

**Independent Expert Panel Review of the
Family Farm Alliance's Information Quality Act
Correction Requests**

Prepared for



U.S. Fish and Wildlife Service
134 Union Boulevard
Lakewood, CO 80228

Prepared by



PBS&J
1211 SW 5th Ave, Suite 790
Portland, OR 97204

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Attachments

- Attachment 1 – Panelists CVs
- Attachment 2 – USFWS PowerPoint Presentation

List of Acronyms and Abbreviations

TERM	DEFINITION
%	percent
BA	Biological Assessment on the Continued Long-term Operations of the Central Valley Project and the State Water Project, U.S. Department of the Interior, Bureau of Reclamation (August 2008)
BO	Biological Opinion on the Proposed Coordinated Operations of the Central Valley Project and State Water Project, U.S. Department of the Interior, Fish and Wildlife Service (December 2008)
CALFED	CALFED Bay-Delta Program
CALSIM-II	California Department of Water Resources Water Simulation Model
CDEC	California Data Exchange Center
cfs	cubic feet per second
CR	Correction Request = Request for Correction of Information
CVP	Central Valley Project
DAYFLOW	A computer program used for determining historical Delta boundary hydrology
Delta	Sacramento River-San Joaquin River Delta
DWR	California Department of Water Resources
EA	Effects Analysis (<i>Effects of the Proposed Action</i> in the BO)
EQ	Environmental Quality
FFA	Family Farm Alliance
FMWT	Fall Midwater Trawl
IQA	Information Quality Act
mm	millimeter
NBA	North Bay Aqueduct
OCAP	Operations Criteria and Plan
OMR	Old and Middle Rivers
PBS&J	Post Buckley Shuh & Jernigan
P.L.	Public Law
POD	Pelagic Organism Decline
PRQ	Panel Review Question
SWP	State Water Project
USFWS	U.S. Fish and Wildlife Service
X2	Location in the Delta defined by the 2 parts-per-thousand salinity isohaline

Introduction

The U.S. Fish and Wildlife Service (USFWS) requested that Post Buckley Shuh & Jernigan (PBS&J) assemble an independent panel of experts (Panel) to conduct an expert review of an Information Quality Act (IQA; Section 515 of P.L. 106-554) appeal filed by the Family Farm Alliance (FFA) to the USFWS's *Effects of the Proposed Action* analysis (Effects Analysis) included in the 2008 Biological Opinion (BO) for the Operations Criteria and Plan (OCAP) for the long-term joint operations of the federal Central Valley Project (CVP) and California State Water Project (SWP) (USFWS 2008). This report documents the expert Panel review process and presents the results of that review. The review was conducted pursuant to the USFWS's *Information Quality Guidelines* (USFWS 2006). The report presents the Panel's responses to specific questions on the validity of the scientific foundations of the BO's Effects Analysis. The Panel met from October 16 through 18, 2009, in Sacramento, California, to conduct the review.

Background

On December 15, 2008, the USFWS issued a Final BO evaluating the effects of the OCAP on the federally listed delta smelt (*Hypomesus transpacificus*), an endemic pelagic fish occurring in the Sacramento River-San Joaquin River Delta (Delta), part of the larger San Francisco Bay estuary. On December 14, 2008, the FFA submitted a *Request for Correction of Information* (Correction Request; CR) to the USFWS pursuant to the IQA commenting on the October 17, 2008, Draft Effects Analysis in the BO. On March 12, 2009, the USFWS responded to the FFA IQA request that specific corrections be made to the BO. The FFA subsequently appealed the USFWS response on April 1, 2009, on a variety of legal, policy, and scientific grounds. Subsequently, the USFWS asked the Panel to conduct an expert review designed to address two issues:

- Scientific topics raised in the FFA appeal; and
- Scientific data, assumptions, conclusions, and interpretations in the December 15, 2008 Effects Analysis in the Final BO.

Expert Review Process

Panelist Selection

To assemble an independent panel, PBS&J contacted expert scientists not currently involved in Delta science activities, but known for their expertise in estuarine ecology, fishery science, biostatistics, or hydrology. Prospective panelists were asked a series of questions to screen for potential or perceived conflicts of interest. All prospective panelists indicating they were interested in serving were asked to complete a National Academy of Sciences' *Background Information and Confidential Conflict of Interest Disclosure* form (BI/COI FORM 2). The qualifications and disclosure forms for the selected Panel members were reviewed and approved by the USFWS. The selected Panelists were:

- Dr. William V. Sobczak, Associate Professor, Biology Department, College of the Holy Cross, Worcester, Massachusetts;
- Dr. Ronald T. Kneib, Senior Research Scientist, University of Georgia Marine Institute, Sapelo Island, Georgia;
- Dr. Ronald M. Thom, Staff Scientist, Marine Sciences Laboratory, Pacific Northwest National Laboratory, Sequim, Washington;

- Dr. David G. Hankin, Professor, Department of Fisheries, College of Natural Resources and Sciences, Humboldt State University, Arcata, California; and
- Dr. John (Jack) H. Humphrey, P.E., Hydmet, Inc., Palo Cedro, California.

The curriculum vitae of each panelists is included in Appendix 1 to this report. PBS&J provided each panelist with the entire BO (2008), a complete set of references used by the USFWS in the BO, the FFA's IQA appeal (2009), and FFA's *Detailed Request List* (2009). Panel members reviewed as many of these materials as possible prior to the Panel meeting in Sacramento, California. The Panel convened in PBS&J's Sacramento office on October 16 and worked through October 18, 2009, to complete the independent review. Post-meeting communication among the panelists on the draft report continued until October 21 when the final independent expert panel report was submitted to the USFWS. PBS&J staff facilitated the review process and provided logistical support. The views expressed in this document are those of the Panel and do not represent those of the panelist's affiliated institutions or of PBS&J staff.

Question Development

The FFA appeal contained 25 primary CRs. The specific elements of numerous CRs appeared to be redundant of other CRs. Therefore, PBS&J staff, in consultation with the USFWS, condensed and summarized the scientific topics being contested into a suite of nine panel review questions (PRQs). Topics of policy, legal issues, or CRs determined by the USFWS not to meet the "influential information" standard of the IQA were eliminated by the USFWS from the review. A list of final PRQs was approved by the USFWS and provided to the review panelists in advance of the October review meeting.

Panel Consultations

Because the consultation process under the Endangered Species Act is very different than the standard peer review process typical of a scientific journal, the USFWS requested access to the independent review Panel for the sole purpose of explaining to the Panel the process and context for BO preparation. Cay C. Goude (Assistant Field Supervisor, Sacramento Fish and Wildlife Office, USFWS) and Ryan Olah (Coast Bay Branch Chief, Sacramento Fish and Wildlife Office, USFWS), gave a short presentation (Attachment 2) to the Panel on October 16 and answered questions from the Panel regarding the BO preparation process. The Panel also arranged a phone call with Dr. Lenny F. Grimaldo (California Department of Water Resources and University of California, Davis) on the morning of October 17, 2009, during which the Panel asked for clarifications regarding the development of Figure E-1 used in the BO Effects Analysis (page 247 of Final BO). At the request of the Panel, Dr. Grimaldo also provided the Panel with the salvage data illustrated in Figure E-1 on October 21, 2009.

Panel Responses

Panel responses generally consist of non-quantitative statements of opinion based on professional judgment and review of materials described previously. In some cases, Panel responses also include illustrative calculations or tables designed to provide readers with information or to assist in getting points across. Given the very short period of time during which the Panel's review was developed, it was not possible to thoroughly check these illustrative calculations to make certain that there were no errors. Any calculation errors which may exist are unintentional and, the Panel hopes, not so serious as to confuse or alter the conclusions presented herein.

Terminology

The FFA *Detailed Correction List* including terminology that was considered potentially ambiguous by the Panel. The following definitions were used by the Panel in conducting the Effects Analysis review.

Natural Condition - The term “natural” is defined to refer to the pristine environment of the Delta (i.e., absent Euro-American settlement and development of the Delta).

Unimpaired Condition - Natural flows with no diversion or storage as affected by current levees and other channel and landform alterations.

Historical Condition - The historical condition or historical baseline is defined per the USFWS as the hydrological conditions of the Delta existing during the period from 1967 to 2007.

Current Condition - The current condition or current baseline refers to the results of CALSIM II Study 7.0 as defined in the BO.

Project – The combined operation of the Central Valley Project and State Water Project

Expert Review Questions and Answers

This list of PRQs are those that were specifically posed to the expert review Panel for consideration. They are based on the summarization of the CRs in the FFA IQA appeal. The CR numbers in parentheses following each PRQ refer to the FFA's *Detailed Request List* numbers that that particular PRQ addresses entirely or in part.

PRQ 1. Review use of Rose (2000) as appropriate for the USFWS's position on three assumptions of Project effects. Is the approach for interacting stressors consistent with the Rose paper? If so, does the paper support the assumptions as used by the USFWS? (CRs 1, 5, 6, 7)

PANEL RESPONSE 1. The assumptions stated on page 203 in the *Effects of the Proposed Action* section of the BO are as follows: (1) “...the proposed CVP/SWP operations affect delta smelt throughout the year either directly through entrainment or indirectly through influences on its food supply and habitat suitability”; and, (2) “...that any of these three major categories of effects described above will adversely affect delta smelt, either alone or in combinations.” The BO further states that “This approach is also consistent with Rose (2000), who used several different individual-based models to show how multiple interacting stressors can result in fish population declines that would not be readily discernable using linear regression-based approaches.”

Rose (2000) posits that quantifying the effects of anthropogenic changes in the environmental quality (EQ) on fish populations has remained elusive and controversial. In his paper, Rose illustrates six issues that can improve the quantification of EQ effects on fish populations. Rose proposes that, by considering these issues in the analysis and by taking a multidisciplinary approach that combines individual-based modeling and life history theory, quantification can be achieved. Rose defines EQ as “...the suite of abiotic variables that either exert a direct effect on individuals of the population of interest, or cause an indirect effect via directly affecting the population's competitors, predators, or prey.” Abiotic factors include a wide array of water and sediment properties as well as contamination, all of which can influence growth, mortality, and reproductive rates of individuals. Harvest and introduction of exotic species do not affect EQ but may alter the population.

The Panel believes that Rose's paper presents legitimate reasons explaining why it is generally difficult to develop quantitative relationships between EQ and fish populations. Further, the Panel feels that the issues and approach outlined in the paper are valid and robust in terms of improving the quantification of effects. The recommendation for use of true multidisciplinary study teams in addressing EQ vs. fish population relationships is supported by the Panel. The Panel reviewed the BO relative to the six issues identified by Rose and found that much of the material in the sections on *Status of the Critical Habitat*, *Environmental Baseline*, *Effects of the Actions*, and *Cumulative Effects* utilized to a varying degree Rose's approach. The spatial extent and long-term nature of the data set on fish and other factors in the Delta region provide a strong basis for addressing the issues of *detectability*, *regional predictions*, and *community interactions*. The issue of *sublethal effects* appeared to receive the least treatment. The issue of *cumulative effects* was addressed specifically, but the analysis was not extensive or quantitative.

The Panel felt that a direct assessment of the Rose approach in dealing with the assumptions was made more difficult because the BO does not specifically cite how it addresses each of Rose's six issues, and how "true" multidisciplinary studies were incorporated. If Rose is the approach used for the Effects Analysis, then the Panel recommends that either the Effects Analysis be organized according to the six issues or a table and discussion be developed showing how the issues were addressed.

Additionally, the Panel thought that a simple conceptual model would have served to guide the reader through all sections of the BO. The model could have been used to summarize the potential impacts associated with the project as well as provide a framework for discussing recommendations, uncertainties and ultimately the reasonable and prudent alternative actions.

Because the BO is restricted to analysis of the OCAP, assessment of the relative effects of all potential stressors to the population of delta smelt was not addressed specifically. That said, the *Baseline* section of the BO does cover several stressors of relevance to the population. Also, the analysis of the interaction of stressors in producing cumulative effects is not addressed in the Effects Analysis section. The BO specifically states that the *Cumulative Effects* section must be restricted to only those "...effects of future State, Tribal, local and private actions that are reasonably certain to occur in the area considered in this biological opinion." The Panel felt that the *Baseline* section of BO did describe the role of several stressors on the smelt population, and *in effect* does cover past and present multiple stressor effects.

In conclusion, the Panel felt over all that the BO credibly employed the Rose approach through involvement of a multidiscipline team, use of model results, and analysis of extensive temporal and spatial data sets. Further, the panel believes that the three assumptions in the BO were addressed including a fourth assumption of interacting effects. However, the Panel noted a varied degree of support developed relative to each assumption. The Panel's assessment of these is treated more fully below.

PRQ 2. Does entrainment of delta smelt at Project facilities drive the smelt population and what is the frequency of these events? If so, is the methodology presented in the Effects Analysis based on the best available scientific and commercial data, accurately calculated, and based on scientifically valid assumptions? (CRs 2, 3, 14, 15, 16, 23)

PANEL RESPONSE 2. It would be extremely difficult, with high statistical confidence, to isolate any single factor, including entrainment, as the key driver of smelt population dynamics. Researchers have consistently acknowledged that multiple factors affect the quantity and quality of habitat for delta smelt and are potentially important contributors to the abundance of delta smelt. Multiple stressors that smelt may be exposed to include: declines in food availability,

predation, multiple contaminants (including mercury, selenium, and herbicides), low dissolved oxygen, excessive turbidity, alterations in Delta hydrodynamics (including changes in the timing, duration, and magnitude of high outflow events), increases in temperature, increases in salinity, and entrainment. It is difficult to weight the relative importance of these numerous factors, but long-term changes and declines in food resources have been repeatedly implicated as a critical stressor on the delta smelt population. Not all of these factors are subject to practical management, but changes in the operation of the project facilities to protect biological populations of concern in the Delta remain a practical management tool. It should be recognized that the identification of a factor that ‘drives’, or is an ‘important’ contributor to, population dynamics is not necessarily determined by magnitude alone. Small annual differences in vital rates may sometimes determine whether a population increases or decreases in a given year. In the case of delta smelt, there is no doubt that population size is currently at an historical low, and that entrainment at project facilities results in direct mortality.

Total entrainment alone, however, is not a particularly useful metric for assessing potential population impacts. A better measure of potential impact would be provided by a ratio of entrainment to abundance. The Panel believes that the BO could present useful information of this kind of “scaled” impact. First, Newman (2008) has made an attempt to generate total monthly abundance estimates for adult delta smelt over the period 1990 through 2006. The Panel compared Newman’s December abundance estimates with the salvage data used by Grimaldo et al. (2009) to provide a sense of the potential population impacts of project pumping relative to delta smelt abundance (Table 1).

Year	Winter Salvage¹	Population estimates Age 0 and Age 1 in December (after Newman 2008)	Salvage as a % of population
1993	447	866,000	0.05
1994	2,632	91,000	2.89
1995	5,745	554,000	1.04
1996	2,396	618,000	0.39
1997	1,075	691,000	0.16
1998	2,185	366,000	0.60
1999	12,631	1,405,000	0.90
2000	8,821	1,087,000	0.81
2001	6,877	144,000	4.78
2002	14,359	277,000	5.18
2003	8,148	242,000	3.37
2004	2,018	37,000	5.45
2005	324	45,000	0.72

1. Salvage data were obtained from Grimaldo (personal communication); differences between annual winter salvage values in the table and those presented in Grimaldo et al (in press) are due to tabulation methods applied. In Grimaldo et al. (in press), winter salvage for a given year was based on the previous Dec and the first quarter of the calendar year (e.g., 1993 was the sum of salvage from Dec 1992, Jan 1993, Feb 1993 and Mar 1993). In Table 1 above, winter salvage was the sum of adult-size smelt salvaged beginning in December through March of the following calendar year (e.g. 1993 winter salvage is the sum of salvage from Dec 1993, Jan 1994, Feb 1994 and Mar 1994). This allowed for a more direct association between Newman’s (2008) estimates of population size in Dec and the salvage losses affecting that cohort directly during the spawning season.

