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Reference No: 151
Date Received: 1-10-03

NPRB PROPOSAL SUMMARY PAGE
(To be filled in by applicant)

Project Title: Early Marine Ecology of Juvenile Chum Salmon (*Oncorhynchus keta*) in Kuskokwim Bay, Alaska

Project Period: From Date:__01 May 2003__________ to____30 April 2006_________

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Research Priorities Addressed:

Identify up to three priorities from list in RFP (a-g): _a, b, c, f_______________________

Summary of Proposed Work (250 words or less):
The proposed work will examine the early marine ecology of chum salmon in Kuskokwim Bay, Alaska. Our goal is to assess the effect of physical and biological environmental factors on feeding, condition, and growth of juvenile chum salmon in Kuskokwim Bay. Using a bioenergetically-based food web model coupled with directed sampling for diet composition, growth, size structure, and energy content will help us to understand patterns observed in feeding, growth and condition of chum salmon juveniles. Specifically, our objectives include (1) determining the spatial and seasonal distribution of chum salmon juveniles throughout Kuskokwim Bay, (2) assessing the spatial and seasonal patterns of environmental variables, and (3) describing the relationship between juvenile distribution patterns and these variables. In addition, we will (4) describe food habits, (5) analyze length, weight, condition, (6) diurnal feeding patterns, and (7) growth of chum salmon. Finally, (8) we will model the bioenergetics and growth of chum salmon juveniles in Kuskokwim Bay

Funding: Total NPRB Funding Requested: $__624,025_

Total Matching Funds Used: $___40,017_

Legally Binding Authorizing Signature and Affiliation:

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(NOT TO EXCEED ONE PAGE)

Early Marine Ecology of Juvenile Chum Salmon (*Oncorhynchus keta*)
in Kuskokwim Bay, Alaska

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Proposal Summary

Estuaries, deltas, and bays may function as important nursery and transitional habitats for juvenile salmon migrating from freshwater to marine environments. Mortality during the freshwater to marine transition and early marine residence is high and may ultimately determine year-class strength. Although recognized as a critical period, very little work has been conducted on this life history stage throughout most of Western Alaska.

Chum salmon (*Oncorhynchus keta*) are an important environmental, cultural, and economic resource in the Kuskokwim watershed. Declines in chum salmon runs, since 1998, have resulted in closure and restriction of subsistence and commercial fisheries in the Kuskokwim and other Western Alaska Rivers. The causes of these declines are unknown. Because so little is known about the early life history of salmon populations in western Alaska, it is difficult to develop or test hypotheses concerning population regulation and the role of environmental variation or change.

The proposed work will examine the early marine ecology of chum salmon in Kuskokwim Bay, Alaska. Our goal is to assess the effect of physical and biological environmental factors on feeding, condition, and growth of juvenile chum salmon in Kuskokwim Bay. Using a bioenergetically-based food web model coupled with directed sampling for diet composition, growth, size structure, and energy content will help us to understand patterns observed in feeding, growth and condition of chum salmon juveniles. Specifically, our objectives include (1) determining the spatial and seasonal distribution of chum salmon juveniles throughout Kuskokwim Bay, (2) assessing the spatial and seasonal patterns of environmental variables, and (3) describing the relationship between juvenile distribution patterns and these variables. In addition, we will (4) describe food habits, (5) analyze length, weight, condition, (6) diurnal feeding patterns, and (7) growth of chum salmon. Finally, (8) we will model the bioenergetics and growth of chum salmon juveniles in Kuskokwim Bay

An improved knowledge of environmental conditions, food resource availability, duration of residence, and growth of juvenile chum salmon during their early marine residence is needed to evaluate hypotheses of population regulation in western Alaska chum salmon. The proposed work will serve to fill significant data gaps concerning the early life history of salmon in the Kuskokwim watershed. If funded, this study will be one of the first studies ever conducted on juvenile salmon in the Kuskokwim drainage.

Responsiveness to NPRB Research Priorities

This project directly addresses NPRB's enabling legislation, as it constitutes a *cooperative research effort* between UAF and USGS with a goal to address *marine ecosystem information needs.* Our study directly follows the NPRB's mission to request research that will improve our understanding of the dynamics of the Bering Sea ecosystems and their fisheries.

The proposed work directly addresses four research priorities identified in the 2003 request for proposals. First, this project fulfills the NPRB Research priority requesting *studies of factors affecting salmon stock dynamics, mortality and migration throughout their range and life cycle, particularly for Western Alaska salmon stocks* (f.3.).

Second, the proposed work addresses the NPRB research priority requesting projects that *develop ecosystem models that will aid resource managers* (a.3.). This work will provide a bioenergetically based trophic model to assess the growth potential and spatially explicit model of migration and habitat use by juvenile chum salmon in Kuskokwim Bay. These models will provide important information that will aid resource managers attempting to develop biologically based escapement goals for the Kuskokwim basin. Developing the goals will ultimately require inputs related to mortality and growth during all life stages. This project will represent the only study of Kuskokwim River juvenile chum salmon migration and growth potential during the transition to the marine environment.

