Bonneville Power Administration
Fish and Wildlife Program FY99 Proposal

Section 1. General administrative information

Evaluation of interactions between American shad and salmon in the Columbia River

Bonneville project number, if an ongoing project 9077

Business name of agency, institution or organization requesting funding
U.S. Geological Survey, Biological Resources Division

Business acronym (if appropriate) USGS-BRD

Proposal contact person or principal investigator:

Name	Dennis W. Rondorf
Mailing Address	5501a Cook-Underwood Rd.
City, ST Zip	Cook, WA 98605
Phone	(509) 538-2299 ext.228
Fax	(509) 538-2843
E-mail address	dennis_rondorf@usgs.gov

Subcontractors.

Organization	Mailing Address	City, ST Zip	Contact Name
USFWS	9317 Hwy 99 Suite I	Vancouver, WA 98665	Travis Coley
CRITFC	729 N.E. Oregon Suite 200	Portland, OR 97232	Tom Backman

NPPC Program Measure Number(s) which this project addresses.

5.7 Reduce predation and competition, 5.7A.2 Explore the population ecology of shad..., 5.7B.9 Explore population ecology of shad... adverse interactions with salmonids.... 5.7B.11 ...reduce numbers of shad..., 6.1B.1 Evaluate effects of shad population increases on adult salmon passage at mainstem dams

NMFS Biological Opinion Number(s) which this project addresses.

NMFS BiOp 13.h. The BPA shall investigate the effects of the intensified competition for food resulting from the introduction of non-native species and production of hatchery fish in the Columbia River Basin

Other planning document references.

NMFS Recovery Plan 2.8.b.2 ...control fishes that prey on or compete with juvenile salmonids, 2.8.b.3 ...reduce American shad in the Columbia River

Wy Kan Ush Me Wa Kush Wit section 5, hypotheses 9: Large numbers of shad also impede salmon passage through adult fishways.

Columbia River Fish Management Plan, 1996 All-Species Review, Shad Management Issues: 1) competition between shad and juvenile salmonids for limited food and habitat resources. 2) noncompetitive, but stressful, interactions between shad and salmon, such as disease transmission or migration delay at dam fish passage facilities. 3) inaccurate counts of other concurrently migrating species. 4) contribution of shad to the forage base and ultimately the survival of predators of juvenile salmonids

Subbasin.

Short description.

Assess the interactions between increasing abundance of American shad and declining numbers of salmon relative to competition, salmon predator adundance and the changing ecosystem of the Columbia River.

Section 2. Key words

Mark	Programmatic Categories	Mark	Activities	Mark	Project Types
X	Anadromous fish		Construction		Watershed
	Resident fish		O & M		Biodiversity/genetics
	Wildlife		Production	*	Population dynamics
	Oceans/estuaries	X	Research	X	Ecosystems
	Climate	*	Monitoring/eval.		Flow/survival
	Other	*	Resource mgmt		Fish disease
			Planning/admin.		Supplementation
			Enforcement		Wildlife habitat enhancement/restoration
			Acquisitions		

Other keywords.

ecological interactions, life history, predation, American shad, salmonids, harvest, food web, juvenile salmonids

Section 3. Relationships to other Bonneville projects

Project #	Project title/description	Nature of relationship

Section 4. Objectives, tasks and schedules

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Identify interactions of juvenile American shad with juvenile fall chinook salmon		
		a	Determine spatial and temporal occurrence and abundance of juvenile American shad and juvenile fall chinook salmon
		b	Determine food habits of juvenile American shad and juvenile fall chinook salmon to identify competitive interactions
		c	Determine larval and juvenile American shad effects on food resources of juvenile fall chinook salmon
		d	Develop bioenergetics model to describe juvenile American shad growth and feeding dynamics as related to feeding of juvenile fall chinook
2	Determine role of American shad as supplemental food source contributing to salmonid predator fitness		
		a	Determine importance of juvenile American shad in diet of northern squawfish near hydroelectric facilities
		b	Estimate effect of American shad biomass on growth and fecundity of northern squawfish
3	Describe Columbia River American shad life cycle		
		a	Conduct literature review and

			analyze existing data on American shad
		b	Charactarize adult American shad migration patterns, spawning sites, and spawning habitat requirements
		c	Determine age, growth and fecundity of spawning population of adult American shad
		d	Identify determinates (biotic and abiotic) of year class strength and develop American shad freshwater phase life cycle model
4	Develop methods to control Columbia River American shad population		
		a	Explore harvest methods
		b	Explore biological control methods
		c	Evaluate effects of shad biomass on salmonid passage.

Objective schedules and costs

Objective #	Start Date mm/yyyy	End Date mm/yyyy	Cost %
1	06/1999	12/2003	30
2	06/1999	12/2003	25
3	01/1999	12/2003	30
4	01/1999	12/2003	15

Schedule constraints.