An apparent increase in the proportional losses due to the salvage component of entrainment mortality since the beginning of the current decade (i.e., after 2000) coincides with recent observations of prolonged low abundance of adult delta smelt (Figure 1).

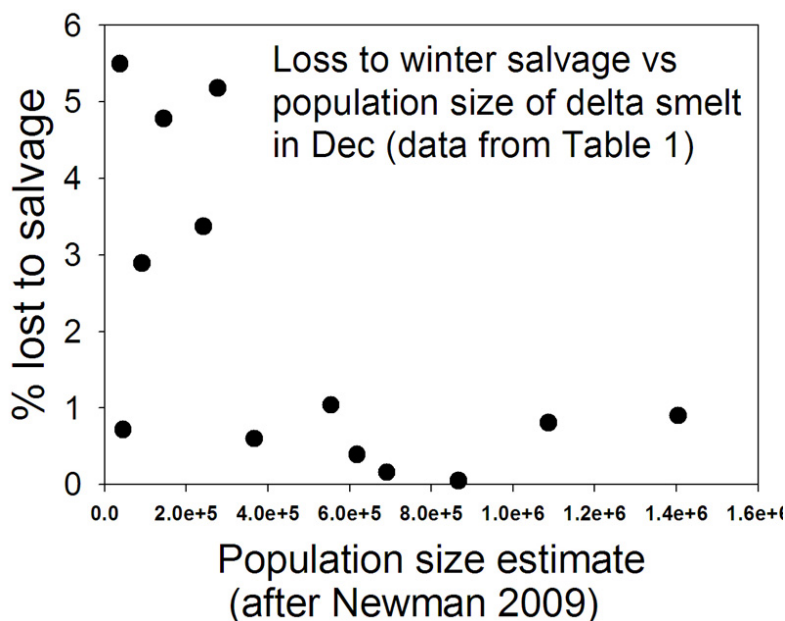


Figure 1

Scatter plot of winter salvage losses (Dec, Yr x through Mar, Yr x+1) versus adult delta smelt population size estimated for Dec (Yr x) from 1993 to 2005. Data are plotted from Table 1 (present report) and illustrate that greater proportional losses of adults to entrainment have occurred at lower population sizes. Note that estimated salvage losses represent an unknown portion of adult mortality due to entrainment; passage through the louvers and predation in the Clifton Bay Forecourt must produce additional losses.

Second, alternative estimates of proportional loss due to entrainment, considerably higher in some years, have been developed by Kimmerer (2008) as shown in Table 2. The Panel did not have time to conduct an independent review of the methodologies employed by Kimmerer (2008) or Newman (2008). The Panel believes, however, that these estimates of “proportional entrainment,” based on Newman (2008) and Kimmerer (2008), which have been peer reviewed, constitute the best scientific and commercial data available to the USFWS at the time of BO preparation. Together they suggest that entrainment-related mortality may account for a substantial proportion of the population in some years, thus supporting a contention that pumping may have an important ‘sporadic’ effect on delta smelt abundance, particularly during the past decade.

Table 2. Estimates of cumulative adult lost due to entrainment based on Kimmerer (2008)		
Year	Cumulative Adult Loss (%)	95 % Confidence Limits
2002	15	5-24
2003	50	19-69
2004	19	6-31
2005	7	2-12
2006	4	1-6

Although the numbers of smelt accounted for at fish collection facilities (“salvage”) have been the focus of efforts to assess adult mortality due to project pumping, these values clearly underestimate mortality due to entrainment, which includes losses due to the passage of individuals through the louvers at fish collection facilities and losses due to predation in Clifton Court Forebay. The Panel is extremely concerned about the lack of information about predation on delta smelt in Clifton Court Forebay, in advance of the fish collection facilities. The panel believes that predation in Clifton Court Forebay may be a substantial source of smelt mortality directly related to Project operations based on pre-screen loss studies for various fish taxa (Fujimura 2009).

The impact of ‘sporadic’ losses on a population generally depends on the size of the population at the time of such loss. For example, if a low value for the delta smelt population is considered to be 0.5 million potential spawners and half are lost in one year (50% mortality), a doubling of the population in the subsequent year would return the population to the previous low value. However, if the population was reduced to 50,000 (90% mortality) it would take 3–4 consecutive years of doubling to return to the low value of 0.5 million individuals. There would then be a 4-year interval between years that the population was at the minimum 0.5 million individuals. If at any time during that period, another event reduced the population by 90%, the length of time to recovery would be extended further. For example, if a second episodic major mortality event occurred in the second year when the population had recovered to 200,000 resulting in another 90% reduction (to 20,000) it would require an additional 4–5 consecutive years of doubling before the population would return to 0.5 million, and the interval between years when the population was at the desired minimum level of 0.5 million would be extended to 7. Both the severity and the timing of the sporadic catastrophic loss will drive the recovery period. Anything that contributes to lengthening the recovery period, increases the risk of setting recovery back even further because, in a sporadic impact scenario, it increases the probability that another major impact will introduce a setback to recovery.

These are extreme examples, which are not data-based, but are meant only to illustrate a point about the potential impact of sporadic or occasionally large contributions to mortality in an annual species. The episodic frequency of catastrophic impacts on survival can make the difference between survival and extirpation when the population is small.

PRQ 3. A three-part question. (CRs 2, 4, 13, 17, 18, 19, 20, 21)

A. Do Project operations control the hydrodynamics of the Delta?

PANEL RESPONSE 3A. Project operations have greatly modified the direction and magnitude of flows through the Delta at all times of the year. Nearly all of the river flow available for export is obtained from Sacramento River runoff and its storage reservoirs. The majority of Sacramento River flow now leaves the river via the Delta Cross Channel and modified former natural channels and flows southwest across the eastern Delta. A proportion of the Sacramento River flow continues downstream as outflow to San Francisco Bay. There are relatively minor contributions to Delta inflows from the Cosumnes, Mokelumne, and San Joaquin rivers. The normal (except in very wet months where San Joaquin River and east tributaries become important) southward flows toward the export facilities in Old and Middle rivers (OMR) are assigned a negative flow value. The principal pumping facilities are operated by the CVP and SWP projects (Banks and Jones export facilities), but there are other sources of water diversion (North Bay Aqueduct, Contra Costa Water District, local agriculture, and power plants). The great complexity of operations could only be simulated by computer models. The CALSIM II,

DAYFLOW and some other delta hydrodynamic models were used in the BO to determine the influence of the project existing and proposed operations on Delta flows. The CALSIM II model used water years 1922–2003, a monthly time step and attempted to meet regulatory and operational priorities for the 2005 level of development (Study 7.0). The DAYFLOW model reproduced historical operations and resulting Delta flows for 1967–2007.

Project pumping is the primary force acting on the hydrodynamics of the Delta, based on the fact that the net flow direction has changed since the initiation of pumping. The direction of flow across the Delta is radically changed since project pumping induces Sacramento River flow to be directed toward the southwest to the pumps. Tide and weather effects operate on much shorter time scales than the monthly averages used to evaluate the project. Tides and winds vary over a scale of hours and days and do not significantly influence Delta monthly average inflow and outflow. Delta outflow interaction with tides determines the location of the X2 isohaline salinity gradient. The location of X2 is directly influenced by project pumping and resulting reduction in Delta outflow. By weather it is assumed that reference is being made to the strong winds in the Delta generated by air pressure differences through the convergence funnel created by the Sacramento River being the only passage from the Central Valley to the Pacific Ocean. This topography is responsible for frequent strong westerly winds, especially in the western Delta in summer. These winds can have some influence on the Delta water surface and currents. However, the project has no influence on wind or tide and these factors are minor compared to project induced changes in Delta hydrodynamics. For example, in the absence of any wind and weather affects, project induced flows in OMR would be the same.

B. Is the assertion by the USFWS that Project operations exacerbate the effects these other factors have on smelt based on the best available scientific and commercial data?

PANEL RESPONSE 3B. The assertion seems reasonable based on the findings and observations of numerous researchers in the Delta who have related shifts in habitat quantity (e.g., information on X2) and quality (e.g., food supply) to aspects of pumping operations. Intuitively, hydrodynamics define estuaries and drive many estuarine processes. Project operations move large volumes of water against natural elevation gradients, and it would be less than responsible to maintain this would have no effect on a species such as delta smelt, which has such a narrow range of habitat requirements in the vicinity of the pumping operations.

C. Are low stable fall flow conditions dependent on Project operations? If so, do these flows reduce phytoplankton production, improve conditions for *Corbula amurensis*, or non-native fish, and if they do, what is the affect on smelt?

PANEL RESPONSE 3C. This question is addressed in **PRQ 9** below.

PRQ 4. Is the linear relationship used by the USFWS to relate OMR flow to smelt salvage scientifically valid and based on the best available and commercial data? (CR 6)

PRQ 5. Is the relationship in Grimaldo et al. (2009) scientifically sound and was it used properly by the USFWS? (CR 6, 10)

PANEL RESPONSES 4 and 5. Questions 4 and 5 are closely related and the Panel devoted a substantial amount of time to discussion of these questions and development of appropriate responses. Given the very short amount of time available to the Panel to arrive at their conclusions, the Panel was unable to develop a single consensus response to these two questions. Instead, the Panel presents responses developed independently by two panelists. These responses make some similar points but also differ with respect to the issue of whether or not a

linear relationship can provide a meaningful description of the relationship between salvage and OMR flow.

Panelist A Response to PRQ 4

The issue of whether salvage is linearly or exponentially related to OMR flow may be of some importance in estimating the potential of the pumping operations to inflict mortality on that portion of the delta smelt population that is vulnerable to entrainment. Assuming a constant size for the vulnerable population (an unlikely assumption), a linear relationship would indicate no density dependence (i.e. the pumps remove fish in direct proportion to the volume pumped); and an exponential relationship would indicate that salvage inflicts a disproportionately greater mortality than would be expected by the filtration of volume alone. This could be interpreted to mean that higher pumping rates draw a greater proportion of the total delta smelt population into the vulnerable population subject to entrainment.

In a purely statistical sense, the validity of the relationship used in the BO is presented in the peer-reviewed source of the information; there is a significant linear relationship for the dataset presented. Based on personal communication with the principal author of the study Grimaldo et al. (2009) study, fitting the data to an exponential model resulted in a marginally poorer fit; this is not an unusual situation when there is considerable variability in the data or there are relatively few data points. Perhaps the underlying relationship is truly exponential, but for the 14 annual points presented, it is not statistically distinguishable from a linear relationship. However, from a common-sense viewpoint (and based on the fact that others have demonstrated), the relationship is expected to be non-linear.

Panelist B Response to PRQ 4

Origin of the Linear Relationship

The linear relationship between salvage and OMR flow, presented in Figure E-1 of the BO, originates from a draft manuscript of a paper that was published in the North American Journal of Fisheries Management in 2009 (Grimaldo et al. Factors affecting fish entrainment in massive water diversions in a tidal freshwater estuary: Can fish losses be managed?). Grimaldo et al.'s original figure and Figure E-1 of the BO differed from the published Figure 8, delta smelt, in two respects. First, the published Figure 8 rescaled the x-axis to cubic meters per second rather than cubic feet per second as illustrated in the BO. Second, the published Figure 8 rescaled the y-axis as daily mean salvage for the December to March period rather than as a total salvage for the same period as illustrated in the BO. Thus, the graphs differ in terms of scale, but not in terms of substance or inference.

Scientific Validity

To the extent that Grimaldo et al.'s manuscript was subjected to the peer review process prior to revision, acceptance and publication, it is reasonable to conclude that the presented linear relationship is "scientifically valid." There are, however, several objectionable features to the relationship presented in Figure E-1 and relied upon elsewhere in the BO (e.g., to generate relative salvage impacts presented in Table E-5a of the BO). These objectionable features can best be understood in the context of a description of the salvage/entrainment process itself.

The Entrainment Process

For an individual delta smelt to be entrained by the diversion pumps it must be either in the OMR system itself or attracted to the OMR system. Given presence in or attraction to the

OMR system, it must then be physically drawn to the pumps, a process that is associated with the negative flow (and velocity) of the OMR system. Once entering the pumps (or the fish salvage facilities), it seems clear that all delta smelt juveniles and adults must be counted as mortalities. Thus, the conditional probability of entrainment can be viewed as a function of OMR flow, where we condition on an individual fish being “near or in the OMR system.”

The total salvage at the fish collection facilities (or total entrainment at the pumps) must reflect not only the conditional probability that an individual fish will be entrained, but also the total abundance and spatial distribution of delta smelt that could become attracted and entrained. If, at the time of intense winter pumping and high negative OMR, the “nearby” abundance of delta smelt adults is high, then entrainments would be expected to be high. If, on the other hand, the nearby abundance of delta smelt were low, either due to low overall abundance or due to the spatial distribution of the population being far removed from the OMR system, then the expected entrainments would be low, regardless of pumping rate.

Therefore, an essential ingredient of any satisfactory analysis of delta smelt salvage (entrainment) data should be an attempt to account for the “nearby abundance” (i.e., vulnerable individuals) of delta smelt.

Assessment of the Scientific Merits of Figure E-1

1. For juvenile delta smelt, for which an index of “nearby abundance” was available based on 20mm trawl survey data, Grimaldo et al. (2009) found a significant statistical influence of “nearby abundance” (via this index) on salvage of juveniles. This finding is consistent with the logic of the entrainment process, as outlined in the previous paragraphs.
2. In their multiple regression analyses of monthly adult delta smelt salvage data, Grimaldo et al. (2009) found no statistical effect of abundance as measured by the fall midwater trawl survey (FMWT), but they acknowledged that the fall midwater trawl survey index was not a suitable index of “nearby adult abundance”. They did, however, find that monthly winter salvage numbers were statistically related to turbidity, and an interaction between OMF flow and X2 one month previous.
5. When Grimaldo et al. (2009) collapsed the entrainment data by combining them over the entire winter period (December-March), they found that entrainment depended only on OMR flow, thus leading to the disputed Figure E-1 in the BO. This result is a purely statistical one, of course, in that it could lead to the false inference that salvage can be predicted strictly on the basis of OMR flow. That would lead to the conclusion that expected salvage at, say, -8000 cubic feet per second (cfs) OMR, would be the same in 2009 (when the total population of delta smelt adults, regardless of where they are located, may number in the several thousands) as compared to, say, 1999 when there may have been more than 1 million adults in the population (Newman 2008).

Is there a strong case for having fit a linear as opposed to non-linear model?

*Assuming a constant available population that could be entrained (salvaged), the case for linearity of the relationship between salvage and OMR plotted on Figure E-1 is weak on an *a priori* basis. An alternative non-linear decline in salvage with OMR flow would have the clear advantage of predicting essentially no entrainment at very high positive OMR flows (consistent with an inability of a 2-inch fish to swim upstream for a long distance against a strong current). In contrast, the linear model predicts clearly nonsensical negative entrainment (salvage) at sufficiently high positive OMR flows. The scatter of the data*

plotted on Figure E-1 also seems perhaps more consistent with a non-linear model than with a linear model and non-linear relations appear to have been fitted by other parties working with these same data (e.g., Figures B-3 and S-8 in the BO).

