**_Oncorhynchus mykiss_ life history variability in the Middle Fork system: Migratory decisions in a disturbed wilderness environment**

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**Abstract**

Organisms make decisions about migratory and reproductive strategies based upon both inherited genotypes and cues from their environment. In some case, these decisions are based upon snapshots of their past experiences or relative performance in a habitat, yet the decisions are critically important for determining the organisms' relative rates of reproductive success. Presently, we as humans have tremendous ability to change both the habitats and the ecological cues that provide the template for the expression of these life history decisions. Steelhead and rainbow trout (*Oncorhynchus mykiss*) represent a unique twist on the novel life history strategy of most salmonids, which is to undergo large scale migrations that eventually return individuals to natal spawning areas where reproductively mature fish breed once and die. Unlike other salmonid species, *O. mykiss* populations are often represented by individuals that have adopted both a migratory life history and a resident life history with fish exhibiting significant variability in migration timing, maturation timing and freshwater movements.

The proposed graduate project will study life history variation in *O. mykiss* throughout Big Creek. The key questions that we propose to address are: 1) What is the relative representation of the different life histories? 2) How do the strategies differ in their respective contribution to future generations? 3) How is life history variation driven by the dynamic biophysical and geomorphic processes that occur throughout the watershed? And 4) How do the relationships between habitat and life history expression in Big Creek compare to those for *O. mykiss* in pristine streams throughout the entire distribution in the Pacific rim? This graduate project will integrate Big Creek with an international array of salmon observatory sites in Russia, Alaska and British Columbia whose mission it is to study the ecological causes and consequences of life history variation in *O. mykiss*.

**Introduction and statement of the problem**

Organisms are confronted with many possible solutions for achieving the same ultimate reproductive goal, maximizing their own fitness. Because of the centrality of this concept for integrating behavior and demographics, studies of the variation in life history decisions form a cornerstone for much of ecological and evolutionary theory. Understanding how the life history decisions of individuals is influenced by ecological conditions is an implicit goal in understanding the ecology of a species and is prerequisite for understanding how changes in habitat, productivity or temperature can influence phenotypes in a population and, ultimately, result in natural selection. Salmonids (fish in the family Salmonidae) provide textbook cases for our study of life history because of their unique strategies for maximizing reproductive output and the variation of strategies expressed both within and among representative families.

Within the family Salmonidae, the life history of the steelhead-rainbow trout complex (*Oncorhynchus mykiss*) is the most varied, the most difficult to generalize and therefore the most challenging to understand from a theoretical or population structure perspective (Quinn 2005). Because both anadromous (ocean migrants) and resident (non-migratory) individuals can co-exist within the same river, we have little power in single, short-term studies for identifying the selective ecological forces that pit these competing strategies against one another. However, at large scales where the expression of these strategies may differ, we can use this behavioral and genetic diversity to begin to understand these fundamental relationships. The proposed research focuses on *O. mykiss* as an indicator of salmonid life history response to variation in environmental and ecological factors among observatory rivers throughout the Pacific Rim. *O. mykiss* are similar to Atlantic salmon (*Salmo salar*) in exhibiting variable time in fresh water before migrating to sea (1 - 7 years), variable time at sea prior to maturation (1 - 5 years), variable distribution in salt water (estuarine to high seas anadromy) and a strong tendency to remain resident in freshwater but with considerable migratory behavior within the river system. The working hypothesis is that life history variation in *O. mykiss* derives from environmental (ocean-estuary-freshwater) influences operating within the genomic framework of the species and therefore, this variation responds to productivity and food web dynamics as mediated by the complex ecological, hydrological, physical and climatic processes at work in river systems. In the proposed initiative, I will work with a graduate student to study how evolutionary systems respond to anthropogenic change in a single system at Taylor Ranch Biological Field Station (TRBFS) and in the process establish a system of measurements and analyses that allow us to integrate our findings into a network of international salmon observatories.

