PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Diet, Distribution & Life History Of Neomysis Mercedis In John Day Pool

BPA project number: 20076
Contract renewal date (mm/yyyy): ☐ **Multiple actions?**

Business name of agency, institution or organization requesting funding
University of Montana

Business acronym (if appropriate) ______________________

Proposal contact person or principal investigator:

Name	Jack Stanford
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NPPC Program Measure Number(s) which this project addresses

FWS/NMFS Biological Opinion Number(s) which this project addresses

Other planning document references
Return to the River

Short description
Quantify key variables describing the ecology of the exotic mysid Neomysis mercedis that has recently invaded mainstem Columbia reservoirs. Determine the potential N. mercedis has for negatively affecting food web structure in the Columbia River.

Target species
Neomysis mercedis

Section 2. Sorting and evaluation

Subbasin

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more caucus	If your project fits either of these processes, mark one or both	Mark one or more categories
☐ Anadromous fish ☐ Resident fish ☐ Wildlife	☐ Multi-year (milestone-based evaluation) ☐ Watershed project evaluation	☐ Watershed councils/model watersheds ☐ Information dissemination ☐ Operation & maintenance ☐ New construction ☒ Research & monitoring ☐ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
9101901	Mysis relicta research on Flathead Lake by CS and K Tribes.	Similar Mysis relicta work conducted on Flathead Lake by Confederated Salish and Kootenai Tribes will allow Neomysis mercedis investigations in mainstem Columbia to be placed in a regional and ecological context. Studies will augment each other.

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Describe the life history strategy of Neomysis mercedis in John Day Pool. Ho: Neomysis has a one year life history.	a	Quantify spatial and temporal abundance, population body-size structure and individual caloric content of Neomysis.
2	Describe temporally and spatially explicit Neomysis food habits. Ho: Neomysis food habits do not change in time or space.	b	Quantify spatial and temporal differences in gut contents of Neomysis.
3	Quantify vertical habitat use by Neomysis during day and night in stratified and non-stratified seasons. Ho: Neomysis are uniformly distributed in the water column during a diel cycle, and during periods of stratification and non-stratification.	c	Perform diel depth specific sampling during the stratified and non-stratified seasons.
4	Identify abiotic habitat variables that limit Neomysis distribution. Ho: Neomysis abundances are independent of limnological variables (e.g. temperature, turbidity, oxygen pH, conductivity).	d	Correlate Neomysis abundance with limnological variables.
5	Quantify Neomysis benthic microdistribution. Ho: Neomysis remain above substrate continuously.	e	Observe Neomysis behavior via underwater video

	Ha: Neomysis burrow into substrate.		
6	6. Quantify the seasonal accumulation of caloric reserves in Neomysis. Ho: Caloric accumulation is directly proportional to seasonal gain in body mass. Ha: Caloric accumulation is not directly proportional to seasonal gain in body mass.	f	Quantify seasonal caloric accumulation in Neomysis by monthly bombcalorimetric analyses

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	11/1999	10/2000	a		20.00%
2	11/1999	10/2000	b		20.00%
3	3/2000	7/2000	c		7.00%
4	4/2000	6/2000	d		21.00%
5	5/2000	7/2000	e		20.00%
6	11/1999	10/2000	f		12.00%
				Total	100.00%

Schedule constraints

No foreseen constraints.

Completion date

10/2000

Section 5. Budget

FY99 project budget (BPA obligated):

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel		%41	72,297
Fringe benefits		%15	27,601
Supplies, materials, non-expendable property		%10	18,200
Operations & maintenance		%0	700
Capital acquisitions or			

improvements (e.g. land, buildings, major equip.)			
NEPA costs			
Construction-related support			
PIT tags	# of tags:		
Travel		%3	5,617
Indirect costs		%26	46,743
Subcontractor	energetic analyses	%2	5,000
Other			
TOTAL BPA FY2000 BUDGET REQUEST			$176,158

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
Total project cost (including BPA portion)			$176,158

