populations at differing locations at the same time that the populations are being sampled. It must be recognized that available information at present is insufficient to determine if a relationship exists between polycheate density and infection level, and whether reducing polycheate densities would result in a reduction in disease incidence in either fish or polychaetes.

2. Establishment of Spatial Boundaries for Sampling

The primary management area proposed by the Aug 2007 Ceratomyxosis Management Research Workshop panel members includes the stretch of river from Iron Gate Dam to the Scott River confluence. The proposal to focus on this area is based on out-migrant infection status, data from sentinel fish exposures using hatchery rainbow trout, polycheate host surveys conducted by investigators from Oregon State University, and water sampling studies. Data from our field sampling supports the finding that this section of river harbours a relatively high polycheate density. While polychaetes were detected from samples throughout the entire lower river, both prevalence and density were greater in the upper than in mid-river and lower-river sections below Iron Gate Dam (Fig. 1). We suggest that the high polycheate densities immediately below the Iron Gate Dam likely reflect polycheate response to high quality planktonic food resources supplied by the reservoir as these are released over the dam. A large literature supports a finding of high densities of invertebrate filter-feeders below dams and natural lake outlets that is attributable to high quality planktonic food particles. Although samples were not systematically collected above Iron Gate Dam, polychaete prevalence and density within the entire Klamath basin were observed to be highest in the Williamson River, where polycheate infection levels are presumed to be low.

While we agree with panel members of the Aug 2007 Ceratomyxosis Management Research Workshop that the stretch of river between Iron Gate Dam and the Scott River should be the primary focus of study, we also recommend occasional sampling with artificial substrates of lower reaches of the river where polycheate densities are presently sparse. An unintended consequence of flow or other manipulations to reduce polycheate densities in the upper river may result in altered distribution and increased downstream densities through polycheate dispersal. This effect would not be detectable if the lower river is not monitored.

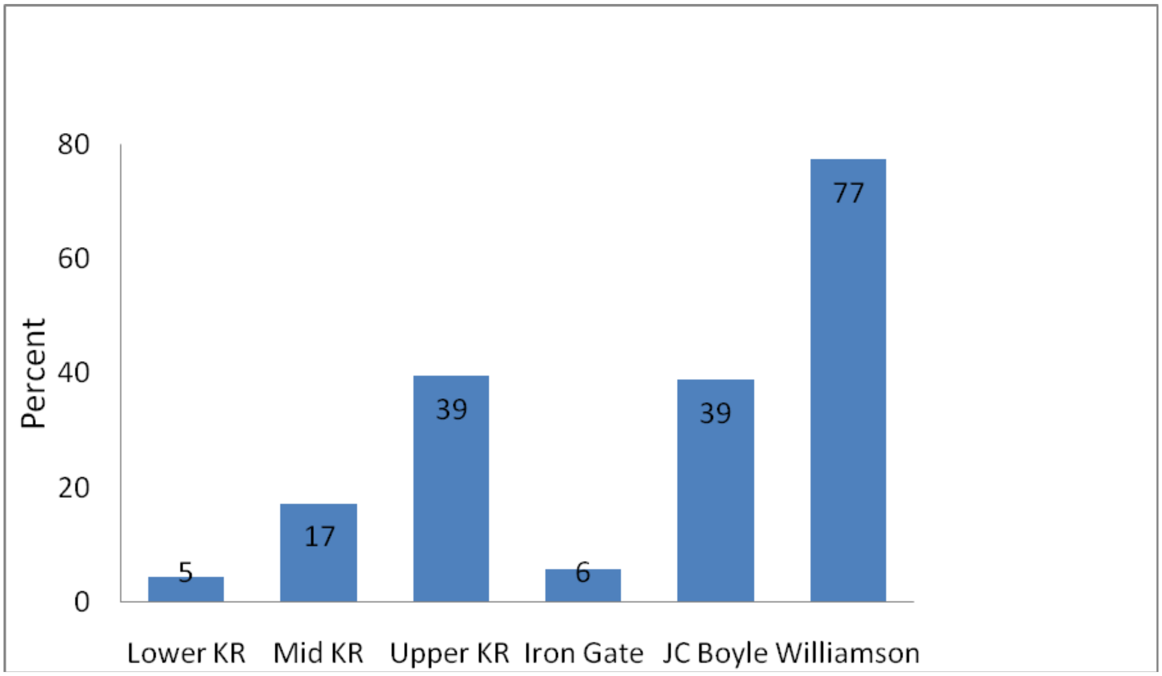

Figure 1. Percent of samples (total n = 325) in which the polychaete *Manayunkia speciosa* was present during field surveys conducted on varying dates between 2005-fall 2006. Iron Gate, JC Boyle, and Williamson samples were taken at the reservoir inlets.