Life history theory attempts to draw generalizations about the mechanistic basis for why one strategy for survival and reproduction may be more common or more favorable in some environments while its expressions is less favorable in other habitats or under a different set of environmental conditions (Stearns 1989). Migratory anadromous American shad (*Alosa sapidissima*) in the eastern United States demonstrate a latitudinal decrease in semelparity from Florida to Nova Scotia (Leggett and Whitney 1972, Leggett and Carscadden 1978). In other words, individuals from northern populations are likely to breed repeatedly whereas those from southern population breed once and die. Long term studies of these populations revealed that, consistent with life history theory, overall productivity and the predictability of juvenile rearing habitats in southern regions were likely responsible for the adoption of a semelparous life history. A research program that seeks to understand first, how variation in life history of *O. mykiss* is expressed, secondly, how this behavioral variation relates to variation in environmental factors, such as productivity, growing season, annual hydrograph and thermal fluctuations and, lastly, how the expression of these strategies would likely change under a scenario of global climate change, must study these populations over broad geographic and temporal scales. The proposed initiative for TRBFS will partner Big Creek with a number of emerging international salmon observatories in the northern Pacific including the Kol and Utkholok Rivers in Kamchatka, Russia, the Kwethluk River in Alaska, and the Kitlope River in British Columbia, Canada. By assembling such observatories where wild salmon still reside, the collaborating scientists hope to build a better understanding of the evolution and maintenance of salmon life histories. Collectively as scientists and regions, the overarching goals of establishing a network of river sites in which common data are collected are 1) to quantify and describe the fundamental biophysical and geomorphic processes that salmon rivers share and how these processes interact over time and space to create and maintain diversity life history variability; and, 2) to formulate and promote new conservation and management protocols for wild salmon rivers that are based on an emerging paradigm for how dynamic processes in rivers shape biodiversity not just at species scales but at genetic, behavioral and population scales as well.

The Shifting Habitat Mosaic (SHM) hypothesis predicts that the productivity of river habitats is controlled by dynamic and non-linear biophysical processes that occur over time scales, which are longer than those normally considered or measured in ecological systems (Stanford et al. 2005). Furthermore, the SHM predicts that the key biological manifestation of the SHM in lotic habitats is the maintenance of complex life histories of the aquatic residents and migrants that occupy these dynamic habitats. Interruption of the processes that occur at these large space and time scales is one of the unrecognized and underappreciated impacts that humans have upon the landscape. Therefore, developing a better understanding of both proximate and ultimate causes of life history variation as well as the population consequences of this variation is a fundamental goal of the Salmon Rivers Observatory Network (SaRON, http://www.umt.edu/flbs/Research/SaRON.htm). SaRON is a large international project whose reach extends to the full extent of *O. mykiss* distribution in largely pristine habitats in Russia, Alaska and Northern British Columbia. The overarching hypothesis motivating the SaRON effort is that the population structure and dynamics of the *O. mykiss* are robust indicators of general habitat conditions in freshwater and the ocean for all anadromous salmonid fishes as well as the attributes of riverine biodiversity that are associated with the relative complexity of the shifting habitat mosaic and marine nutrient subsidy of the observatory rivers. The specific objectives of studies occurring at salmon observatory sites are to:

- Establish the strength of nonlinear ecological controls or drivers (e.g. functional relationship between productivity at different spatial scales (reach and watershed) and the degree or frequency of movements and migrations) of Pacific salmon life history diversity expression and selection.

- Compare/contrast consistently measured parameters from across the observatory rivers to develop a unifying theory between habitat features, environmental variability and life history expressions.
- Use research results to help partners and others foster an alternative salmon management and conservation paradigm that is based on habitat and food web dynamics in natural ecosystem context.