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget				

Section 6. References

Watershed?	Reference
☐	Beattie, W.D., P.T. Clancy and R. Zubik. 1988. Effects of the operation of Kerr and Hungry Horse Dams on the reproductive success of kokanee in the Flathead River system. Montana Department of Fish, Wildlife and Parks, Kalispell. Final report to BPA
☐	Chess, D. and J.A. Stanford. 1998. Comparative energetics and life cycle of the opossum shrimp (Mysis relicta) in native and non-native environments. Freshwater Biology in press.
☐	Chigbu, P. and T. H. Sibley. 1994. Predation by Neomysis mercedis: effects of temperature, Daphnia magna size and prey density on ingestion rate and size selectivity. Freshwater Biology 32:39-48.
☐	Cooper, K. L., K.D. Hyatt, D.P. Rankin. 1992. Life history and production of Neomysis mercedis in two British Columbia coastal lakes. Hydrobiologia

	230:9-30.
☐	Fraley, J., B. Marotz, J. Decker-Hess, W. Beattie, and R. Zubik. 1989. Mitigation, compensation, and futue protection for fish populations affected by hydropower develpment in the Upper Columbia system, montana, USA. Reg. Riv. 3 :3-18.
☐	Heubach, W. 1969. Neomysis awatschemsis in the Sacrametno-San Joaquim estuary. Limnology and Oceanography 14:533-546.
☐	Lasenby, D. C., T. G. Northcote, et al. 1986. Theory, practice and effects of Mysis relicta introductions to North American and Scandinavian Lakes. Can. J. Fish. Aquat. Sci. 43: 1277-1284.
☐	Muir , W.D. and R.L. Emmett. 1988. Food habits of migrating salmonid smolts passing Bonneville Dam in the Columbia River, 1984. Regulated Rivers 2:1-10.
☐	Northcote, T. G. 1991. Successes, problems, and control of introduced mysid populations in lakes and reservoirs. American Fisheries Society Symposium 9: 5-16
☐	Robbins, O. Jr. 1966. Flathead Lake Fishery Investigations, 1961-64. US Dept Interior: Bur. Sport Fish and Wildl. Tech. Pap. No. 4.
☐	Spencer, C.N., B.R. McClelland and J.A. Stanford. 1991. Shrimp stocking, salmon collapse and eagle displacement. Bioscience 41: 14-21.

PART II - NARRATIVE

Section 7. Abstract

The magnitude, timing and management implications of food web impacts caused by the recent invasion of the mysid *Neomysis mercedis* in the lower Columbia River are completely unknown yet may be of key importance in future management of native Columbia River fish. Interestingly, *Neomysis* has not been reported as a food item in Columbia River native fishes, suggesting that it is not available fish forage. However, if *Neomysis* has the same adaptive advantages as its cousin, *Mysis relicta*, complex food web interactions that are potentially very negative for salmon and steelhead restoration may already be occurring in John Day pool and other mainstem reservoirs. In the proposed research, we will quantify *Neomysis* diet, spatial and temporal population structure, and life history strategy. Quantification of these variables is critical to a holistic understanding of realized and potential *Neomysis* food web impacts in the Columbia River proper.

Section 8. Project description

a. Technical and/or scientific background

Many populations of anadromous and resident native fish in the Columbia Basin are undergoing numerical declines. In response to these trends Bonneville Power Administration (BPA) has reconstructed physical habitat, engaged in artificial propagation, and developed hydropower operational guidelines. Yet fish populations continue to decline. We believe that an adequate understanding of the dominant structuring food web interactions has largely precluded successful mitigation to date. Without a basic scientific understanding of the dominant processes that drive aquatic systems in the Pacific NW and existing food web dynamics, management initiatives that seek to alter food webs to favor native species will probably not be successful regardless of monetary investment.

This research will focus on how native fish survival is in part dictated by critical food web structuring organisms. A common food web concern throughout the Columbia River system is the introduction of exotic species. The roles of exotic species in structuring food webs have been studied in some systems, while even species occurrance insunknown in others. For example, although a comprehensive mechanistic understanding of food web function is unknown in Flathead Lake, Montana biological history has been documented.

