PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project **Indexing Salmon Carrying Capacity to Habitat, Population, & Physical Fitness Surveys**	
BPA project number	**20103**
Contract renewal date (mm/yyyy)	
Multiple actions? (indicate Yes or No)	
Business name of agency, institution or organization requesting funding **Oregon State University**	
Business acronym (if appropriate)	**O.S.U.**
Proposal contact person or principal investigator:	
Name **Mailing address** **City, ST Zip** **Phone** **Fax** **Email address**	**Hiram W. Li** **104 Nash Hall, Oregon State University** **Corvallis 97331-3803** **(503) 737-1963** **(503) 737-3590** Hiram.Li@orst.edu
NPPC Program Measure Number(s) which this project addresses **4.1B, 4.3B, 5.0E, 7.1A.1, 7.1C.3, 7.1G, 7.6A.2, 7.6C**	
FWS/NMFS Biological Opinion Number(s) which this project addresses **NMFS ESUs Snake River spring chinook salmon (threatened), Snake River steelhead Threatened), Middle Columbia River steelhead (proposed threatened), USFWS: Inland rainbow trout (candidate species**	
Other planning document references Run of the River, Upstream	
Short description The objective of this proposal is to develop a fast reliable method to determine salmonid carrying capacity for watersheds based on remotely sensed data. The initial research will test this approach by linking remotely sensed data to habitat quality as defined by population densities and the physical fitness of salmonids. If as the preliminary evidence suggests, that the method will work, we can rely on remotely sensed images of stream temperature and riparian condition to inventory the potential of watersheds to support salmonids. This will be a tremendous boon for monitoring stream restoration efforts and developing policy. Our approach to ground truthing will establish protocol for calibration to specific watersheds should very precise estimates be required in future work.	
Target species spring chinook salmon and inland steelhead trout (both anadromous and resident forms)	

Section 2. Sorting and evaluation

Subbasin Drainages of the Blue Mountain Ecoregion: Grande Ronde, John Day, Umatilla

Evaluation Process Sort

CBFWA caucus		**CBFWA eval. Process**		**ISRP project type**	
X one or more caucus		If your project fits either of these processes, X one or both		X one or more categories	
X	Anadromous fish	X	Multi-year (milestone-based evaluation)		Watershed councils/model watersheds
X	Resident Fish		Watershed project eval.		Information dissemination
	Wildlife				Operation & maintenance
					New construction
				X	Research & monitoring
					Implementation & mgmt
					Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

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

Project #	**Project title/description**
9405400	Bull Trout (ODFW-David Buchanan
	Lamprey project (CTUIR—David Close) (BRD—Jim Seelye)

Other dependent or critically-related projects

Project #	**Project title/description**	**Nature of relationship**
	Redband trout Candidate Species (USFWS) ID Critical limiting factors	Cooperative working relationship with ODFW (Kim Jones & Jeff Dambacher)
	Redband trout temperature program (Oregon DEQ)	Cooperative working relationship with ODEQ (Bruce Hammons)
	Geomorphic, ecologic, hydrologic connectivity: Implication for Columbia River Endangered Salmonids	Development of understanding and methodologies for understanding normative watersheds in the Mid-

	(EPA/NSF)	Columbia and Snake River watersheds.

Section 4. Objectives, tasks and schedules

Past accomplishments (NOT APPLICABLE)

Year	Accomplishment	Met biological objectives?

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
I	Determine whether or not the carrying capacities for spring chinook salmon and inland rainbow trout of the John Day and Grande Ronde basins are similar.	A	
		a	Collect thermal and truce color images of the John Day and Grande Ronde catchments. Classify and quantify habitats into types based on established criteria for thermal tolerances of salmonids.
		b	Determine from clinical indicators of physical fitness whether or not Grande Ronde spring chinook juveniles are healthier than those from the John Day <u>at the end of the growing season</u> (Following smolts survival from specific habitat types from different basins warrants a full blown PIT tagging effort and expensive sampling equipment, *i.e.* screw traps. This proposal covers the first stage.)
		d	Establish relations of thermal habitat types to stream features of stream sinuosity, expanse of riparian vegetation and type, volume of large woody debris, and the frequency of large pools.

		e	Determine the average densities of juvenile salmonids from each thermal habitat type.
		f	Calibrate techniques for population censuses and clinical indicators of physical fitness.
II	Determine from PIT tagging data available on the Stream Net Web site, whether or not survival rates to Bonneville Dam are similar for salmonids migrating down through 8 dams versus those that migrate through fewer dams.		
III	Given the results of objectives I and II, determine whether or not the differences in productivity of anadromous salmonids between the Grande Ronde and John Day basins appear to be due more to differences in the quality and quantity of habitat or to differential survival through 3 vs. 8 dams.		

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
I	1Oct99	14Aug02	Determine salmonid carrying capacities of the Grande Ronde vs. John Day drainages using application of remote imagery and clinical indicators of physical fitness of salmonids	Collect Remote imagery & quantify habitats by temperature class within John Day and Grande Ronde Basins	20%
	1June00	15July00		Calibrate Fish Density Survey	10%
	15July00	20Aug01		Enumerate salmonid densities in habitats by temperature class	20%
	1Aug00	15Aug01		Gather clinical indicators of physical fitness for salmonids	20%

				from habitats of different temperature classes	
	1Oct 00	1Aug02		Determine relationships between salmonid densities & habitat temperature class.	10%
	1Oct 00	1Aug02		Determine relationships between salmonid physical fitness & habitat temperature class	10%
II	1Jan01	1Jan02	From available PIT tagging data, determine approximate relative values of survival of salmonid smolts migrating through 3 vs. 8 dams.	Consult with tagging researchers	5%
III	1Jan02	1Sep02	Determine the relative limiting factor of dam passage vs. habitat quality and quantity for Grande Ronde and John Day basins		5%
				Total	100%

Schedule constraints
Bad flying weather
Completion date
30 November 2002

Section 5. Budget

FY99 project budget (BPA obligated):	$

FY2000 budget by line item

Item	Note	% of total	FY2000 ($)
Personnel	**34% of total budget**		**$123,402**
Fringe benefits	**10% of total budget**		**$35,140**

Supplies, materials, non-expendable property	**8% of total budget**		**$29,100**
Operations & maintenance			
Capital acquisitions or improvements (e.g. land, buildings, major equip.)			
NEPA costs			
Construction-related support			
PIT tags	# of tags:		
Travel	**5% of budget**		**$16,500**
Indirect costs	**24% of budget**		$**87,060**
Subcontractor	**15% of budget**		**$55,000**
Other (**tuition)**	**5% of budget**		**$17,190**
TOTAL BPA REQUESTED BUDGET			**$363,392**

Cost sharing

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

Outyear costs

	FY2001	**FY02**	**FY03**	**FY04**
Total budget	$378,233	$393,805		

Section 6. References

Watershed?	**Reference**
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Columbia River	Becker, C.D. and M.P. Fugihara. 1978. The bacterial pathogen, *Flexibacter columnaris,* and its epizootiology among Columbia River fish: a review and synthesis. American Fisheries Society Monograph No. 2.
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John Day, Grande Ronde	Hanson, M.L. 1987. Riparian zones in eastern Oregon. Oregon Environmental Council, Portland OR, 74 p.
John Day, Grande Ronde	Howell, P.J. and D.V. Buchanan. 1992. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis, OR.
Columbia River	Independent Science Group. 1996. Return to the river: Restoration of salmonid fishes in the Columbia River Ecosystem, Document 96-6. Columbia River Basin Fish and Wildlife Program, Northwest Power Planning Council, Portland, OR.
John Day Basin	Li, H.W., G.A. Lamberti, T.N. Pearsons, C.K. Tait, J.L. Li, and J.C. Buckhouse. 1994. Cumulative effects of riparian disturbance in small streams of the John Day Basin, Oregon. Transactions of the American Fisheries Society 123: 627-640.
John Day, Grande	Li, H.W. et al. 1998. Geomorphic, hydrologic and Ecological Connectivity in Columbia River Watersheds: implications for endangered salmonids. Page 64, *in Proceedings of*