Third, this project addresses the NPRB research priority requesting research that will examine *endangered and stressed species responses to ocean climate trends and prey availability* (b.2.). Chum salmon, an important subsistence and commercial resource in Western Alaska communities can be described as a *stressed species* given declines in abundance experienced since 1998. The factors causing these declines are unresolved in part due to significant gaps in our understanding of the role of environmental variation in the dynamics of population regulation in western Alaska salmon. This study meets this priority by providing important information concerning prey availability and growth potential of chum salmon during a transitional period during which associated mortality may result in determining the ultimate year class strength.

Fourth, the proposed work will address the NPRB research priority requesting studies addressing *fish habitat mapping* (c.1.). This project meets this priority by addressing significant information gaps concerning the early marine stage of salmonids in Western Alaska. Juvenile life history stages have received little attention in Western Alaska.

With the exception of Bristol Bay sockeye salmon, little has been done to examine early marine growth, diet, and survival of juvenile salmon in this region. An improved knowledge of environmental conditions, food resource availability, duration of residence, and growth of juvenile chum salmon during their early marine residence is needed to evaluate hypotheses of population regulation in western Alaska chum salmon.

Project Design and Conceptual Approach

The transition from freshwater to marine phase is a critical period of high mortality in the life history of salmonids (Pearcy 1992). In chum salmon (*Oncorhynchus keta*), mortality rates initially following ocean entry may range as high as 38-49% per day in Puget Sound (Bax 1983), or 3-25% per day in coastal waters off the coast of Japan (Fukuwaka and Suzuki 2002). Food limitation is assumed to drive much of this mortality (Salo 1991) but Beamish and Mahnken (2001) hypothesized that initial mortality rates in the marine environment are primarily driven by predation. Beamish and Mahnken (2001) further hypothesize that there is a second stage of mortality occurring later in the first year of ocean residence that is mediated by size. Little to no data concerning the early marine ecology of juvenile chum salmon from western Alaska Rivers are available. However, a better understanding of environmental conditions, food resource availability, and growth of juvenile chum salmon during their early marine residence is needed to evaluate hypotheses of population regulation in western Alaska chum salmon.

Understanding the early marine life history of salmonids from these streams requires information concerning duration of estuary and nearshore residence, diet and feeding ecology, and growth of juvenile salmonids. Estuary and nearshore dependence or utilization differs among species. Chum salmon enter these habitats shortly after emergence at a small size, and remain in brackish water habitats of estuaries or river plumes (Healey 1982; Simenstad et al. 1982; Fukuwaka and Suzuki 1998). Juvenile chum salmon remain in estuaries of the Fraser and Nanaimo Rivers for up to three weeks.

Chum salmon enter the estuaries at a comparatively small size. Thus, the period of estuarine residency might be particularly important for chum salmon juveniles because rapid growth and subsequent larger size might substantially reduce the risk of intense predation pressure in the marine environment. Estuarine food density and composition may affect early marine survival, either directly through starvation or indirectly through decreased growth rates, which will lead to longer duration at a stage particularly vulnerable to predation. While no data exist on diet and prey selectivity of juvenile chum salmon in the Kuskokwim Bay area, chum salmon elsewhere apparently rely on a detritus-based food web (Sibert et al. 1977; Salo 1991). Several studies have indicated the predominance of small harpacticoid copepods in the diet of chum juveniles during their residence in estuaries (Healey 1979; Landingham 1982). Variations in growth rates of chum salmon juveniles might be due to their prey composition: juvenile chum salmon growth rates were high when harpacticoid copepods predominated the diet. In comparison, lower growth rates were observed when amphipods were the predominant prey item (Pearcy et al. 1989).

The metabolic costs of migration and maintenance are key energetic constraints on the production and survival of juvenile chum salmon migrating through estuaries and the nearshore environment (Wissmar and Simenstad 1988). As a result, prey availability and abundance as juvenile chum salmon enter these habitats are important factors determining the growth potential and mortality rates of juvenile chum salmon at this stage (Mason 1974;Healey 1982; Salo 1992). Bax (1983) and Mason (1974) suggest that, although early-marine mortality may be high, processes in the open marine environment determine year class strength and adult returns

Little is known about this critical stage in the life history of salmonids in western Alaska streams and rivers draining to the Bering Sea. The proposed work will examine the early marine life history of juvenile salmon with an emphasis on chum salmon in the Kuskokwim Bay, Alaska. These studies will include monthly surveys to determine the relative abundance of juvenile salmonids and other fishes throughout Kuskokwim Bay during the summer and early fall. Environmental correlates such as salinity and water temperature will be measured simultaneously to determine associations and habitat use by juvenile salmon. Stomach contents and prey availability will be examined to determine feeding ecology and energetics of juvenile salmon during initial marine residence. Duration of estuary or marine residence and associated growth will be determined using otolith microchemistry and microstructure.