The Big Creek ecosystem represents a unique environment for addressing life history questions within the steelhead salmon complex for several reasons. In the heart of the Frank Church River of No Return Wilderness, Big Creek represents one of the last untrammeled watersheds in the contiguous United States. As such, it currently represents among the southern and eastern most destination for anadromous *O. mykiss* in their Pacific distribution. Despite its remoteness and virtual inaccessibility, the system has experienced unique anthropogenic impacts when compared to the comparable salmon observatories throughout the Pacific distribution of *O. mykiss*. At the largest scale, migratory populations experience the hydrologic challenges created by the presence of dams in the Lower Snake and Columbia Rivers. Population growth in the Columbia River system has resulted in significant changes in the land use patterns, nutrient loading and species composition of the watershed as a whole. At finer scales, systems in the Salmon River have been increasingly settled throughout the last two centuries creating changes in the hydrology, geomorphology and disturbance regime of tributaries like Big Creek. Finally, as rivers throughout the Salmon River drainage experience declining anadromous runs of salmon, subsidies of marine-derived nutrients and carbon decline and perpetuate a decreasing trend of interrelated productivity, reproduction and recruitment. Little has been done to understand how these long term changes may affect the expression of life history in salmonids, but the implications of such studies will have broad significance as fish stocks worldwide decline (Worm et al. 2006).

**Objectives**

Funding of this project will initiate a process of establishing Taylor Ranch Biological Field Station and Big Creek as a satellite site (the only one in the contiguous 48 states) for the SaRON project and will begin the scientific process of documenting how biological and ecological responses can be a function of a changing environment, at both global and local scales. The overall objectives of the proposed research to occur at TRBFS are:

1) To collect physical and biological data in the Big Creek drainage that are consistent with those data being collected within the SaRON network of sites.
2) To compare biophysical characteristics of Big Creek to that of other SaRON sites and identify ways in which life history variation can be understood and explained based upon biophysical and habitat differences among sites.

3) To quantify life history variation (frequency of migration, frequency of residence and intermediate forms) compare patterns of life history of resident steelhead in Big Creek to that of other SaRON sites.

The work will be accomplished through a combination of field and laboratory approaches. Fieldwork will include measurements of habitat availability and productivity throughout the system as well as snorkeling surveys and electroshocking for *O. mykiss* density and community assemblage measurements. The student will be involved with the field efforts of both NOAA and IDFG scientists based at TRBFS to develop field methods for quantifying fish strategies and analyzing the resulting data. These techniques give us point estimates of fish behavior at specific moments of time, i.e. when a fish moved. It tells us less about the non-moving population or about the events that could have preceded a fish's movement. Otolith microchemistry and structure will provide and opportunity to quantify the environmental history and age-specific growth rates and reconstruct the migrational history of individual fish (Kennedy et al. 2000, 2002).

**Integrating efforts**

An important objective of this proposed graduate research project is to make full use of existing and future research opportunities at Taylor Ranch Biological Field Station. The proposed work integrates with efforts at an international level, but takes advantages of many unique opportunities that can only occur because of the collaborations and infrastructure that are co-located at TRBFS.

The proposed project utilizes many exciting approaches for studying *O. mykiss* movements and life history variation in the Idaho wilderness. NOAA – PNWFCS (Pacific Northwest Fisheries Science Center) under the leadership of Steve Achord, and with the help of some of us at UI, have invested significant resources and time in infrastructure and instrumentation that allows us to quantify the movements of individual fish in the Big Creek Drainage past stationary antenna located at TRBFS. The PIT tag antennas or "readers" are successfully recording the movements of PIT tagged fish in Big Creek. Data from the first summer, available online at http://www.psmfc.org/pittag/Data_and_Reports/ suggests that the antenna will be a reliable way to track both moving and migrating steelhead/rainbow and that individual fish are in some cases highly mobile in the TRBFS area of Big Creek. Jody White, IDFG, is discussing some exciting ways to capture, tag and follow the mobile portion of the population – both smolts and returning adults. He has proposed to use combined methods of trapping and underwater sonar techniques to get estimates of migratory *O. mykiss*. In the interest of building a research program in Big Creek, Jody will be helpful in two additional ways. First, ~~Jody~~ seasonal field assistants working periodically in Big Creek will be a critical asset to the DeVlieg GRA for assisting with secondary productivity measures as well as densities of juvenile *O. mykiss* throughout the basin. Additionally, Jody has discussed the possibility of expanding the IDFG goal of identifying genetic relationships among Idaho *O. mykiss* by including individuals from Big Creek in their analysis. Partnerships at Big Creek would provide the opportunity to study and quantify all aspects of resident and migratory fish, from fry to returning adult. Finally, as Project Leader for the SaRON project, Dr. Jack Stanford at Flathead Lake Biological Field Station has pledged his support for the research efforts to occur at TRBFS that are consistent with those of the SaRON initiative. Drs. Kennedy and Stanford and others will be working closely to establish consistent and extensive analyses of otolith microchemistry and structure for individual fish across all SaRON sites as a way to quantify the frequency, size-dependency and fitness consequences of different life history strategies for *O. mykiss*.