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Columbia River	Maule, A. G., C. B. Schreck, C. S. Bradford, and B. A. Barton. 1988a. Physiological effects of collecting and transporting emigrating juvenile chinook salmon past dams on the Columbia River. Transactions American Fisheries Society 117:245-261.
Columbia River	Maule, A. G., R. A. Tripp, S. L. Kaattari, and C. B. Schreck. 1988b. Stress alters immune function and disease resistance in chinook salmon (*Oncorhynchus tshawytscha*). J. Endocrinology 120: 135-142.
John Day, Grande Ronde	McIntosh, B.A., J.R. Sedell, J.E. Smith, R.C. Wissmar, S.E. Clarke, G.H.Reeves, and L.A. Brown. 1994. Historical changes in fish habitat for select river basins of eastern Oregon and Washington. Northwest Science 68: 36-53.
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Columbia Basin	Ratliff, D.E. and P.J. Howell. 1992. The status of bull trout populations in Oregon. Pages 10-17, *in* P.J. Howell and D.V. Buchanan (eds.). Proceedings of the Gearhart Mountain bull trout workshop.
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Snake	Skalski, J.R. 1998. Estimating season-wide survival rates of outmigrating salmon smolt in the Snake River, Washington. Can. J. Fish. Aquat. Sci. 55:761-769.
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John Day	Tait, C.K., J.L. Li, G.A. Lamberti, T.N. Pearsons, and H.W. Li. 1994. Influences of riparian cover on benthic community structure in high desert streams. Journal of the North American Benthological Society 13:45-56.
John Day	Torgersen, C.E., D.M. Price, B.A. McIntosh, and H.W. Li. 1995. Thermal refugia and chinook salmon habitat in Oregon: applications of airborne thermal videography. Pages 167-171, *in* Proceedings of the 15th Biennial Workshop on Videography and Color Photography in Resource Assessment. American Society for Photogrammetry and Remote Sensing, Department of Geography, Geology and Anthropology, Indiana State University, Terre Haute, Indiana, ID.
John Day	Torgersen, C.E., D. Price, H.W. Li and B.A. McIntosh. 1999. Multiscale thermal refugia and stream habitat associations of chinook salmon in northeastern Oregon. Ecological Applications (*In Press)*.
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Columbia Basin	Wissmar, R.C., J.E. Smith, B.A. McIntosh, H.W. Li, G.H. Reeves, and J.R. Sedell. 1994. Ecological health of river basins in forested regions of eastern Washington and Oregon. Northwest Science 68:1-35.

PART II - NARRATIVE

Section 7. Abstract

We propose a novel approach to rapid determination of carrying capacities of catchment basins for anadromous salmonids. This comprises linking the following elements (1) remote sensed inventory of habitat quality features, (2) estimating population densities for different habitat categories, and (3)

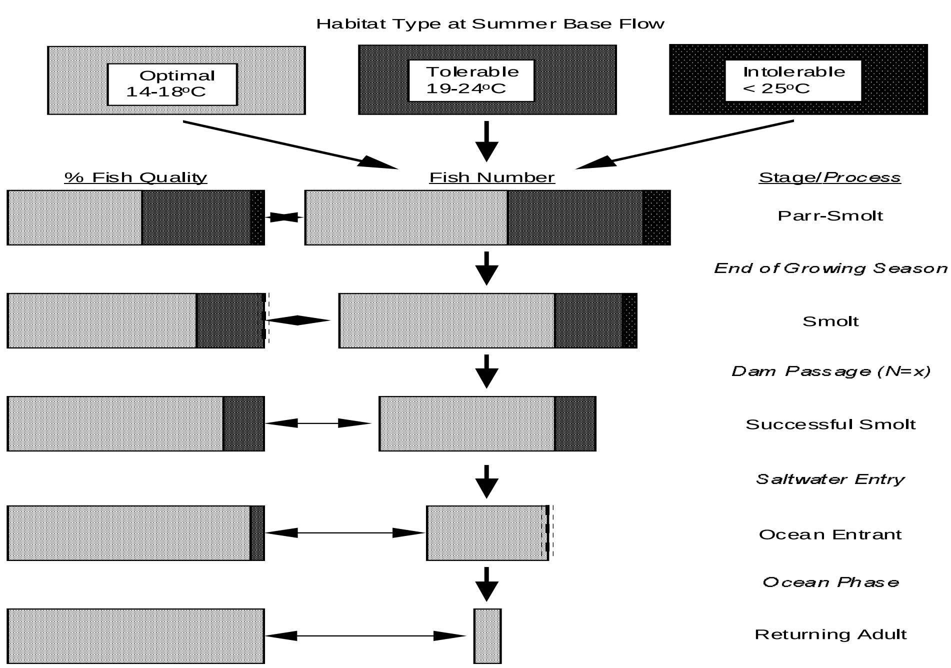
determining the physical fitness of fishes produced by different habitats rated by type and class. We propose that survival to the smolt stage and beyond is ultimately a product of its physical fitness which is determined not only by genetics, but by its rearing environment. Although, we will be developing this approach by examining the ecology and biology influencing smolt production in freshwater, we suggest that estimates of salmonid production from remotely sensed data will be at least as precise and as accurate as that developed from Hankin and Reeves Surveys for a fraction of the cost. The premises are that (1) optimal, tolerable, and intolerable habitats can be determined from physiological criteria and fish population densities estimated in the field. (2) we can determine the amounts of habitat in each class by remote sensing, and (3) the potential carrying capacity of each basin can be determined by summing the quantitities of habitat available by type. GIS software will be used to store and analyzed spatially explicit data. Development of the approach will be ground truthed and calibrated. We will compare factors limiting salmonid carrying capacity of the of the Grande Ronde and John Day basins and determine the utility of this approach for other systems.

Section 8. Project description

a. Technical and/or scientific background

The ability to identify the salmonid carrying capacities of watersheds in the Columbia Basin is critical to the mission Columbia River Fish and Wildlife Program (NWPPC 1994). It is especially important that it can be done rapidly so that restoration efforts can be effectively implemented and monitored. Defining carrying capacities for subbasins is not a new idea; the Subbasin Planning concept was an early attempt using traditional population models. Unfortunately, the data demands were unrealistically demanding and effort needed to realistically reflect field conditions was too onerous. The Hankin and Reeves (1988) survey was a welcome advance, but it too, is time consuming and costly and may lack the precision for monitoring (Gordon Reeves, pers. comm.). W e propose a new approach to indexing the carrying capacities of Columbia Basin watersheds that links remotely sensed, geographically registered, images to physiological processes influencing the growth and survival of salmonids. Our major premise is that habitat quality affects salmonid production in two ways the number of fish produced and the physical fitness of each individual. Our minor premises are that (1) we can rank the quality of a specific habitat by using (a) both clinical indicators of physical fitness, and (b) demographic parameters; (2) we can detect a signature from the habitat that is highly correlated with physical fitness. (3) Based upon this relationship stream productivity for salmonids can be estimated by quantifying the amount of habitat in various categories. If we consider a mean fecundity of 8,000 eggs per female chinook, maintaining such a population would require a lifelong survival rate of 0.025%. We suggest that this survival rate may be largely determined by physically fit fishes produced in optimal habitats which are unfortunately in short supply (Figure 1).