3. Sampling Design:

We believe that it is critical to annually acquire aerial photo-based maps of macrophyte distribution and coverage (including beds of vascular plants and mats of filamentous algae) within the primary management area, as these represent the primary habitat of the polychaete.   Although we collected *M. speciosa* from all particle size categories of inorganic substrate (silt through boulders and bedrock), they were most commonly collected from organically enriched fine sediments (sand, silt) at the base of rooted vascular plant and filamentous algal beds. Macrophyte beds also provide the range of current velocities and water depths with which we found to polychaete to be associated (mean depth of 95 cm; mean current velocity 5 cm/s). We hypothesize that positive relationships exist between polychaete densities and macrophyte coverage, and between macrophyte coverage and discharge (after factoring in seasonality/temperature effects). Quantification of these variables would allow these hypotheses to tested. If supported, these relationships could then be used to guide management strategies.

Acquiring maps of macrophyte coverage could also be used to select annual sampling locations for deployed artificial substrates. For example, a common design for aquatic faunal surveys of large rivers involves dividing the sampling area into sections of equal area or length, with one or more sampling stations within each section being selected randomly (Elliott 1977). Within each section, we recommend random selection of sampling stations, but restricted to areas of macrophyte coverage.

4. Sampling Technique:

We recommend the use of artificial substrates as a sampling device for the polycheate. These offer several advantages over other types of sampling devices, including a small and fixed sampling area, reduced sampling time in the field, greatly reduced sample processing time in the laboratory, they are less sacrificial to other organisms, and most importantly, they allow colonization time and substrate attributes to be standardized and flow effects to be evaluated. Use of artificial substrates requires 2 site visits for each sampling episode (one for deployment and one for pickup after a 1-month colonization period), and the substrate offered for invertebrate settlement does not adequately represent the full array of all substrate attributes present at a site. Nonetheless, we believe that this disadvantage is offset by the advantages, particularly given an objective of evaluating treatment effects on relative population densities of the polychaete. We have tested several types of artificial substrates (various types of plastic plants, ceramic tiles, scrubbing pads), and have found a design that is durable and stable and that works well in efficiently capturing and removing the polychaetes. This consists of common bricks wrapped with a double layer of 0.8 mm mesh plastic screen.

The appropriate number of bricks to use at each sampling station can be calculated for a specified degree of precision, as described by Elliott (1977). One first decides how large an error can be tolerated in the estimate of the population mean (e.g., a standard error equal to 20% of the mean is a reasonable error in most freshwater benthic samples). The ratio of standard error to arithmetic mean provides an index of precision (D), with D given by the general formula:

$$D = \frac{1}{\bar{x}}\sqrt{\frac{s^2}{n}}$$

The number of sampling units in a random sample is given by:

$$n = \frac{s^2}{D^2 \bar{x}^2}$$

For a 20% error, the number of samples units is equal to 25 times the variance, divided by the square of the arithmetic mean.

5. Timing of Polychaete Sampling:

Our studies on the timing of life cycle activities in lab culture and from preserved samples suggest that the generation time of the polycheate is approximately annual. Adult females (2-4mm in length) brood young within their tubes during late winter and spring for approximately 6-8 weeks, depending on temperature. Immature polycheates leave the tube for an independent existence in summer (June, July) at 1 -1.2 mm in length and begin to outnumber adults. Adults appear to largely die off by the end of summer (August/September), and juveniles reach reproductive size in early winter.

This information is relevant to the choice of a timeframe for sampling. A sampling time of late spring-early summer (May, June) would collect reproducing adults, and most of the sample would consist of larger individuals. In July, one would be likely to capture equal numbers of tiny immatures and adults. After this point and until December, one would collect largely immatures. Flow or other manipulations designed to reduce the polychaete population would be ideally timed for fall – when none of the individuals would be reproductively mature. Selection of the best timeframe for long term monitoring depends on monitoring objectives. If the monitoring is designed to track changes in polychaete population dynamics and to evaluate potential relationships with macrophyte features, sampling would be best done in summer, at the height of macrophyte development. Sampling in September-October, to coincide with use of the river by adult anadromous salmonids, would allow evaluation of relationships between polychaete densities and infection levels with myxospore concentrations. Sampling in spring to coincide with the downstream migratory movement of salmon smolts would be most informative for evaluating the relationship between disease incidence and polychaete densities. Irrespective of the choice of other sampling times and sampling designs, we strongly recommend that artificial substrates for polychaete colonization be set out to collect polychaetes at the same time and location that sentinel fish exposure tests are being run.

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Appendix 1. Sample date, geographic coordinates, site description, and presence/absence of invertebrate samples collected during the polychaete host survey conducted by Wilzbach and Cummins.