Delayed funding of project would necessitate schedule change

Completion date.
2003

Section 5. Budget

FY99 budget by line item

Item	Note	FY99
Personnel	USGS-BRD, USFWS, CRITFC Combined	234,003
Fringe benefits	Combined	59,865

Supplies, materials, non-expendable property	Combined	20,810
Operations & maintenance	Combined	55,648
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		0
PIT tags	# of tags: 100	290
Travel	Combined	39,960
Indirect costs	Combined	137,058
Subcontracts		0
Other		0
TOTAL	Combined	547,634

Outyear costs

Outyear costs	**FY2000**	**FY01**	**FY02**	**FY03**
Total budget	600,000	650,000	650,000	600,000
O&M as % of total	0	0	0	0

Section 6. Abstract

The increasing abundance of American shad in the Columbia River Basin has prompted concerns about their potential impacts on dwindling salmonid populations. Managers do not know if recent large increases in American shad contribute to declines in chinook salmon or are a response to a changing ecosystem. This study addresses the lack of information on American shad recognized in the NPPC=s Fish and Wildlife Program, the NMFS=s Biological Opinion and Proposed Recovery Plan and the Columbia River Fish Management Plan. Our objectives are to identify the interactions between juvenile American shad and juvenile fall chinook salmon rearing in reservoirs and the estuary, where larval shad may be a food resource for juvenile fall chinook salmon and juvenile shad may be a competitor. We will determine the importance of shad as an abundant prey species which may enable predators such as northern squawfish to increase fecundity and overwinter survival. We will identify the determinates of year class strength of shad and the migration and reproductive patterns of shad to develop potential shad harvest or biological controls.

Section 7. Project description

a. Technical and/or scientific background.

Little knowledge is available on the ecology and population dynamics of American shad in the Columbia River basin. American shad were introduced to the Columbia River in 1871 (Scott and Crossman 1973) and have increased dramatically in recent decades. Prior to 1960 , the annual run of adult shad above Bonneville Dam was usually less than

20,000 (Chapman et al. 1991).   Since 1960, numbers of returning adult American shad passing The Dalles Dam on the Columbia River have increased from 81,000 shad in 1960 to over 4 million in 1990 (2.7 million shad in 1997). Conversely, adult chinook salmon numbers have steadily declined from almost 500,000 in 1960 to approximately 110,000 in 1995 (Williams et al. 1996). During that time, The Dalles dam was completed in 1957 and John Day Dam in 1968, and the Lower Snake River dams were completed in the 1960s and 70s, further modifying the hydrograph.

The increase of American shad and decline of fall chinook salmon may be related directly to changes in habitat or partially to interactions between the two species. The increase in abundance of American shad and decline of fall chinook salmon may reflect the changes in habitat and passage resulting from impoundments and dams built on the Columbia River during the 1950's and 1960's. Both American shad and fall chinook salmon are native to large rivers and juveniles of both rear in riverine habitats.   Several recent reviews of regulated rivers conclude that non-native species, in this case American shad, often increase in abundance as flow regimes become more regulated in rivers and native species such as fall chinook salmon in the Columbia River often decline in abundance (Stanford et al. 1996, Poff et al. 1997). Alternatively, the impoundments of the regulated Columbia River may provide the planktivorous juvenile American shad a competitive advantage over juvenile fall chinook salmon when the juveniles of both species rear in reservoirs.

The high abundance of juvenile shad and diet overlap with juvenile fall chinook salmon indicate a potential competitive interaction. The fecundity of American shad ranges up to 600,000 eggs per female (Scott and Crossman 1973). Adult American shad ascend the Columbia River to spawn from May through July, with most spawning above Bonneville Dam taking place between John Day Dam and the confluence of the Snake and Columbia rivers (Quinn and Adams 1996). In that reach, the presence of high numbers of larval and juvenile American shad coincides with the early August median passage dates of emigrating wild juvenile fall chinook salmon from the Snake River based on PIT tag detections. Furthermore, this spatial and temporal overlap is not limited to the reservoirs. It is estimated that at least 600 million juvenile shad enter the Columbia River estuary annually to feed and grow. This rearing also overlaps with the rearing of juvenile fall chinook salmon (Chapman et al. 1991).

It is well established that planktivorous fishes such as American shad can alter the abundance and size structure of zooplankton resources.   Larval and juvenile American shad are effective planktivores that feed predominantly on crustacean zooplankton (Crecco and Blake 1983). Preliminary studies suggest that juvenile American shad in the Columbia River estuary feed on amphipods, calanoid copepods, cladocerans and insects (Dirkin et al. 1979). Rondorf et al. (1990) found that zooplankton (mostly *Daphnia* spp.) were a primary component of subyearling chinook salmon diets in reservoir habitats. If rearing American shad greatly reduce or alter zooplankton abundance and community structure then reservoir food webs may be inadequate for emigrating juvenile fall chinook salmonids. Furthermore, there may be significant overlap with the diet of fall chinook salmon through fall and into the spring in the estuary (McCabe et al. 1983).

As juvenile salmon numbers decline, shad may extend the prey base for piscivorous fishes during the late fall and winter, thus serving to maintain predator populations at high levels (Kaczynaki and Palmisano 1993). For example, large populations of juvenile American shad could provide an abundant prey source, and thus lead to increases in condition, overwinter survival, and reproductive fitness of salmonid predators (e.g., northern squawfish). American shad may also affect declining salmonid populations through other direct and indirect mechanisms. Conversely, larval and juvenile American shad may reduce predation on juvenile salmonids by providing an alternate prey source for predators. Early life stages of American shad could also directly benefit juvenile salmonids by providing an abundant, nutritive food resource to salmonids in reservoir habitats.

The high numbers of returning adult American shad in fish ladders may cause avoidance or delay by adult salmon. The peak shad migration is from mid June to late July, and coincides with adult migrations of sockeye and summer chinook salmon. One solution to adult passage problems has been to modify passage configuration so that adult shad can readily pass and not accumulate in the ladders. Ironically, such passage improvements have extended the range of shad to Priest Rapids Dam on the Columbia River and above Lower Granite Dam on the Snake River (Monk et al. 1989). We speculate that the consequences of opening access to such large reaches of spawning and rearing habitat suitable to American shad may not be fully realized at this time. Harvest offers one alternative to reduce the number of adult American shad, but they are generally underutilized. For example, between 1977-97 the commercial harvest rates have ranged as high as 8%, but the rates declined to 1% in 1997.

b. Proposal objectives.