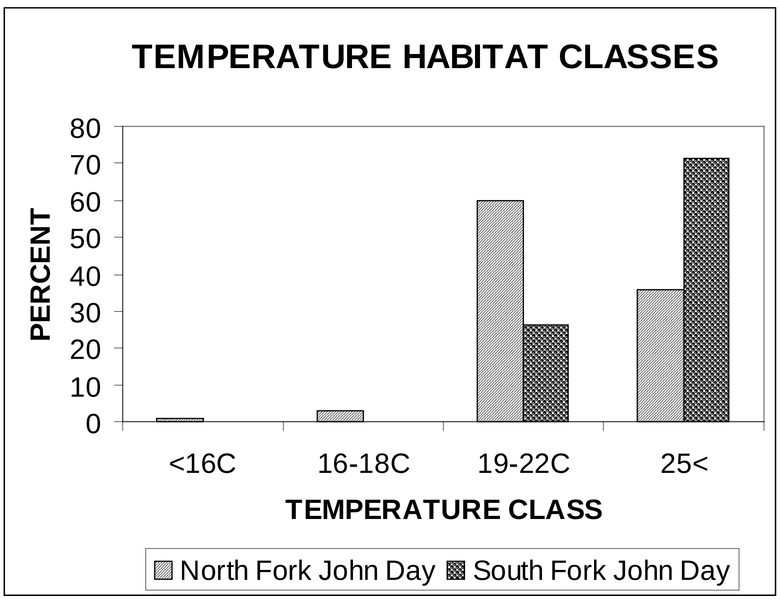
Figure 1



We propose that (1) aerial infrared videography capturing continuous spatial distributions of stream temperature during summer base flow can index carrying capacity, at least in the high deserts of the eastside, which roughly comprises 75% of the Columbia Basin. (2) We can classify the number of stream miles (or area) into habitat quality based upon physiological tolerances of salmon and trout. For example most salmonids have an optimal temperature range of 14 - 18°C, 19 -24°C is marginal, but tolerable and 25°C < is intolerable, above the upper incipient lethal temperature. (3) We suggest that habitat quality affects physical fitness and in turn affects survival. (4) Therefore differences in survival will be correlated with habitat quality.

The application of this approach is that carrying capacities of different watersheds can be rapidly determined and a host of questions can be posed. For instance, the Figure 2 describes a comparative study of habitats from a wilderness stream, North Fork John Day River (NFJD) vs. the Middle Fork John Day River (MFJD), a catchment basin which is intensively grazed. Not surprisingly, the relative carrying capacity for adult spring chinook salmon in the NFJD is nearly double that of the MFJD (35 adults/km vs. 18 adults/km—Li et al. 1998). The critical components for this approach have already been developed. What is required is connecting the components comprehensively.

Figure 2

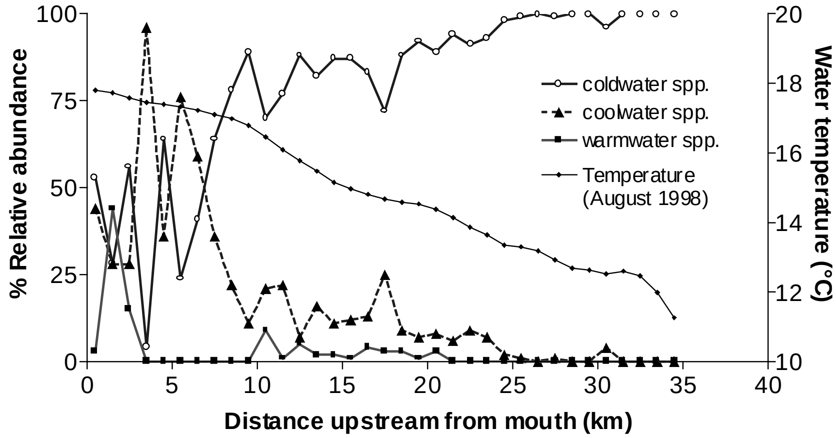


We have developed the capability of remotely sensed technology are to capture data that define the carrying capacity for native salmonids in the Blue Mountain Ecoregion (Torgersen et al. 1995, Torgersen et al. 1999). Our research has shown that it is possible to trace physical fitness levels of hatchery salmonids to their rearing environments,*e.g.,* rearing densities, water quality, hatchery handling procedures (Maule *et al*., 1988a; Barton and Schreck, 1987a,b; Schreck *et al*., 1991), migration environments, *e.g.,* stress and dam passage, barged vs. swimming smolts (Maule *et al*., 1988b), and through time and size of release studies that fish condition translates into greater survival and return of adults.

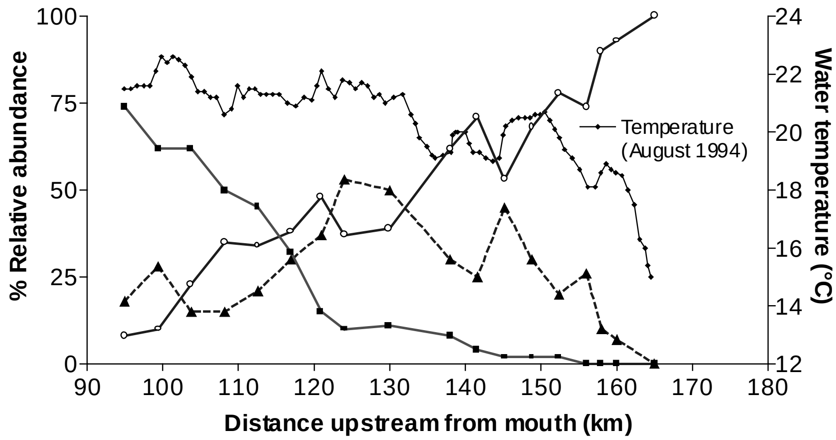
Remotely sensed indicators of habitat quality and salmonid carrying capacity: During the past 5 years, we have used the combination of imagery from forward-looking infrared (FLIR) and true-color videography and radio tracking techniques to examine habitat selection by adult spring chinook salmon in 7 river basins in the Blue Mountain ecoregions of northeastern Oregon. We captured FLIR and true-color

Figure 3

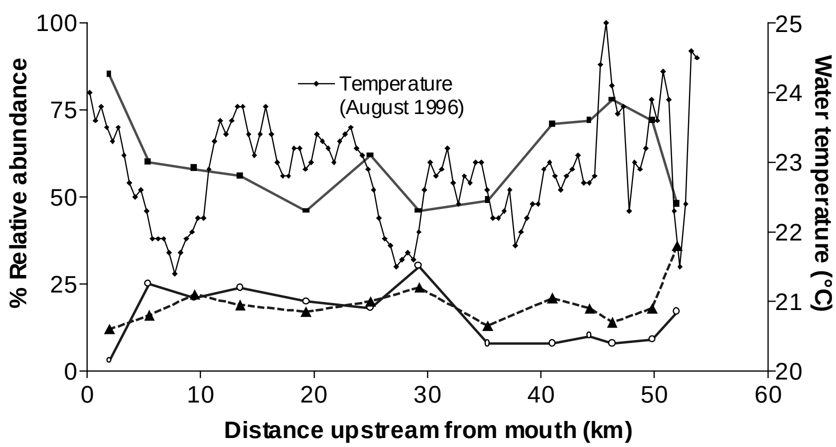
Fish distribution in the Wenaha River
August 1998



Fish distribution in the North Fork John Day River
August 1997



Fish distribution in the Middle Fork John Day River
August 1996



images over expanses of stream up to 70 km in length within each drainage and followed radio-tagged, migrating salmon up to 300 km of river reach . Fish were followed for 8-12 weeks and supplemental observations were conducted using snorkeling techniques (Price 1998).