This graduate experience will help initiate a large-scale multi-university and multi-agency initiative. Partners in this project include Brian Kennedy at the University of Idaho, Jack Stanford at the University of Montana, Nick Gayeski at Washington Trout, Steve Achord at Northwest Fisheries Science Center, and Jody White at Idaho Fish and Game. Consequently, this project will be a rare collaboration among many entities with disparate and sometimes even conflicting goals.

**Project Schedule and Expected Results**

This work is intentionally proposed from a broad conceptual framework in order to solicit input from collaborators and other interested parties on scope and direction of preliminary field collection in Big Creek. The group that has been assembled to collaborate on this project represents many entities, but there is other work being done in the Middle Fork that will share relevance to this study, including work being done on juvenile Chinook energetics and trophic relationships (Kennedy and Cromwell), riparian-aquatic linkages (Braatne and Baxter), marine derived trophic subsidies (Sanderson) and Chinook movements and life history in the Middle Fork (Kennedy with partnerships at RMRS and NOAA-NMFS). We wish to allow for flexibility in recruiting and mentoring a potential MS student from a range of different backgrounds and interests in fish ecology. Ideally, the entire project as it is proposed here could constitute a single MS project, but it is possible for the candidate to specialize in some aspect of steelhead/rainbow life history. This student will work closely with Dr. Kennedy to achieve the stated objectives of the proposed research, but could maintain enough independence to focus on an individual aspect of the project if (s)he so chooses. For example, a student with interests in large-scale landscape interests could work on landscape level drives of productivity and its impact on life history expression. Alternatively, a student interested in the technical aspect of otolith microchemistry or genetics could work more extensively on establishing links between steelhead movements and life history. All of these relevant projects would integrally contribute to the overall goal of establishing Big Creek as a research site in which there is long term interest in the relationship between life history expression and developing a spatially explicit predictive model that links the bioenergetics of individual Chinook. ?

This study will start with the successful recruitment of an exceptional graduate student and run for 2.0 years. My goal will be to recruit a graduate student immediately with a broadly advertised announcement. I will hope to get a student in Moscow before the summer of 2007. This will provide time in the field before the first semester of classes and will allow a full academic year after the last field season to analyze data and prepare manuscripts. During this first field season, the student will overlap with an existing graduate student (Kara Cromwell) in the lab, who will also be doing field work in Big Creek. Kara is currently working on the food availability and trophic relationships of juvenile Chinook salmon in the Big Creek watershed in an effort to understand potential energetic limitations during their first summer. To the extant that this student will be working on relationships between productivity and life history expression, these two projects will serve complementary roles for our understanding of aquatic production in Big Creek.

My prospective timeline is as follows:

**2007**

| | |
|---|---|
| *January* | Begin advertising for graduate student. |
| *Feb. – June* | Travel by Dr. Kennedy to establish field sites and coordinating with partners at other universities and agencies on how to optimize the work proposed in Big Creek with that of other salmon observatory sites. |
| *May – August* | First field season for new graduate student who overlaps with existing field crew in at Taylor Ranch Biological Field Station. |
| *Sept. – Dec.* | Analyses of first summer's data and class work for student. |

**2008**

| | |
|---|---|
| *Jan. – April* | Student enrolls in second semester of classes and plans for the second field season. |
| *May* | We prepare the first annual project report. |
| *May – Aug.* | Both graduate student and undergraduate assistant at Taylor Ranch doing fieldwork. Dr. Kennedy assisting at Taylor for some time during this period. |
| *Sept. – Dec.* | Analysis of second summer's data and any remaining class work for student. |

**2009**

| | |
|---|---|
| *Jan. – June* | Synthesis of data and preparation of manuscripts. Completion of manuscripts and preparation of future grant proposals. |
| *June* | Final progress report. |

The graduate student, under the close supervision of Dr. Kennedy, will finish two manuscripts during this period of study. One will be based upon the comparison of life history variation of Big Creek steelhead in comparison to other Pacific populations. The second manuscript will be build upon the data to develop a spatially explicit predictive model of *O. mykiss* life history variation and relative success in relation to productivity and temperature distributions throughout the Middle Fork Salmon River.