DATE	SAMPLE #	GPS Coordinates	Description	Polychaetes Present? (Y=yes, N=no)	Sample Split?	Sample sorted?	Sample ID, coded?	Data entered?	Comments
Fall 2005									
Lower									
9/17/05	1	N41° 30' 42.7" W124° 00' 06.5"	Above boat launch at Klamath Glen						
9/17/05	2	"	"	N	N	Y	Y	Y	
9/17/05	3	"	"	N	N	Y	Y	Y	
9/17/05	4	N41° 30' 30.2"	Dredge	N	N	Y	Y	Y	

		W124° 00' 30.2"						
9/17/05	5	N41° 28' 35.6° W123° 56' 43.3"	Dredge	Y (1 total)	N	Y	Y	Y
9/17/05	6	N41° 28' 28.4" W123° 56' 40.2"		N	N	Y	Y	Y
9/17/05	7	"		N	N	Y	Y	Y
9/17/05	8	N41° 23' 43.8" W123° 55' 52.7"	Dredge, near "Bear Riffle"	N	N	Y	Y	Y
9/17/05	9	N41° 23' 27.5" W123° 55' 29.0"		N	N	Y	Y	Y

9/17/05	10	“		N	N	Y	Y	Y
9/17/05	11	“		N	N	Y	Y	Y
9/17/05	12	“		N	N	Y	Y	Y
9/17/05	13	N41° 20’ 52.2” W123° 51’ 57.9”	Dredge, Johnson’s Hole	N	N	Y	Y	Y
9/17/05	14	N41° 20’ 51.3” W123° 51’ 57.9”		N	N	Y	Y	Y
9/17/05	15	N41° 20’ 48.7” W123° 51’ 43.9”		N	N	Y	Y	Y
9/17/05	16	“		N	N	Y	Y	Y

9/17/05	17	N41° 18' 24.2" W123° 52' 23.4"	Dredge, Above Mawah Ck	N	N	Y	Y	Y
9/17/05	18	N21° 18' 21.8" W123° 53' 21.9"		N	N	Y	Y	Y
9/17/05	19	"		N	N	Y	Y	Y
Middle								
9/25/05	1	N41° 48' 22.4" W123° 20' 54.4"	Klamath River Resort Inn above Happy Camp	Y (10 in split, 40 total)	Y (1/4)	Y	Y	Y
9/25/05	2	N41° 47' 24.5" W123° 22' 44.2"	Indian Creek above confluence	N	N	Y	Y	Y

9/25/05	3	“	“	N	N	Y	Y	Y
9/25/05	4	“	“	N	Y (1/2)	Y	Y	Y
9/25/05	5	“	“	N	N	Y	Y	Y
9/25/05	6	N41° 39’ 34.6” W123° 26’ 59.5”	Independence	N	N	Y	Y	Y
9/25/05	7	“	“	N	N	Y	Y	Y
9/25/05	8	N41° 34’ 30.6” W123° 32’ 22.4”	Dillon Creek below campground	N	N	Y	Y	Y
9/25/05	9	“	Klamath River above confluence with Dillon Ck	N	N	Y	Y	Y
9/25/05	10	“	“	N	N	Y	Y	Y

9/25/05	11	“	“	N	N	Y	Y	Y
9/25/05	12	N41° 25’ 58.9” W123° 30’ 25.4”	Green Riffle	N	N	Y	Y	Y
9/25/05	13	N41° 22’ 44.4” W123° 28’ 18.5”	Salmon River @ Blue Hole	N	N	Y	Y	Y
9/25/05	14	“		N	N	Y	Y	Y
9/25/05	15	N41° 18’ 54.0” W123° 31’ 36.7”	Dolan’s Bar	N	N	Y	Y	Y
9/25/05	16	“	“	N	Y (1/2)	Y	Y	Y
9/25/05	17	N41° 15’ 16.0” W123° 38’	Big Bar	Y; probable contaminant (1 in split, 2 total)	Y (1/2)	Y	Y	Y

		04.6”						
9/25/05	18	“	“	N		Y	Y	Y
Upper								
10/8/05	1	N41° 55’ 52.4” W122° 28’ 30.9”	Below Iron Gate Hatchery	N	Y (1/4)	Y	Y	Y
10/8/05	2	“	“			N		
10/8/05	3	N41° 55’ 33.1” W122° 26’ 50.2”	Private fishing area	N		Y		N
10/8/05	4	“	“	N	Y (1/4)	Y	Y	Y
10/8/05	5	N41° 53’ 57.3” W122° 30’ 30.4”	Copco-Ager Bridge			N		

10/8/05	6	“	“	N	Y (1/4)	Y	Y	Y	
10/8/05	7	N41° 50’ 57.3” W122° 34’ 16.2”	I-5 at US 96 Rest Area	Y (5 in split, 20 total)	Y (1/4)	Y	Y	Y	
10/8/05	8	“	“	N	Y (1/4)	Y	Y	Y	
10/8/05	9	N41° 49’ 16.4” W122° 35’ 30.1”	Shasta River	N	Y (1/4)	Y	Y	N	2 subsamples sorted
10/8/05	10	N41° 49’ 48.6” W122° 36’ 19.5”	Klamath River below Shasta R		Y (1/4)	N			
10/8/05	11	N41° 51’ 51.5” W122° 49’ 08.9”	Below Beaver Creek		N	N			