The results of our previous research suggest that stream temperature is a good index for salmonid carrying capacity because of its physiological effects on fish (Li *et al* 1994) and effects on the trophic dynamics and food web structure on trout/salmon streams (Tait *et al*. 1994). We found that adult spring chinook salmon elected to hold in coldwater refugia and deep, cold pools in the warmer, resource exploited watershed of the Middle Fork John Day ($P< 0.01$). Whereas, temperature was an insignificant factor ($P < 0.30$) in habitat choice in the cooler, wilderness reaches of the North Fork John Day and a wider range of habitats were utilized (Torgersen et al., 1999). Our research suggests that temperature reflects or is partially correlated with several ecosystem functions governing of carrying capacity of the normative river, *vis-a-vis,*.(ISG 1996). Longitudinal temperature patterns of streams taken during summer base flow suggest underlying causes of the distribution and community structure of stream fishes (Li et al. 1998). For instance, the Wenaha, the Middle Fork John Day, the North Fork John Day Catchment Basins have different longitudinal temperature patterns (Figure 3). The Wenaha pattern best represents the normative condition, being gradual, smooth and nearly linear. The pattern in the NFJD resembles a positive, but ragged assymptotic function. MFJD exhibits a very ragged, non-linear pattern. Interestingly, the Wenaha is the watershed in the best condition, that of the NFJD is intermediate and the MFJD represents a catchment basins that suffers from intensive live stock grazing and timber harvest. Note that the longitudinal faunal patterns reflect the thermal patterns of each catchment basin. The coldwater species (salmonids) in both the Wenaha and NFJD are always dominant. The difference between these two drainages is that coolwater fishes decline faster in the NFJD, the coolwater species (sculpins, mountain sucker, mountain whitefish) peak in the middle reaches of the NFJD in contrast to the Wenaha where they peak near the lower reaches. Warmwater fishes (exotic game fishes, native cyprinids, and most catostomids) are nearly absent in the Wenaha, and rise gradually downstream in the NFJD. Warmwater fishes are always dominant in the MFJD. The relative percentages of warmwater species rises and falls with temperature. Both coolwater and coldwater fishes have patterns of abundance inversely related to warmwater species.

Physiological Indicators of Physical Fitness: Relatively few fish survive to successfully spawn in their natal stream; the cliché is that the fittest survived. We advance the notion that relatively few habitats produce the lion's share of fish production. This stems from notion that very fit individuals are larger, faster and physically more resilient and that physical fitness of a fish results from its cumulative environmental history (Patino *et al*., 1986; Schreck and Li 1991). This is far from a new idea, much of the research in the aquacultural field is directly concerned with this idea (*e.g*., Patino *et al*., 1986**)** but, there are no similar studies of wild salmonids reared in the Columbia Basin. A recent pilot study suggests that such studies will provide important information for management. We found that rainbow trout captured from cold stream reaches (maximum temperature 19^{o}C) have high fat content, high condition index, full stomachs; whereas fish from warm reaches (maximum temperature 24^{o}C) were lean, skinny, and had empty stomachs (Rodnick and Li, unpublished data). We speculate that the fish from cold reaches are better prepared to cope with stress, diseases, to overwinter, to migrate and to endure multiple dam passages.

Elevated stream temperatures may be stressful (Barton and Schreck, 1987a). They are exposed to greater infection because disease virulence increases (Becker and Fugihara 1978**)**. Moreover, recent studies have shown that a number of immune functions of fish (fish quality) are suppressed by chronic exposure (weeks) to crowding or other stressors (Maule *et al*., 1988a; Pickering 1993, Schreck *et al*., 1991). Stress elevates metabolic rates and can affect growth rates of individuals (Barton and Schreck, 1987b)). Dam passage is also stressful, although modifications to the passage system can reduce the stress imposed (Maule *et al*., 1988). The stress of passage is more an accumulation of acute events rather than a chronic one. Effects of acute stress (seconds to minutes) are more equivocal than chronic stress, resulting in transient decreases or increases in immune function or disease resistance at various intervals after exposure to a single acute stressor (Maule *et al*., 1988b). Activation of chronic diseases (e.g., bacterial kidney disease) by stress or increased susceptibility to new pathogens encountered during downstream migration could be a major cause of mortality for juvenile chinook salmon during early marine life. Cumulative stress effects, in concert with slowed migration through reservoirs, could also deplete energy reserves needed by smolts for acclimation to the marine environment. Stress could also adversely affect the integrity of cell membranes and the function of ion-transport mechanisms, thereby compromising hypo-osmoregulatory ability in seawater (Specker and Schreck, 1980)**.**

Application and Test Case: The relative role of dam impacts vs. watershed conditions on the decline of salmon has been a point of controversy for the past 30 years. It has remained controversial because we were technically unable to handle a problem of this scope. With the advent of remote sensing, GIS, PIT tags and advances in clinical physiology, the task is now possible. Ideally, the tests should be conducted on similar watersheds within the same ecoregion; however, intensity of land use may different leading to differences in watershed health. Moreover, in the ideal test case, migrating salmon should be forced to negotiate more dams to one catchment basin than the other. We believe that we have two such watersheds in the Blue Mountain Ecoregion: the John Day basin vs. the Grande Ronde basin. The two catchment basins are literally on opposite sides of the same mountain. The John Day basins supports one of the strongest runs of wild spring chinook salmon in the Columbia Drainage, with escapements ranging from 1,000-2,500 fish annually (Oregon Water Resources Department 1986). Wild spring chinook are a federally listed threatened species in the Grand Ronde and escapement in recent years have been measured in hundreds rather than in the thousands (Jeff Zakel, ODFW, personal communication).

What might account for these differences? One explanation is that the survival rates of smolts migrating to the ocean from the Grande Ronde and John Day basins are of the John Day Basin range from 32%-35% vs. 65-68%, respectively based upon the estimates of Skalski (1998). We presume that significant differences also affects adult escapement. Another explanation is that the basins differ with respect to the quality and quantity of habitat. The John Day Basin is about twice as big as the Grande Ronde and so one might expect it to be more productive, but not by an order of magnitude. Each basin contains two wilderness rivers, and each basin is subjected to similar natural and human disturbances (Hanson 1987). However, arguably, the Grande Ronde watershed may be in better shape than the John Day. Bull trout (*Salvelinus confluentus)* are rare in the John Day Basin (Ratliff and Howell 1992), but relatively common in the Grande Ronde. Three of the eight bull trout strongholds on the eastside are found in the Grande Ronde drainage. Bull trouts are resident freshwater salmonids and are the most sensitive salmonid species to habitat quality (Howell and Buchanan 1992). This evidence suggests that the Grande Ronde may be tremendously under-seeded. We can address this controversy through a comparative examination of the quality and quantity of salmonid habitat in each drainage in light of studies of migration survival in the Columbia Basin.

b. Rationale and significance to Regional Programs

The recommended breaching of the four Snake River Dams by Drs. Carl Walters, Steve Carpenter, Jeremy Collie and Saul Saila, is controversial. Our study will provide critical information from which to decide management policy concerning this recommendation. Our work also fulfils the need to evaluate carrying capacity of habitats as described by the Columbia River Basin Fish and Wildlife program (NPPC 1994), to examine normative processes of watersheds and catchment basins (ISG 1995), and to examine mechanisms necessary for the understanding of habitat restoration (National Resource Council 1996 **).** The study areas have ESA listed species or candidates for listing.

c. Relationships to other projects

We are basing this prosed research on the extensive FLIR data bases we have accumulated in the following basins: South Fork John Day (1996), Middle Fork John Day (1994-1998), North Fork John Day (1994-1998), Upper Grande Ronde (1994), Wenaha (1998). This work was funded jointly by the Confederated Tribes of Warm Springs, ODFW, U.S.D.A. Forest Service, and through an EPA/NSF watershed grant. Our policy is that our data bases are available to all cooperators at cost (e.g., disks, printing). For instance, we have made our files available for lamprey researchers (BRD substation at Cook, WA and the Confederated Tribes of the Umatilla Indian Reservation for work on defining the carrying capacity and habitat relationships of the Pacific lamprey (*Lampetra tridentata).* We share all our results with cooperators through seminars and annual reports. We are providing FLIR data for the BPA funded project on bull trout (*Salvelinus confluentus)* in northeastern Oregon supervised by David Buchanan (ODFW). We are working cooperatively with Richard Carmichael's group (ODFW) with respect to testing for differences in physical fitness between wild and hatchery fishes in the Looking Glass in the Grande Ronde Basin. This also provides a very different, but complementary perspective to the work to assess fish quality in the mainstem Columbia River by Jim Congleton (University of Idaho), ourselves, and that of our cooperators, Ron Pascho and diane Elliott of the Western Fisheries Science Center (BRD) in Seattle. It also complements the work we have done comparing stress of dam passage (barging vs. fish passage ways) funded by the U.S. Army Corps of Engineers.