The goal for our project is to document seasonal and spatial patterns in prey use by chum salmon juveniles during their first summer and fall in the nearshore area of Kuskokwim Bay. We will assess prey selection, condition and growth in relation to the prey environment and use spatially explicit foraging/bioenergetic modeling to understand observed patterns. We will use the acquired information to develop a bioenergetically-based food-web model, which will let us assess the growth potential of juvenile chum salmon in Kuskokwim Bay. Early marine residence is considered to be a critical time in the life of chum salmon and sub-optimal prey densities might result in poor juvenile feeding success and condition, reduce growth rates, and increased mortality rates.

Objectives

- Survey relative abundance of juvenile salmonids (with an emphasis on chum salmon) at survey stations throughout the pelagic zone of Kuskokwim Bay in monthly surveys from late May through late September in 2003 and 2004.
- Collect temperature, depth, salinity, chlorophyll concentration, and zooplankton abundance and species composition data at fish sampling stations to describe the spatial and temporal distribution of environmental variables.
- Describe relationship between distribution of chum salmon juveniles and environmental factors in Kuskokwim Bay.
- Describe food habits and feeding ecology of juvenile chum salmon relative to prey availability and physical variables.
- Determine length, weight and body composition (caloric content) of chum salmon juveniles.
- Analyze diurnal feeding patterns during 24-hour feeding study and estimate gut evacuation rates of juvenile chum salmon.
- Determine duration of marine residence and marine growth in juvenile chum salmon collected.
- Model energetics and growth of juvenile chum salmon in Kuskokwim Bay.

<u>Field methods</u>

A total of five research cruises will be conducted each year of the study. During each cruise, 20 stations will be sampled at fixed stations along transects in Kuskokwim Bay (Figure 1). This schedule will provide relatively high spatial and temporal resolution of pink salmon feeding during their first summer and fall at sea. Each cruise will last about 8 days, with approximately three-week intervals between cruises. The first cruise will occur shortly after break-up (i.e., last week of May) or as close to that time as possible. On this schedule the last cruise should occur about the last week of September. On each cruise we will:

A. Survey stations with a surface-trawl or purse seine.
B. Collect zooplankton samples at each fish sampling station.
C. Record physical data at each sampling station using a CTD (Conductivity, Temperature, Density) system.
D. Conduct a 24-hour study of feeding at a single station.

Collected fish will be identified, measured and weighed. Chum salmon juveniles will be preserved either in alcohol or in 5% buffered formalin seawater solution. Sub samples of all non-target fishes will be preserved. Zooplankton samples will be concentrated and preserved in 5% buffered formalin seawater solution.
Zooplankton will be collected with a 1 m^2 NIO/Tucker trawl fished in undisturbed water at the surface alongside the vessel. The mesh is 0.3 mm, and the trawl will be equipped with a digital flowmeter centered in the net opening. Zooplankton samples will be fixed immediately in 5% buffered formalin.

At every station we will make a CTD cast to within 1 m of the bottom. We will use a SeaBird Electronics SBE-19 Seacat CTD equipped with a fluorometer to measure temperature, salinity and fluorescence at 0.5-m intervals.

During each cruise, a 24-hour feeding study will be conducted at the station with highest juvenile chum abundance. Upon arrival at that position, sampling will commence every 4 hours for 24 hours. Processing of fishes caught in this study will be the same as for the survey samples described above.