Objective 1: Identify interactions of juvenile American shad with juvenile fall chinook salmon

Ho: Juvenile American shad and juvenile fall chinook salmon occur uniformly over space and time.
Ho: Diets of juvenile American shad and juvenile fall chinook salmon do not overlap.
Ho: Food resources of juvenile fall chinook salmon remain unaltered with the presence of larval and juvenile American shad**.**
Product: Annual technical report.

Objective 2: Determine role of American shad as supplemental food source contributing to salmonid predator fitness

Ho: The diet of predators (northern squawfish) is not changed by the presence of American shad in the Columbia River.
Ho: The rate of feeding by predators (ration) is not changed by the presence of American shad in the Columbia River.
Ho: Altered diet and/or ration caused by the presence of American shad does not increase

the growth or reproductive potential of predators.
Product: Annual technical report.

Objective 3: Describe Columbia River American shad life cycle
Ho: American shad migrate and spawn uniformly throughout the available habitat.
Ho: American shad exhibit no difference in age, growth, or fecundity throughout the Columbia River Basin.
Ho: American shad year classes are not affected by biological, physical, or chemical processes.
Product: Annual technical report.

Objective 4: Develop methods to control Columbia River American shad population
Ho: The presence of American shad in fishways does not disrupt salmonid passage.
Product: Annual technical report.

c. Rationale and significance to Regional Programs.

Objective 1: Identify interactions of juvenile American shad with juvenile fall chinook salmon
This objective and related hypotheses address specific concerns related to potential competitive interactions between Columbia River American shad and juvenile salmonids. Specific plan measures are: NPPC=s FWP 5.7 Reduce predation and competition, 5.7B.9 Explore population ecology of shad to determine the extent of adverse interactions with salmonids; NMFS BiOp 13.h. The BPA shall investigate the effects of the intensified competition for food resulting from the introduction of non-native species and production of hatchery fish in the Columbia River Basin; NMFS Recovery Plan 2.8.b.2 Control fishes that prey on or compete with juvenile salmonids; Columbia River Fish Management Plan, 1996 All-Species Review, Shad Management Issues: 1) competition between shad and juvenile salmonids for limited food and habitat resources; 2) noncompetitive, but stressful, interactions between shad and salmon, such as disease transmission or migration delay at dam fish passage facilities; 3) inaccurate counts of other concurrently migrating species; and 4) contribution of shad to the forage base and ultimately the survival of predators of juvenile salmonids.

Objective 2: Determine role of American shad as supplemental food source contributing to salmonid predator fitness
This objective and related hypotheses address specific concerns related to the Columbia River American shad=s potential contribution as a forage base for juvenile salmonid predators thereby increasing predator success. Specific plan measures are: NPPC=s FWP 5.7 Reduce predation and competition; NMFS Recovery Plan 2.8.b.2 Control fishes that prey on or compete with juvenile salmonids; Columbia River Fish Management Plan, 1996 All-Species Review, Shad Management Issues: 4) contribution of shad to the forage base and ultimately the survival of predators of juvenile salmonids.

Objective 3: Describe Columbia River American shad life cycle
This objective and related hypotheses address directly the NPPC=s FWP measure 5.7B.9 Explore population ecology of shad to determine the extent of adverse interactions with salmonids.

Objective 4: Develop methods to control Columbia River American shad population
This objective and hypothesis addresses directly the NPPC=s FWP measures 5.7A.2 Eliminate shad from the Columbia River system above Bonneville and reduce the shad population below Bonneville Dam, 5.7B.9 Identify effective methods for control, 5.7B.11 Managers should use whatever methods are available to reduce the numbers of shad that spawn below Bonneville, 6.1B.1 Evaluate the effects of shad population increases on adult salmon passage at mainstem dams; NMFS Recovery Plan 2.8.b.2 Control fishes that prey on or compete with juvenile salmonids, 2.8.b.3 Reduce American shad in the Columbia River; Columbia River Fish Management Plan, 1996 All-Species Review, Shad Management Issues: 2) noncompetitive, but stressful, interactions between shad and salmon, such as disease transmission or migration delay at dam fish passage facilities. 3) inaccurate counts of other concurrently migrating specie; and Wy Kan Ush Me Wa Kush Wit section 5, hypotheses 9: Large numbers of shad also impede salmon passage through adult fishways.

d. Project history

e. Methods.

Task 1.a: Determine the spatial and temporal occurrence and abundance of juvenile American shad and juvenile fall chinook salmon.