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

Not Applicable

e. Proposal objectives

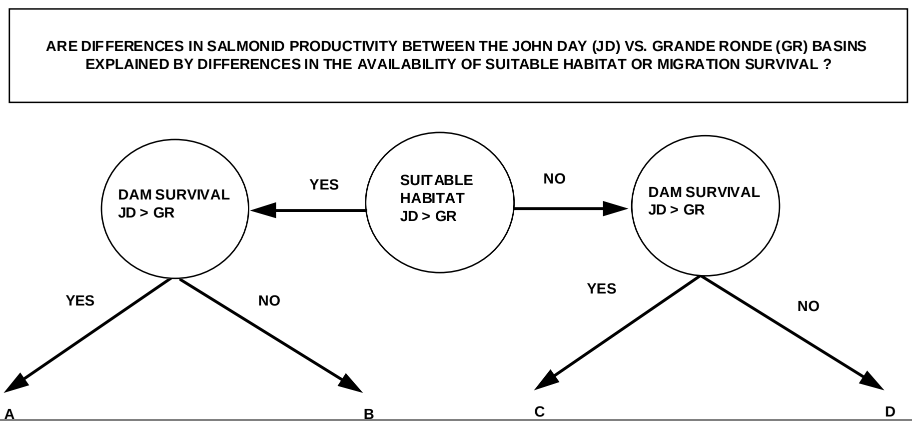
The working hypotheses are displayed in both outline form and in decision trees below.

I. Determine whether or not the carrying capacities for spring chinook salmon and inland rainbow trout of the John Day and Grande Ronde basins are similar.
   - A. Collect thermal and truce color images of the John Day and Grande Ronde catchments. Classify and quantify habitats into types based on established criteria for thermal tolerances of salmonids.
   - <u>B.</u> Determine from clinical indicators of physical fitness whether or not Grande Ronde spring chinook juveniles are healthier than those from the John Day <u>at the end of the growing season</u> (Following smolts survival from specific habitat types from different basins warrants a full blown PIT tagging effort and expensive sampling equipment, *i.e.* screw traps. This proposal covers the first stage.)
     1. Determine if health/condition of spring chinook is correlated with habitat type in both river systems.
     2. Determine whether the correlation between health/condition and habitat type in spring chinook differs between the two river systems.
   - C. Determine the average densities of juvenile salmonids from each thermal habitat type.
     1. Determine if they are correlated with temperature.
     2. Determine if they are correlated with health status.
     3. Determine if the correlations are similar between watersheds.
   - D. Conduct correlations of thermal habitat types to stream features of stream sinuosity, expanse of riparian vegetation and type, volume of large woody debris, and the frequency of large pools.
   - E. Calibrate techniques for population censuses and clinical indicators of physical fitness.

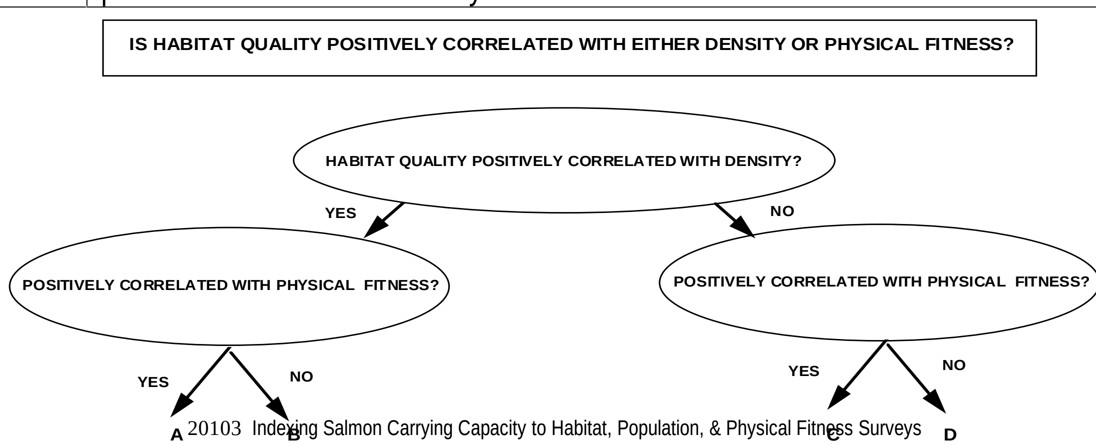
1. Use mark and recapture techniques to compare electrofishing efficiency vs. observational estimates using snorkeling techniques.
2. Compare effects of temperature in laboratory environments using hatchery vs. wild salmon from the Looking Glass in the Grande Ronde Basin.

II. Determine from PIT tagging data available on the Stream Net Web site, whether or not survival rates to Bonneville Dam are similar for salmonids migrating down through 8 dams versus those that migrate through fewer dams.
   A. Compare rates from different basins
   B. Compare rates over different years.

III. Given the results of objectives I and II, determine whether or not the differences in productivity of anadromous salmonids between the Grande Ronde and John Day basins appear to be due more to differences in the quality and quantity of habitat or to differential survival through 3 vs. 8 dams.



Outcome	Potential Conclusion
A	The John Day has more suitable habitat (see relationship to physical fitness of fish below) and its smolts have greater survival rates to Bonneville Dam (as inferred from proxy data, there are no data for migration survival of John Day smolts).
B	The John Day has more suitable habitat (see relationship to physical fitness of fish below), but its smolts have no greater survival rate to Bonneville Dam (as inferred from proxy data, there are no data for migration survival of John Day smolts).
C	The amount of suitable habitat is no greater in the John Day in relation to the Grande Ronde Basin, but its smolts have greater survival rates to Bonneville Dam (as inferred from proxy data, there are no data for migration survival of John Day smolts).
D	Neither available habitat nor smolt migration survival rates explains the greater salmonid production rates of the John Day in relation to the Grande Ronde basin.



Outcome	Potential Conclusion
A	Habitat quality is positively correlated with both fish density and physical fitness
B	Habitat quality is positively correlated with fish density, but not physical fitness
C	Habitat quality is positively correlated with physical fitness but not fish density
D	Habitat quality is not positively correlated with fish density or physical fitness

f. Methods

Testing for Differences in Habitat Availability: FLIR videography provides a continuous thermal maps of stream habitat of both basins that will be stored as GIS files in ArcInfo™. Procedures for ground truthing and data gathering will follow the procedures of Torgersen et al. (1999). GIS will be used to coordinate geographically specified data bases. ArcInfo™ software will be used to classify and quantify the amount of habitat falling into 4 temperature classes for spring chinook salmon (Armour 1991): (1) optimal (14-16^{o}C), (2) Oregon Mandated Standard (16-17.8^{o}C), physically tolerable (18-24^{o}C), and lethal (25^{o} C $\leq$). Kolmogorov-Smirnoff tests will be used to examine for differences in distribution. Other indices of habitat quality can be detected using remote sensing via true-color videography which is simultaneously recorded on FLIR surveys. Georeferenced images will provide data on (1) stream sinuosity, (2) number of large woody debris jams, and (3) frequency of large pools. Estimates of the number of pools 1 m deep <, substrate embeddedness, and volumes of large woody debris will be obtained from the survey data base maintained at the USFS-PNW Laboratory at Oregon State University. We will use one-tailed, paired t-tests to compare watersheds for each variable. Methods of Barton et al. (198) will be used to measure cumulative influences of the upstream riparian zone. As described above,

Correlation of Habitat Quality to Fish Density: We will use a nested ANOVA to test for differences in fish density between basins. Basins form the 1st strata and the temperature-based habitat classes will form the 2nd. We will use discriminant function analysis (DFA) to determine whether stream indices obtained by true color videography are characteristics that help discriminate among temperature-based habitat classes. If so, this helps to corroborate our assertion that temperature is a good surrogate for habitat quality in general.