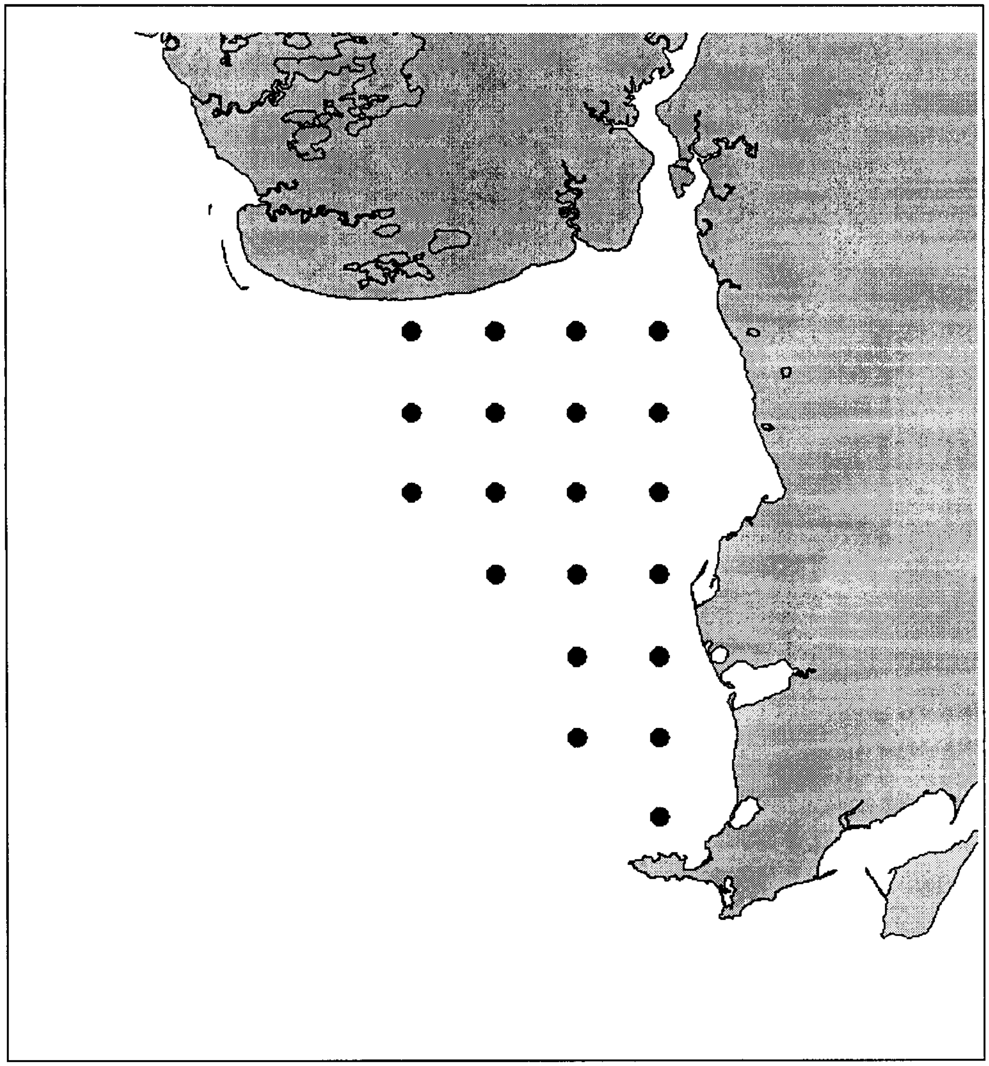

Figure 1. Sampling stations, Kuskokwim Bay, Alaska.

Laboratory Analyses – Zooplankton, Feeding, and Condition

We will analyze chum salmon samples for stomach contents, growth, and energy content. Zooplankton samples will be shipped to the Sea Fisheries Institute, Plankton Sorting and Identification Center in Poland (Table 1). This center has broad experience identifying zooplankton samples from the North Pacific and Bering Sea under contract with NOAA Fisheries.

Table 1. Distribution of laboratory analyses for samples from each field year: University of Alaska Fairbanks, Juneau (UAF), U.S. Geological Survey, Alaska Science Center (USGS)

Samples	Lab
Stomach contents – chum salmon	UAF
Zooplankton	Polish Sorting and Identification Center
Calorimetry – chum salmon	UAF
Otolith samples – chum salmon	USGS

The juvenile chum salmon will be measured for fork and standard length and weighed. Fish from each station will be divided into 10-mm-size classes. Stomach contents will be analyzed for ten individuals within each size class. Stomachs will be excised and the contents removed and weighed. Stomach contents will be sorted and counted by prey type. Prey will be identified to the lowest feasible taxon. A subsample of prey items will be weighed, and prey biomass will be calculated as the product of average prey weight times prey number. The wet weight of each prey category will also be determined by direct weighing of all groups [blotted-dry wet weights], which for bioenergetic modeling minimizes extrapolation errors.

Caloric content of chum salmon juveniles will be determined using bomb calorimetry. Standard length, wet weight, dry weight and whole body energy content will be measured on 10 to 15 frozen chum salmon from each station. The specimens will be freeze-dried, or placed in a convection drying oven at 60°C until they reach constant weight. They will then be homogenized in a mill and pressed into pellets of about 0.15 g. Pellets will be combusted in a Parr semi-micro bomb calorimeter to determine whole body energy content.

Laboratory Analysis - Otolith

Otolith analyses will be conducted in a two-phase process. First, counts of post-emergence daily increments will be used to age each fish. Second, strontium to calcium ratios (Sr/Ca) will be measured along transects on each otolith to determine otolith growth occurring in freshwater and marine environments. In combination, these analyses will provide an age (roughly in days) and duration of marine/estuarine residence for each fish.

Otolith preparation and analysis will follow the methods of Volk et al. (1984), Zimmerman and Reeves (2000), and Zimmerman et al. (in press). One sagittal otolith from each fish will be sectioned in the sagittal plane exposing the nucleus. Microstructure (daily increments) will be counted and measured under 300x magnification. Elemental analyses (Sr/Ca ratios) will be conducted with a Cameca SX-50 wavelength dispersive microprobe at Oregon State University, School of Oceanography. Microprobe analyses will be conducted on line transects bisecting a primordium and continuing to the edge of the otolith. Each transect of Sr/Ca will be plotted to describe the migrational history of the fish and related to age.

Data analyses and modeling

For zooplankton the mean number per cubic meter will be calculated for every taxon at each station. We will compare abundance of zooplankton among stations with ANOVA on log(x+1) transformed data. If transformed data still depart from parametric assumptions we will use Kruskal-Wallis tests. Sheffe's post-hoc tests will be used to examine distribution patterns when significant differences occur among stations.

Diet descriptions at each station will include: total stomach contents, as a per cent of body weight, diet composition by percent weight, and diet composition by percent number. Feeding will be compared among stations on each cruise. Mean total stomach contents (% body weight) will be compared among stations with ANOVA, or, if parametric assumptions are violated, with Kruskal-Wallis tests. Post-hoc identification of important patterns will be based on Scheffe's test (Zar 1984). Differences in composition among stations will be tested with contingency table analyses.