Methods: We propose to use hydroacoustic fish stock assessment techniques to assess the distribution and abundance of juvenile American shad and juvenile fall chinook salmon in the John Day Reservoir and the Columbia River Estuary from early August through November. Hydroacoustic techniques have been used successfully to assess the distribution and abundance of migratory fishes in the Columbia River since 1980 (Thorne and Johnson 1993). The Columbia River Research Laboratory has used hydroacoustics to assess the behavior and distribution of juvenile salmonids since 1991 and has considerable expertise in the deployment of mobile hydroacoustic systems. Fish distribution will be assessed along transects at selected index sites with a mobile hydroacoustic system deployed from a boat. Fixed-aspect point sampling may also be used in areas where reservoir morphology prohibits mobile sampling. Water velocity will also be measured along the selected transects using an acoustic Doppler current profiler (ADCP) to assess water velocity availability/usage estimates for juvenile American shad. Vertical distribution, horizontal distribution, mean water velocity and fish density will be measured in 0.5 m depth strata along 10 m segments. Hydroacoustic data will be analyzed using echo counting techniques when fish densities are sufficiently low that returned echos are from individual fish (Thorne 1983). As fish density increases (due to the presence of large numbers of juvenile American shad) to the point that returned echos are from multiple targets, echo integration will be used to obtain biomass estimates (Thorne 1983). All hydroacoustic data will be geo-referenced using a Global Positioning System (GPS). Mean fish density in selected depth strata and segments will be compared using an analyses of variance (ANOVA) to determine if fish density differs significantly between depth strata, segment and/or index study site. Regression analyses will be conducted to identify environmental variables (e.g., temperature, turbidity, light level) that may be determinates of fish density at index sites. Factors that may limit the success of this task include adverse weather conditions and the presence of excessive ambient noise at hydroacoustic sampling sites. However, based on previous experience we believe these factors will not significantly compromise the success of this task.

Supplemental fish distribution data will also be collected using trawling, beach seining and purse seining techniques. These techniques will be used to gather data in areas not easily sampled using hydroacoustic techniques such as, nearshore and shallow backwater habitats. Trawl data will provide population species composition estimates at the index sites sampled with hydroacoustics. A portion of the juvenile American shad captured using these capture methods will be preserved and examined at a later date to determine their food habits.

Task 1.b: Determine the food habits of juvenile American shad and juvenile fall chinook salmon to identify competitive interactions

Methods: Juvenile fall chinook salmon captured as described in task 1.a will have their stomach contents removed using a non-lethal stomach pumping technique currently used at the Columbia River Research Laboratory (CRRL) and the contents will be frozen. This method allows easy removal of stomach contents without sacrificing the individual fish. Selected juvenile shad collected under task 1.a will be frozen for food habits analysis. The stomach contents of juvenile shad and juvenile fall chinook salmon will be analyzed to assess prey preference, diet overlap, and total food consumption (Adams and Breck 1992). Analyses and diet comparisons between juvenile American shad and juvenile fall chinook salmon will be made to determine if potential competitve interactions may exist between the two species during their co-occurrence in lower Columbia River reservoirs and the estuary. Success of this task will require sufficient sample sizes of juvenile fall chinook salmon stomach samples.

Task 1.c: Determine larval and juvenile American shad effects on the food resources of juvenile fall chinook salmon.

Methods: We propose to sample zoolplankton populations from early June through November to evaluate the effects large numbers of larval and juvenile shad may have on the adundance and structure of zooplankton populations. Zooplankton sampling will be scheduled concurrently with hydroacoustic sampling throughout 24 h diel periods at selected index sites in John Day Reservoir and the estuary. Zooplankton abundances and population structures will be evaluated to determine the effects of the growing shad biomass throughout the time period larval and juvenile American shad are present in the reservoir. We anticipate being fully successful in accomplishing this task.

Task 1.d: Develop a bioenergetics model to describe juvenile American shad growth and feeding dynamics as related to feeding of juvenile fall chinook salmon.

Methods: Bioenergetics models have been used as powerful simulation tools over the past 20 years, most often to predict consumption by predators or project fish growth as a function of temperature and prey availability (Ney 1993). We propose to use a bioenergetics model described by Hewett and Johnson 1992 to estimate the grazing rates on the zooplankton community by juvenile shad and fall chinook salmon. The number of shad will be estimated from hydroacoustic surveys described in task 1.a. Empirical food consumption rates will be estimated as described task 1.b and will be used in the model to simulate growth. Modeling of growth rates of shad will be constrained by empirical growth rates estimated from otoliths of juvenile shad. The relation between growth and otolith patterns has been verified (Limburg 1996). The physiological parameters for the model such as maximum consumption, respiration rates, specific dynamic action are available in Limburg (1994). These parameters were derived from Hudson River American shad stock and initial stockings in the Columbia River were American shad from the Hudson River. Success of this task will require being fully successful at above tasks.

Task 2.a: Determine the importance of juvenile American shad in the diet of northern squawfish near hydroelectric facilities

Methods: To determine if the diet of predators is altered by the presence of American shad in the Columbia River, predators will be sampled from August to late October and diets determined. Field and laboratory methods of Poe et al. (1991) and Petersen et al. (1990) will be used for diet determinations. Predators will be collected by boat electroshocking, gut contents removed, and samples analyzed in the laboratory for percent composition of major diet items (juvenile salmon, juvenile shad, other fish, crustaceans, other prey; see Ward et al. 1995). Predators will be sampled in John Day Reservoir, where shad are abundant, and in Priest Rapids Reservoir, where shad have not been observed. Diets of predators in these two areas will be compared with the method of Somerton (1990), which uses a randomization procedure to test for diet differences at a specific probability level.

To determine if the rate of feeding by predators is altered by the presence of American shad in the Columbia River, field data will be collected as described immediately above. Because water temperature in the Columbia River is relatively high during August-October (average monthly temperatures 16.8 - 21.6 EC; USACE unpublished data), we will use the method of Adams (1982) to estimate ration for predators. This method applies to warmwater fish that feed asynchronously (Adams and

Breck 1992). Average ration (%) will be compared between areas using *t-tests* on transformed data. We expect to be fully successful with this task.

Task 2.b: Estimate the effects of American shad biomass on growth and fecundity of northern squawfish.