Prior to major food web changes associated with exotic introductions, the Flathead Lake zooplankton community was dominated by cladocerans (*Daphnia thorata, D. longiremis, Bosmina logirostris, Leptodora kindtii*), copepods (*Epishura nevadensis, Diaptomus ashlandi, Diacyclops bicuspidatus*) and many rotifer species. The native fish community was dominated by native salmonids (westslope cutthroat trout, bull trout, mountain and pygmy whitefish), catostomids (longnose and largescale suckers), and cyprinids (peamouth, squawfish and redside shiner). However, these and other components of the Flathead Lake food web have been greatly altered. Lake whitefish, lake trout, kokanee salmon and perch were introduced into the lake system by the 1930's. By 1963 the sport fish catch was dominated by kokanee salmon (76-95%), with over 100,000 fish harvested annually (Beattie *et al.* 1988, Robbins 1966). Kokanee were used heavily by native wildlife including grizzly bears and bald eagles (Spencer *et al.* 1991). During this time, lake trout, feeding heavily on kokanee, provided a trophy fishery with fish over 18 kg not uncommon.

In 1981 *Mysis relicta*, a freshwater shrimp that appears to play a dominant role in food web (re)structuring processes (Lasenby, Northcote et al. 1986; Northcote 1991), was documented in Flathead Lake. Within seven years two of the four principal cladocerans (*D. longiremis and L. kindtii*) disappeared from lake samples and the two others (*D. thorata and B. longirostris*) persisted but at greatly reduced densities (Spencer *et al.* 1991). Similar trends occurred in copepod populations. Although kokanee salmon numbers had previously been affected by hydroelectric dam induced redd dewatering in both Flathead Lake and the South fork of the Flathead River (Fraley *et al.* 1989), the kokanee population collapsed after *M. relicta* colonization (Spencer *et al.* 1991). In spite of recent massive restocking efforts funded by BPA, kokanee are virtually absent from Flathead Lake. Lake trout and lake whitefish populations have greatly increased whereas native salmonids continue to decline. Since 1981-83 bull trout have decreased from an average 2.1 fish per survey gillnet to an average of 0.2 in 1992-96. Westslope cutthroat have decreased from 2.7 to 0.7 fish per net, lake trout have increased from 0.1 to 1.7 and lake whitefish have increased from 2.7 to 9.7 fish per net. Concurrently, bull trout redd counts at State monitoring sites have decreased from a high of 600 in 1982 to 114 in 1997 (State of Montana Fish Wildlife and Parks, unpublished data). It is important to note that exotic fishes of concern were well established by the 1930's, yet native species of concern did not decline to dangerously low levels until the recent introduction of *M. relicta* and the concurrent increases in lake trout and lake whitefish populations.

Similar problems associated with introductions of *M. relicta* have occurred in Lake Pend O'rielle, ID, and Priest Lake, WA, and the beasts are now present in Lake Roosevelt, behind Grand Coulee Dam. Very likely, *M. relicta* will be a problem for kokanee management in Lake Roosevelt (kokanee are the mitigation target for anadromous losses upstream of Grand Coulee in the Fish and Wildlife Plan), as they have been elsewhere (Northcote 1991, Spencer *et al.* 1991). Moreover, *M. relicta* probably are in the process of establishing in other, if not all, mainstem reservoirs, possibly along with lake trout which likely also are moving downstream from sources in the Columbia River headwaters.