10/8/05	12	"	"	N	Y (1/4)	Y	Y	Y	2 subsamples sorted, id'd, measured, and entered into electronic file
108/05	13	N41° 49' 24.4" W123° 00' 17.1"	Horse Creek	Y (110 total)	N	Y	Y	Y	
108/05	14	"	"	Y (90 in split, 360 total)	Y (1/4)	Y	Y	Y	
10/8/05	15	N41° 46' 42.6" W123° 02' 12.7"	Scott River	N		Y	Y	Y	
10/8/05	16	N41° 46' 43.2" W123° 02' 11.3"	Klamath River above Scott R.	Y (1 in split, 4 total)	Y (1@1/2 & 2@1/4)	Y	Y	Y	
10/8/05	17	-	Klamath River below Scott R.		Y (1/2)	N			

10/8/05	18	N41° 51' 45.9" W123° 16' 10.2"	New 49'ers Camp	Y (2 total)	N	Y	Y	Y
Summer 2006								
Lower								
7/18/06	1	N 41˚30'42.7" W 124˚00'06.5"		N	N	Y	Y	Y
7/18/06	2	N 41˚28'28.3" W 123˚56'40.8"		N	35%	Y	Y	Y
7/18/06	3	N 41˚23'24.7" W 123˚55'27.9"		N	40% sorted	Y	Y	Y

7/18/06	4	“		N	20% sorted	Y	Y	Y	Almost no inverts
7/18/06	5	N 41˚20’49.3” W 123˚51’45.1”		N	N	Y	Y	Y	
7/18/06	6	N 41˚18’21.3” W 123˚51’45.1”		N	N	Y	Y	Y	
Middle									
8/1/06	18 or 18a	N41° 48’ 22.4” W123° 20’ 54.4”	Klamath River Resort Inn	N	N	Y	Y	Y	Plant sample, unsure which plant sample from this location is 18, which is 18a
8/1/06	21	“	“	Y (1 total)	N	Y	Y	Y	
8/1/06	20	“		N	N	Y	Y	Y	
8/1/06	19	“		N	N	Y	Y	Y	Substrate corresponding

									to # 18
8/1/06	18 or 18a	"		N	N	Y	Y	Y	Plant sample, unsure which plant sample from this location is 18, which is 18a
8/1/06	17	N 41º 47' 24.5" W123º 22' 44.2"	Indian Creek above confluence	N	N	Y	Y	Y	
8/1/06	16		"	N	N	Y	Y	Y	
8/1/06	15		"	N	N	Y	Y	Y	
8/1/06	14	N 41º 39' 34.6" W 123º 26' 59.5"	Independence	N	N	Y	Y	Y	Plant sample
8/1/06	13		"	N	N	Y	Y	Y	
8/1/06	12		"	Y (1 total)	N	Y	Y	Y	
7/29/06	11	N41˚ 34'	Dillon Creek below	N	N	Y	Y	Y	

		34.9” W123˚ 32’14.1”	confluence					
7/29/06	10	N41˚ 34’ 40.8” W123˚ 32’ 24.1”	Dillon Creek below campground	N	N	Y	Y	Y
7/29/06	9	“	“	N	N	Y	Y	Y
7/29/06	8	N41˚ 25’ 59.5” W123˚ 30’ 23.6”	Green Riffle	N	N	Y	Y	Y
7/29/06	7	“		N	N	Y	Y	Y
7/29/06	6	N41˚ 22’ 44.5” W123˚ 28’ 17.0”	Blue Hole	N	N	Y	Y	Y
7/29/06	5	“	“	N	N	Y	Y	Y

7/29/06	4	N41˚ 18' 51.8" W123˚ 31' 33.3"	Dolan Bar	Y (2 total)	N	Y	Y	Y	
7/29/06	3	"	"	N	N	Y	Y	Y	
7/29/06	2	N41˚ 15' 07.0" W123˚ 38' 04.1"	Big Bar	N	N	Y	Y	Y	dessicated
7/29/06	1	"	"	Y (1 total)	N	Y	Y	Y	
Upper									
8/2/06	33	N 41º 55' 52.4" W 122º 28' 30.9"	Iron Gate Fish Hatchery	N	N	Y	Y	Y	
8/2/06	32		"	N	Y	Y	Y	Y	Plant sample, washed waste
8/2/06	31		"	N	N	Y	Y	Y	