Methods: We propose to examine how abundant juvenile American shad may influence the size structure or reproductive success of important predators of juvenile salmon, especially northern squawfish. If juvenile American shad supplement the diet or increase the feeding rate of predators, the potential for predation-related mortality on juvenile salmon could be intensified.

We speculate that the presence of shad in the Columbia River could cause increased growth of predators by: 1) high-energy shad replacing a low-energy diet component such as crayfish (4,506 Joules/g; Petersen and Ward *In review*), or 2) the high densities of shad may stimulate predators to consume a higher overall ration than when shad are not present. Models of growth and fecundity for predators, with input from field data described above, will be used to test these ideas. Bioenergetics models for northern squawfish (Shuter and Post 1990; Petersen and Ward *In review)* will be used to predict how growth of individual fish could be changed during August-November through a diet shift to shad or by increasing the overall ration. Regression models of predator fecundity (eggs produced per gram of predator; ODFW data) will then be used to predict how alterations in the fall diet or ration could influence reproductive output of predators the following summer. These analyses will require making some assumptions about the constancy of overwinter survival for predators of different size. Results will be expressed as potential fecundity of predator populations with shad present versus without shad present. We expect to be fully successful with this task.

Task 3.a: Conduct literature review and analyze existing data on American shad

Methods: An exhaustive literature review will be completed. Existing data from the Corps of Engineers, Fish Passage Center, National Marine Fisheries Service, and the Biological Resources Division of USGS will be complied and reviewed. After review of existing data, pertinent analysis will be conducted. Product will be provided to Project 8810804 PSMFC.

Task 3.b: Characterize adult American shad migration patterns, spawning sites and spawning habitat requirements.

Methods: Adult American shad will be sampled throughout the lower Columbia River using hydroacoustics, electrofishing, gill net, beach seine, and purse seine. Since American shad are known to be vulnerable to handling stress (L. Basham, Fish Passage Center, Portland, OR, pers. comm.) we will evaluate the efficacy and utility of internal, external, and oral radio tags (Kynard and O=Leary 1993). Temporal and longitudinal progression of up-river migration will be monitored by dam counts.

Task 3.c: Determine age, growth and fecundity of spawning population of American shad.

Methods: Fish will be captured by the same methods as above. Fish will be weighed, measured, and sexed. Scales will be collected for aging and verified by subsampling otoliths taken from incidental mortalities or fish sacrificed for food habit analysis (Devries and Frie 1996). Ovaries will be excised, weighed and a weighed subsample of eggs enumerated.

Task 3.d: Identify determinates of year class strength and develop American shad freshwater phase life cycle model

Methods: We will develop a shad life cycle model to quantify the factors and key life stages that determine year class strength and population abundance, relying on the data obtained in tasks a-c above and using previously established models for salmon and other clupeids as a template. The model will be separated by at least three key life stages, juvenile freshwater, ocean, and adult return to spawning. We will identify relationships between these 3 life stages and the biotic and abiotic factors that potentially determine shad growth and survival in each stage using quantitative and statistical techniques. Crecco et. al. (1983) suggests that year class strength is established prior to the juvenile stage. We will use hydroacoustic population estimates and dam passage counts to determine year class strength. Using the adult upstream migration dam counts and juvenile shad downstream migration counts, corrected by the age structure identified using scales and otoliths, we will establish juvenile to adults (JAR) survival rates. We will then relate the JAR=s to ocean conditions using the PAPA index and annual estimates of plankton productivity (Moyle 1988; Marmorek et al. 1996). For survival and fecundity in the adult freshwater stage, we will investigate the potential influence of food availability, habitat, dam passage (inter-dam loss), and the abiotic factors described for the juvenile life stage above. JAR=s and spawner abundance will be corrected for in-river harvest and repeat spawners where possible (CRFMP, All Species Review, 1996). Success of objective 3 will rely somewhat on the success of objective 1 and the ability to successfully radio-tag adult American shad.

Task 4.a: Explore harvest methods

Methods: We will review harvest methods previously used by tribal and commercial fishers to harvest American shad on both the east and west coast. This task will be a summary of the information gathered while conducting a thorough literature review (task 3.a). We will also look at existing and new harvest technologies that have not been previously tested in the Columbia River American shad fishery. Emphasis will be placed on modifying existing or developing new harvest technologies that eliminate or minimize negative impacts to juvenile and adult salmonids present during the harvest season.

Task 4.b: Explore biological control methods

Methods: We will examine alternative methods of control including an evaluation of fish ladder design and habitat modification to determine if adult American shad passage at Columbia River Dams can be diverted without inhibiting adult salmonid passage. This task will be a synthesis of information from the literature (task 3.a), and observations made during other tasks of this project. The habits and behavior of adult American shad to be characterized in task 3.b may provide insight in controlling the Columbia River American shad population.

Task 4.c: Evaluate the effects of shad on salmonid passage

Methods: Evaluate fish passage facilities (upstream and downstream) at dams to determine if passageways similar to submerged orifices removed from Ice Harbor dam in approximately 1984/5, could be Aretooled≅ to control American shad upstream migrations at selected sites and still allow for optimum anadromous salmonid use. We will also evaluate potential methods to prevent American shad from Alocking-through≅ the dams with vessel traffic.

Although little is known about the Columbia River American shad, all of the methods we have proposed to use in this study are well developed tools that have been used successfully in fisheries assessment. For example, hydroacoustic techniques have been used for population assessments in many different habitats, including the Columbia River. Additionally, food habits, year-class strength determination and bioenergetics modeling are well defined areas that are also widely used in fisheries assessments. Therefore, we conclude that any critical assumptions that may exist are insignificant compared to the knowledge base to be gained with minimal investment in understanding the American shad and it=s role in the Columbia River ecosystem.

f. Facilities and equipment.