Concurrent to *M. relicta* downstream movement is an upstream movement of two other exotic crustaceans, *Corophium salmonis,* a gammarid amphipod, and *Neomysis mercedis,* a mysid shrimp. Both are typically estuarine species. The extent of the upstream invasion of these species, and their food web impact, are unknown. In 1984 *Corophium* was the dominant diet item in migrating spring salmonids constituting 99% of steelhead, 87% of sockeye salmon, 94% coho, 97% of yearling chinook salmon and 90% of the diet in subyearling chinook salmon (Muir and Emmett 1988). *Neomysis* were first observed by ISG members in smolt monitoring stations in the lower Columbia River in 1994 and subsequently *Neomysis* were collected from the water column of John Day pool (Stanford unpublished data). Although the reasons *Corophium* and *Neomysis* have advanced upstream are unstudied, changes in Columbia River hydrology caused by hydroelectric impoundments are probably key. Heubach (1969) found that net velocities greater than $0.12\ m \bullet s^{-1}$ formed hydrologic barriers to the upstream movement of mysids. Decreased mean fluvial flows caused by impoundment, absence of seasonal flushing flows, and suitable habitat created by dam construction, coupled with upstream transportation of invertebrates in fish transportation barges may have resulted in upstream colonization of these exotic invertebrates.

The relatively recent documentation of invading *Neomysis* in the lower Columbia may be of key importance in future management of native Columbia River fish. The magnitude, timing and management implications of *Neomysis* related food web impacts are completely unknown. Interestingly, *Neomysis* has not been reported as a food item in Columbia River native fishes, suggesting that it is not available fish forage. However, if *Neomysis* has the same adaptive advantages as its cousin, *M. relicta*, complex food web interactions that are potentially very negative for salmon and steelhead restoration may already be occurring in John Day pool and other mainstem reservoirs. Indeed, the dramatic food web changes, and associated decline in fish production of valued species elicited by *Mysis* in Upper Columbia water bodies suggests study of *Neomysis* in the Lower River is very warranted (ISG, in press).

Predicting food web changes induced by *Neomysis*, based on experience with *Mysis* in the Upper Columbia River system is tenuous at best. There are important ecological distinctions between the two genera. *Neomysis mercedis* is morphologically similar to *M. relicta* but attains a smaller adult size (≈17 mm vs. 25mm adult body size) (Cooper *et al* 1992). While *Mysis* is physiologically excluded from water whose temperature is > 15 °C, *Neomysis* has been found to be unaffected at temperatures >20°C (Cooper *et al* 1992, Chess and Stanford 1998). Where *Mysis* abundance and life-history stage has been found to be predictable based on water depth (Chess and Stanford 1998), *Neomysis* abundance and population structure can be variable with water depth (Cooper *et al* 1992). Occurrence of *Neomysis* in shallow water, depths typically uninhabited by *Mysis*, indicates *Neomysis* may be adapted for higher light intensity than *Mysis* (Cooper *et al*. 1992).

Although there has been no quantification of *Neomysis* diet in the Columbia River, the physiological and habitat preference differences between *Neomysis* and *Mysis* suggest different prey selectivity (Chigu and Sibley 1994), that may translate into different effects of predation on native zooplankton and benthic communities. In addition, different habitat preferences among *Neomysis* and *Mysis* may dictate different availabilities as forage for native fishes. *Mysis relicta* can be an important diet component of salmonids, while *Neomysis* has not been documented in salmonid guts in the Columbia River proper. Microdistribution of the mysids may result in their different susceptibility to predation. For example, *Neomysis* may burrow into substrate seeking a physical separation from foraging fish. Quantification of *Neomysis* microdistribution, and therefore susceptibility to predation, is key in predicting *Neomysis* mediated food web alterations in the Columbia River. Knowing what *Neomysis* feeds upon is also crucial, because they may be better competitors than juvenile salmon and steelhead for the same forage in these reservoirs.

Quantification of the *Neomysis* life history and food habits in the Columbia River is critical to a holistic understanding of realized and potential *Neomysis* food web impacts in the River proper. Monitoring of lipid concentrations and caloric content of individual Mysids in relation to foods injested is an ecologically meaningful, cost effective and objective way of elucidating Mysid life history strategy (Chess and Stanford 1998). Chess and Stanford (1998) found that the life history of *Mysis relicta* in two lakes in Montana differing in food web structure had markedly different life history strategies. In Waterton Lake *Mysis* required two years to accumulate enough lipid to enable reproduction while in Flathead Lake a single year was sufficient. Caloric content of iindividual Mysids can be compared with literature values, where concentrations associated with known life history strategies have been documented.