Although a strong argument could be made that a non-linear model provides a better description of the relationship between salvage and OMR flow, it is important to remember that both models would share in the very serious deficiency that predicted salvage depends only on OMR flow. Further, the importance of whether a linear or non-linear model were used can only be established if one examines how the relationship in Figure E-1 was used by the USFWS in their BO. This latter issue is addressed in **PRQ 5** below.

Panelist A Response to PRQ 5

The soundness of the relationship between salvage and combined OMR flows during December to March in the 14-year period represented by the data is straightforward. However, the use of this relationship to predict future entrainment (even in a relative sense – i.e., percentage increase or decrease) is questionable because the reliability of the estimate is completely dependent on the size or proportion of the population that is vulnerable (or becomes vulnerable due to pumping operations).

Salvage is best used as a measure of the number of subadult and adult delta smelt killed as a result of the pumping operation; as such, it can be a spatially-explicit component of the total mortality rate for the delta smelt population, as well as a measure the pumping operations contributions to future production foregone (i.e., the adults that would have been alive in the population as offspring of the adults killed by pumping).

Panelist B Response to PRQ 5

The linear relation displayed in BO Figure E-1 appears to have been the key relation used to develop Table E-5c (page 214 of the BO). Table E-5c provides calculated percent differences between *expected winter salvage* predicted from historic and CALSIM II modeled OMR median winter flows (calculated as $100 * (\text{expected modeled salvage} - \text{expected historic salvage}) / \text{expected historic salvage}$), based on the linear regression presented in Figure E-1.

For example, for CALSIM II Study 7.0, calculations of expected historic and modeled salvage for a “Wet” water-year type appear to have proceeded as follows:

Step 1. Assume that the relation in Figure E-1 can be used to predict expected salvage from OMR flows: $\text{Expected winter salvage} = 3,757 - 0.4657 \text{ OMR}$ (from Figure E-1).

Step 2. Calculate expected salvage under historic flows: the median modeled historic OMR flow was -1033 cfs, leading to an expected winter salvage of 4,238 smelt.

Step 3. Calculate expected salvage under modeled Study 7.0 flows. Under the CALSIM II model, median OMR Study 7.0 flow was -5256 cfs, leading to an expected winter salvage of 6,205 smelt.

Step 4. Calculate and report the percentage difference between Steps 2 and 3. The resulting percentage difference would be 46.4%.

Table 3 summarizes the results of such calculations.

Table 3. Percent difference from historical median salvage to predicted salvage based on December-March OMR flows from CALSIM II studies				
Water Year	Expected Entrainments		Calculated % Difference	Reported % Difference
	Historical	CALSIM II		
Wet	4238	6205	46.4	45.6
Above Normal	6168	7114	15.3	15.2
Below Normal	4877	6766	38.7	38.2
Dry	6323	6758	6.9	6.8
Critical	6103	5875	-3.7	-3.7

The Panel interprets the essential agreement between BO-reported and calculated % differences as supporting our interpretation of how USFWS generated the values presented in Table E-5c.

Would it have made a difference if the USFWS had instead used a non-linear model?

Based on the scatter of points displayed on Figure E-1, the difference between predictions made by a fitted non-linear model as compared to a linear model would probably not be substantial over the range of about -7,500 cfs to + 5000 cfs OMR flow. Based on Table E-5a, across all CALSIM II studies, there are no modeled median winter OMR flows that are more negative than -8,000 cfs and there are few water-year types for which median flows were more negative than -7,500 cfs. Only when negative flows were outside of that range would a non-linear model predict substantially *greater* salvage than the fitted linear model. Thus, as a practical matter, it would have made little difference if the USFWS had used a non-linear model as compared to the linear model that they adopted. Also, the linear model would be more *conservative* (i.e., predicted fewer salvaged fish) in its predictions of expected salvage.

Further Comments from the Panel in Response to PRQ 5

An improved assessment of expected salvage (entrainment) might have been made if the USFWS had fitted monthly (rather than winter (December-March)) salvage against median monthly OMR flow and used estimated parameters for this fitted model in the calculations that drove their comparisons between “historical” and CALSIM II-modeled expected salvage. If that had been done, predictions generated from non-linear and linear models might have been quite different from those generated by a linear model. The median winter OMR flows “hide” substantial variation in monthly OMR flows that would be captured in the monthly CALSIM II models. For example, modeled CALSIM II Study 7.0 OMR flows during December frequently fall within the range -8,000 to -9,300 cfs (where a non-linear model would predict greater salvage than a linear model), but modeled February OMR flows were frequently under -5,000 and in some years positive (where non-linear and linear model predictions would be similar).

Panel Conclusion Regarding PRQs 4 and 5

One might argue strenuously that it is not meaningful to predict salvage on the basis of OMR flow alone in that it leads to an obviously impossible result that salvage would be substantial even if Delta smelt were extinct. Therefore, it is important for USFWS to more appropriately characterize the nature and value of these calculations and the inferences to be drawn from them. The fitted linear model is based on data from 1993–2005, during which time there were large-scale changes in abundance of adult smelt, as indexed by the FMWT, but they are applied over a

much broader period of years (1967–2007 and 1922–2003, respectively) when smelt abundance was, on average, substantially greater. At best these calculations can provide only a very crude index of hypothetical salvage numbers under different flow scenarios. Nevertheless, it seems to the Panel well established that salvage numbers are affected by abundance and distribution of the smelt population and by the degree of negative flow in OMR.

PRQ 6. Is the USFWS discussion of entrainment of *P. forbesi* in the BO based on the best scientific and commercial data, scientifically valid, and does the Project entrain *P. forbesi* at a level which could affect smelt populations? (CR 7, 12)

There are well established historical declines of *Psuedodiaptomus forbesi* in the central Delta and there is ample documentation in the scientific literature that *P. forbesi* currently is an important food resource to delta smelt. In addition, there is good evidence that delta smelt are food limited and that declines in lower and higher trophic levels are linked. The BO uses the best available scientific and commercial data when asserting that actions negatively impacting *P. forbesi* also negatively impact smelt regardless of the time of the year.

However, the Panel was unable to fully evaluate the potentially negative role of “entrainment” of *P. forbesi* on overall *P. forbesi* population dynamics. The BO does not provide entrainment data or publications that provide strong inference on this connection. Please note that the Panel did not have access to the cited Kimmerer et al. (in preparation) paper.

Overall, the Panel strongly supports the premise that actions impairing the *P. forbesi* population are highly likely to have negative consequences on the smelt population; however, the BO does not provide sufficient *P. forbesi* entrainment data or analysis to quantify export impacts on *P. forbesi* abundance, biomass, and distribution.

PRQ 7. A two-part question. (CR 8)

A. Based on the available data (e.g., Feyrer et al. 2007; ~~Manly 2008~~) is the location of X2 a scientifically defensible index for identifying suitable delta smelt habitat availability?

PANEL RESPONSE 7A. The panel strongly concurs with the USFWS's use of X2 as an index for identifying delta smelt abiotic habitat. The X2 index is extremely well supported as scientifically valid. For example, the original X2 article (Jassby et al. 1995) has been cited 168 times and has withstood over a decade of continual scientific examination. Few ecological indices are as robust and well studied as X2. Feyrer et al. (2007) highlight the continued and well-supported value of the X2 index, but also highlight the need to identify additional environmental metrics for evaluating suitable smelt habitat. Feyrer et al. (2007) argue that light availability (as a metric for habitats that support primary production) is an additional environmental variable that is likely useful in evaluating smelt habitat since the population's food supply is chronically low and reliant on phytoplankton production. The Panel did not have access to Manly 2008. Manly 2008 is cited in FFA IQA request on page 17 but not in the BO. The FFA IQA request does not provide citation information.

Overall, the Panel supports the USFWS's use of the X2 index. USFWS's use of the X2 index uses the best available scientific and commercial data and is highly defensible. The Panel supports the assertion that hydrologic events and actions that alter the X2 location directly impact suitable delta smelt abiotic habitat.

B. Based on the Best Commercial and Scientific Data are there better indices available, than those used by the USFWS in the Effects Analysis, for predicting future smelt abundance (e.g., food, temperature, turbidity, etc.) than fall X2?

PANEL RESPONSE 7B. Responses to **PRQ 7B** were regarded as beyond the purview of the Panel.

PRQ 8. Is the comparison of modeled data to historical conditions a valid exercise as presented in the BO? Did the comparison of modeled data to historical conditions bias the results and, further, did the USFWS bias the results by the selection of years to use?
(CR 11)

PANEL RESPONSE 8. Comparison of modeled to historical data is a valid exercise. The current review Panel was in substantial agreement with the previous review panel concerning the validity of the comparisons of “historical” vs. CALSIM II modeled scenarios (PBS&J 2008). Below this Panel reproduces the salient points of the discussion of the prior panel with which it agrees:

The Panel suggests that the definition of baseline conditions be carefully considered because of its importance as the basis of evaluation of impacts and interpretation of the various simulated scenarios. Typically, baseline conditions used in an EA are meant to represent population status before the impact of a proposed project. However, in this case, water operations have been in place before the period of assessment began. Baseline conditions here are representative of the current conditions in the smelt population including the effects of operations. For this, the EA used historical data (1967–2007 for adult salvage, larval-juvenile percent losses, habitat; 1988–2007 for *Pseudodiaptomus forbesi*) as the baseline condition. These time periods are characterized by a downward trend in the delta smelt population, various trends in environmental variables, changes in operational requirements (e.g., X2 standards), and a variety of changes in structure of the ecosystem. Superimposed on these is the Pelagic Organism Decline (POD) period. Because the system has changed so frequently, the choice of time period used to define baseline can greatly affect the computed values of baseline conditions. For example, salvage of adults would in general be higher in earlier years and lower in recent years, and confounded with how operations varied within and among years. A long historical baseline would therefore show a higher level of salvage than a baseline comprising only more recent years. In contrast to this approach, the revised Biological Assessment (BA) and previous BO both used the results of a simulation study to define the baseline.

The historical baseline differed greatly from CALSIM-II Study 7.0 simulated results. Although Study 7.0 includes some changes from current operations, the Panel was surprised at the degree of divergence between these results. The large difference between Study 7.0 results and the historical baseline conditions defined with data can confuse the comparisons of metrics, such as relative percent changes, between a simulated study and historical baseline. This also raises the question of how representative Study 7.0 is of current and near-future conditions.

Ideally, a model-simulated baseline should be available that is consistent with the historical data for several periods within the historical record; for example, baselines could be prepared for an early period, a pre-POD period, and a post-POD period. The Panel noted that the BA included a pre-POD study (Study 6.1) but that there were concerns as to how well this scenario mimicked the actual historical record. It is unfortunate that model-generated baselines with a high degree of reliability were not made available for this analysis.

To the above comments provided by the previous review team, we add our own Panel’s belief that any fair and unbiased comparison of models must fix the time period over which the comparison is made. In the BO, the CALSIM II models are driven over the period 1922 through 2003 whereas the “historical” DAYFLOW model is driven over the period 1967–2007. The only fair comparison would be over the period 1967–2003 over which the two time series overlap exactly and share the identical set of water years, irrespective of whether or not this time series of water years adequately represents the expected distribution of water years over the long term.

The Panel felt that a comparison of CALSIM II studies with historical (1967–2003) Project operations provided a more appropriate assessment of pumping impacts on delta smelt than would have comparisons to CALSIM II studies against CALSIM Study 7.0. The Panel, however, agrees with the previous panel that it would have been useful to have more period-specific comparisons (e.g., pre-POD, POD, post-POD). As long as the operational models are valid and generate accurate estimates of median winter flows, a comparison of “historical” to modeled data is appropriate.

In order to address the issue of bias the Panel conducted an exercise with available information to compare with the approach used in the BO. In the tables (Tables 4 and 5) below, the Panel has used the linear salvage vs. OMR flow relationship displayed in Figure E-1 to calculate historical and CALSIM II Study 7.0-modeled “expected salvage” using the shared period 1967–2003 as compared to the imperfectly-overlapping periods presented in the BO. We have compared these more appropriate comparative calculations with the calculations presented in the BO. The revised comparisons show generally more, rather than less, contrast between historical and CALSIM II-modeled expected salvage, thus allowing the Panel to conclude that the USFWS did not seriously bias its conclusions by having used imperfectly-overlapping years in the comparisons of historical with modeled scenarios.

Table 4. Revised Tables E-5a and E-5c Presentation. Fixed Period (1967–2003) for Historical and CALSIM II Study 7.0					
Water Year	OMR Median Winter Flows		Expected Winter Salvage		Percent Difference
	Historical	CALSIM II	Historical	CALSIM II	
Wet	-944	-5297	4197	6234	48.3
Above Normal	-5140	-7445	6151	7224	17.5
Below Normal	-1351	-8789	4386	7850	79.0
Dry	-5613	-7411	6370	7208	13.1
Critical	-5509	-4624	6322	5910	-6.5

Table 5. Original Tables E-5a and E-5c Presentation. Historical= 1967–2007; CALSIM II = 1922–2003					
Water Year	OMR Median Winter Flows		Expected Winter Salvage		Percent Difference
	Historical	CALSIM II	Historical	CALSIM II	
Wet	-1033	-5256	4238	6205	46.4
Above Normal	-5178	-7209	6168	7114	15.3
Below Normal	-2405	-6461	4877	6766	38.7
Dry	-5509	-6443	6323	6758	6.9
Critical	-5037	-4547	6322	5875	-3.7

PRQ 9. This is a two-part question. (CR 17, 20)

A. Check veracity of statement that Project increases fall flows?

PANEL RESPONSE 9A. The Panel referred to the detailed CR submitted by the FFA for clarification of this question: The FFA states that extremely stable low delta outflow conditions in the fall occur naturally, and project operations actually increase flow levels and alleviate conditions that may be caused by low flow.

As discussed below, “natural” flows were not available, but “unimpaired” flows were available and they could be used to provide the same assessments. In the BO, “Project” operations are assumed to be the “current” operations from CALSIM II Model 7.0. “Historical” DAYFLOW model conditions are provided for comparison.

Natural and unimpaired flow has the same potential hydrologic basin runoff. However, pre-levée natural flow had landscape features different from today. Unimpaired flow assumed that mountain watersheds and river channels function in their present configuration with modifications for reclamation, flood control, and navigation. In effect, simulation of unimpaired runoff was made by only eliminating the influence of storage and diversion projects from observed flows.

Unimpaired flows for Delta outflows were obtained from the “California Central Valley Unimpaired Flow Data, Fourth Edition, Draft, Bay-Delta Office, California Department of Water Resources, May 2007.” These data were available for calendar years 1921–2003. A graph of September-October-November (fall) average monthly outflows is shown in Figure 2. The years 1967–2007 were illustrated to facilitate comparison with the other outflow studies.