Office, laboratory space, shop, and storage space are furnished at the Columbia River Research Laboratory of the Biological Resources Division, U.S. Geological Survey. A computer network and analytical software are available to project staff. USGS-BRD, CRITFC and USFWS will provide boats up to 27 feet in length that are adequate for deployment of all sampling gear. While using the boats the project will pay for all modifications, operations, and maintenance.

g. References.

Adams, S. M., R. B. McLean, and M. M. Huffman. 1982. Structuring of a predator population through temperature-mediated effects on prey availability. Can. j. Fish. Aquat. Sci. 39:1175-1184.

Adams. S. M., and J. E. Breck. 1992. Bioenergetics *In* C. B. Shreck and P. B. Moyle (eds.), Methods for Fish Biology. American Fisheries Society, Bethesda, MD.

Chapman, D.W., A. Giorgi, M. Hill, A. Maule, S. McCutcheon, D. Park, W. Platts, K. Pratt, J. Seeb, L. Seeb, and F. Utter. 1991. Status of Snake River chinook salmon. Prepared for PNUCC by Chapman Consultants, Inc., Boise, ID.

Columbia River Fish Management Plan, All Species Review, 1996

Crecco, V., and M. Blake. 1983. Feeding ecology of coexisting larvae of American shad and blueback herring in the Connecticut River. Transactions of the American Fisheries Society 112:498-507.

Crecco, V.A., T.F. Savoy, and L. Gunn . 1983. Daily mortality rates of larval and juvenile American shad (*Alosa sapidissima)* in the Connecticut River with changes in year-class strength. Canadian Journal of Fisheries and Aquatic Sciences. 41:1216-1223.

Crecco, V.A. and T.F. Savoy. 1984. Effects of Fluctuations in Hydrographic Conditions on Year-Class Strength of American shad (*Alosa sapidissima)* in the Connecticut River. Canadian Journal of Fisheries and Aquatic Sciences 41:1216-1223.

DeVries, D.R. and R.V. Frie. 1996. Determination of age and growth. Pages 483-508 *in* B.R. Murphy and D.W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Dirkin, J.T., S.J. Lipovsky, and R.J. McConnell. 1979 (Jan.). Biological impact of a lowline disposal project near Pillar Rock in the Columbia River Esruary. Final report of research submitted to the U.S. Army Corps of Engineers, Portland District. Available from: Nat. Marine Fish. Serv., Coastal Zone and Estuarine Studies Division, Seattle, WA. 92 pp.

Hewett, S.W. and B.L. Johnson. 1992. Fish bioenergetics model 2. University of Wisconsin Sea Grant Institute WIS-SG-92-250.

Kaczynaki, V.W. and J.F. Palmisano. 1993. Oregon=s wild salmon and steelhead trout: A review of the impact of management and environmental factors responsible for the decline and lack of recovery of Oregon=s wild anadromous salmonids, dated 04/93.

Limburg, K.E. 1994. Ecological constraints on growth and migration of juvenile American shad (*Alosa sapidissima* Wilson) in the Hudson River Estuary, New York. Ph.D. dissertation, Cornell University, Ithaca, N.Y.

Limburg, K.E. 1996. Growthand migration of 0-year American shad (*Alsoa sapidissima*) in the Hudson River estuary: otolith microstructural analysis. Canadian Journal of Fisheries and Aquatic Sciences 53:220-238.

Marmorek D.R. (ed.) And 21 others. 1996. Plan for analyzing and testing hypotheses (PATH): Final report on retrospective analyses for fiscal year 1996. Compiled and edited by ESSA Technologies Ltd., Vancouver, B.C.

McCabe, G.T., Jr., W.D. Muir, R.L. Emmett, and J.T. Durkin. 1983. Interrelationships between juvenile salmonids and nonsalmonid fish in the Columbia River estuary. Fishery Bullentin: 81:(4)815-826.

Monk, B., D. Weaver, C. Thompson, and F. Ossiander. 1989. Effects of flow and weir design on the passage behavior of American shad and salmonids in an experimental fish ladder. North American Journal of Fisheries Management 9:60-67.

Moyle, P.B. and J.C. Cech, Jr. 1988. Fishes: An introduction to ichthyology. Second Edition. Prentice Hall, New Jersey.

Ney, J.J. 1993. Bioenergetics modeling today: Growing pains on the cutting edge. Transactions of the American Fisheries Society 122:736-748.

Petersen, J. H., M. G. Mesa, J. Hall-Griswold, W. C. Schrader, G. W. Short, and T. P. Poe. 1990. Magnitude and dynamics of predation on juvenile salmonids in Columbia and Snake River reservoirs. Annual Report 1989. Bonneville Power Administration, Portland, Oregon.

Petersen, J. H. and D. L. Ward. In review. Development and corroboration of a bioenergetics model for northern squawfish feeding on juvenile salmonids in the Columbia River. Trans. Am. Fish. Soc.

Poe, T. P., H. C. Hansel, S. Vigg, D. E. Palmer, and L. A. Pendergast. 1991. Feeding of predaceous fishes on out-migrating juvenile salmonids in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120: 405-420.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. BioScience 47(11):769-784.

Quinn, T., and D. Adams. 1996. Environmental changes affecting the migratory timing of American shad and sockeye salmon. Ecology 77:1151-1162.