The research proposed here will provide empirical data critical to understanding and predicting the ecological impact of the exotic *Neomysis mercedis* in the Lower Columbia River system. The proposed research (quantification of limiting abiotic habitat variables, diet, spatial distribution, and life history strategy of *Neomysis mercedis* in John Day pool) will enable prediction of whether *Neomysis* has the potential to initiate dramatic food web change in the mainstem Columbia River, like *M. relicta* has done in the Upper Columbia drainage, or whether *Neomysis* is ecologically benign. Moreover, the sampling scheme proposed here also will elucidate the presence or absence of *M. relicta* and food web implications should it be present. No other food web studies to date have dealt in any way with this potentially serious problem for recovery of anadromous native fishes in the Columbia River system.

b. Rationale and significance to Regional Programs

The research proposed here will provide empirical data critical to understanding and predicting the ecological impact of the exotic *Neomysis mercedis* in the Lower Columbia River system. The proposed research (quantification of limiting abiotic habitat variables, diet, spatial distribution, and life history strategy of *Neomysis mercedis* in John Day pool) will enable prediction of whether *Neomysis* has the potential to initiate dramatic food web change in the mainstem Columbia River, like *M. relicta* has done in the Upper Columbia drainage, or whether *Neomysis* is ecologically benign. Moreover, the sampling scheme proposed here also will elucidate the presence or absence of *M. relicta* and food web implications should it be present. No other food web studies to date have dealt in any way with this potentially serious problem for recovery of anadromous native fishes in the Columbia River system.

c. Relationships to other projects

The proposed research has been endorsed by and will be collaborative with the fish restoration efforts of the Yakama Indian Nation. Recovery of Yakima River salmon and steelhead, in which the Council and BPA have invested millions of dollars, is directly tied to food web dynamics in the mainstem reservoirs that facilitate successful outmigration of Yakima River and other stocks. This project also will complement *Mysis relicta* research currently being conducted by the Confederated Salish and Kootenai Tribes in Montana (BPA proposal 9101901).

d. **Project history** (for ongoing projects)

(Replace this text with your response in paragraph form)

e. Proposal objectives

The proposed research (quantification of limiting abiotic habitat variables, diet, spatial distribution, and life history strategy of *Neomysis mercedis* in John Day pool) will enable prediction of whether *Neomysis* has the potential to initiate dramatic food web change in the mainstem Columbia River, like *M. relicta* has done in the Upper Columbia drainage, or whether *Neomysis* is ecologically benign

f. Methods

Objective one will be addressed by conducting five spatially comprehensive samplings (n=40) of John Day reservoir (i.e. February, April, June, August, and October). Samples will be single vertical tows using a 1m diameter plankton net (bottom to surface) using a depth stratified sampling design. Samples will be preserved in ethanol, and counted and measured to the nearest 0.1 mm in the laboratory. Size-frequency distributions will be constructed for each depth strata, and year class cohorts identified. Some samples will be transported to the laboratory live, total caloric value of six individuals (+/- 1 SD from the mean body mass) for each cohort from each sampling date will be determined by bomb calorimetry. Interannual migrations of *Neomysis* size classes among water depth strata will be identified by comparing areal abundances among sampling dates.

Neomysis foreguts will be removed (n=6) from each of 3 depth strata for each sampling date. Gut contents will be submerged in glycerin, identified with light microscopy and quantified. Differences in diet among seasons and locations will be tested (Objective two).

Using a closing plankton net, *Neomysis* abundance at 8 specific depth strata at one deep water station, will be quantified once during day and once during night, during summer stratification and during a non-stratified period (Objective three).