Prey selection by chum salmon juveniles will be calculated using the observed proportionate mean number of zooplankton taxa in the environment and in the juvenile diet. Three different selection indices will be calculated: the natural log of the Odds Ratio (Gabriel 1978), Chesson's alpha (Chesson 1978, 1983), and Pearre's (Pearre 1982).

Whole body energy content is an accurate measure of condition, and is also a necessary parameter in bioenergetics modeling. At each station, mean body energy content expressed in cal/g dry weight and Joules/g wet weight will be calculated. In addition, we will calculate Fulton's index, percent dry weight, and length-weight regressions. Energy content, percent dry weight and Fulton's index will be compared among stations with ANOVA, using Scheffe's post-hoc test to identify patterns. Slopes of length-weight regressions will be compared with ANCOVA.

Daily ration for juvenile chum salmon will be estimated using stomach content data collected in the 24-hour study field experiments during each of the cruises (Elliot and Persson 1978).

We will use a bioenergetic modeling approach to evaluate the quality of the estuarine habitat for chum juveniles. Habitat quality will be defined by the growth potential for chum juveniles. We will estimate growth potential by modeling consumption with an encounter rate model and using a bioenergetics model to calculate daily weight-specific growth, i.e., the growth potential. Several variables are necessary as input into this model, namely (1) prey consumption rates based on predator/prey encounter rates, (2) the temporal pattern in diet composition over the period of interest; (3) the average daily temperatures that the consumer experienced, (4) and the energy density of predators and prey.

Consumption rates are estimated using a bioenergetics model given estimates of (1) incremental growth of juvenile predators, (2) the temporal pattern in diet composition over the period of interest, (3) the average daily temperatures over the period of interest, (4) the energy density of the consumer and prey, and (5) the relative or absolute abundance of juvenile chum salmon and their prey.

The consumption of a foraging fish may be modeled based on an encounter rate with prey. The encounter rate is typically a function of fish swimming speed, distance at which predators perceive prey, and prey density (Brandt et al. 1992). We will model consumption rates using a modified version of the Gerritson and Strickler (1977) model that does not incorporate swimming speed of prey, since in the case of zooplanktivorous fishes the swimming speeds of prey are very low relative to the predator.

We will use the Wisconsin bioenergetics model. This energy-balance model requires that over any specified time interval, total energy consumption (C) must satisfy the net gain or loss of weight (G) observed over that period plus the metabolic costs (M) and waste losses (W) that accrued over that period. Thus, solving for growth or growth potential, consumption is estimated, and growth is given by:

$$G = C - (M + W)$$

The model operates on a daily time step. Thus, estimates of consumption, metabolic and waste costs, and growth are generated for each day based on the size and thermal experience of the organism. The status of the organism is updated for each daily time step and computations proceed for the next day in the simulation. Consumption rates can be quantified for daily through annual periods.

Diet information for any size-class of juvenile chum salmon enters the bioenergetics model as proportional contribution of each prey category in the diet by wet weight (or volume). Differential digestion is a concern if prey is easily digested, such as larval fish. Diel differences in prey composition may also be important. Our diet analyses of chum salmon will provide detailed quantitative descriptions on relatively fine spatial and temporal scales. We will take into account the relative digestion rates, and our 24-hour studies of feeding will allow us to incorporate diel variability into the model.

Temperature is an important parameter in all formulae in the bioenergetics model. We will measure water temperatures at all stations, and use those values in the model.

The energy content of prey will determine how much prey biomass must be consumed for a predator to obtain any given amount of energy. We will use literature values for prey energy content, when available, and will use bomb calorimetry when such estimates are not found.

Predator energy can change seasonally or with increasing body size. For salmonids energy density is a positive function of body mass up to a threshold weight and remains relatively constant thereafter. We will measure the energy content of chum salmon at all stations where they occur over the sampling period of our study.

Project Management and Experience and Qualifications of Personnel

Laboratory work will be divided between laboratories. Food habits of juvenile chum salmon will be analyzed at the Juneau Center of the University of Alaska Fairbanks under the direction of Dr. Hillgruber. Dr. Hillgruber has worked on the analyses of fish diets and prey selection for more than ten years. These studies will be the basis for a M.S. thesis project for a student at the University of Alaska Fairbanks. Drs. Hillgruber, Haldorson, and the M.S. student will conduct condition and bioenergetic modeling. Dr. Haldorson has extensive field experience in the Gulf of Alaska and the Bering Sea and is a principal investigator in a GLOBEC 2000 project, where he investigates feeding and bioenergetics of juvenile pink salmon (*Oncorhynchus gorbuscha*) in the Gulf of Alaska. He will oversee the bioenergetic modeling. Otolith growth and microchemical studies will be conducted at the USGS Alaska Science Laboratory of Dr. Zimmerman. Dr. Zimmerman has worked on juvenile salmon and trout ecology since 1988. His research has included investigations on the timing of first feeding in sea-run brown trout, population genetic structure of coastal cutthroat trout, population biology of steelhead and resident rainbow trout, migration and precocial maturation of chinook salmon, and zoogeography. Dr. Zimmerman is currently conducting research on fish ecology within the Yukon River Delta, life history variation in Kamchatka rainbow trout, testing archival and acoustic tags in marine environments, and otolith microchemistry to describe marine entry in chum salmon from the Yukon River. Dr. Zimmerman serves as Chair of the Scientific and Technical Committee to the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative a five-year initiative to identify critical research needs and implement research within western Alaska.