Rondorf, D., G. Gray, and R. Fairley. 1990. Feeding ecology of subyearling chinook salmon in riverine and reservoir habitats of the Columbia River. Transactions of the American Fisheries Society 119:16-24.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184. 966 pp.

Shuter, B.J., and J. R. Post. 1990. Climate, population viability, and the zoogeography of temperate fishes. Transactions of the American Fisheries Society 119:314-336.

Somerton, D. A. 1990. Detecting differences in fish diets. Fishery Bull., U.S. 89:167-169.

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: Research and Management 12:391-413.

Thorne, R.E. 1983. Hydroacoustics. In: Fisheries Techniques pages 239-259 *in* L.A. Nielsen and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Thorne, R. E., and G.E. Johnson. 1993. A review of hydroacoustic studies for estimation of salmonid downriver migration past hydroelectric facilities on the Columbia and Snake rivers in the 1980s. Reviews in Fisheries Science 1(1):27-56.

Ward, D. L., J. H. Petersen, and J. J. Loch. 1995. Index of predation on juvenile salmonids by northern squawfish in the lower and middle Columbia River and in the lower Snake River. Transactions of the American Fisheries Society 24:321-334.

Williams, R.N. and eleven coauthors. 1996. Return to the river: restoration of salmonid fishes in the Columbia River ecosystem. Portland (OR): Northwest Power Planning Council.

Section 8. Relationships to other projects

This is not intended to duplicate the Relationships table in Section 3. Instead, it allows for more detailed descriptions of relationships, includes non-interdependent relationships, and includes those not limited to specific Bonneville projects.

No known relationships to other projects exists

Section 9. Key personnel

Dr. Thomas W. H. Backman, Senior Fishery Scientist

EDUCATION:
B.Sc. and M.Sc. in Marine Biology, San Diego State University.
Ph.D. in Fisheries, University of Washington.

CURRENT EMPLOYMENT:
Columbia River Inter-Tribal Fish Commission 729 N. E. Oregon, Suite 200
Portland, OR. 97232

Dr. Backman has been a Senior Fishery Scientist with the Commission since 1991. During that time he as served as the President of the Oregon Chapter of the American Fisheries Society, a member of the CBFWA shad group. Dr. Backman provides scientific expertise on salmon recovery issues by conducting research, developing scientific papers and analyses, participation in workshops, formulating recovery strategies, and providing expert testimony.

Prior to CRITFC, Dr. Backman was a Fishery Biologist (GS-13) with the US Fish and Wildlife Service (FWS). His duties with FWS were: Administrated and participated in technical groups for the U.S. Fish and Wildlife Service under the Emergency Stripped Bass Act. Administrated the Andramous Grants Program. Dr. Backman was Principle Investigator and Project Leader for a shad research program at the National Research Laboratory in Wellsboro PA. Dr. Backman's graduate research (NSF funded) focused on fish habitat related research, including developed genetic concepts and restoration technology for depleted and damaged submerged aquatic vegetation and habitat.

T. W. H. Backman. 1989. Entrainment Net Effect Means for Transporting Juvenile American Shad. U.S. Fish and Wildlife Service, Research Information Bulletin 89-93.

T. W. H. Backman and R. M. Ross. 1990. Group size is important in behavior and survival of Sub-yearling American shad. Research Information Bulletin 90-69. U.S. Dept. of Interior, Fish and Wildlife Service.

T. W. H. Backman. 1992. Larval American Shad: Effects of Age and Group Size on Swimming and Feeding Behavior. Transactions of the American Fisheries Society 121(4):508-516.

T. W. H. Backman, and R. M. Bennett. 1993. Evaluation of Habitat Suitability Index Models for Riverine Life Stages of American Shad, with Proposed Models for Premigratory Juveniles. U.S. Fish and Wildlife Service Biological Report 14.

R. M. Bennett, and T. W. H. Backman. 1993. Habitat Use by Spawning Adult, Egg, and Larval American Shad in the Deleware River. Rivers:4(3):227-238.

Dennis W. Rondorf, Fishery Research Biologist

EDUCATION:
M.S. Oceanography and Limnology, University of Wisconsin, Madison, 1981
B.S. Wildlife Management, University of Minnesota, St. Paul, 1972

CURRENT EMPLOYMENT AND RESPONSIBILITIES:
D.W. Rondorf serves as a Fishery Research Biologist and Section Leader for the Anadromous Fish Ecology section at the Columbia River Research Laboratory, Biological Resources Division, U.S. Geological Survey, Cook, Washington. Current areas of research include the behavior and ecology of Snake River wild and hatchery fall chinook salmon, the distribution of smolts and relation to gas supersaturation in the main stem Columbia River, and behavior of smolts to evaluate a prototype surface collector at Lower Granite Dam, Washington. In recent years, D.W. Rondorf has lead research teams using radio telemetry, geographic information systems (GIS), global positioning systems (GPS), remotely operated underwater vehicles (ROV), hydroacoustic fish stock assessment systems, and acoustic Doppler current profilers (ADCP) as research tools. Between 1979 and 1997, D.W. Rondorf was employed by the research division of the U.S. Fish and Wildlife Service and the National Biological Service to conduct research on juvenile salmon in the Columbia River basin.

Adams, N.S., D.W. Rondorf, S.D. Evans, J.E. Kelley, and R.W. Perry. 1998. Effects of surgically and gastrically implanted radio transmitters on swimming performance and predator avoidance of juvenile chinook salmon. (*In Press*) Canadian Journal of Fisheries and Aquatic Sciences.