Limnological variables (depth profiles of temperature, conductivity, pH, turbidity, irradiance and oxygen concentration) will be measured using a multisensor CTD system during sampling in Objective 1. *Neomysis* abundance will then be correlated with limnological variables using Pearson product-moment correlations with Bonifferoni adjustments to protect type I error rates (Objective four). An underwater video camera will be used to quantify microdistribution of benthic *Neomysis* (Objective five).

We will quantify seasonal caloric accumulation in *Neomysis* by monthly bomb calorimetric analyses of animals (n=6) collected during abundance and distribution sampling (Objective six).

Where statistical assumptions are met, all hypotheses will be tested using ANOVA. Inequality of variance and normality assumptions of statistical tests will be addressed by $\log_{10}$ or $\log_{10+1}$ transformation. If parametric statistical assumptions cannot be met with appropriate transformations, non parametric techniques suited to the data type will be used (e.g. Mann-Whitney U). The proposed temporal and spatial sampling regime, as well as sample sizes, are consistent with those successfully used in ongoing *Mysis relicta* research on Flathead Lake (e.g. Chess and Stanford 1998). The proponents are uniquely suited to perform the proposed research because of their existing physical presence in the Lower Columbia and their experience with mysid research.

g. Facilities and equipment

The Flathead Lake Biological Station has an optics room and microscopes, zoobenthos and plankton identification lab and museum, sample prep facility, electronics repair shop, photographic lab, image analyses system (for gut analyses and enumeration) and multisensor (CTD) systems (for limnological variables that can be deployed in John Day pool). The Flathead Lake Biological Station currently has full-time personnel working on the Yakima River on salmon and steelhead habitat problems in collaboration with the Yakama Indian Nation, the US Bureau of Reclamation and the Yakima Basin irrigation community. We expect to develop a long-term collaboration with the Yakama Indian Nation and other appropriate tribes and agencies to solve mainstem food web problems, if this exploratory research shows that *Neomysis* is a management problem for fisheries recovery. Hence, full logistical support for the project is already in place. We will move a 16-foot outboard boat and sampling gear from the Biological Station to the Yakima for use on this project. We are requesting an underwater video camera and cable to enable us to visually quantify movements and behavior of the crustaceans and potentially to determine *Neomysis*-fish interactions.

h. Budget

The proposed budget will enable all objectives to be addressed in a fiscally responsible manner. Personnel, fringe, supplies and operation costs were priced so that study objectives could be met in the most parsimonious manner possible.

Section 9. Key personnel

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EDUCATION:

B.S.	Fisheries Science	Colorado State University	1969
M.S.	Limnology	Colorado State University	1971
Ph.D.	Limnology	University of Utah	1975

PROFESSIONAL EXPERIENCE:

Bierman Professor of Ecology, The University of Montana (1986-present). Ongoing research includes ecosystem-level consequences of river regulation, dynamics of lotic and hyporheic zoobenthos, especially Plecoptera, and advective circulation of nutrients as controls on microbial production and other food web interactions in lakes of glacial origin.

Director, Flathead Lake Biological Station (1980-present). Administrative responsibility for all Biological Station activities, including the academic program and limnological studies in the Freshwater Research Laboratory.

SELECTED REFEREED PUBLICATIONS (from 110 total in peer-reviewed books/journals):

Stanford, J. A. and J. V. Ward. 1988. The hyporheic habitat of river ecosystems. *Nature* 335:64-66.

Spencer, C. N., B. R. McClelland and J. A. Stanford. 1991. Shrimp stocking, salmon collapse and eagle displacement: cascading interactions in the food web of a large aquatic ecosystem. *BioScience* 41(1):14-21.

Hall, C. A. S., J. A. Stanford and F. R. Hauer. 1992. The distribution and abundance of organisms as a consequence of energy balances along multiple environmental gradients. *Oikos* 65:377-390.

Stanford, J. A. and J. V. Ward. 1992. Management of aquatic resources in large catchments: Recognizing interactions between ecosystem connectivity and environmental disturbance, pp. 91-124. IN: Naiman, R. J. (ed.), Watershed Management: Balancing Sustainability with Environmental Change. Springer-Verlag, New York, New York.