Coordination and Collaboration

The proposed work will serve to fill a critical gap in research efforts between the freshwater and marine environments and complement similar or related research throughout western Alaska, the Bering Sea, and the North Pacific Ocean. The Ocean Carrying Capacity (OCC) Program of the NOAA Auke Bay Laboratory is conducting research on juvenile salmon in marine waters adjacent to Kuskokwim Bay and throughout the Bearing Sea. The proposed work will provide complimentary research on juvenile salmon in nearshore habitats adjacent and connected to those being sampled by the OCC program.

Researchers from LGL Incorporated and the Norton Sound Economic Development Corporation have proposed to examine the distribution and food habits of juvenile salmon in Norton Sound. Our work will complement these studies and provide an opportunity to compare and contrast juvenile chum salmon ecology between Norton Sound and Kuskokwim Bay.

One of the authors of this proposal (Zimmerman) is conducting research on the distribution, timing of migration, habitat use, and feeding ecology of juvenile salmonids in the Yukon River Delta.

As Chair of the Scientific and Technical Committee of the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative, Christian Zimmerman serves as liaison and advisor to the Kuskokwim Fisheries Resources Coalition (KFRC) research planning effort. The KFRC is a group consisting of federal, state, regional, native, and other groups or agencies with fishery resource responsibility and interests in the Kuskokwim watershed. As a result, Dr. Zimmerman has direct connections to resource managers and community representatives in the project area. Community outreach and coordination with research and management efforts within the Kuskokwim region will be facilitated by this relationship.

Cooperation and collaboration with the above studies will be facilitated to the maximum extent possible.

Possible Peer Reviewers

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Project Costs

The duration of the proposed work is three years with an expected starting date of May 2003. An itemized budget of UAF and the USGS is attached to this proposal. Salaries include annual support for the graduate student, two months of salary for Dr. Hillgruber and 0.7 month salary for Dr. Haldorson. A large part of our proposed budget is attributed to the chartering of a research platform for five 8-day cruises in year one and two of funding and to purchase the nets to collect juvenile salmon. Also, a CTD system has to be purchased to measure physical variables, which are of outmost importance for the bioenergetic model. Budgeted costs include multiple trips to Kuskokwim Bay, and travels to scientific meetings to present the results of our work and discuss our findings within the scientific community.

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Zimmerman, C. E., R. W. Stonecypher, and M. C. Hayes. In Press. Migration of precocious male hatchery chinook salmon in the Umatilla River, Oregon. North American Journal of Fisheries Management.

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Education:

Ph.D. Fisheries Biology, University of Hamburg, Germany. 2001.
Dissertation: Vergleichende Untersuchungen über die Ernährungsstrategien mariner Fischlarven – Alaska Pollack, Blauer Wittling und Atlantische Makrele – unter besonderer Berücksichtigung von Beutefeld, Licht und Turbulenz. (Comparative studies on the foraging strategies of marine fish larvae – walleye pollock, blue whiting and Atlantic mackerel – with special regard to prey field, light, and turbulence).

M.S. Fisheries, University of Alaska Fairbanks. 1994.
Thesis: Feeding of larval walleye pollock (*Theragra chalcogramma*) in the oceanic domain of the Bering Sea.

B.S. Biology, University of Hamburg, Germany. 1991.

Professional Experience:

- Assistant Professor of Fisheries, Juneau Center, School of Fisheries and Ocean Science, University of Alaska Fairbanks, January 2002 to present.
- Biologist, TUHH-Technologie GmbH (TuTech), Hamburg, Germany, February 2001 to October 2001.
- Research Assistant, Biological Institute of Helgoland, Alfred-Wegener-Institute for Polar and Marine Research, Hamburg, Germany, April 1994 to February 2001.
- Graduate Research Assistant, Juneau Center, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, September 1991 to April 1994.

Peer-reviewed Publications:

Kloppmann M, Hillgruber N, von Westernhagen H (2002) Wind-mixing effects on feeding success and condition of blue whiting larvae in the Porcupine Bank area. Marine Ecology Progress Series 235: 263-277.

Hillgruber N, Kloppmann M (2001) Small-scale patterns in distribution and feeding of Atlantic mackerel (*Scomber scombrus* L.) larvae in the Celtic Sea with special regard to intra-cohort cannibalism. Helgoland Marine Research 55: 135-149.

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Hillgruber N, Kloppmann M, Wahl E, von Westernhagen H (1997) Feeding of larval blue whiting and Atlantic mackerel: a comparison of foraging strategies. Journal of Fish Biology 51 (Supplement A): 230-249.