Calibration of Fish Density Estimates: Fish sampling in streams is necessarily confined to spatial scales between habitats and short reaches. We need to express fish abundances that are (1) independent of sampling gear and local habitat influences on capture efficiency, and (2) that can be aggregated across watershed scales. Given that population estimates from all reaches that need to be sampled to account for spatial variation would be prohibitively expensive, a prerequisite for abundance estimation on the scale required is the ability to predict the probability of capture or observation.

There are still significant and wide differences in capture efficiencies among sizes of individual fish, local environmental conditions, and some taxonomic groups (Bayley et al. 1989; Bayley and Dowling 1990; Rodgers et al. 1992; Bayley and Dowling 1993). However, the efficiencies of corresponding taxa in comparable habitats in different watersheds can be indistinguishable given a consistent sampling protocol. Therefore, data will be tested with previous model predictions in similar environments to provide more robust estimates from combined models where feasible.

We shall apply standardized sampling methods within ranges of environmental conditions encountered in wadeable streams in the region. We shall use calibration approaches adapted for stream work (Bayley et al. 1989; Bayley and Dowling 1990; Bayley and Dowling 1993; Peterson 1996). The essence of this approach is to fish a closed area using a procedure mimicking a standardized protocol, called the primary method. Closure will often require heavily anchored block nets of 6-mm-diagonal mesh

upstream and downstream when riffles are not sufficiently shallow. One or two calibration procedures, A and B, will be used, depending on local conditions, availability of marked fish, and current rulings on takes:
Procedure A: Marked fish from the primary method will be released into the enclosure. A secondary method, comprising an intense combination of gears independent of the primary method, will yield marked and unmarked fish. The proportion of marked fish recovered will determine the original number of fish (N) vulnerable to capture by the primary method:

$$\text{abundance} = N = R_U/(R_M/M) + P$$

where P = number of fish caught by primary method,
M = number of marked fish released,
R_M = number of marked fish caught by secondary method , and
R_U = number of unmarked fish caught by secondary method.

In order that marked fish can be presumed to behave similarly to unmarked fish during the secondary method, gentle but fast handling and marking of fish is critical (Bayley and Dowling 1993; Peterson 1996). Fish, which are never removed from water during the whole process, will be marked by an oblique caudal fin clip that can subsequently be recognized but is not so extreme as to prevent normal swimming behavior. Released marked fish will be returned to their habitats between the block nets and allowed 20-30 minutes to adjust to their normal behavior before implementing the secondary method. The capture efficiency of the primary sampling method, q = C/N, where C=catch of the species and length group concerned.
Procedure B: A variation of Procedure A (Peterson 1996) is direct but depends on marked fish only. Fish for marking are first collected, using a sampling method different from the primary method so that marked fish are not a biased sample of individuals that would be vulnerable to the effects of the same gear. The primary method is then applied inside a closed reach where the marked fish have been released. Fig. 3 shows a comparison between procedure B in the Ozarks and A in Illinois. If the combination of secondary gears in Procedure A produces inadequate quantities of recaptured fish in some calibration situations, Procedure B will be employed.

Analysis: Explanatory variables will measured that might affect capture efficiency and potentially improve its prediction. These include stream width, depth, physical cover, substrate type, temperature, turbidity, electrical conductance, and velocity. Subsets of these variables are expected to be significant and will subsequently be included in logistic-linear predictive models using GLIM (Generalized Linear Interactive Modeling) (Payne 1987). A general form of the model (McCullagh and Nelder 1989) is

$$\log_e\{q/(1-q)\} = ß_0 + ß_1 x_1 + ß_2 x_2 + ... \qquad (1)$$

where q is efficiency, x_i are explanatory variables, and $ß_i$ are corresponding coefficients. Extra-binomial variance (Williams 1982)) is anticipated and will be incorporated (Bayley 1993).
Correlating Physical Fitness to Habitat Quality: Physical fitness of juvenile salmonids will be determined by indices which reflect growth, its correlate, metabolism and general health. Fishes will be sampled from optimal, tolerable, and intolerable habitats identified grounds within the Grande Ronde and John Day River basins. Whenever possible we will sample non-lethally, but we reserve the option to lethally sample small numbers of fishes in order to increase the resolution of the results where necessary (this will be performed on the comparison of wild vs. hatchery spring chinook salmon from the Looking Glass drainage, a program already in effect). Sampling will consist of humanely killing the fish in a lethal anesthetic overdose and obtaining blood, gills, kidneys, livers and carcasses. Non-lethal physiological indices examined would include: (1) Plasma cortisol (measurement of stress); (2) Triglycerides (an indicator of lipid metabolism); (3) Evaluation of red blood cell membrane to peroxidative lysis (stress/diet interaction); (4) Lysozymes (non-specific immune response), and (5) size/condition index. Lethally

obtained physiological indices will provide the following additional information: (1) Lipid, protein, and water content of viscera and eviscerated carcass (measure of utilization of energy reserves); (2) HSP-70 and HSP-90 expressions of environmental stress; (3) Liver IGF-I mRNA (Instantaneous growth rates); (4) Evaluation of red blood cell membrane to peroxidative lysis (stress/diet interaction); (5) Bacterial kidney disease; (BKD); and (6) Goedde index.

Plasma cortisol concentrations are a useful means of assessing the presence of stress and will be measured by radioimmunoassy (Foster and Dunn, 1974) as modified for use with salmonid plasma (Redding *et al*., 1984). Heat shock protein induction has been utilized as an indicator of environmental stress in fish and specifically in salmonids (Triebskorn *et al*.,1997; Vijayan *et al*.,1998; Williams *et al*.,1996). The expression of heat shock proteins (HSP-70, HSP-90) will be measured by enzyme-linked immunosorbent assay in kidney and liver as described by Forsyth *et al*. (1997). IGF-I is involved in the endocrine regulation of growth in many fish (Peter and Marchant, 1995). Liver samples will be analyzed for IGF-I mRNA using a solution hybridization/ribonuclease (RNase) protection assay following the procedure developed by Duan *et al*. (1993). Plasma glucose, triglyceride, cholesterol, chloride, sodium, potassium, and calcium will be determined by use of a Dupont Dimension model AR-1MT autoanalyzer. Muscle and visceral lipid will be extracted by the method of Foch *et al*. (1957) and the quantity determined by the method of Frings *et al*. (1972). Lysozymes constitute one of the primary infection-defense systems of fish as part of a non-specific immunity and will be assayed according to Litwack's method (1955), modified by Sankaran and Gurnani (1972). Sample sizes will consist of fifteen fish per habitat per basin. Each habitat/basin will be sampled in three replicates. Therefore, total number of fish sampled will be 15 fish X 3 habitat types X 3 replicates = 135 fish per basin. Since the fish of concern within the Grande Ronde Basin are protected under the ESA, the sampling methods and design are dependent on allowable "takes". The number and type of physiological indices examined will be modified (see below) such that sampling will be conducted non-lethally if dictated by permit. Field sampling will be conducted from August through October of each year.