Adams, N.S., D.W. Rondorf, S.D. Evans, and J. E. Kelley. 1998. Effects of surgically and gastrically implanted radio transmitters on growth and feeding behavior of juvenile chinook salmon. Transactions of the American Fisheries Society 127:128-136.

Parsley, M.J., D.W. Rondorf, and M.E. Hanks. 1998. Remote sensing of fish and their habitats. Proceedings of instream and environmental flows symposium-technology and policy issues. (*In Press*) North American Lake Management Society and others, Denver, Colorado.

Adams, N.S., D.W. Rondorf, E.E. Kofoot, M.J. Banach, and M.A. Tuell. 1997. Migrational characteristics of juvenile chinook salmon and steelhead in the forebay of Lower Granite Dam relative to the 1996 surface bypass collector tests. U. S. Army Corps of Engineers, Walla Walla, Washington.

Travis C. Coley, Fishery Biologist

EDUCATION:
B.S. Mississippi State University, Fisheries Management, 1976.
M.S. University of Idaho, Fisheries Resources, 1979.

CURRENT EMPLOYMENT:
U.S. Fish and Wildlife Service
Columbia River Fisheries Program Office
9317 N. E. Highway 99, Suite I
Vancouver, WA 98665

Travis is the team leader for the Habitat and Natural Production Team at the Columbia River Fisheries Program Office, U.S. Fish and Wildlife Service. Supervises a staff of 12 biologists and technicians working primarily on habitat assessment, habitat restoration, and fish population assessment and monitoring. Travis has served in this capacity since 1991. Prior to the current position he served as Assistant Project Leader of the Idaho Fisheries Resources Office, U. S. Fish and Wildlife Service, Ahsahka, Idaho.

Travis worked for the National Marine Fisheries Service from 1978 to 1986. The majority of duties were Columbia River estuary fish ecology and salmonid smoltification research.

Durkin, J.T., T.C. Coley, K.J. Verner, and R.L. Emmett. 1981. An evaluation of aquatic life found at four hydraulic scour sites in the Columbia River estuary elected for potential sediment disposition. Proceedings of the National Symposium of Freshwater Inflow to Estuaries, USFWS, San Antonio, Texas. Vol. I: 436-452.

McCabe, G.T., Jr., T.C. Coley, R.L. Emmett, and J.T. Durkin. 1981. The effects of Mt. St. Helens on the fishes in the Columbia River estuary (abstract). Estuaries 4(3):247

Giorgi, A.E., G.A. Swan, W.S. Zaugg, T.C. Coley, and T.Y. Barila. 1988. Susceptibility of chinook salmon smolts to bypass systems at hydroelectric dams. North American Journal of Fisheries Management 8:25-29.

Muir, W.D., A.E. Giorgi, and T.C. Coley. 1994. Behavioral and physiological changes in yearling chinook salmon during hatchery residence and downstream migration. Aquaculture 127(69-82).

Muir, W.D. and T.C. Coley. 1996. Diet of yearling chinook salmon and feeding success during downstream migration in the Snake and Columbia Rivers. Northwest Science 70(298-305).

Dr. James H. Petersen

Education: Degree or training, School, and Date Received
Ph. D., Marine Ecology, University of Oregon, 1983
Rotary Fellowship, University of Queensland, Australia, 1976
B. S., Biology, Boise State University, Idaho, 1975

Expertise: Primary areas of expertise include predator-prey dynamics, population dynamics, and application of various modeling techniques to fisheries.

Experience

1995-Present Research Fishery Biologist, U.S. Geological Survey, Biological Resources Division, Columbia River Research Laboratory, Cook, WA.
Current responsibilities: Project leader on research project to determine survival of summer steelhead over their first winter in the Wind River Basin (WA). Co-leader on various mainstem Columbia and Snake River projects concerning juvenile salmon passage, predation, and reservoir drawdown.

1994 Acting Director, Columbia River Research Laboratory, USGS, Cook, WA.

1988-93 Research Fishery Biologist, Columbia River Research Laboratory, U.S. Fish and Wildlife Service.

1984-88 Associate Research Curator, Section of Fishes, Natural History Museum of Los Angeles County, Los Angeles, CA.

1983-84 Environmental Scientist, Section of Fishes, Natural History Museum of Los Angeles County.

1977-83 Graduate Teaching Assistant, University of Oregon, Eugene, OR.

Publications and Reports

Petersen, J. H., and D. L. DeAngelis. 1992. Functional response and capture timing in an individual-based model: predation by northern squawfish (*Ptychocheilus oregonensis*) on juvenile salmonids in the Columbia River. Can. J. Fish. Aquat. Sci. 49:2551-2565.

Petersen, J. H. 1994. The importance of spatial pattern in estimating predation on juvenile salmonids in the Columbia River. Trans. Am. Fish. Soc. 123:924-930.

Petersen, J.H. and D.M. Gadomski. 1994. Light-mediated predation by northern squawfish on juvenile salmon. J. Fish Biol. 45: 227-242.

Ward, D. L., J. H. Petersen, and J. J. Loch. 1995. Index of predation on juvenile salmonids by northern squawfish in the lower and middle Columbia River and in the lower Snake River. Trans. Am. Fish. Soc. 124:321-334.

Petersen, J. H. and D. L. Ward. In review. Development and corroboration of a bioenergetics model for northern squawfish feeding on juvenile salmonids in the Columbia River. Trans. Am. Fish. Soc.

Section 10. Information/technology transfer

The technology transfer will be accomplished by oral presentations and technical reports. Managers will use the results of this project to determine the extent of negative impacts American shad have on salmonid population in the Columbia River Basin.