8/2/06	30	N 41º 55' 33.1" W 122º 26' 50.2"	Private Fishing Area	N	Y (30%)	Y	Y	Y	
8/2/06	29		"	N	N	Y	Y	Y	Plant sample
8/2/06	28	N 41º 53' 57.3" W 122º 30' 30.4"	Copco-Agar Bridge	N	N	Y	Y	Y	
8/2/06	27		"	N	N	Y	Y	Y	
8/2/06	26		"	N	N	Y	Y	Y	Plant sample
8/2/06	25	N 41º 50' 57.3" W 122º 34' 16.6"	I-5 Rest Stop	N	80%	Y	Y	Y	
8/2/06	24		"	Y (2 in split, 5 total)	Y (40%)	Y	Y	Y	
8/2/06	23	N41° 49'	Shasta River below CDFG	N	N	Y	Y	Y	

		16.4” W122° 35’ 30.1”	fish weir						
8/2/06	22		“	N	10%	Y	Y	Y	
8/2/06	21	N41° 49’ 48.6” W122° 36’ 19.5”	Below Shasta River	Y (3 in split, 18 total)	Y (1/6)	Y	Y	Y	
8/2/06	20		“	N	N	Y	Y	Y	Plant sample
8/2/06	19	N41° 51’ 51.5” W122° 49’ 08.9”	Below Beaver Creek	N	N	Y	Y	Y	Plant sample
8/2/06	18		“	Y (3 total)	N	Y	Y	Y	
8/2/06	17		“	Y (41 in split, 123 total)	Y (1/4)	Y	Y	Y	
8/2/06	16	N41° 49’ 24.4”	Horse Creek	Y (2 total)	Y	Y	Y	Y	Plant sample

		W123° 00' 17.1"							
8/2/06	15		"	Y (14 total)	N	Y	Y	Y	
8/2/06	14		"	Y (2 total)	N	Y	Y	Y	
8/2/06	13		"	N	N	Y	Y	Y	Plant sample
8/2/06	12		"	Y (13 total)	N	Y	Y	Y	
8/2/06	11		"	Y (1 in split, 5 total)	Y (20%)	Y	Y	Y	
8/1/06	10	N41° 46' 43.2" W123° 02' 11.3"	Klamath River above Scott River Confluence	Y (4 in split, 16 total)	Y (1/4)	Y	Y	Y	
8/1/06	9		"	N	N	Y	Y	Y	Plant Sample
8/1/06	8		"	N	N	Y	Y	Y	
8/1/06	7	N41° 46' 42.6" W123° 02'	Scott River Mouth	N	N	Y	Y	Y	

		12.7”							
8/1/06	6		Below Scott River	Y(3 total)	N	Y	Y	Y	
8/1/06	5		“	N	50%	Y	Y	Y	
8/1/06	4	N41° 51’ 45.9” W123° 16’ 10.2”	New 49’ers Camp	N	N	Y	Y	Y	Plant Sample
8/1/06	3		“	N	Y (10%)	Y	Y	Y	
8/1/06	2		“	N	N	Y	Y	Y	
8/1/06	1		“	N	20%	Y	Y	Y	

Extra Samples Summer 2006

8/28/06

Artificial substrates

(only polychaetes picked)

8/28/06	1	N 41º 49' 24.7" W 123º 00' 15.5"	Horse Creek	Y (3 total)	100%?	Y	Scanned for polychaetes only	Y	Artificial substrate: long leaf plant
8/28/06	2	"	"	Y (1 total)	100%?	Y	Scanned for polychaetes only	Y	Artificial substrate: round leaf plant
8/28/06	3	"	"	N	?	Y	Scanned for polychaetes only	Y	Artificial substrate: scrubber pad

8/28/06	4	"	"	Y (3 in split, 6 total)	50%	Y	Scanned for polychaetes only	Y	"
8/28/06	5	"	"	Y (2 total)	100%	Y	Scanned for polychaetes only	Y	"
8/28/06	7	"	"			N			30 sec sample?
8/28/06	8		Klamath River Resort Inn	N	100%	Y	Scanned for polychaetes only	Y	Artificial substrate: scrubber pad
8/28/06	9		"	N	100%	Y	Scanned for polychaetes only	Y	"
8/28/06	10		"	N	100%	Y	Scanned for polychaetes only	Y	"
8/28/06	11		"	N	100%	Y	Scanned	Y	Artificial substrate: long

							for polychaetes only		leaf plant and Easter grass
9/26/06 Williamson									
9/26/06	WLM 1		Williamson River E. Bank	Y (88 in split, 352 total)	Y (25%)	Y	Y	Y	
9/26/06	WLM 2		“			N			
9/27/06 Upper									
9/27/06	1	N 41º55’ 52.5” W 122º 26’ 30.3”	IGH under bridge			N			Set out artificial substrates (plant and scrub pad)
9/27/06	3		Fish Hook Restaurant	N	10%	Y	Y	Y	