Statistical Justification: The number of samples should allow us to detect a 10ng/ml difference in cortisol. Recent work suggests that these sample sizes are sufficient for lysozyme analysis as well. Based on sampling of fish for determination of stress and clinical indices in previous years, we have found that a sample size of 15 fish will be adequate for detection of between-sample differences of 15 to 20% with a power of 0.75 ($P_\alpha \leq 0.05$). The power of this test is lower than the usually preferred criterion of 0.8, but the power of the more important tests for differences between sampling sites (habitats) within a basin (N = 45 for all dates combined) and between basins (N = 45) will be > 0.8.

Method of Analysis: Factorial analysis of variance (ANOVA) will be used to test for differences in physiological indices among habitat types and between basins. The residual mean square will be used as an error term and effects will be considered significant at $P_\alpha \leq 0.05$. In cases of significance, means may be compared pairwise by Fisher's Protected Least Significance Difference Test with the significance level at $P_\alpha \leq 0.05$.

Limitations: Our ability to collect fish may be limited by either fish availability or weather-related events such as floods. The number and scope of physiological indices examined is conditional on the type of sampling allowed under ESA guidelines and may be reduced if non-lethal sampling is necessary. If flow and temperature conditions influencing habitat conditions differ between years, comparison of results between years will resolve some uncertainty about the effects of inter-annual variation.

Testing for Mortality Associated with Dams and Dam Passage: We will use the data available in the Columbia Basin Dart Files on the internet and communicate with researchers such as John Skalski, University of Washington and Danny Lee, U.C. Davis.

g. Facilities and equipment

Computers: 10 Pentium PC personal computers, 3 McIntosh 8100 computers, 4 printers, scanner, 2 data servers and complete connection to email and the internet.
GIS: A complete GIS laboratory, including diitizers, work stations, ArcView, ArcInfo, and frame grabbing GIS software, GPS units and digital video cameras
Software: Word, WordPerfect word processors, Excel and quatrop-pro spreadsheets; SAS, Statgraphics and BMDP statistical packages, Mathcad and Stella modeling software; Powerpoint and Visio graphical software, Procite and Absearch bibliographic software.
Field Equipment: 3 travel trailers, flow meters, 40 temperature loggers, snorkeling gear, electrofishers, underwater cameras, 3 field vehicles, boats, gps units, field kits for physiological assays.
Clinical Laboratory: Fully equipped laboratory: centrifuges, Wild and Zeis microscopes, analytical scales, automatic pipetters, RIA analyzers, ultracold freezers, refrigerators, fish holding facilities at Smith Farm Experimental Fish Facility.
University Facilities: The university provides offices, laboratory space, communications photocopying, accounting, secretarial and library services.

h. Budget

Hiram W. Li
Budget Justification

Salaries and Fringe Benefits

Year 1	Year 2	Year 3
$158,542	**$168,489**	**$173,839**
44% of budget	**45% of budget**	**44% of budget**

PI: Hiram W. Li , Fisheries and Wildlife	Fish Ecology, No cost , 0.10 FTE
PI: Carl Schreck, Fisheries and Wildlife	Fish Physiology, No cost, 0.05 FTE
PI: Peter Bayley, Fisheries and Wildlife	Population Estimation, 0.15 FTE
FRA: Tom Stahl, Fisheries and Wildlife	Project leader: fish physiology, 0.25 FTE
Fish culturist: Rob Chitwood, Fisheries & Wildlife	Rearing and health care of Looking Glass Creek spring chinook salmon at Smith Farm Experimental Fish Facility
RA: Bruce McIntosh, FSL	Landscape Ecology, 0.27 FTE
FRA: Russ Faux, FSL	GIS technician, 0.5 FTE
GRA: 3 students, 1 per PI	0.5 FTE

Field work will be extensive: Hiram W. Li will be in charge of the fish surveys. Peter Bayley will work with Li and McIntosh to set up the sampling strategy and calibrate survey accuracy, as well as work with the fish tagging data base. Bruce McIntosh is in charge of collecting and analyzing the remotely gathered images taken from helicopter surveys. Russ Faux will convert the images to GIS data bases. Carl Schreck will oversee the physiological work, but Tom Stahl will carry out the field duties to determine physical fitness of fishes. Rob Chitwood will maintain and care for fishes brought into the Smith Farm Experimental Fish Facility for experimental work in a laboratory setting. 4% inflation was incorporated for succeeding years.

Graduate students will help on aspects of the research as assigned by their major professors.

Domestic Travel

Year 1	Year 2	Year 3
$16,500	$17,160	$17,846
5% of budget	5% of budget	5% of budget

Study sites range from 350-550 miles from campus and much time will be spent in the field. Included in the travel costs are 1 national meeting a year per PI.

Tuition

Year 1	Year 2	Year 3
$17,190	$18,054	$18,954
5% of budget	5% of budge	5% of budget

Tuition is for 3 quarters of the academic year and is set by O.S.U. We requested 3 graduate students for the project.

Supplies:

Year 1	Year 2	Year 3
$29,100	$30,264	$31,474.56
8% of budget	8% of budget	8% of budget

GIS supplies are roughly $1K per year. Fish Ecology is $6K for the first year to build an electric seine and for routine supplies, $4k per year thereafter. The remainder will be used by the physiologists for reagents, chemicals and assay supplies.

Subcontract:

Year 1	Year 2	Year 3
$55,000	$57,200	$59,488
15% of budget	15% of budget	15% of budget

The subcontract is for Snowy Butte Helicopters, INC. They are the only company capable of handling FLIR work for stream surveys. It is their specialty. The costs include ferrying the helicopter to and from the site, per diem, air time for collecting the imagery and for image collection and processing.

Indirect Costs:

Year 1	Year 2	Year 3
$87,022	$85,729	$89,204

Oregon State University sets the Indirect costs according to national standards and agreements with specific agencies. They are percentages of the total costs less tuition and for the first $25,000 of subcontracts. The percentages are 26% for FSL and 43% for Fisheries and Wildlife.

Section 9. Key personnel

CURRICULUM VITAE

HIRAM W. LI,
Aquatic/Fisheries Ecologist
Professor and Assistant Leader
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Department of Fisheries and Wildlife
Oregon State University, Corvallis OR 97331-3801.
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EDUCATION: A.B. - Zoology, University of California, Berkeley, 1966; **M.S. - Fishery and Wildlife Biology**, Colorado State University, 1973; **Ph.D.- Ecology,** University of California, Davis, 1973

EXPERIENCE: Professor and Assistant Leader, Oregon Cooperative Fishery Unit, Department of Fisheries and Wildlife, Oregon State University. 1988-Present; **Associate Professor and Assistant Leader**, Oregon Cooperative Fishery Unit, Department of Fisheries and Wildlife, Oregon State University. 1979 to 1988; **Assistant Professor**, Department of Wildlife and Fisheries, University of California, Davis. July 1973 to January 1979.

PROFESSIONAL ACTIVITIES: **Ecology Advisory Panel** for the National Science Foundation 1984-1987; **Associate Editor** for Transactions of the American Fisheries Society 1986-1988; **Foley-Hatfield Congressional Team** on Eastside Forest Health Assessment, 1992-1993; **Referee** for 14 primary journals

HONORS AND AWARDS: Commendation Award, Sport Fishing Institute (1978); **Quality Performance Awards,** U.S. Fish and Wildlife Service (1982, 1989, 1990, 1991); **Director's Research Excellence Award**, U.S. Fish and Wildlife Service (1991); **Special Achievement Award**, U.S. Fish and Wildlife Service (1992, 1993, 1994); **Outstanding Group Achievement Award, American Institute of Fishery Research Biologists** (awarded to the Cooperative Fish and Wildlife Research Units) (1992), **Award of Merit (**Oregon Chapter of the American Fisheries Society)

PUBLICATIONS: 30 refereed papers in Primary Journals, 10 Book Chapters, 30 Technical reports.