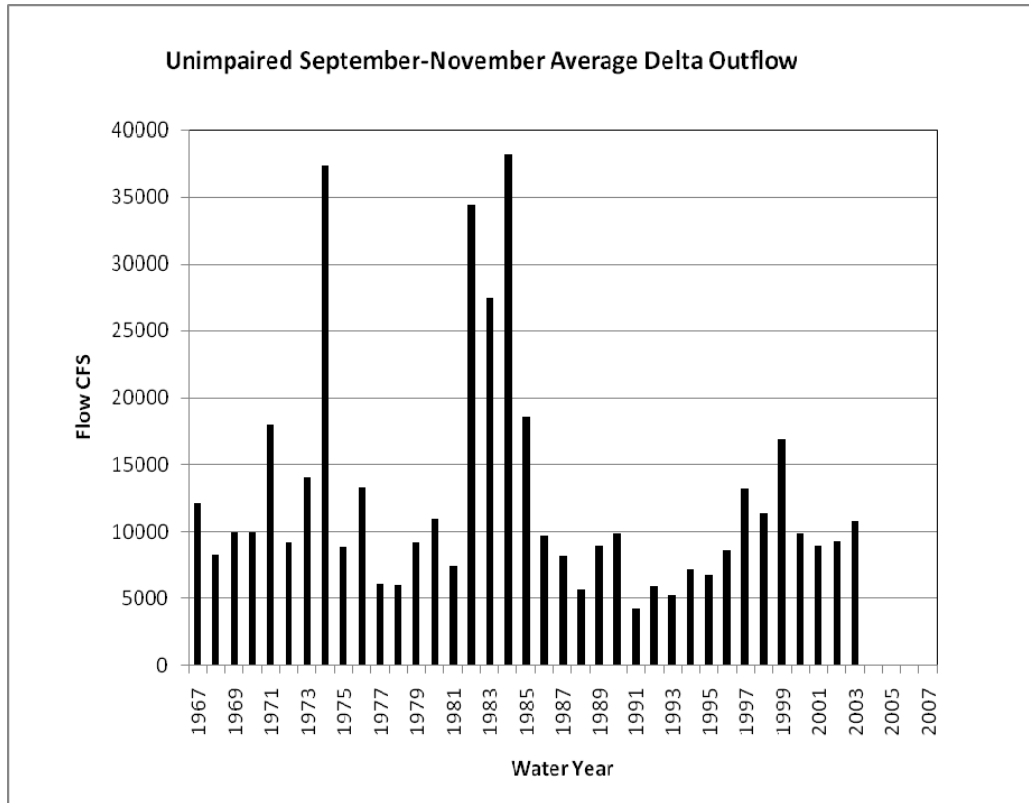


Figure 2

Historical Delta outflow data were obtained from DAYFLOW data files (DWR 1967–2007). A graph of September-October-November monthly flows is shown in Figure 3.

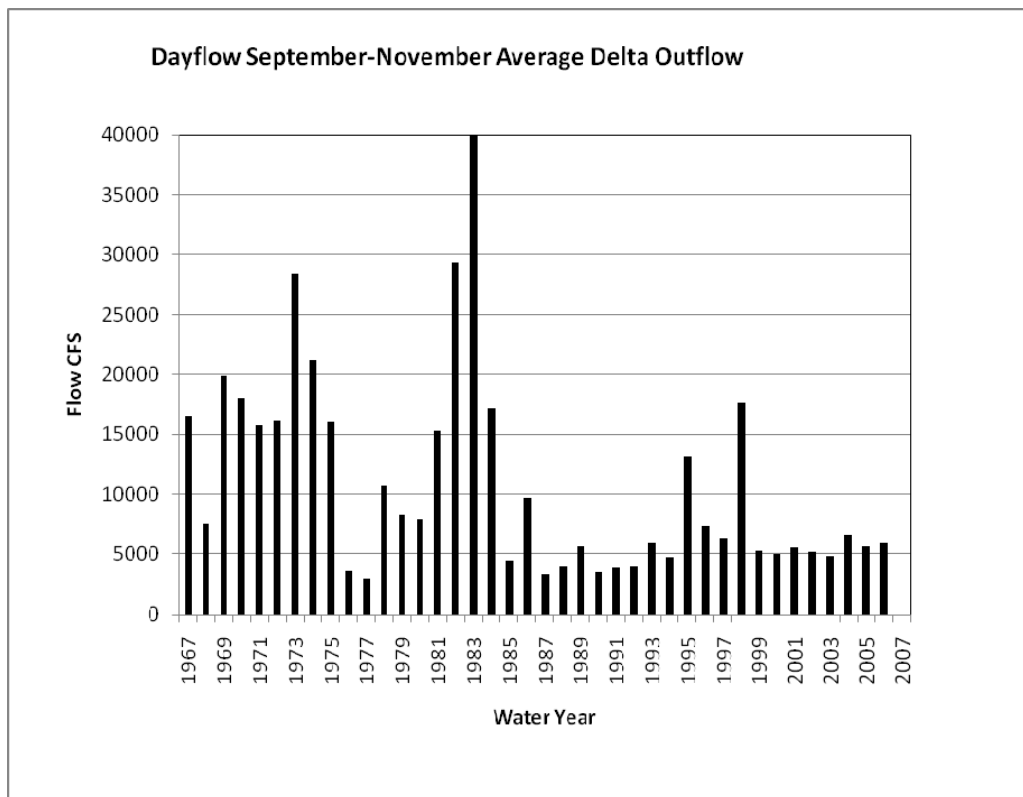


Figure 3

The BO used the CALSIM II Study 7.0 as the current baseline. The model timeframe was 1922–2003 (82 years). Project operations and assumptions were updated to the 2005 level of development. To facilitate comparisons, the 1967–2003 period for September-October-November is shown in Figure 4.

Means and standard deviations were computed for the 1967–2003 (37 years) period, by water-year type and shown in the Table 6.

Table 6. Fall (September-November) mean and standard deviations of Delta outflow (cfs) for the years 1967–2003										
Model	Critical (n=7)		Dry (n=6)		BN (n=3)		AN (n=6)		Wet (n=15)	
	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev	Mean	StDev
Unimpaired	7436	3095	10227	4168	8875	501	9474	3342	17529	11168
DAYFLOW	3784	546	6564	4369	10653	4750	10470	9057	17285	10113
CALSIM II	4826	2062	5670	3224	6198	226	5235	1429	11753	10017

Sources:
 Unimpaired California Central Valley Unimpaired Flow data, 4th Edition - Draft. DWR, May 2007.
 DAYFLOW DWR, CDEC, www.water.ca.gov/dayflow/
 CALSIM II: OCAP BA Appendix E, OCAP_2008_DeltaFlowsRegs.xls

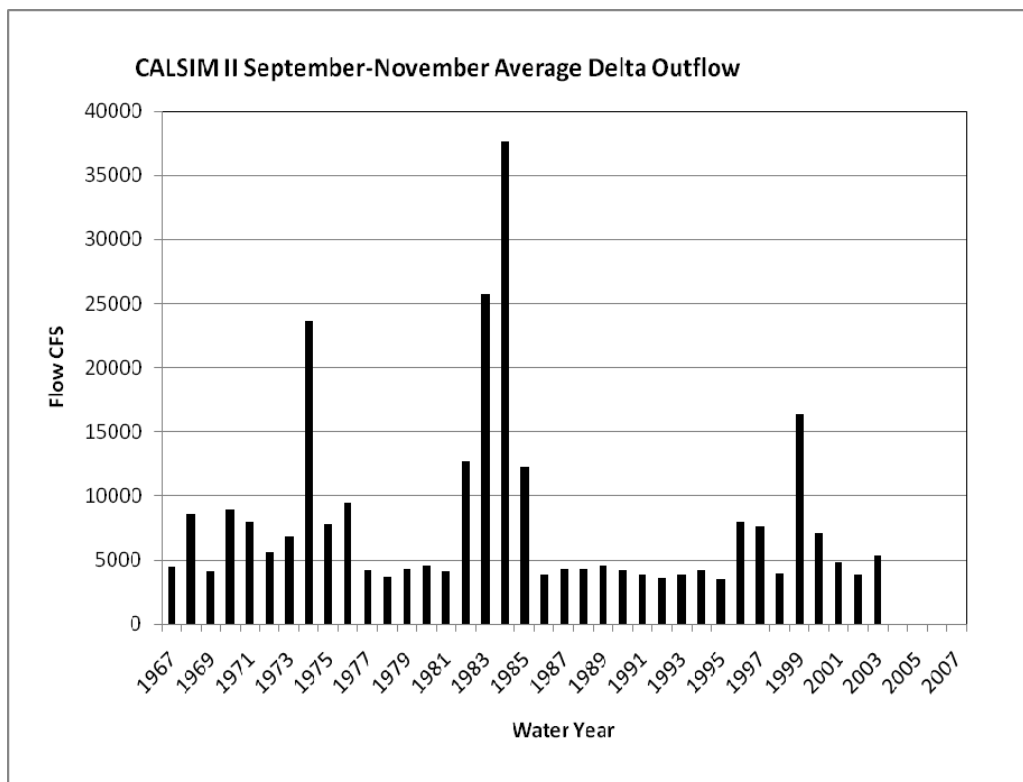


Figure 4

Figure 2 of unimpaired (approximately “natural” flows as discussed above) fall Delta outflow, except for wet years, shows average flows varying from approximately 5,000 to 10,000 cfs. This may be considered stable compared to wet year variation of 10,000 to 38,000 cfs, but certainly not *extremely* stable.

Historical operations as simulated by DAYFLOW (Figure 3) show a reduction in flow, compared to unimpaired, for all water-year types as shown by the means in the statistical summary table. For example, mean flows in critical years decrease from 7436 to 3784 cfs due to project operations. For critical years only, standard deviation, if used as an index to stability, had a decrease (more stable) from 3095 to 546 cfs.

The CALSIM II model, representing the 2005 level of project operations back-modeled to 1967, also shows a reduction in standard deviation of 30–50 percent for all water-year types except wet, implying more stable flows (Figure 4). However, this increased stability occurs with significant flow reductions, compared to unimpaired conditions, of 30–40 percent for critical to above normal water years.

Referring to the basis of the FFA correction request, both the DAYFLOW and CALSIM II Delta outflow simulation models showed a reduction in Delta outflow, not an increase, compared to unimpaired conditions.

B. Are low stable fall flow conditions dependent on Project operations? If so, do these flows reduce phytoplankton production, improve conditions for *Corbula amurensis*, or non-native fish, and if they do, what is the effect on smelt?

PANEL RESPONSE 9B. Given that the project pumping operations contribute to low, stable fall-flow conditions by decreasing Delta outflow (as explained in Panel Response 9A), there are

likely consequences to a variety of biological and chemical factors that influence the delta smelt population. Here the Panel limits its discussion to the western portion of the Delta since this is where delta smelt are likely concentrated in the fall. The eastward shift in X2 is likely the most predictable negative outcome of decreased fall outflow. As previously discussed, X2 provides a scientifically compelling environmental index for suitable abiotic smelt habitat. In addition, this shift in the western Delta's salinity regime would be beneficial to *Corbula amurensis*. The potential eastward migration of *Corbula amurensis* may decrease phytoplankton biomass and the base of the Delta's foodweb at a critical stage in the life history of delta smelt.

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Attachment 1 – Panelists CVs



CURRICULUM VITAE

Kneib, Ronald Thomas

University of Georgia Marine Institute, Sapelo Island, GA 31327
Office Phone (912) 485-2297 FAX (912) 485-2182
E-mail address: rtkneib@uga.edu or rjk@dariantel.net

Expertise: Wetland ecology, coastal landscape ecology, fisheries, population, community and production dynamics, restoration ecology

Education

PhD in Ecology, University of North Carolina, Chapel Hill, 1980

Doctoral Dissertation: "The responses of a soft-sediment intertidal community to experimental manipulations of the population size structure and density of a predator, *Fundulus heteroclitus*", 181 p., Major Advisor: A.E. Stiven.

MA in Ecology, University of North Carolina, Chapel Hill, 1976

Master's Thesis: "Feeding, reproduction, growth and movements of killifishes on a North Carolina salt marsh", 139 p., Major Advisor: A.E. Stiven.

BS in Zoology, Pennsylvania State University, 1972 (major advisor, E.L Cooper)

Professional Experience

Current Appointments:

- Senior Research Scientist, University of Georgia Marine Institute, 1994-present.
- Adjunct Senior Research Scientist, School of Marine Programs, UGA, 1994-present.
- Graduate Faculty, University of Georgia, 1991-present (until 2012).

Previous Appointments:

- Temporary Graduate Faculty, University of South Carolina, Columbia, SC. 2003 - 2006.
- Honorary Research Fellow, Swire Institute of Marine Science, Univ. of Hong Kong, 2000-2002.
- Research Fellow, The Swire Institute of Marine Science, University of Hong Kong, 1995-98.
- Invited Visitor, Dept. Ecology & Biodiversity, University of Hong Kong, June-July 1996.
- Adjunct Associate Professor of Marine Sciences, University of Georgia, 1992-1994
- Adjunct Associate Research Scientist, Zoology, University of Georgia, 1989-1996.

Professional Experience (*Previous Appointments*, continued)

- Temporary Graduate Faculty, University of North Carolina, Chapel Hill, 1991-1994.
- Associate Research Scientist, University of Georgia Marine Institute, 1986-1994.
- Adjunct Assistant Professor, Zoology Department, University of Georgia, 1985-1988.
- Visiting Associate Professor, College of Marine Studies, University of Delaware, Fall Semester, 1986. (Designed and taught a graduate course in statistics for the marine sciences.)
- Assistant Research Scientist, University of Georgia Marine Institute, 1984-1986.
- Research Associate, University of Georgia Marine Institute, 1980-84.

Professional Certifications:

Senior Ecologist, Board of Professional Certification-Ecological Society of America, 2002-2012

Small Business Operations:

Sole Proprietor, RTK Consulting Services, providing professional ecological consulting services (e.g. reviews, reports, project planning assistance, research) specializing in tidal wetland restoration and fisheries production, 1994-present. Major clients have included: the [Estuary Enhancement Program](#) of the Public Service Enterprise Group of New Jersey, CALFED Science Program (http://www.science.calwater.ca.gov/science_index.html), National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS).

Partner in [Science Partners LLC](#), which is an independent science company whose partners include a group of eminent scientists, clinicians and engineers that supports major corporations by providing authoritative, accurate information about environmental and human health aspects of industrial activities, 2006-present.

Member, Alliance of Experts in [Science First Dispute Resolution LLC](#), the purpose of which is to end costly disputes efficiently and quickly based on objective science, 2009-present.

Professional Society Membership

American Society of Ichthyologists and Herpetologists

Estuarine and Coastal Sciences Assoc. (U.K.)

American Society of Limnologists and Oceanographers

Estuarine Research Federation

Association of Southeastern Biologists

Fisheries Society of the British Isles

American Fisheries Society

Society for Ecological Restoration

Ecological Society of America

Society of Wetland Scientists

Publications:

Journal Articles:

Kneib, R.T. (In preparation). Does Georgia contain one-third of the salt marshes on the Atlantic coast of the USA? For submission to *Estuaries & Coasts*.

Kneib, R.T. (In preparation). Efficacy of passive integrated transponder (PIT) tags for measuring growth and movements of mummichogs (*Fundulus heteroclitus*) in intertidal marsh creeks. For submission to *Journal of Experimental Marine Biology & Ecology*.

Kneib, R.T. 2009. Genotypic variation does not explain differences in growth rates of mummichogs (*Fundulus heteroclitus*) from simple and complex tidal marsh landscapes. *Marine Ecology Progress Series* 386:207-219.

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Publications (*journal articles, continued*)

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Publications (*journal articles, continued*)

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Kneib, R.T. 1978. Habitat, diet, reproduction and growth of the killifish, *Fundulus luciae*, from a North Carolina salt marsh. *Copeia* 1978:164-168.