## Project Budget

DeVlieg – Taylor Ranch Graduate Research Assistantship
Budget Year (06/01/2007 - 05/31/2009)

| **Salary, Wages and Stipend** | *DeVlieg* | *Kennedy matching** | *Other matching*** |
|---|---|---|---|
| GSRA appointment for two years | 18,000/yr | | |
| Summer Salary (Brian Kennedy) (2007 - 08 ~2.0 months) | | 11,000*** | |
| Professional time (Steve Achord NOAA, Jody White IDFG) | | | 6,000 |
| Work study student (undergraduate help during 2 school years) and field assistants supplied by IDFG | | 3,000/yr | 6,000 much higher |
| *Total Salary/Wages* | *36,000* | *17,000* | *12,000* |
| | | | |
| **Supplies, Services and Travel** | | | |
| Research Supplies (including backpack shocker, nets, snorkeling gear, misc. field and laboratory eqpt.) | | 8,000 | 2,000 |
| Travel by faculty, advisors and field assistants | | 2,000 | 2,000 |
| Housing and board at Taylor Ranch | 500/yr | 2,000 | 2,000 |
| Publication/Page Reprint/Postage Charges | | 200 | 200 |
| Lab fees & services (e.g. isotope, elemental & genetic analysis) | | 4,000 | 4,000 |
| *Total Operating Costs* | *1,000* | *16,200* | *10,200* |
| **TOTAL DIRECT COSTS** | **37,000** | **33,200** | **22,200** |

*Kennedy matching comes from start-up and other relevant funded projects in the Middle Fork Salmon River.

**This represents probably the minimal amount of matching for this project (e.g. more than $100K has been invested in the PIT tag antenna deployment) and includes contributions of time, equipment, and additional sample analysis by IDFG and NOAA-NWFSC.

***This is time that will be spent ensuring coordination of research efforts with partners, acquiring appropriate permitting and developing a successful research project and graduate experience.

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## Professional Preparation

Colgate University, Major: Biological Sciences, B.A. 1991
Dartmouth College, Major: Ecology and Evolutionary Biology, Ph.D. 2000
University of Michigan, Geological Sciences, School of Natural Resources and Ecology and Evolutionary Biology, 2001-present

## Appointments

University of Idaho, College of Natural Resources, Assistant Professor – 2005 – present
University of Michigan, *Postdoctoral Fellow and visiting assistant professor* – 2001 to 2005
Conservation International Foundation, *Aquatic Ecology Consultant* – 2000 to 2001
Dartmouth College, *Graduate Research Assistant* – 1994 to 2000
Michigan State University, *Research Assistant* – 1991-1994

## Publications

**Kennedy, B.P.,** Nislow, K.H., C.L. Folt. *In review at Ecology.* Establishing the links between consumption, growth and survival for juvenile Atlantic salmon (*Salmo salar*)

**Kennedy, B.P.,** Chamberlain, C.P., Blum, J.D., Nislow, K.H. and Folt, C.L. (2005) Comparing naturally occurring stable isotopes of nitrogen, carbon, and strontium as markers for Atlantic salmon juvenile rearing locations. *Canadian Journal of Fisheries and Aquatic Sciences,* ***62****: 48-57.*

**Kennedy, B.P.,** Klaue, B., Blum, J.D., and Folt, C.L. (2004) Integrative measures of consumption rates in fish: expansion and application of a trace element approach. *Journal of Applied ecology,* **41**: 1009-1020.