FIVE PUBLICATIONS RELATED TO THIS PROPOSAL :

Li, H.W., G.A. Lamberti, T.N. Pearsons, C.K. Tait, J.L. Li. 1994. Cumulative impact of riparian disturbance in small streams of the John Day Basin, Oregon. Transactions of the American Fisheries Society 123(4):627-640.

Bayley, P.B. and H.W. Li. 1992. Riverine Fishes. Chapter 12. Pages 251-281 in P. Calow, G.E. Petts (eds.). The Rivers Handbook, Hydrological and Ecological, Volume 1. Blackwell Scientific.

Tait, C.K., J.L. Li, G.A. Lamberti, T.N. Pearsons, and H.W. Li. 1994. Relationships between riparian cover and the community structure of high desert streams. Journal of the North American Benthological Society 13(1):45-56.

Li, H.W. and J.L. Li. 1996. Fish Community Composition. Pages 391-406 *in* F.R. Hauer and G.A. Lamberti (eds). Methods in stream ecology. Academic Press, N.Y., N.Y.

Torgersen, C.E., D. Price, H.W. Li and B.A. McIntosh. 1999. Multiscale thermal refugia and stream habitat associations of chinook salmon in northeastern Oregon. Ecological Applications (*In Press)*.

CURRICULUM VITAE
BRUCE A. MCINTOSH
FISHERIES/LANDSCAPE ECOLOGY

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Research Associate
Department of Forest Science
Oregon State University, Corvallis OR 97331-3801.

EDUCATION:
B.S. - Wildlife Biology, University of Montana, Missoula, 1982; **M.S. - Forest Ecology**, Oregon State University, Corvallis, 1992; **Ph.D. - Forest Ecology**, Oregon State University, Corvallis, 1995.

EXPERIENCE:
Research Associate, Department of Forest Science, Oregon State University, 1995 - Present; **Research Assistant**, Department of Forest Science, Oregon State University, 1992-1995.

EXPERTISE:
Dr. McIntosh has been conducting research on riverine ecosystems and salmonid habitats in the Columbia River basin for the past nine years. His research has focused on historical changes in riparian and stream habitats, salmonid life history, and the use of remote sensing for stream and riparian research and monitoring. In addition, he has been involved in several assessments of eastside ecosystems for the Federal Government.

FIVE PUBLICATIONS RELATED TO THIS PROPOSAL:

C.E. Torgersen, D.M. Price, B.A. McIntosh, and H.W. Li. *in press*. Multiscale thermal refugia and stream habitat associations of chinook salmon in Northeastern Oregon. Ecological Applications.

Faux, Russell N., B.A. McIntosh, D.J. Norton, and J.R. Sedell. 1998. Thermal remote sensing of water temperature. Annual Report. U.S. Environmental Protection Agency, USDA Forest Service, and Bureau of Land Management. 88 p.

McIntosh, B.A. 1995. Historical changes in stream habitats in the Columbia River basin. Ph.D. dissertation. Corvallis, OR: Oregon State University. 175 pp.

McIntosh, B.A., J.R. Sedell, J.E. Smith, R.C. Wissmar, S.E. Clarke, G.H. Reeves, and L.A. Brown. 1994. Historical changes in fish habitat for select river basins of eastern Oregon and Washington. Northwest Science, 68 (Special Issue):36-53.

Torgerson, C.E., N.J. Poage, M.A. Flood, D.J. Norton, and B.A. McIntosh. 1996. Airborne thermal remote sensing of salmonid habitat for restoration planning in Pacific Northwest watersheds. In: Proceedings of Watershed 96, June 1996, Baltimore, MD. Water Environment Federation.

Carl B. Schreck

Expertise	Research in environmental physiology of fish including stress, health and reproductive quality, and behavior of salmonids. Project management. Publication.	
Current Position	Leader, Oregon Cooperative Fish and Wildlife Research Unit, Biological Resources Division-U.S.G.S., *and* Professor, Dept. of Fisheries and Wildlife, Oregon State University. Corvallis, Oregon	
Education	University of California, Berkeley A.B.-Zoology, 1966	Colorado State University M.S.-Fisheries Science, 1969 Ph.D.-Physiology/Biophysics and Fisheries, 1972

Experience

- 25 years research in Columbia River system on juvenile and adult salmonids in streams, rivers, reservoirs, dams, and estuary
- 30 years research and project management leading to nearly 200 publications
- Editor or editorial board of 5 scientific journals; presently *General and Comparative Endocrinology*, *Diseases of Aquatic Organisms*, and *Aquaculture*
- Formerly Assistant Profssor- Fisheries, Virginia Polytechnic Institute and State University

Recent Publications:

Schreck, C.B., B.L. Olla, and M.W. Davis. 1997. Behavioral responses to stress. p. 745-170. In: G.W. Iwama, J. Sumpter, A.D. Pickering, and C.B. Schreck (eds.). Fish stress and health in aquaculture. Cambridge University Press., Cambridge.

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EXPERIENCE: Associate Professor Department of Fisheries & Wildlife, Oregon State University, 1994- ;
Adjunct Associate Professor, Dep. of Ecology, Ethology, and Evolution, U. of Illinois, 1991- ;
Professional Scientist, Illinois Natural History Survey, 1983-94;
Fisheries Researcher in Brazil (1976-79) Kenya (1972-75), Bolivia (1969-70), Biostatistician consultant in Canada 1975-76.

PROFESSIONAL ACTIVITIES: Editorial board member of Fisheries Management and Ecology (Blackwell, UK) 1994- ;
Co-editor for Journal of Freshwater Biology special publication of the First International Workshop on Lowland Stream Restoration, Sweden. 1992.
Illinois River Ecology and Economics Advisory Committee (Illinois Government task force) 1994.
Advisor to fisheries management policy in the Brazilian Amazon, IBAMA, Brasilia, Brazil, 1993.

PUBLICATIONS: 33 refereed papers in primary journals, 13 other refereed publications, 2 book chapters, 31 final technical reports, 70 papers, posters, and seminars presented at conferences and universitiest (inc. 5 plenary presentations, 13 international meetings, 27 invited papers)

FIVE PUBLICATIONS RELATED TO THIS PROPOSAL :

Bayley, P. B. and H. W. Li 1996. Riverine fishes. pp 92-122 in G. E. Petts and P. Calow (Eds.) River Biota: diversity and dynamics. Blackwell Science, Oxford.
Bayley, P. B. 1993. Quasi-likelihood estimation of marked fish recapture. Canadian Journal of Fisheries and Aquatic Sciences 50: 2077-2085.
Bayley, P. B. and L. L. Osborne. 1993. Natural rehabilitation of stream fish populations in an Illinois catchment. Freshwater Biology 29: 295-300.
Bayley, P. B., and D. C. Dowling. 1993. The effect of habitat in biasing fish abundance and species richness estimates when using various sampling methods in streams. Polish Archives in Hydrobiology 40: 5-14.
Bayley, P.B., R.W. Larimore, and D.C. Dowling. 1989. Electric seine as a fish-sampling gear in streams. Trans. Am. Fish. Soc. 118:447-453.

Section 10. Information/technology transfer

We will publish in refereed publications. We will present papers at scientific meetings. We will work with our Sea Grant Extension Agent to desseminate information to watershed councils. We will present our findings in a presentation to NWPPC. We will conduct workshops for watershed councils and agenciessuch as we have done in Prineville, John Day and LaGrande on our research work. We will set up a web page for persons to follow our progress and to download information and data.

Congratulations!