Hillgruber N, Haldorson LJ, Paul AJ (1995) Feeding selectivity of larval walleye pollock *Theragra chalcogramma* in the oceanic domain of the Bering Sea. Marine Ecology Progress Series 120: 1-10.

Current Research:

Chilkat River Sockeye Radio Tagging

Vitae

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EDUCATION

Ph.D. University of California, Santa Barbara, 1978.

M.A. University of California, Santa Barbara, 1973.

B.A. University of Minnesota, 1963.

EXPERIENCE

1980 - Present	Faculty, School of Fisheries and Ocean Sciences, University of Alaska.
1977 - 1979	Fisheries Biologist, LGL Ltd., Ecological Research.

PUBLICATIONS

Else, P., L. Haldorson and K. Krieger. 2002. Shortspine thornyhead (*Sebastolobus alascanus*) abundance and habitat associations in the Gulf of Alaska. Fish. Bull. 100:193-199.

Rooper, C. N. and L. Haldorson. 2000. Consumption of Pacific herring (*Clupea pallasi* spawn by greenling (Hexagrammidae) in Prince William Sound, Alaska. Fish. Bull. 98:655-659.

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Haldorson, L., M. Prichett, A. J. Paul and D. Ziemann. 1993. Vertical distribution and migration of fish larvae in a Northeast Pacific bay. Mar. Ecol. Prog. Ser. 101:67-80.
Haldorson, L., M. Pritchett, D. Sterritt and J. Watts. 1993. Abundance patterns of marine fish larvae during spring in a southeastern Alaskan bay. Fish. Bull. 91:36-44.

Haldorson, L. and J. Collie. 1991. Distribution of Pacific herring larvae in Sitka Sound, Alaska. In: Proceedings of the International Herring Symposium. University of Alaska, Fairbanks.

Haldorson, L. and M. Love. 1991. Maturity and fecundity in the rockfishes (*Sebastes*), a review. Mar. Fish. Rev. 53:25-31.

Paul, A. J., K. O. Coyle and L. Haldorson. 1991. Interannual variations in copepod nauplii prey for larval fishes in an Alaskan Bay. ICES J. mar. Sci. 48:157-165.

Haldorson, L., M. Pritchett, D. Sterritt and J. Watts. 1990. Interannual variability in the recruitment potential of larval fishes in Auke Bay, Alaska. In: Ziemann, D. A. and K. W. Fulton-Bennett (Eds.) APPRISE - Interannual Variability and Fisheries Recruitment. The Oceanic Institute. Honolulu, HI. pp. 319-356.

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Education:

Ph.D.- Fisheries Science, Oregon State University, 2000.
Dissertation: Ecological relation of sympatric steelhead and resident rainbow trout in the Deschutes River, Oregon.

M.S. - Fisheries Science, Oregon State University, 1996.
Thesis: Population structure of coastal cutthroat trout (*Oncorhynchus clarki clarki*) in the Muck Creek basin, Washington.

B.S. - Fisheries, Humboldt State University, 1992.

Experience:

- Research Fishery Biologist, U.S.G.S. Alaska Biological Science Center. October 2001 to present.
- Chair, Scientific and Technical Committee, Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative, September 2002 to present.
- Research Scientist, University of Washington, School of Aquatic and Fishery Sciences. June 2000 to October 2001.
- Graduate Research Assistant, Oregon State University, Department of Fisheries and Wildlife. January 1997 to June 2000.
- Fishery Biologist, Pacific Northwest Research Station, U.S. Forest Service, 1995 to 1997.
- Graduate Research Assistant, Oregon State University, Department of Fisheries and Wildlife, 1993 to 1995.
- Fishery Biologist, Pacific, Land, and Water Consultants and Thomas R. Payne and Associates, Arcata, California. 1992.
- Teaching Assistant, Department of Fisheries, Humboldt State University, 1991-1992.
- Research Assistant, Institute of Limnology, University of Uppsala, Sweden, 1991.
- Fisheries Technician, Redwood National Park, Arcata, California 1989-1990.

Publications:

Zimmerman, C.E., R. W. Stonecypher, and M.C. Hayes. In Press. Migration of precocious male hatchery chinook salmon in the Umatilla River, Oregon. North American Journal of Fisheries Management.

Zimmerman, C.E., and G.H. Reeves. 2002. Identification of steelhead and resident rainbow trout progeny in the Deschutes River, Oregon revealed with otolith microchemistry. Transactions of the American Fisheries Society. 131:986-993.

Zimmerman, C.E., and D.E. Ratliff. In press. Invited chapter. Life history diversity and distribution of fishes within the Deschutes River: role of geologic and geomorphic controls. *In*: O'Connor, J.E, and G.E. Grant. The geology and geomorphology on the Deschutes River, Oregon—an analysis of the effects of a dam complex on an unusual river system. American Geophysical Union.

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Zimmerman, C., and H. Mosegaard. 1992. Initial feeding in migratory brown trout (*Salmo trutta* L.) alevins. Journal of Fish Biology. 40:647-650.

Current Research:

Yukon River Delta Juvenile Salmon Ecology.