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Kneib, R.T. 1972. The effects of man's activity on the distribution of five stream fishes in Little Pine Creek, Pennsylvania. *Proceedings of the Pennsylvania Academy of Science* 1972:49-51.

Book/Symposium chapters:

Weslawski, J.M., P.V.R. Snelgrove, L.A. Levin, M.C.V. Austen, **R.T. Kneib**, T.M. Iliffe, J.R. Garey, S.J. Hawkins and R.B. Whitlach (2004). Marine sedimentary biota as providers of sustainable ecosystem services. (Chapter 4) pp. 73-98, *In: Wall, D (ed.) Sustaining Biodiversity and Ecosystem Services in Soils and Sediments*, SCOPE Series, Vol. 64. Island Press, Washington, D.C.

Snelgrove, P.V.R., M.C.V. Austen, S.J. Hawkins, T.M. Iliffe, **R.T. Kneib**, L.A. Levin, J.M. Weslawski, R.B. Whitlach and J.R. Garey. (2004). Vulnerability of marine sedimentary ecosystem services to human activities. (Chapter 7) pp. 161-190, *In: Wall, D (ed.) Sustaining Biodiversity and Ecosystem Services in Soils and Sediments*, SCOPE Series, Vol. 64. Island Press, Washington, D.C.

Ineson, P., L.A. Levin, **R.T. Kneib**, R.O. Hall, J.M. Weslawski, R.D. Bardgett, D.A. Wardle, D.H. Wall, W.H. Van der Putten & H. Zadeh. (2004). Cascading effects of deforestation on ecosystem services across soils and freshwater and marine sediments. (Chapter 9) pp. 225-248, *In: Wall, D (ed.) Sustaining Biodiversity and Ecosystem Services in Soils and Sediments*, SCOPE Series, Vol. 64. Island Press, Washington, D.C.

Peterson, C.H. & **R.T. Kneib** (Coordination/Editors) (2003) Restoration scaling in the marine environment. Theme Section, Marine Ecology Progress Series 264:173-307.

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Kneib, R.T. 1994. Spatial pattern, spatial scale and feeding in fishes, pp. 171-185, *In*: D. J. Stouder, K. L. Fresh, R. J. Feller (eds.), *Theory and Application in Fish Feeding Ecology*, University of South Carolina Press, Columbia, SC.

Peer-reviewed Reports:

Kneib, R.T., C.A. Simenstad, M.L. Nobriga & D.M.Talley (2008) Tidal marsh conceptual model. Sacramento (CA): **Delta Regional Ecosystem Restoration Implementation Plan.**

Reviewed Web Publications:

Kneib, R.T. 2000. MEPS Discussion Forum 2: Peer-review system - time for re-assessment?
http://www.int-res.com/forum/peer_review.html

Peer-reviewed Abstracts:

Craig, A & R.T. Kneib. 1999. Effectiveness of minnow traps in capturing common mummichog, *Fundulus heteroclitus*. Georgia J. Sci. 57: 142-143.

Gallagher, L.J. & R.T. Kneib. 1999. Can grass shrimp (*Palaemonetes pugio*) assess predation risk? Georgia J. Sci. 57: 144-145.

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Lerberg, S. & R.T. Kneib. 1996. Tidal effects on dynamics of prey resources for larval killifishes in an intertidal estuarine nursery. Georgia J. Sci. 54: 214.

Knowlton, M.K. & R.T. Kneib. 1996. Survival of grass shrimp (*Palaemonetes pugio*) zoea and juveniles in the presence and absence of juvenile white shrimp (*Penaeus setiferus*). Georgia J. Sci. 54: 212.

Hermeno, E., R.T. Kneib & S.Y. Newell. 1996. Effect of natural food sources on survival, growth and reproduction of the amphipod *Uholrchestia spartinophila*. Georgia J. Sci. 54: 211-212.

Cross, R.E., R.T. Kneib & A.E. Stiven. 1995. Size-dependent interactions among fish and shrimp in refuge environments. Bull. Ecol. Soc. Amer. 76(2, Suppl.):56.

Covi, M.P. & R.T. Kneib. 1991. Effects of tidal inundation on the distribution of the amphipod *Uholrchestia spartinophila* in an intertidal salt marsh. Georgia J. Sci. 49:162-163.

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- Reynolds, K., R.T. Kneib & D.M. Goshorn. 1991. Changes in the gross conversion efficiency and growth rate of *Fundulus heteroclitus* larvae over a range of ingestion rates. Georgia J. Sci. 49:164-165.
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- Kneib, R.T. 1990. Microhabitat availability and mortality of larval fishes in an estuarine nursery. Bull. Ecol. Soc. Amer. 71(2):215.
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- Fallon, R.D., R.T. Kneib & B.F. Sherr. 1986. Meroplankton feeding on heterotrophic nanoplankton. Trans. Amer. Geophysical Union. 66:1314.
- Kneib, R.T. 1985. Effects of semi-lunar spawning on the population dynamics of the killifish, *Fundulus heteroclitus*. Bull. Ecol. Soc. Amer. 66:210.
- Arnold, W.S. & R.T. Kneib. 1983. The size distribution of blue crabs (*Callinectes sapidus* Rathbun) along a tidal gradient in a Georgia salt marsh. Georgia J. Sci. 41:93.
- Kneib, R.T. 1982. The distribution of infaunal invertebrates along an elevation gradient in the vegetated intertidal zone: Observations before the experiments. Bull. Ecol. Soc. Amer. 63:141.
- Taylor, M.H., L. DiMichele, R.T. Kneib & S. Bradford. 1981. Comparison of reproductive strategies in Georgia and Massachusetts populations of *Fundulus heteroclitus*. Amer. Zool. 21:921.
- Stiven, A.E. & R.T. Kneib. 1981. Complex predator-prey interactions in the intertidal vegetated soft-sediment benthic community. Bull. Ecol. Soc. Amer. 62:151.
- Stiven, A.E. & R.T. Kneib. 1980. Some responses of the salt marsh infaunal and epifaunal communities to fish predation and *Spartina* litter. Bull. Ecol. Soc. Amer. 61:98.
- Kneib, R.T. 1977. Diet and growth of the killifish, *Fundulus heteroclitus* (Pisces: Cyprinodontidae), from a North Carolina salt marsh. ASB Bull. 24:63

Technical Reports:

Alberts, J.J., **R.T. Kneib**, S.Y. Newell & S.C. Pennings. 2001. Health indicators for salt marsh estuaries of the South Atlantic Bight. U.S. EPA, National Center for Environmental Research, EPA Grant No. R825147 Final Report
(<http://ws.epa.gov/ncer/final/grants/96/eoass/alberts.html>).

Ringwood, A.H., A.F. Holland, **R. Kneib**, P. Ross. 1996. EMAP/NS&T pilot studies in the Carolinian Province: Indicator testing and evaluation in southeastern estuaries. Final Report. NOAA Technical Memorandum NOS ORCA 102. National Oceanic & Atmospheric Administration, Silver Spring, MD, USA.

Kneib, R.T. 2001. Report in connection with Nekton production from natural and restored intertidal vegetated estuarine habitat. Prepared for Industrial Economics, Inc, Cambridge, MA.

Kneib, R.T. 2002. Restoration and creation of tidal marsh in support of nekton production: estimation of trajectory to full functional value and expected longevity. Prepared for Industrial Economics, Inc, Cambridge, MA.

Program Reviews:

Bertness, M.D., Bollens, S.M., Cowan, J.H. Jr., **Kneib, R.T.** (Managing Editor), MacCready, P., Moll, R.A., Smith, P.E., Solow, A.R. & Spies, R.B. 2005. San Francisco Estuary Sacramento-San Joaquin Delta Interagency Ecological Program on Pelagic Organism Decline, **Final Report to CALFED Science Program**

Lichatowich, J (Panel Chair), Anderson, J, Cowan, J, **Kneib, R**, Monismith, S, Rose, K, Smith, P, Solow, A, & Thompson, B. 2007. Environmental Water Account 2006, **Final Report to CALFED Science Program.**

Miscellaneous articles/contributions:

Kneib, R.T. (2003) Georgia at the Edge - Value and Vulnerability of Estuaries. Newsletter of the Center for a Sustainable Coast, Spring 2003.

Research Grants (*P.I.: R. T. Kneib unless otherwise indicated*)

Proposals under consideration:

NOAA, Georgia Sea Grant College Program, "Using landscape interfaces and ecological activity to determine zones of influence on tidal marshes by upland development in Georgia", Co-PIs: RT Kneib (UGAMI) and Jeb Byers (UGA School of Ecology), 2-yr duration, \$139,809 (requested) Submitted 14 May 2009

Previous grant support:

National Science Foundation, "Functional genomics: interactions among ecology, population biology and gene expression", (D.L. Crawford - Univ. of Miami - RSMAS, D.D. Duvernell - So. Illinois Univ., R.T. Kneib, UGA Marine Institute, B.B. Rees - Univ. Southwestern Louisiana, R.N. Winn - Univ. Georgia) December 2002-January 2008, \$1,998,733.

Australian Research Council (International Researcher Exchange Scheme) "Structural and functional responses of coastal wetlands to habitat alteration: how different are Australian salt marsh ecosystems?" (Co-PI with S.Y. Lee, Griffith University), March 2001-February 2003, \$A7,800.

National Science Foundation, "Drainage complexity, nekton populations and production transfers across a marsh landscape", March 1997-February 2003, \$720,169.

U.S. Dept. of Commerce (NOAA/CZM, Estuarine Research Reserves) "Effect of channel complexity on residence times, growth and movements of juvenile white shrimp (*Penaeus setiferus*) within tidal marsh nursery habitats" (Graduate fellowship for Stacey Webb), June 1998-May 2001, \$47,227.

U.S. Environmental Protection Agency, "Health indicators for salt marsh estuaries of the South Atlantic Bight" (Co-principal investigator with J.A. Alberts, S.Y. Newell and S.C. Pennings), November 1996-October 2000, \$786,349.

Marsh Ecology Applied Research Program (supported by Public Service Electric & Gas of New Jersey), "Use of intertidal resources by nekton populations within salt marsh landscapes - an initial study of young resident nekton in New Jersey", (Co-PI with M. A. Hardisky), 1996, \$40,000.

U.S. Department of Commerce (NOAA, Georgia Sea Grant College Program), "Residence times, movements and growth of white shrimp within tidal marsh drainages supplying Georgia sounds" (proposal development), 1996-98, \$54,092.

U.S. Department of Commerce (NOAA, MARFIN), "Maturity, spawning and fecundity of red drum in the central South Atlantic Bight", (Co-principal investigator with L.R. Barbieri, S.K. Lowerre-Barbieri and A.G. Woodward), 1995-98, \$237,630.

U.S. Department of Commerce (NOAA, Georgia Sea Grant College Program), "Spawning habitat and spawning site fidelity of red drum in Georgia inshore waters", (Co-principal investigator with S.K. Lowerre-Barbieri and L.R. Barbieri), 1995-96, \$49,982.

Research Grants (*previous*, continued)

U.S. Department of Agriculture, "Evaluating the ecological functions of wetlands: technique development and testing", 1993-96, \$100,000 (P.I.: D. Veal, Mississippi State University), subcontract to University of Georgia (R. T. Kneib), \$11,000.

South Carolina Sea Grant Consortium, "Indicator testing and evaluation in estuaries of the Southeastern United States during summer 1993", 1993-94, \$224,980 (co-P.I.s: A.F. Holland and A.H. Ringwood), subcontract to University of Georgia (R. T. Kneib), \$40,000.

U.S. Department of Commerce (NOAA, Georgia Sea Grant Program), "The biological environment of estuarine nurseries: resource availability and the effects of resident species on the growth and survival of juvenile penaeid shrimp", 1992-95, \$95,920.

U.S. Department of Agriculture, "Evaluating the ecological functions of wetlands: technique development and testing", subcontract from Mississippi State University, 1992-93, \$6,684.

U.S. Department of Commerce (NOAA, Georgia Sea Grant Program), "The biological environment of estuarine nurseries: resource availability and the effects of resident species on the growth and survival of juvenile penaeid shrimp", 1990-92, \$73,400.

U.S. Department of Commerce (NOAA, Georgia Sea Grant Program), "Use of the vegetated intertidal marsh by the young of estuarine-dependent fishes and crustaceans", continuation of previous award for an additional 2 years, 1988-90, \$102,228.

National Science Foundation, "Effect of juvenile fish on primary and secondary producers in a salt marsh nursery habitat" (ROA supplement to award OCE-8715449), 1988-90, \$14,437.

National Science Foundation, "The effects of competition, predation and the physical environment on recruitment of young fishes and shrimp in an estuarine nursery", 1988-91, \$220,000.

U.S. Department of Commerce (NOAA, Georgia Sea Grant Program), "Use of the vegetated intertidal marsh by the young of estuarine-dependent fishes and crustaceans", 1987-88, \$37,100.

U.S. Department of Commerce (NOAA, National Estuarine Sanctuary Program), "Distribution and population dynamics of *Hargeria rapax* in the Sapelo Island National Estuarine Sanctuary", 1985-86, \$10,004.

National Science Foundation, "Complex interactions and community organization: The experimental analysis of predation as a multi-dimensional mechanism", 1983-85, \$77,999.

Research Grants (*previous*, continued)

Sapelo Island Research Foundation, "Biological interactions among aquatic and benthic components of the salt marsh community", 1983-84, \$5,400.

Sapelo Island Research Foundation, "Biological interactions affecting the export of white shrimp production to nearshore Georgia waters", 1982-83, \$10,125.

University of Georgia Research Foundation (Faculty Research Grant), "Temporal and spatial patterns of abundance in the eggs, larvae and juveniles of *Fundulus heteroclitus* from an intertidal salt marsh", 1982-83, \$4,260.

Other previous grants:

Sapelo Island Research Foundation, "Filter-feeding bivalves: a link between productivity in the water column and sediments of the Georgia nearshore environment", 1981-82, \$7,000.

University of Georgia Research Foundation, "Travel support to collaborate with Dr. Shing Yip Lee on preliminary studies of juvenile-adult interactions in grapsid crabs from Old World mangrove ecosystems in Hong Kong, 1996, \$3,000

University of Georgia Research Foundation, "Travel assistance award to attend decapod behavior workshop in Bangor, Wales", 1994, \$855.

University of Georgia Research Foundation, "Support of travel to Spain for collecting preliminary samples of fishes from the Guadalquivir River estuary", 1992, \$844.

National Science Foundation, "Uninterruptable power source system to support facilities/equipment at the Marine Institute" (Co-principal investigator with J.J. Alberts, A.G. Chalmers, R. P. Kiene), 1990-91, \$36,000.

National Science Foundation, "Equipment/facilities upgrade and acquisition at the Marine Institute" (Co-principal investigator with J.J. Alberts, A.G. Chalmers, C.S. Hopkinson, R.P. Kiene), 1988-91, \$33,000.

National Science Foundation, "Equipment/facilities improvement and upgrade at the Marine Institute" (Co-principal investigator with J.J. Alberts, A.G. Chalmers, R.D. Fallon, C.S. Hopkinson, S.Y. Newell, B.F. Sherr and E.B. Sherr), 1986-87, \$30,000.

National Science Foundation, "Equipment improvement for marine biological research conducted at the University of Georgia Marine Institute" (Co-principal investigator with A. G.