			Boat launch near RV park						
9/27/06	4		Copco-Agar Bridge	N	20%	Y	Y	Y	Set out artificial substrates by old bridge structure
9/27/06	5		Upstream of I-5 Bridge			N			Downstream of log lam
9/27/06	6		"			N			Faster current
9/27/06	7		Gottsville River Access			N			Set out plant substrate
9/27/06	8		Downstream of Beaver Creek			N			Set out plant and scrub pad substrates
9/27/06	9		Eddy just below mouth of Horse Creek	N	10%	Y	Y	Y	Set out scrub pad
Klamath L, Williamson	Link 3P	N 42º 13'	Link River, West bank by	N	10%	Y	Scanned for	Y	Lost of oligochaetes

River 10/26/06		01.4” W 121º 47’ 20.2”	freeway off ramp sign				polychaetes only		
10/26/06	Link 4P	N 42º 13’ 07.1” W 121º 47’ 18.5”	Link River, North end, off 1st boat dock	N	10%	Y	Scanned for polychaetes only	Y	
10/26/06	WR 1P	N 42º 28’ 03.6” W 121º 57’ 25.2”	Williamson, East bank, near mouth			N			Artificial substrate: scrubber pad
10/26/06	WR 2P	“	“	Y (106)	100%	Y	Scanned for polychaetes only	Y	Artificial substrate: broad leaf plant, + sand and silt from river
10/26/06	WR 3P	“	“	Y (27)	100%	Y	Scanned for polychaetes only	Y	Artificial substrate: narrow leaf plant
10/26/06	WR 5P	“	“	Y (49)	100%	Y	Scanned for polychaetes	Y	30 sec sample at substrate location

							only		
Upper									
10/27/06									
10/27/06	1P	N 41º 55' 46.2" W 122º 26' 34.6"	IGH, east bank by fish ladder	N	20% of ½ split	Y	Scanned for polychaetes only	Y	~5 m south of pool at foot of fish ladder
10/27/06	5P		IGH mouth of Bogus Creek	Y (2 in split, 20 total)	10%	Y	Y	Y	
10/27/06	7P	N 41º 55' 52.5" W 122º 26' 31.1"	IGH under bridge to hatchery	N	100%	Y	Scanned for polychaetes only	Y	Artificial substrate: scrubber pad
10/27/06	8P		"	N	20% of ½ split	Y	Scanned for polychaetes only	Y	
10/27/06	9P	N 41º 53'	Copco-Agar	N	1/6	Y	Scanned	Y	Artificial substrate:

		57.6” W 122º 30’ 29.2”	Bridge				for polychaetes only		scrubber pad
10/27/06	10P	“	“	N	100%	Y	Scanned for polychaetes only	Y	Artificial substrate: broad leaf plant
10/27/06	11P	“	“	N	100% sorted	Y	Y	Y	Along bank
10/27/06	12P	“	“	N	20%	Y	Scanned for polychaetes only	Y	
10/27/06	13 P	N 41º 53’ 57.9” W 122º 30’ 32.1”	Downstream of Copco-Agar bridge	N	10%	Y	Y	Y	Tule Bed; put out substrate
10/27/06	14P	N 41º 52’ 15.5” W 122º 33’ 34.1”	Half way between Copco-Agar and I-5 bridges	N	50%	Y	Scanned for polychaetes only	Y	Right bank in foamy eddy

10/27/06	15P	N 41º 52' 15.5" W 122º 33' 34.1"	"	N	20% of ½ split	Y	Scanned for polychaetes only	Y	Live sample here had low density of polychaetes
10/27/06	18P	N 41º 52' 14.6" W 122º 33' 34.2"	I-5 rest stop	N	20% of ½ split	Y	Scanned for polychaetes only	Y	
10/28/06									
10/28/06	19P	N 41º 49' 35.6" W 122º 39' 37.2"	Tree of Heaven	Y (20 in split, 80 total)	Y (1/4)	Y	Y	Y	Head of pool in reeds at cobble bar (1st) off gravel road
10/28/06	20P	N 41º 51' 29.9" W 122º 45' 00.8"	Gottsville river access	N	20% of ½ split	Y	Scanned for polychaetes only	Y	
10/28/06	21P	"	"	N	100%	Y	Scanned	Y	Artificial plant + substrate

							for polychaetes only		
10/28/06	22P	N 41º 51’ 51.8” W 122º 49’ 08.9”	Below Beaver Creek	Y (2)	100%	Y	Scanned for polychaetes only	Y	
10/28/06	23P	“	“	N	100%	Y	Scanned for polychaetes only	Y	Artificial substrate: broad leaf plant
10/28/06	26P	N 41º 50’ 27.0” W 122º 55’ 19.0”	Donna Creek (Walker Pt. road)	Y (4 in split, 20 total)	20%	Y	Scanned for polychaetes only	Y	Bank below confluence
10/28/06	27P	“	“	N	10%	Y	Scanned for polychaetes only	Y	Pools in bedrock at mouth
10/28/06	28P	N 41º 49’ 24.5” W 123º 00’	Horse Creek mouth	N	25%	Y	Scanned for polychaetes	Y	Left substrate