Fuller, R.L., **Kennedy, B.P.,** and Nielsen, C. (2004) Macroinvertebrate responses to algal and bacterial manipulations in streams. *Hydrobiologia*, **523**: 113-126.

**Kennedy, B.P.,** Klaue, A, Blum, J.D., Folt, C.L. and Nislow, K. (2002). Reconstructing the lives of salmon using Sr isotopes in otoliths. *Canadian Journal of Fisheries and Aquatic Sciences,* **59**: 925-929.

Nislow, K.H., Magilligan, F.J., Folt, C.L, and **Kennedy, B.P**. (2002) Within-basin variation in the short term effects of a major flood on stream fishes and invertebrates. *Journal of Freshwater Ecology*. **17**: 305-318.

**Kennedy, B.P.,** Blum, J.D., Folt, C.L. and Nislow, K. (2000) Using natural strontium isotopic signatures as fish markers: methodology and application. *Canadian Journal of Fisheries and Aquatic Sciences,* **57**: 2280-2292.

**Kennedy, B.P.** (2000). Understanding Atlantic salmon (*Salmo salar*) performance, survival and dispersal through the use of environmental tracers. Dartmouth College, Hanover, N.H. Ph.D. Dissertation.

Mack, A.L., Ickes, K., Jessen, J.H., **Kennedy, B.P.,** and Sinclair, J.R. (1999) Ecology of *Aglai mackiana* (Meliaceae) seedlings in a New Guinea rain forest. *Biotropica*. **31**: 111-120.

Harrington, R., **Kennedy, B.P.,** Chamberlain, C.P., Blum, J.D., and Folt, C.L. (1998) $N^{15}$ enrichment in agricultural catchments: field patterns and applications to tracking Atlantic salmon (*Salmo salar*). *Chemical Geology*, **147**: 281-294.

**Kennedy, B.P.,** Folt, C.L., Blum, J.D., and Chamberlain, C.P. (1997) Natural isotope markers in salmon. *Nature*. **387**: 766-767.

Hedin, L.O., von Fischer, J.C., Ostrom, N.E., **Kennedy, B.P.,** Brown, M.G., and Robertson, G.P. (1997) Thermodynamic constraints on nitrogen transformations and other biogeochemical processes at soil-stream interfaces. *Ecology*. **79**: 684-703.

**Scientific Reports**

**Kennedy, B.P.,** Blum, J.D., Nislow, K and Coggins, L. (2004). Watershed-scale geochemical signatures and the identification of natal origins of fishes in the Colorado River Basin.

**Kennedy, B.P.,** and Blum, J.D. (2002). Using stable isotopes of strontium and elemental ratios to identify the natal origins of Chinook salmon in the Middle Fork of the Salmon River.

**Kennedy, B.P.,** and Kumilgo K. (2001). Survey of the aquatic community and habitat structure of streams in the Wanui watershed, Wide Bay Wildlife Management Area, East New Britain Province.

**Invited Talks**

*November 2005.* Department of Biological Sciences, University of Idaho, Moscow, ID.
Linking life cycle stages of fish: It's elementary. B.P. Kennedy, Dept. of Fish and Wildlife Resources, University of Idaho.

*October 2005.* Grand Canyon Monitoring and Research Center, Mesa, AZ.
A test of the utility of otolith chemistry for studying movements of fishes in the Colorado River. B.P. Kennedy, Dept. of Fish and Wildlife Resources, University of Idaho.

*January 2002.* Department of Geological Sciences, University of Michigan, Ann Arbor, MI.
Reconstructing the lives of salmon through the use of Sr stable Isotopes. B.P. Kennedy, Dept. of Geological Sciences, University of Michigan.

*June 2001.* North American Benthological Society Annual Meeting. Lacrosse, WI.
Using natural strontium signatures to track the movements and migrations of salmon. B.P. Kennedy, A. Klaue, J.D. Blum & C.L. Folt.

*April 2001.* Great Lakes Environmental Research Laboratory, NOAA. Ann Arbor, MI.
Linking Atlantic salmon habitat, foraging, and survival through the use of environmental tracers. B.P. Kennedy, Dept. of Geological Sciences, University of Michigan.