Chalmers, R. D. Fallon, C. S. Hopkinson, S. Y. Newell, B. F. Sherr and E. B. Sherr), 1984-85, \$18,000.

National Science Foundation, "Bringing the Marine Institute into the computer age, and other improvements" (Co-principal investigator with A.G. Chalmers, R.D. Fallon, C.S. Hopkinson, S.Y. Newell, J.R. Robertson, B.F. Sherr and E.B. Sherr), 1983-84, \$75,000.

Invited Presentations (*R. T. Kneib*)

Where in the world do tidal marshes have a critical function as nursery habitat?, Invited plenary in special session on "Geographical variability in the nursery function of coastal salt marshes for fishery species" (Co-organizers: Lawrence Rozas, Cuizhang Fu, Ronnie Baker), Coastal and Estuarine Federation biennial conference, Portland, OR 1-5 Nov 2009.

Going with the flow: ecosystem function and management on the Georgia coast, Invited workshop presentation for the Institute for Georgia Environmental Leadership Program (UGA Fanning Institute), Sapelo Island, GA September 2009.

What role for science in restoration and remediation in coastal Georgia, Invited speaker, Coastal Georgia Colloquium '09, Coastal Georgia Center, Savannah, GA, 11 August 2009.

Individual growth rates and residence times as success metrics in estuarine nekton habitat quality. Invited contribution to symposium on Restoration of Estuarine Environments: Metrics to Assess Impact on Nekton Habitat Quality. Estuarine Research Federation Biennial Meeting, Providence, RI, November 2007.

Georgia's Coastal Marshlands Protection Act: Tracking a Moving Target. Invited luncheon speaker, The American Society of Landscape Architects (Savannah Section), Savannah, Georgia, April 2007.

POD: Pelagic Organism Decline or Price Of Development. Invited plenary presentation at 4th Biennial CALFED Bay Delta Program Science Conference, Sacramento, California, October 2006.

Expressions of nekton in estuarine landscapes. Invited seminar, University of Southern Mississippi, Gulf Coast Research Laboratory, Ocean Springs, MS, September 2006.

Landscape structure and the quality of nursery habitat in tidal marshes. Invited contribution to symposium on Estuary-Dependent Fishes: Patterns and Processes of Environmental Influences on Nursery Habitat Quality. American Fisheries Society Annual Meeting, Lake Placid, New York, September 2006.

Invited Presentations (continued)

Measuring growth rates and movements of individual fishes and prawns in estuarine landscapes using coded tag technology. Invited contribution to symposium on Innovative Approaches for Assessing Nekton Nursery Value of Estuarine and Coastal Wetlands. 27th Annual Meeting of the Society of Wetland Scientists, Cairns, Australia, July 2006.

Living and working in tidal time: a quarter century of learning from dynamic coastal landscapes. Griffith University - Nathan Campus, Queensland, Australia, May 2006.

Populations, individuals, genes and the structure of estuarine landscapes. University of Delaware, College of Marine Studies, Lewes, Delaware, September 2005.

Human use, structural changes and sustainability of ecosystem benefits from coastal marshes. Invited contribution to symposium on Ecological and Societal Values of Estuarine Habitats, 17th Biennial Conference of the Estuarine Research Federation, Seattle, WA, Nov 2003.

A landscape perspective on marsh nekton production and trophic transfers. University of South Carolina, Belle W. Baruch Institute, Georgetown, South Carolina, May 2003.

Is spatial structure important to ecological functioning of coastal marsh landscapes? Louisiana Universities Marine Consortium, Chauvin, Louisiana, February 2003.

Relating function to spatial structure in tidal marsh ecoscapes. Department of Biological Sciences, University of North Carolina at Wilmington, January 2003.

Viewing estuarine fish habitat in an ecoscape context - finding common ground for coastal fishery and land-use managers. Invited contribution to symposium on 'Bays, Sounds, Gulfs, Lagoons: Estuarine Fisheries in the 21st Century', 132nd Annual Meeting of the American Fisheries Society, Baltimore, Maryland, August, 2002.

Landscape complexity and abundance of juvenile white shrimp *Litopenaeus setiferus* in subtidal and intertidal estuarine habitats (R.T. Kneib & S.R. Webb), 16th Biennial Conference of the Estuarine Research Federation, St. Pete Beach, Florida, November 2001.

Nekton use of tidal marshes: importance of landscape structure. School of Environmental and Applied Sciences, Griffith University Gold Coast, Gold Coast, Qld, Australia, July 2001.

Understanding and managing salt marshes. Invited guest/speaker, Annual Coastal Cooperative Research Centre Workshop, Noosa, Queensland, Australia, July 2001.

Structure and dynamics of habitats and nekton assemblages in tidal wetlands. Marine Fisheries Seminar Series, Department of Marine Biology, Texas A & M University - Galveston and NOAA/NMFS, Galveston Laboratory, Galveston, Texas, March 2000.

Invited Presentations (continued)

Marsh mummies - what's up with them? (The role of estuarine nekton in the movement of marsh production to the open estuary). 13th Annual Science & Engineering Lecture Series, Jacksonville University, Jacksonville, Florida, February 2000.

Intertidal salt marsh landscapes and estuarine nekton: linking structure and function, (Plenary speaker), ECSA 29, Estuarine Research and Management in Developed and Developing Countries, University of Port Elizabeth, South Africa, July 1998

Salt marsh ecoscapes and production of estuarine nekton along the southeastern coast of the U.S., (Plenary speaker), Special International Conference on Concepts and Controversies in Tidal Marsh Ecology, Vineland, New Jersey, April 1998.

How do we demonstrate trophic support of estuarine nekton by intertidal salt marsh production? Special Workshop on Intertidal Marsh Production sponsored by the Estuary Enhancement Program of the Public Service Electric & Gas Co., Newark, NJ, November 1997

Nekton of intertidal marshes -- defining the role of resident species in production transfers to the open estuary. Department of Ecology & Biodiversity, University of Hong Kong, Hong Kong, June 1996.

How are nekton populations involved in the export of intertidal marsh production? 13th Biennial International Estuarine Research Federation Conference, Corpus Christi, Texas, November 1995.

What are the values of tidal marshes for nekton?, Marsh Ecology Applied Research Program Workshop, "The importance of tidal marsh production for fisheries", Academy of Natural Sciences, Philadelphia, Pennsylvania, October 1995.

Quantifying the functional role of nekton across an intertidal landscape. Symposium on quantification of estuarine fish populations, 125th Annual Meeting of the American Fisheries Society, Tampa, Florida, August 1995.

Foraging across a marsh ecoscape: spatial patterns and access to resources. Science Seminar, North Georgia College, Dahlonega, Georgia, April 1995.

Collecting nekton from the semi-terrestrial environment of intertidal marshes. Workshop on Estuarine Nekton, Sampling Methods and Standards, National Biological Survey, Gainesville, Florida, September 1994.

Behaviour separates potential and realized effects of predatory decapods in salt marsh communities. Decapod Workshop, University College of North Wales, Bangor, Wales, September 1994.

Invited Presentations (continued)

Landscapes through a fish eye. Ecology Seminar, University of North Carolina, Chapel Hill, North Carolina, February 1994.

Coupling intertidal marshes and coastal waters: the shrimp connection. 12th Biennial International Estuarine Research Federation Conference, Hilton Head, South Carolina, November 1993.

Spatial patterns, scale and feeding in fishes. Keynote paper in Gutshop '92 session on application of landscape ecological theory to feeding ecology in fishes, Orcas Island, Washington, November 1992.

Evaluating the nursery function of intertidal marshes. Biology Seminar, Georgia Institute of Technology, Atlanta, Georgia, May 1992.

Patterns in nekton use of intertidal marshes during flood tides. Coastal Wetland Ecology and Management Symposium, New Orleans, Louisiana, December 1991.

Indirect effects in experimental studies of marine infaunal communities. Symposium on new perspectives in soft-sediment ecology, 1990 Annual Meeting of the American Society of Zoologists, San Antonio, Texas, December 1990.

The nursery function of intertidal marshes for fish species. Colloquium presentation at The Netherlands Institute for Sea Research, Texel, The Netherlands, November 1990.

A comparison of fish and crustacean densities in different intertidal marsh habitats on Sapelo Island, Georgia. Symposium on fisheries habitat utilization: Marshes, 1990 Annual Meeting of the Southeastern Division of the American Fisheries Society, Richmond, Virginia, October 1990.

Evaluating the nursery function of intertidal marsh habitats. Biology Department, Virginia Commonwealth University, Richmond, Virginia. October 1990.

Use of the intertidal marsh surface by juvenile fishes and crustaceans. Biology Department, Georgia Southern College, Statesboro, Georgia. February 1990.

Indirect effects of predators on the benthic macrofaunal assemblages of intertidal soft substrata. Symposium on complex interactions in benthic and littoral communities, 1988 Annual Meeting of the Ecological Society of America, University of California, Davis, August 1988.

Intertidal marshes as estuarine nurseries and sites for the experimental investigation of recruitment. Fish in Estuaries Conference, Southampton University, Southampton, Great Britain, July 1988.

Invited Presentations (continued)

Determinants of invertebrate distribution patterns in the intertidal soft sediments of estuaries. International Estuarine Research Conference, New Orleans, Louisiana, October 1987.

Experimental analysis of complex trophic interactions in the intertidal marsh. College of Marine Studies, University of Delaware, Lewes, Delaware. October 1986.

On the role of *Fundulus heteroclitus* in salt marsh trophic dynamics. Annual Meeting of the American Society of Zoologists, Philadelphia, Pennsylvania. December, 1983.

Patterns of invertebrate distribution and abundance in the intertidal salt marsh: Causes and questions. 7th International Estuarine Research Conference, Virginia Beach, Virginia. October 1983.

Community interactions in the salt marshes of Sapelo Island, Georgia. University of North Carolina Marine Institute, Morehead City, North Carolina. October 1983.

Field experiments: Testing ecological concepts. Davidson College, Davidson, North Carolina. April 1983.

The responses of salt marsh invertebrates to changes in predator population structure. Skidaway Institute of Oceanography, Skidaway Island, Georgia. April 1981.

Professional Service Activities:

In the past five years (2004-2009), I have provided *ad hoc* reviews and comments on a large number of manuscripts submitted for publication and research proposals submitted for funding. As a Contributing Editor for the journal *Marine Ecology Progress Series*, Review Editor for *Endangered Species Research*, Associate Editor for *Wetlands*, and Guest Editor for *Southeastern Naturalist*, I annually handled several additional manuscripts through the review process, and have served as co-coordinator for a Special Theme Section on Restoration in the Marine Environment with contributions from 16 authors.

The following are journals and granting agencies for which I have provided reviews and/or served on technical review boards:

Ad hoc Reviewer

Journals: American Zoologist, Aquatic Ecology, Bulletin of Marine Science, Bulletin of the New Jersey Academy of Science, Conservation Biology, Copeia, Contributions in Marine Science, Ecology, Ecological Engineering, Estuaries, Estuarine Coastal & Shelf Science,

Fisheries, Fishery Bulletin (US), Hydrobiologia, Journal of Crustacean Biology, Journal of Experimental Marine Biology and Ecology, Journal of Fish Biology, Journal of the Marine Biological Association of the United Kingdom, Journal of North Carolina Association of Science, Limnology & Oceanography, Mangroves and Salt Marshes, Marine Biology, Marine Ecology Progress Series, North American Journal of Aquaculture, North American Journal of Fisheries Management, Oecologia, Proceedings of the European Ichthyological Congress, Proceedings of the International Senckenberg Conference on Muddy Coasts 97, Restoration Ecology, Reviews in Fish Biology and Fisheries, Science, Transactions of the American Fisheries Society, Wetlands, Wetlands Ecology & Management.

Granting Agencies: National Science Foundation (Ecology Cluster and Biological Oceanography Programs), U.S. Department of Commerce (NOAA, Sea Grant College Program -- NC, SC, TX, NY, NJ, LA, MS-AL/National Undersea Research Program and Chesapeake Bay Stock Assessment Program), Hudson River Foundation, Louisiana Universities Marine Consortium (LUMCON)/Minerals Management Service Cooperative Program, LUMCON Coastal Restoration and Enhancement through Science and Technology program (CREST), Research Enhancement Program for the San Francisco Bay-Delta, Gulf of Maine Regional Marine Research Program, J. Francis Allen Scholarship Program, Research Grants Council of Hong Kong, Marsh Ecology Research Program (Academy of Natural Sciences-Philadelphia), NJ Water Resources Research Institute, U.S. Civilian Research & Development Foundation Cooperative Grants Program, U.S. Environmental Protection Agency (STAR Program).

Proposal Review Panels

- New York Sea Grant Technical Review Panel, convened August 2006, New York, NY.
- *US EPA STAR Program*, Peer Review Panel for Effects of Climate Change on Ecosystem Services Provided by Coral Reefs & Tidal Marshes, convened August 2004, Washington, DC.
- *North Carolina Sea Grant* Technical Review Panel, convened October 1999, Raleigh, NC.
- New York Sea Grant Technical Review Panel, convened September 1999, New York, NY.
- *US EPA STAR Program*, Graduate Fellowship Panel, convened February 1999, Alexandria, VA.
- *NOAA Undersea Research Program*, National Science Panel, convened October 1994, Groton, CT.
- *NOAA Sea Grant College Program*, National Panel (Fisheries), convened October 1993, Lewes, DE.

Science & Technical Advisory Committees

- *Expert Witness for Stack & Associates*, Case involving alleged incorrect marsh delineation and subsequent issuance of permits to fill marshlands under Georgia's Coastal Marshlands Protection Act at Aiken Island, February-April 2007. (Administrative Hearings in Brunswick - March and Atlanta - April, GA).

- *Appointed member*, Georgia Coastal Advisory Council, quarterly meetings, appointment by the Commissioner of the Georgia Department of Natural Resources under Administrative Order associated with GA Coastal Management Act, 2006-2007; reappointed 2007-2011.
- *Monitoring Advisory Committee* for the Estuary Enhancement Program in Delaware Bay sponsored by Public Service Electric & Gas Company, annual and semi-annual meetings 1994- 2001.
- *Science Advisory Committee*, Florida Keys National Marine Sanctuary Program, Convened December 2000 and September 2007, Marathon, FL.
- *Estuary Enhancement Program Advisory Committee* (EEPAC) for Public Service Enterprise Group in Delaware Bay, 2-3 meetings annually, February 2002- present.
- *Advisory Board member*, Center for a Sustainable Coast, St. Simons Island, Georgia, 2002-present.
- *Advisory Board member*, Satilla Riverwatch Alliance, Waynesville, Georgia, 2004- present.
- *Rapid Response Team member* for Policy Office, Ecological Society of America, 2005-present (Cases included U.S. Supreme Court - Rapanos).
- *Expert Witness for Southern Environmental Law Center*, Cases involving issuance of permits under Georgia's Coastal Marshlands Protection Act., 2001-present. (Cases include: Manhead Marina, St Simons Island, GA; Emerald Pointe, Savannah, GA; Cumberland Harbour, St Marys, GA; Satilla River Landing, Woodbine, GA).
- *Science Advisory Committee*, Florida Keys National Marine Sanctuary Program - Water Quality Protection Program, Convened September 2007, Marathon, FL.

Editorial Boards

Marine Ecology Progress Series

Contributing Editor 1997-2002, Guest Editor 2003, Senior Editorial Advisor 1996-1997, Editorial Advisor 1993-96, Editorial Reviewer 1992-93.