Stanford, J. A. and J. V. Ward. 1993. An ecosystem perspective of alluvial rivers: connectivity and the hyporheic corridor. *Journal of the North American Benthological Society* 12(1):48-60.

Gibert, J., D. Danielopol and J. A. Stanford. 1994. Groundwater Ecology. Academic Press, San Diego, California.

Naiman, R. J., J. J. Magnuson, D. M. McKnight, J. A. Stanford and J. R. Karr. 1995. Freshwater ecosystems and their management: A national initiative. *Science* 270:584-585.

Ward, J. V. and J. A. Stanford. 1995. The serial discontinuity concept: Extending the model to floodplain rivers. *Regulated Rivers* 10:159-168.

Ward, J. V. and J. A. Stanford. 1995. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. *Regulated Rivers* 11:105-119.

Stanford, J. A. and G. C. Poole. 1996. A protocol for ecosystem management. *Ecological Applications* 6(3):741-744.

Stanford, J. A., J. V. Ward, W. J. Liss, C. A. Frissell, R. N. Williams, J. A. Lichatowich and C. C. Coutant. 1996. A general protocol for restoration of regulated rivers. *Regulated Rivers* 12:391-413.

Dr. Dan Wicklum

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Education

1998	**Doctor of Philosophy** (Aquatic Ecology) 1998, University of Montana
1994	**Master of Science** (Aquatic Ecology), University of Calgary, Alberta
1990	**Honors Bachelor of Science** (Biology), University of Guelph, Ontario

Current Employer

Post-doctoral Fellow, University of Montana; Studying mysid diet and population dynamics in Flathead Lake, MT.

Overview of Expertise

Dr. Wicklum has a broad range of experience and formal training in aquatic ecology and uni-, bi- and multivariate statistics. He has expertise in taxonomy of all aquatic organisms, experimental design, data presentation and interpretation.

One of Dan's major strengths is his ability to tailor studies to address specific questions while maintaining the scientific rigor and integrity of the investigation. His combination of formal ecological and statistical training, and practical field experience, make him uniquely suited for food web research issues. He has served as a peer reviewer for Journal of the American Water Resources Association, Regulated Rivers, and Journal of Environmental Management.

Selected Publications

Scrimgeour, G.J., **D. Wicklum**, and S.D. Pruss. 1998. Selection of an aquatic indicator species to monitor organic contaminants in a trophically simple lotic food-web. Archives of Environmental Contamination and Toxicology *In press*.

Wicklum, D. and R.W. Davies. 1997. Mortality, preference, avoidance, and activity of a predatory leech exposed to cadmium. Archives of Environmental Contamination and Toxicology 32:178-183.

Wicklum, D. and R.W. Davies. 1996. The effects of chronic cadmium stress on energy acquisition and allocation in a freshwater benthic invertebrate predator. Aquatic Toxicology. 35:237-252.

Scrimgeour, G.J. and **D. Wicklum**. 1996. Aquatic ecosystem health and integrity: problems and potential solutions. Journal of the North American Benthological Society 15:254-261.

Davies, R.W., R.N. Singhal and **D. Wicklum**. 1995. Changes in reproductive potential of the leech *Nephelopsis obscura* (*Erpobdellidae*) as biomarkers for cadmium stress. Canadian Journal of Zoology 73:2192-2196.

Wicklum, D. and R.W. Davies. 1994. Ecosystem health and integrity? Canadian Journal of Botany 73:997-1000.

Section 10. Information/technology transfer

Deliverables include one or more scientific publications on the role of *Neomysis* in structuring food webs and salmonid forage in John Day pool and inferences about food webs in other mainstem reservoirs relative to influences of *Neomysis* and *M. relicta*. We will prepare a formal report for BPA as required. We also expect to make oral presentations to national scientific audiences, the National Marine Fisheries Service and the NW Power Planning Council (provided our travel costs can be paid) in addition to routine consultations with interested agencies and tribes.

Congratulations!