*January 2001.* Department of Biology, University of Michigan, Ann Arbor, MI.
Linking Atlantic salmon habitat, foraging, and survival through the use of environmental tracers. B.P. Kennedy, Dept. of Geological Sciences, University of Michigan.

*February 1999.* Connecticut River Atlantic Salmon Commission - Tech Meeting. Hadley, MA.
Effects of extreme floods on habitat and biotic communities in Atlantic salmon rearing streams. K.H. Nislow, F.J. Magilligan, B.P. Kennedy & C.L. Folt.

*July 1998.* American Fisheries Society Early Life History Section. Ann Arbor, MI.
Tracing the tributary origins and movements of anadromous Atlantic salmon (*Salmo salar*) through the use of stable isotopes. B.P. Kennedy, R. Harrington, C.L. Folt, J.D. Blum & C.P. Chamberlain.

**Scholarly Presentations**

*September 2000.* Goldschmidt International Conference for Geochemistry. Oxford, UK.
Sr isotope markers in otolith growth increments of Atlantic Salmon. A. Klaue, B. P. Kennedy, J. D. Blum, C. L. Folt, and K. C. Lohmann.

*August 2000.* Ecological Society of America. Snowbird, UT.
The relationship between consumption rates and habitat in Vermont salmon streams: application of a trace metal mass balance approach. B. P. Kennedy, K. H. Nislow, C. L. Folt, and J. D. Blum

*July 2000.* International Conference on the Biology of Fish. Aberdeen, Scotland.
Testing the predictions from a spatially-explicit bioenergetic model for age-0 Atlantic salmon using fluxes of trace elements. B. P. Kennedy, C. L. Folt, and K. H. Nislow.

*May 1999.* North American Benthological Society Annual Meeting. Duluth, MN.
Within-basin variation in the effects of a major flood. K. H. Nislow, F. J. Magilligan, B. P. Kennedy, and C. L. Folt.

*April 1997.* Northeast Fisheries and Wildlife Conference. Amherst, MA.
Distinguishing salmon populations based upon their stable isotope chemistry. B. P. Kennedy, C. L. Folt, J. D. Blum, C. P. Chamberlain, and R. Harrington.

*August 1996.* Ecological Society of America. Providence, RI.
Tracing tributary origins of migratory salmon using stable isotopes. B. P. Kennedy, R. Harrington, C. L. Folt, J. D. Blum, and C. P. Chamberlain.

*June 1994.* North American Benthological Society. Orlando, Fl.
Controls on nitrogen transformations at hyporheic soil-stream interfaces: an experimental evaluation. B. P. Kennedy, L. O. Hedin, J. C. von Fischer, and M. G. Brown.

**Research Highlights**

Conservation in Practice, "Feathers with Zip Codes: Isotope Signatures Revolutionize how we track animal movements," October 2006, vol. 7, no. 4.
Science: Editor's Choice, August 9, 2002.
University of Michigan: http://www.umich.edu/~newsinfo/Releases/2001/Aug01/r080301e.html
Discovery Channel: "Tracking the migrations of salmon;" aired August, 1997.
Science Daily: http://www.sciencedaily.com/releases/1997/06/970629234900.htm
Scientific American: http://www.sciam.com/article.cfm?articleID=00065888-507E-1C60-B882809EC588ED9F
Boston Globe: "Salmon's return address decoded unique mix of isotopes in bones reveals its origin" Ralph Jimenez, July 6, 1997.

**Awards & Fellowships**

| | | |
|---|---|---|
| DIALOG IV Participant | ASLO sponsorship | 2001 |
| Olin Fellowship | Atlantic Salmon Federation | 1999 – 2000 |
| Dartmouth College Graduate Fellowship | Dartmouth College | 1994 – 2000 |
| Charles W. Tillou Memorial Scholarship | Colgate University | 1988 – 1991 |
| Class of 1929 Memorial Scholarship | Colgate University | 1987 – 1991 |

**Professional Societies**

Ecological Society of America
North American Benthological Society
American Fisheries Society – Idaho Chapter Secretary/Treasurer (2006-08)
Sigma Xi