Endangered Species Research

Review Editor 2004-present

Wetlands

Associate Editor 2006-present

Southeastern Naturalist

Guest Editor 2008

Other

Scientific Session Co-organizer, Applications of Landscape Ecology to Estuarine and Coastal Environments convened at the Coastal and Estuarine Federation Biennial Conference, Portland, OR 1-5 Nov 2009 (Co-organizers: Simon Pittman, Ron Kneib, Charles Simenstad).

Student Training Activities:

*Historically, the principal duties of the faculty at the UGA Marine Institute have focused solely on research. However, I place a high value on education and attempt to share the excitement and benefits that come from scientific exploration of the world around us. To this end, I have made a special effort to seek out opportunities to participate in education at several levels – not always an easy task being located on a limited-access island at a station 250 miles from the campus of the University of Georgia. For many years, I was the only faculty member at the Marine Institute to hold an appointment on the university's **Graduate Faculty**.*

*In addition to providing numerous annual guest lectures on a variety of topics in marine and coastal ecology for class groups visiting the station (and recently via distance-learning technology to campus classes), I have been a regular participant in **teacher training workshops** conducted by the UGA Marine Extension Service and was coordinator of the **UGAMI Student Intern Program** for 13 years (1987-1999). When I took over the leadership of this program in 1987, we were receiving 3-6 applications from graduate students at the University of Georgia. During my tenure, the program expanded to include advanced undergraduates and grew to national prominence, with application rates in excess of 100 per annum for the 3-7 positions that could be offered.*

Following is a list of individual students for whom I have served as either mentor/advisor or as a member of an advisory, reading or examining committee:

Advisor for the following students:

UGAMI student interns:

- Reuben Biel, Colby College (Maine), 2008
- Jennifer Mitton, University of Massachusetts - Dartmouth, 2005
- Amy Rowan, Rutgers University, 2005
- Chad Ellinwood, University of New Orleans, 2004
- Keri York, Jacksonville University, 2000
- Thomas J. Mozdzer, Fairfield University, 1999
- Cheryl C. Dukas, North Georgia College & State University, 1998
- Carrie E. H. Scheele, University of Wisconsin, 1998
- Gretchen L. Arnold (Sea Grant Intern), University of Virginia, 1997
- Stacey R. Webb (Sea Grant Intern), Louisiana State University, 1997
- Jeffrey A. Sample (EPA Intern), Clemson University, 1997
- Alyson H. Craig, University of North Carolina at Chapel Hill, 1996
- Leslie Gallagher, Allegheny College, 1996
- Matthew Huggler (Sea Grant Intern), University of North Carolina at Chapel Hill, 1996
- Edward T. Hermeno, Massachusetts Institute of Technology, 1995
- M. Kathryn Knowlton, University of Georgia, 1994
- Scott Lerberg, Denison University, 1992

- Cindy Rejwan, University of Toronto, 1991
- Sandra Wagner, Salisbury State University, 1991
- Katherine E. Reynolds, Cornell University, 1990
- Michelle Covi, University of Georgia, 1989
- Cynthia A. Weeks, Denison University, 1987
- R. Daniel Turk, Davidson College, 1983
- Malcolm Cambell, Davidson College, 1982
- William S. Arnold, University of Georgia, 1981

Service on Graduate Student Committees (advisory, examining, reading):

- Benjamin L. Carswell, M.S. student, School of Forestry & Natural Resources, University of Georgia
- Brian Boutin, PhD student, Marine Studies, University of Delaware, 2008
- Jennifer Beseres, PhD., Marine Sciences Program, University of South Carolina, 2006
- Pedro Quijon, PhD, Memorial University, St. John's, Nfld, Canada, 2004
- Justin Meager, Ph.D., Nat. Resource Sci., Queensland Univ. of Technology, Australia, 2002
- Simon Pittman, PhD, Geographical Sciences & Planning, Univ. of Queensland, Australia, 2002
- LUI Tak Hang (Henry), MPhil., University of Hong Kong, 1998
- Francis O'Beirn, Ph.D., Zoology, University of Georgia, 1995
- T. Dale Bishop, Ph.D., Ecology, University of Georgia, 1995
- L. Stanton Hales, Jr., Ph.D., Zoology, University of Georgia, 1994
- Randall Cross, Ph.D., Biology, University of North Carolina-Chapel Hill, 1994
- Amita Kanti, Ph.D. student, Zoology, University of Georgia (1992-93)
- Joan E. Sheldon, M.S., Zoology, University of Georgia, 1993
- H. Carl Fitz, Ph.D., Ecology, University of Georgia, 1990
- Mary Anne Mayer, M.S., Biology, Georgia Institute of Technology, 1985
- William S. Arnold, M.S., Zoology, University of Georgia, 1983

Major Advisor for the Following Graduate Students:

- **Brian K. Dresser**, M.S., Ecology, University of Georgia, 2003; Thesis: '*Habitat use and movement of subadult red drum, *Sciaenops ocellatus*, within a salt marsh-estuarine system*'
- **Andrew M. Forrester**, M.S. student, Marine Science, University of Georgia (1999-2000)
- **Stacey R. Webb**, M.S., Marine Science, University of Georgia, 2000; Thesis: '*Growth and movement of juvenile white shrimp *Litopenaeus setiferus* within a tidal marsh landscape*'
- **M. Kathryn Knowlton**, M.S., Zoology, University of Georgia, 1996; Thesis: '*Effects of juvenile white shrimp *Penaeus setiferus* on the survival and distribution of young daggerblade grass shrimp *Palaemonetes pugio**'

- **Suesan E. Saucerman**, Ph.D. student, Zoology, University of Georgia (1992-93)
- **Michelle P. Covi**, M.S., Zoology, University of Georgia, 1992; Thesis: *'Intertidal distribution and population dynamics of the salt marsh amphipod Uthlorchestia spartinophila at Sapelo Island, GA'*

University and Departmental Service:

Current:

- Principal Organizer and Editor, 50th Anniversary Conference for the UGA Marine Institute, est. 1953 (Nov 2003, Jekyll Island, GA; for details see webpage at <http://www.rtkneib.myweb.uga.edu/>)
- Weekend duty officer -- periodic responsibility for emergency services, mail and security of facilities (8-10 times annually), 1980-2009.

Previous:

- Member, Search Committee (research faculty position), UGA Marine Institute
- 2005.Maintenance of Laboratory Equipment (balances), UGA Marine Institute, 1985-2005.
- Temporary Acting Director, UGA Marine Institute, Occasional as necessary in 1990-2003.
- Coordinator, Student Intern Program, UGA Marine Institute, 1987-2000
- Chair, Search Committee (research faculty position), UGA Marine Institute, 1997-98.
- Member, Search Committee (faculty position in Biological Oceanography), UGA Department of Marine Sciences, 1997.
- Participant, Working Group to develop 5-yr strategic plan for UGA Sea Grant Program, 1994
- Member, Search Committee (two faculty positions in Biological Oceanography), UGA Department of Marine Sciences, 1993.
- Seminar Coordinator, UGA Marine Institute, 1984-1988.
- Member, Curriculum Committee, School of Marine Programs, UGA, 1988.
- Co-chair, Computer Committee, UGA Marine Institute, 1984-1991.

Honors & Other Recognition:

- Recognized by Shaw Environmental & Infrastructure, Inc. for Contributing Knowledge Among Professionals in the Technical Community for publication Dresser & Kneib (2007).
- Certified Senior Ecologist, Ecological Society of America, June 2002- May 2007; re-certified June 2007 - May 2012
- Elected to Phi Beta Delta Honor Society for International Scholars, 1997
- Elected to Phi Kappa Phi Honor Society, 1993
- Elected Secretary-Treasurer, Southeastern Estuarine Research Society, 1987-89

- Elected to Sigma Xi, 1976 (Associate member), 2001 (Full member)
- Elected to Phi Sigma Society, 1972
- Invited participant, Conservation Action Plan for Saltmarsh Topminnow (*Fundulus jenkinsi*) Workshop, Biloxi, MS, The Nature Conservancy, Grand Bay National Estuarine Research Reserve and the University of Southern Mississippi, January 2009.
- **Invited model developer/champion, Tidal Marsh Biological Model, Sacramento-San Joaquin Delta Regional Ecosystem Restoration Implementation, US Geological Survey, February 2007-08.**
- Invited member, Ecological Society of America, Rapid Response Team, ESA Policy Office, Washington, DC, 2005-2007; (Invited to second term 2007-2009).
- **Invited participant, Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Model Development Workshop, University of California - Davis, December 2006.**
- **Invited member, Technical Review Panel for California Bay-Delta Authority (CALFED) Environmental Water Account Program, Sacramento, CA, October 2006**
- Invited participant representing the Ecological Society of America at Summit on ‘Waters at Risk: Assessing the importance of tributaries and wetlands that may be affected by the Supreme Court Decision (Carabell/Rapanos), Hall of States, Washington, DC, April 2006
- Invited partner, Science Partners LLC, an independent science company comprising more than two hundred of the world’s leading clinicians, medical and environmental scientists, process and biomedical engineers, biotechnology experts, and other safety and risk specialists, 2006-
- **Invited member, Technical Review Panel for the Interagency Ecological Program Pelagic Organism Decline Work Team, California Bay-Delta Authority (CALFED) Science Program, Sacramento, CA, October, 2005**
- Invited participant, Workshop for the Development of a Delaware Estuary Fishery Ecosystem Model, Vineland, NJ, October 2004
- Invited participant, Workshop for the Development of an Estuary Ecosystem Management Program for the New River - Onslow Bight Region of North Carolina, Department of Defense, Strategic Environmental Research and Development Program, Atlantic Beach, NC, February 2004
- Invited participant, International SCOPE (Scientific Committee on Problems of the Environment) workshop on “Integrating concepts of biodiversity in soils and sediments: a transdisciplinary assessment of the most critical taxa, functions and habitats for sustainability, their vulnerability and management options”, Estes Park, Colorado, October 20-23, 2002.
- Invited participant, NSF-sponsored workshop ‘Networking the “Invisible Colleges”’: application of network theory to biocomplexity’, Greenville, NC and Beaufort, NC, 19-24 March 2001
- Invited participant, International SCOPE (Scientific Committee on Problems of the Environment) workshop on “The role of soil and sediment biodiversity in the functioning

of critical transition zones”, Oregon State University, Corvallis, OR, August 28 - September 1, 1999

- Nominated for Sir Allan Sewell Fellowship at Griffith University, Gold Coast, Queensland, Australia in 1998 and 1999
- Invited participant, Workshop on Fish Production by Tidal Marshes, Public Service Electric & Gas, Newark, NJ, November 25, 1997
- Invited participant, Symposium on Synthesis, Science, and Ecosystem Management, National Center for Ecological Analysis and Synthesis, Santa Barbara, CA, November 17-20, 1996
- Invited participant, Workshop on the development of hydrogeomorphic models for coastal fringe wetlands, U.S. Army Corps of Engineers, Charleston, SC, September 1996

JOHN (JACK) H. HUMPHREY
9855 Meadowlark Way
Palo Cedro, CA 96073
530-241-5995-McFadden (office and fax)
530-547-4743 (home)
Email: Hydmetjack@aol.com

Meteorologist
Hydrologist
Civil Engineer

EDUCATION

Ph.D., 1972, Hydrology, University of Nevada at Reno
B. A., 1964, Meteorology, University of California at Los Angeles

REGISTRATIONS AND CERTIFICATIONS

Civil Engineer, California (C030512), 1979
Certified Consulting Meteorologist, AMS, 1978

EMPLOYMENT

1964-1968: **U.S. Air Force**, Meteorologist. Five years active duty in California, Vietnam and West Germany. Remained in the U.S. Air Force Reserve as a Meteorologist. Retired in 1988 with rank of Lt. Colonel.

1969-1972: **University of Nevada**, Graduate Research Assistant. Managed field research for investigating the hydrologic response of snowpacks to rain and other meteorological variables near Lake Tahoe in the Sierra Nevada.

1973-1977: **CH2M Hill Engineers**, Hydrologist in Bellevue, Washington and Redding, California.

1978-1986: **Ott Water Engineers**, Redding, California, Director of Meteorologic and Hydrologic Services.

1987-Present: **Hydmet, Inc**, Redding, California. This firm is owned by Dr. John H. Humphrey and provides technical expertise in hydrology, meteorology, stream hydraulics, sediment transport, geomorphology, and water quality. Meteorologic, hydrologic, hydraulic, and sediment transport databases, models and analyses are developed for streams and lakes using programs HEC-1, HECRMS, HECRAS, SWMM, HEC-6, FLUVIAL-12, HSPF, BASINS, PRMS, RMA2, CEQUAL-W2, QUAL2E, FLDWAV and FESWMS.

EXPERIENCE

Meteorology

1973: Seattle, Washington, River and Lake Models. Set up and calibrated meteorologic input to urban runoff models of Lake Washington and Lake Sammamish for City of Seattle and Metro.

1974: Coeur d'Arlene, Idaho, I-90 Environmental Impact Report. Air pollution meteorologic analysis for proposed rerouting of Interstate 90 by Idaho Department of Highways.

1974: Bellevue, Washington, 148th Avenue EIR. Air pollution meteorologic analysis for street improvement project.

1974: Kenniwick, Washington, Sewage Lagoon. Set up weather station and determined evaporation rates for leak testing.

1975: Warm Springs Indian Reservation, Oregon, Airport. Two year wind collection and analysis for airport runway siting.

1976: Humboldt River and Tributaries, Nevada, Hydrology Memorandum. Cloudburst and general rain/snowmelt storm analysis for dam design and river flooding projects for U.S. Army Corps of Engineers.

1976: Milwaukee, Wisconsin, Combined Sewer Overflow Control. Historical storm analysis to determine design events.

1976: Denver, Colorado, EPA 208 River Models. Set up and calibrated meteorologic input of precipitation, temperature, sunshine, humidity and wind for water quality models.

1977: Washington, Oregon, Coastal Flooding. Analysis of 40 years of weather maps and coastal meteorologic data for wave hindcasting and storm surge modeling for Federal Emergency Management Agency flood mapping.

1977: Russell Creek, Cold Bay, Alaska, Snow Drifting. Used historical Cold Bay weather observations to determine snowdrift accumulations and snow fence design for fish hatchery access road.

1977: Upper Wisconsin River, Wausau, Wisconsin. Collected meteorologic data and calibrated snowmelt models for operating system of 19 reservoirs on the Wisconsin River for Wisconsin Valley Improvement Company.

1977: Dupont Wharf, Nisqually Reach, Puget Sound, Washington. Collected and analysed wind data for wave and oil spill study for Weyerhaeuser Company.

1978: Fox River Model, Green Bay, Wisconsin. Meteorologic measurements and analysis for water temperature model.

1978: Humboldt River, Nevada, Snowmelt Model. Operational snowmelt flood forecasting using real-time meteorologic data for U.S. Army Corps of Engineers.

1979: Mt. Shasta, California, Ski Area. Snow accumulation and snowmelt analysis using aerial photography and climatological data.

1980: Dillingham Harbor, Alaska, Waves. Prediction of waves from long-term meteorological data and analysis of wave protection for U.S. Army Corps of Engineers.

1980: Truckee River, California, Snowmelt Model. Operational snowmelt spring runoff forecasting for U.S. Bureau of Reclamation.

1982: Ship Creek Cooling Pond, Anchorage, Alaska. Meteorological analysis of potential fog formation from proposed cooling pond for Elmendorf Air Force Base.