		20.5”					only		
10/28/06	29P	“	“			N			Artificial substrate: scrubber pad
10/28/06	31P	N 41º 46’ 48.4” W 123º 02’ 15.4”	Below Scott River	N	25%	Y	Scanned for polychaetes only	Y	End of sand/gravel bar below river mouth, around bend in river. Left substrate
10/28/06	32P	N 41º 47’ 01.1” W 123º 02’ 31.7”	About ½ mile below previous sample	N	20% of ½ split	Y	Scanned for polychaetes only	Y	
10/28/06	34P	N 41º 48’ 58.8” W 123º 07’ 40.0”	Rocky Point	N	100%	Y	Scanned for polychaetes only	Y	Downstream end of rock/sand bar below boat launch. Left substrate

2007 Samples

(5/11-5/14 live samples: not timed or measured)

5/11/07	1	N 41º 50' 41.0" W 123º 18' 10.0"	Seattle Creek	N	n/a	n/a	n/a	n/a	
	2	N 41º 50' 39.2" W 123º 18' 08.4"	"	N	"	"	"	"	
	3	N 41º 48' 05.4" W 123º 18' 51.7"	Below Seattle Creek	N	"	"	"	"	
	4		Just above previous sample	Y (1 in 5 dishes)	"	"	"	"	This was near boat launch; upstream areas may be better, would be accessible by canoe.

5/12/07	Multiple		Keno Eddy	Y	n/a	n/a	n/a	n/a	High density in 1 location in eddy, none in samples below eddy or near tributary creek
5/13/07	1		I-5 rest stop	N	n/a	n/a	n/a	n/a	Bounced net over cobble
	2		Tree of Heaven	N	“	“	“	“	Right above USFWS sentinel boxes
	3		Horse Creek	N	“	“	“	“	6 samples, 3 on each side of river
5/14/07	1	N 41º 53’ 58.0” W 122º 30’ 31.9”	Cayuse (upstream access)	Y (12 in 5 dishes)	n/a	n/a	n/a	n/a	Taken between 2 boulders in back eddy, found recently dead salmon ~20 cm TL
	2	N 41º 51’ 11.6” W 122º 41’	Cayuse (lower access)	Y (10 in 2 dishes)	“	“	“	“	Boulders, cobble, with silt& sand between

		41.1”							
	3	N 41º 49’ 43.9” W 122º 58’ 56.1”	Below hwy 96 bridge	Y (1 in 5 dishes)	“	“	“	“	Head of long gravel bar
(5/11-5/14 preserved samples)									Artificial substrates just scanned for polychaetes, not picked.
5-13-07	1	N 41º 53’ 57.9” W 122º 30’ 32.1”	Copco-Agar bridge	N	40%	Y	Scanned for polychaetes only	Y	Artificial Substrate- was in dense plant bed.
5-13-07	2	“	Copco-Agar bridge	N	50%	Y	“	Y	**15 sec** preserved sample due to dense plant bed. Washed and removed plants
5-13-07	3	N 41º 52’ 14.6” W 122º 33’ 34.2”	I-5 rest stop	Y (37 total)	100%	Y	“	Y	Artificial substrate

5-13-07	4	"	I-5 rest stop	Y (4 adults, 5 brooded young)	100%	Y	"	Y	30 sec sample- bounced net over cobble
5-13-07	5	N 41º 49' 35.6" W 122º 39' 37.2"	Tree of Heaven	Y(39 adults, 198 brooded young)	100%	Y	"	Y	Artificial substrate- was only ½ in water, just upstream of USFWS sentinel boxes
5-13-07	6	"	Tree of Heaven	Y (1 in split, 2 total)	50%	Y	"	Y	30 sec sample
7-3-07									
7-3-07	1	N 41º 51' 11.6" W 122º 41' 41.1"	Cayuse day use access	Y (35)	100%	Y	Scanned for polychaetes only	Y	30 second sample over boulders, mussel bed, freshwater sponge
7-3-07	2	N 41º 51' 11.6" W 122º 41' 41.1"	Cayuse day use access	Y (560)	100%	Y	Scanned for polychaetes only	Y	**30 second sample, same location as #1, but kicked up substrate**
7-3-07	3	N 41º 51' 11.6" W	Cayuse day	Y (29)	100%	Y	Scanned for	Y	Not timed; boulder covered with freshwater

122º 41' 41.1"	use access	polychaetes only	sponge

APPENDIX 2. INVERTEBRATES OF THE KLAMATH RIVER COLLECTED BY THE WILZBACH AND CUMMINS LAB DURING 2005-2007, AND IDENTIFIED BY DAVID MALAUSKAS.