Application of acoustic and archival tags to describe marine migrations in steelhead. *Collaborators*: Dr. Jennifer L. Nielsen and Derek Wilson. USGS.

Evolution of life history variation in steelhead and resident rainbow trout in Kamchatka. *Collaborators*: Drs. Dmitry Pavlov, Ksenia Savvaitova, Kirill Kuzishchin Moscow State University, Dr. Jack Stanford, Flathead Lake Biological Station, University of Montana.

Validation of the relationship between ambient Sr/Ca and otolith Sr/Ca in salmonids and refinement of techniques to describe the chronology of saltwater and freshwater migration.

Fish community structure in southwest Oregon estuaries and lagoons. *Collaborator*: Russ Stauff, Oregon Department of Fish and Wildlife, Gold Beach, Oregon.

NPRB BUDGET SUMMARY FORM

PROJECT TITLE: Early Marine Ecology of Juvenile Chum Salmon (Oncorhynchus keta) in Kuskokwim Bay, Alaska

PRINCIPAL INVESTIGATOR: Hillgruber and Haldorson

FUNDING SOURCE	YEAR 1	YEAR 2	YEAR 3	TOTAL
NPRB Funding	81,050	95,357	82,797	259,204
Match/In Kind				0
TOTAL	81,050	95,357	82,797	259,204

Annual cost category breakdowns will be requested for matching funds only if project is funded

Cost Categories	NPRB Year 1	NPRB Year 2	NPRB Year 3	NPRB TOTAL	Match/In kind TOTAL (all years)
1. Personnel Salaries	28,173	34,480	36,207	98,860	
2. Personnel Fringe Benefits	4,120	4,328	4,544	12,992	
3. Travel (include 1 trip to review meeting in Anchorage)	5,200	5,200	5,800	16,200	
4. Equipment				0	
5. Supplies	4,140	4,140	800	9,080	
6. Contractual/Consultants	8,400	8,900	1,200	18,500	
7. Other (Include $1500 for education and outreach)	5,044	8,801	9,020	22,865	
Total Direct Costs	55,077	65,849	57,571	178,497	0
Indirect Costs	25,973	29,508	25,226	80,707	
TOTAL PROJECT COSTS	81,050	95,357	82,797	259,204	0

NPRB BUDGET SUMMARY FORM

PROJECT TITLE: Early Marine Ecology of Juvenile Chum Salmon (Oncorhynchus keta) in Kuskokwim Bay, Alaska

PRINCIPAL INVESTIGATOR: Zimmerman

FUNDING SOURCE	YEAR 1	YEAR 2	YEAR 3	TOTAL
NPRB Funding	179,902	155,948	28,971	364,821
Match/In Kind				40,017
TOTAL	179,902	155,948	28,971	404,838

Annual cost category breakdowns will be requested for matching funds only if project is funded

Cost Categories	NPRB Year 1	NPRB Year 2	NPRB Year 3	NPRB TOTAL	Match/In kind TOTAL (all years)
1. Personnel Salaries	14,000	14,980	14,980	43,960	40,017
2. Personnel Fringe Benefits				0	
3. Travel (include 1 trip to review meeting in Anchorage)	3,970	3,970	1,500	9,440	
4. Equipment	17,500			17,500	
5. Supplies	3,200	3,200		6,400	
6. Contractual/Consultants	85,400	85,400	2,000	172,800	
7. Other (Include $1500 for education and outreach)			1,500	1,500	
Total Direct Costs	124,070	107,550	19,980	251,600	40,017
Indirect Costs	55,832	48,398	8,991	113,221	
TOTAL PROJECT COSTS	179,902	155,948	28,971	364,821	40,017

NPRB BUDGET SUMMARY FORM

PROJECT TITLE: Early Marine Ecology of Juvenile Chum Salmon (Oncorhynchus keta) in Kuskokwim Bay, Alaska

PRINCIPAL INVESTIGATOR: Hillgruber, Haldorson, Zimmerman - Combined

FUNDING SOURCE	YEAR 1	YEAR 2	YEAR 3	TOTAL
NPRB Funding	260,952	251,305	111,768	624,025
Match/In Kind				40,017
TOTAL	260,952	251,305	111,768	664,042

Annual cost category breakdowns will be requested for matching funds only if project is funded

Cost Categories	NPRB Year 1	NPRB Year 2	NPRB Year 3	NPRB TOTAL	Match/In kind TOTAL (all years)
1. Personnel Salaries	42,173	49,460	51,187	142,820	40,017
2. Personnel Fringe Benefits	4,120	4,328	4,544	12,992	
3. Travel (include 1 trip to review meeting in Anchorage)	9,170	9,170	7,300	25,640	
4. Equipment	17,500	0	0	17,500	
5. Supplies	7,340	7,340	800	15,480	
6. Contractual/Consultants	93,800	94,300	3,200	191,300	
7. Other (Include $1500 for education and outreach)	5,044	8,801	10,520	24,365	
Total Direct Costs	179,147	173,399	77,551	430,097	40,017
Indirect Costs	81,805	77,906	34,217	193,928	
TOTAL PROJECT COSTS	260,952	251,305	111,768	624,025	40,017