Coleoptera
- Dytiscidae
  - *Hygrotus*
- Elmidae
  - *Cleptelmis addenda*
  - *Dubiraphia giulianii*
  - *Lara avara*
  - *Optioservus*
- Haliplidae
  - *Haliplus robertsi*
  - *Peltodytes*
- Hydrophilidae
  - *Tropisternus lateralis*
- Psephenidae
  - *Eubrianax edwardsii*
  - *Psephenus falli*

Diptera
- Athericidae
  - *Atherix pachypus*
- Blephariceridae
- Ceratopogonidae
  - Ceratopogoninae
  - Forcipomyiinae
- Chironomidae
  - Chironominae
    - Chironomini
    - Tanytarsini
      - *Rheotanytarsus*
  - Orthocladiinae
  - Tanipodinae
- Empididae
  - *Hemerodromia*
- Ephydridae
- Phoridae*
- Simuliidae
  - *Cnephia*
  - *Metacnephia*
  - *Simulium*
- Stratiomyidae
  - *Odontomyia*
- Tipulidae
  - *Antocha*
  - *Hexatoma*

Ephemeroptera

Ameletidae

Ameletus cooki

Ameletus validus

Baetidae

Acentrella insignificans

Baetis bicaudatus

Baetis tricaudatus

Callibaetis fluctuans

Callibaetis pictus

Centroptilum

Camelobaetidius maidu

Procloeon quaesitum†

Caenidae

Caenis amica

Ephemerellidae

*Attenella**

Caudatella heterocaudata

Drunella doddsii

Drunella flavilinea

Drunella grandis

Drunella spinifera

*Drunella pelosa***

Ephemerella dorothea infrequens

Serratella teresa

Serratella tibialis

Serratella velmae

Timpanoga hecuba

Heptageniidae

Cinygmula

Epeorus

Heptagenia elegantula

Ironodes

Nixe kennedyi

Rhithrogena

Isonychiidae

Isonychia velma

Leptohyphidae

Tricorythodes minutus

Leptophlebiidae

Paraleptophlebia

Siphlonuridae

Parameletus columbiae

Siphlonurus columbianus

Hemiptera

Corixidae

Hesperocorixa vulgaris

Sigara alternata

Sigara grossolineata

Gelastocoridae

Gelastocoris oculatus

Gerridae

Aquarius remigis
Metrobates trux
Naucoridae
Ambrysus mormon
Saldidae
Saldula hirsuta
Veliidae
Rhagovelia distincta
Rhagovelia obesa

Hymenoptera
"Thrips"

Lepidoptera
Pyralidae
Petrophilus

Megaloptera
Sialidae
Sialis californica

Neuroptera

Sisyridae
Climacia californica

Odonata
Anisoptera
Aeshnidae
Aeshna walkeri
Corduliidae
Epitheca spinigera
Macromia magnifica
Gomphidae
Gomphus kurilis
Octogomphus specularis
Ophiogomphus morrisoni
Ophiogomphus occidentis
Libellulidae
Libellula forensis
Libellula saturata
Zygoptera
Calopterygiidae
Calopteryx aequabilis
Hetaerina americana
Coenagrionidae
Argia agriodes
Argia emma
Argia lugens
Argia vivida
Enallagma boreale
Ischnura cervula
Ischnura perparva

Plecoptera

Capniidae

Capnia

Chloroperlidae

Alloperla

Sweltsa

Leuctridae

Despaxia augustus

Perlidae

Calineuria californica

Claassenia sabulosa

Hesperoperla pacifica

Perlodidae

Cultus

Osobenus yakimae

Pteronarcyidae

Pteronarcys californica

Trichoptera

Brachycentridae

Amiocentrus aspilus

Brachycentrus americanus

Brachycentrus occidentalis

Calamoceratidae

Heteroplectron californicum

Glossosomatidae

Glossosoma

Helicopsychidae

Helicopsyche borealis

Hydropsychidae

Hydropsyche

Hydroptilidae

*Agraylea**

Hydroptila

Ochrotrichia

Oxyethira

Lepidostomatidae

Lepidostoma

Leptoceridae

Mystacides alafimbriata

Mystacides sepulchralis

Nectopsyche gracilis

Oecetis disjuncta

Limnephilidae

Dicosmoecus gilvipes

Hydatophylax hesperus

Onocosmoecus unicolor

Philopotamidae

Wormaldia

Phryganeidae

Phryganea cinerea

Polycentropidae

Polycentropus
Rhyacophilidae
Rhyacophila
Sericostomatidae
Gumaga
Uenoidae
Neophylax
Neothremma

* = Williamson River only

** = Mouth of Horse Creek only

† = Not previously reported in California; ID e based on nymphs