1983: Calkari Arms Apartments, Redding, California. Cloudburst flood study for litigation against Caltrans.

1984: Northern California Coastal Flooding. Meteorological analysis of weather maps for wave hindcasting and storm surge for FEMA flood studies from Monterey to Oregon.

1984: Stephens Passage, Juneau, Alaska. Wind recorder installation and analysis of wind fields for determination of wave conditions for Greens Creek Mine dock.

1985: Shemya Air Force Base, Shemya Island, Alaska. Analysis of weather maps for wave hindcasting for dock design.

1985: Magic Dam, Twin Falls, Idaho. Meteorological study of probable maximum precipitation conditions for Big Woods River and Camas Creek.

1985: Arco Pit D, Kapuruk, Alaska. Meteorological station set up and analysis for determining snowmelt floods for the North Slope.

1985: Eel River Landslide, Redway, California. Analysis of historical precipitation records in Northwest California to determine contributory causes to December 1983 landslide.

1986: Combined Sewer Overflow, Seattle, Washington. Analysis of urban precipitation patterns for calibration of stormwater runoff models.

1987: Baxter EIR, Redding, California. Air pollution meteorological analysis for proposed wood treatment plant.

1987: Combined Sewer Overflow, Everett, Washington. Analysis of urban flood events and precipitation for stormwater runoff model.

1987: Precipitation Gage Master Plan, Orange County, California. Analysis of siting conditions and criteria for location of precipitation gages in Orange County for OCEMA.

1987: Kensington Mine EIR, Juneau, Alaska. Installation of weather station and analysis of weather conditions influencing operation of proposed gold mine.

1988: Rush Creek, Lee Vining, California. Installation of weather station and analysis of meteorological data for stream temperature modeling for California Department of Fish and Game.

1988: Garden Bar Pumped Storage, Marysville, California. Analysis of meteorological data for input to reservoir and Bear River water temperature models.

1988: American River, Sacramento, California. Analysis and input of meteorological data for water temperature modeling of the American River and Folsom Reservoir for Sacramento County.

1988: Chester Lake, Metlakatla, Alaska. Precipitation and runoff analysis for hydropower facility for Alaska Power Authority.

1989: Silver Bow Creek, Butte, Montana. Analysis of meteorological conditions resulting in 100-year and probable maximum floods for Montana Department of Health and Environmental Sciences.

1989: February 18, 1986 Flood, Roseville, California. Cloudburst precipitation analysis for hydrologic model of flood event for City of Roseville.

1989: Rosamond Wash, Mojave Desert, California. Analysis of meteorologic and hydrologic conditions causing cloudbursts and flash floods for L. Bruce Nybo, Inc.

1989: Jawbone and Pine Tree Canyons, Mojave Desert, California. Analysis of meteorologic and hydrologic conditions causing cloudbursts and flash floods for L. Bruce Nybo, Inc.

1989: Placer County, California. Description of precipitation statistics and cloudburst design storm methodology for the Placer County Hydrology Manual.

1989: Santiago Reservoir, Orange County, California. Analysis of meteorologic data for input to water quality model of Santiago Reservoir for the Irvine Company.

1990: Sacramento County Hydrology Manual, California. Analysis of precipitation data for all Sacramento County stations.

1992: Charlotte Air Pollution Study, North Carolina. Analysis of odor problems for Charlotte wastewater treatment plants.

1993: Greater Houston Wastewater Project, Texas. Analysis of precipitation records to determine depth-duration-frequency and areal-reduction-factors.

1994: Spokane County Stormwater Management Study, Washington. Selection and siting of precipitation gages and weather stations for calibration of snowmelt/precipitation runoff models.

1997: Davis County, Utah. Determination of depth-duration-elevation frequency curves for precipitation in the Wasatch Range.

1997: Cedar City, Utah. Analysis of long-term hourly precipitation records in Southwest Utah to derive design storms for a FEMA restudy.

2000: New Orleans, Louisiana. Study of short-duration precipitation data for urban design storms for City of New Orleans and MWH Engineers.

2001: Idaho Falls, Idaho. Analysis of rain-on-snow design precipitation events for the Idaho National Environmental Engineering Laboratory.

2001: Atlanta, Georgia. Study of radar and precipitation gage statistics for urban design storms for City of Atlanta and MWH Engineers.

2002: Oroville, California. California DWR and MWH Set up meteorologic data base for WQRRS for Lake Oroville and Themolito Afterbays for 1922-2003.

2005: St Louis, Missouri. Jacobs and MWD. Set up processor for stationary design storms using Depth-Duration-Frequency data for St. Louis and Depth Areal Reduction Factors from radar meteorology analyses.

2005: Big Bear Municipal Water District. City of Big Bear, California. Set up 57-year HSPF climatologic hourly data base for investigation of future lake levels in Big Bear Lake. Installed telemetered weather station at Snow Summit Ski Area.

2006: U.S. Bureau of Reclamation, MWH Americas, Sacramento. Set up a hourly data base for Fresno 1921-2005 (85 years) for air temperature, dewpoint, wind speed, wind direction, cloudiness and solar radiation. Developed algorithms for estimating hourly data for the 1921-1948 period when only daily maximum-minimum temperatures and daily precipitation data were available. The database is being used for water quality modelling of reservoirs on the San Joaquin River using CEQUAL-W2

2009. Colorado Springs, Colorado and Carleton Engineers. Statistical analyses of long-term rain gage records and radar precipitation for deriving cloudburst design storms. Set up HSPF model for 1949-2008 to determine antecedent precipitation conditions for Fountain Creek.

Hydrology

1974: Water Resources Management Study, Seattle, Washington. Set up and calibration of HSP continuous snowmelt runoff simulation model of the Cedar, Tolt and Green Rivers.

1974: Lake Young, Tacoma, Washington. Water quality simulation of water supply reservoir influenced by urban runoff.

1976: Seneca Creek, Silver Springs, Maryland. Hydrologic simulation using HSP model of urbanizing watershed near Washington, D.C. for Montgomery County Capitol Parks Planning Commission.

1976: Rock Creek Park, Washington, D.C., Maryland. Set up and calibrated water quality model to determine urban runoff influence on Rock Creek for National Park Service.

1977: Humboldt and Walker Rivers, Nevada. Set up and calibrated water quality models for wasteload allocation for Nevada Department of Environmental Quality.

1977: Municipality of Anchorage, Alaska. Set up and calibrated water quality model of urban runoff influences on Campbell and Ship Creeks for EPA 208 study.

1977: St. Louis, Missouri. Set up and calibrated water quality model of urban runoff influences on Meramec River and tributaries for EPA 208 study for Eastwest Gateway Commission.

1978: Del Norte County, California. Drainage study and hydrologic design manual.

1978: Water Resources Atlas, U.S. Forest Service Region 10, Juneau, Alaska. Precipitation maps and hydrologic design manual for Southeast and south Alaska.

1979: Cascade Enterprise Drainage Manual, Redding, California. Stormwater system designs for two developing areas of Redding.

1979: Hydrology Manual, Six Rivers National Forest, Eureka, California. Streamflow regression equations for hydrologic design in northwest coastal California.

1979: Grubers Bay, Lake Wisconsin, Wisconsin. Set up and calibration of water quality model for determining influence of wastewater for Wisconsin Department of Environmental Quality.

1980: Grey Eagle Mine EIR, Happy Camp, California. Hydrologic tailings pond water balance and water quality study for gold mine.

1980: Seward Marina, Fourth of July Creek, Alaska. Hydrologic design criteria for levee and salmon spawning ponds.

1980: Manzanita Creek, Big Bar, California. Flow measurements and hydrologic analysis for U.S.

Forest Service, Shasta-Trinity National Forest prescribed burn study.

1981: Truckee River Water Supply Needs, California-Nevada. Historical and projected water supply study for Reno and Pyramid Lake for USBR.

1981: Fifteen Dam Safety Studies for Utah and Nevada. Site visits and probable maximum flood spillway adequacy studies for U.S. Army Corps of Engineers.

1981: Bradley Lake, Homer, Alaska. Field reconnaissance and water quality assessment of hydropower project operations for U.S. Army Corps of Engineers.

1981: Carson River, Carson City, Nevada. Water quality model of nonpoint pollution to Carson River for Nevada Department of Environmental Conservation.

1982: Sacramento River, Tehama County, California. Historical hydrologic simulation of the influence of Shasta Dam on Sacramento River floods.

1982: Salt Creek, Red Bluff, California. Description and analysis of flooding of an office complex for litigation.

1982: Whiskeytown Reservoir, Redding, California. Water quality measurements and assessment of hydropower operations.

1982: Iron Mountain Mine, Shasta, California. Water quality measurements and hydrologic isolation plans for mine tailings.

1983: Grey Eagle Mine, Yreka, California. 100-year flood hydrologic study for Luther Gulch and Indian Creek.

1984: Red Dog Mine EIR, De Long Mountains, Alaska. Hydrologic water balances for proposed water supply and tailings ponds for lead-zinc-silver mine in Brooks Range.

1984: Hydropower Assessment Program, Portland, Oregon. Hydrologic methodology for determining potential yields of hydropower in Montana, Idaho, Washington and Oregon for Northwest Power Planning Council.

1985: Lemhi River, Salmon, Idaho. Hydrologic description of Lemhi River basin for salmon fishery enhancement for BPA.

1986: Greens Creek Mine, Admiralty Island, Alaska. Hydrologic studies for water supply, hydropower and flood protection on Greens Creek.

1986: Crabtree Creek, Lebanon, Oregon. Hydrology for power projections for Lacombe hydropower facility.

1986: Clover Creek, Redding, California. Hydrologic study on influence of urbanization on 100-year flood.

1986: Foothill Freeway Corridor, Orange County, California. Determination of 100-year floods for proposed freeway crossings near El Toro.

1987: Deadwood Canyon and Big Mosquito Creeks, California. Flow meter installation, flow measurement and hydrologic analysis for hydropower projects near Sacramento.

1987: Withlacoochee River, Georgia. Set up and calibrated water quality model for assessing influence of paper mill wastewater for Georgia Environmental Protection Agency.

1987: James River, Virginia. Set up and calibrated water quality model for assessing impact of wastewater discharge for Owens-Illinois Company.

1988: Big Creek, Hyampom, California. Hydrologic analysis for hydropower project in northwest California.

1988: Garden Bar Pumped Storage, Marysville, California. Study of influence of alternative operations on water temperatures using USCOE Thermal Simulation of Lakes Model and EPA Qual2E for Garden Bar/Camp Far West Reservoirs and Bear River.

1988: Muck Valley EIR, Nubieber, California. Set up and calibrated water quality model for assessing influence of Collett Lake hydropower operations on Pit River.

1989: Irvine Lake/Santiago Reservoir, Orange, California. Set up, calibrated and analyzed water quality of lake for development alternatives using USCOE CEQUAL-R1.

1989: Montgomery Creek, California. Two-year flow measurement and hydrologic analysis for El Dorado hydropower.

1989: Bluford Creek, Zenia, California. Hydrologic studies for expansion of hydropower facility.

1989: Box Canyon Dam Break Inundation, Dunsmuir, California. Used NWS dynamic wave model to determine dam break flooding on upper Sacramento River.

1990: Battle Creek Hydrology Study, Manton, California. For California Department of Fish and Game, compiled long-term monthly flow statistics on Battle Creek to assess influence of diversions on low flow periods.

1990: American River Water Quality Study, Sacramento, California for Sacramento County. Set up, calibrated and tested alternative Folsom Lake release influence on water temperature using EPA Qual2E and USCOE CEQUAL-R1.

1990: Dry Creek Master Drainage Plan, Placer County, California. HEC-1 and HEC-2 modeling of 80 square mile urbanizing watershed.

1991: Auburn/Bowman Community Plan Hydrology Study, California. HEC-1 and HEC-2 modeling of peak flows and water levels resulting from future development.

1991: Morrison Creek Hydrology Study, California, HEC-1 and HEC-2 modeling of Morrison Creek and tributaries in Sacramento County.

1991: Folsom Reoperation Study of American and Sacramento Rivers for USCOE. EPA QUAL2E and USCOE CETHERM-R1 for analyzing influence of Folsom Lake operation alternatives on water temperatures.

1992: City of Redding Stormwater Master Plan, California. HEC-1 and HEC-2 modeling of 100 square miles of tributaries to Sacramento River.

1993: City of Lincoln Stormwater Facilities Plan, California. HEC-1 and HEC-2 modeling of Auburn Ravine, Orchard Creek and Ingram Slough proposed development.

1994: City of Hanford Stormwater Master Plan, California. HEC-1 modeling and system design for existing and proposed stormwater management facilities.

1994: Clover Creek Stormwater Management Plan, Redding, California. Siting of retention/detention basins for control of flooding due to future developments.

1994: Grasshopper Creek, Red Bluff, California. Hydrology and hydraulics 100-year flood study for submittal of application of Letter of Map Amendment for FEMA.

1994: Lemhi River, Salmon, Idaho. Analysis of river flow and irrigation records for 1992-1994 to determine consumptive use and return flow.

1994: Lake Creek, Medford, Oregon. Determination of impacts on hydrology and water quality from proposed hydropower diversions.

1995: Sacramento, County, California. Meteorologic, Hydrologic and Hydraulic analysis of January 10, 1995 flood event in Sacramento County, Roseville, and Placer County.

1995: Redding, California. Design guidelines for control of flood increases due to land development using detention/retention ponds.
Revision of 100-year floodplains for 40 miles of stream using 1994 land use hydrology.

1995: Sacramento County, California. Revision of peak flow frequency curves and depth-duration-precipitation frequency curves for all gage records in Sacramento County. HEC-1 and HEC-2 analyses of January 9-10, 1995 flood event.

1995: Iron Mountain Mine, Redding, California. Peer review of water quality control alternatives for Boulder Creek. Hydrologic analysis of long-term flows using HSPF model.

1997: EIP Associates and Calaveras Cement Corporation, Shasta County, California. Set up HSPF model of Stillwater Creek to provide 1948-1998 flow duration curves for locations used for water quality measurements.

2000: Duncan and Long Canyon, Greek Store, California. For Placer County Water Agency,. Set up PRMS to determine the influence of logging on snowmelt for paired watersheds tributary to the North Fork American River.

2000: Auburn Ravine and Coon Creek, Auburn, California. For Placer County Planning Department. Set up HSPF to determine long-term flow statistics.

2001: EIP Associates and San Bernardino Water District. Derived long-term statistics of daily and peak flow for Mill Creek near Redlands. California.

2001: City of Morgan Hill and Carollo Engineers. Stormwater master plan using HEC-1 and SWMM for City of Morgan Hill.

2002: City of Gilroy and Carollo Engineers. Stormwater master plan using HEC-1 and SWMM for City of Gilroy and vicinity.

2002: Tuolumne Utility District and EIP. Water balance and leak analysis of TUD ditch system near Sonora using HEC-1 and spreadsheets.

2003: EPA and Placer County Water Agency. Long-term simulations of representative Sierra Nevada watersheds using HSPF including climatic change scenarios.

2003: Fidelity Coal Company. Long-term simulations of Tongue River and Tongue River Reservoir flow and water quality using HSPF and CEQUAL, near Miles City, Montana.

2005: Shasta County. FEMA LOMR for Burney Creek. Used HECRAS to set new 100-year flood plains and floodways.

2005: City of Redding. City-wide Master Storm Water Drainage Study. 32 HEC-1 and HECRAS models for all streams in the 100 square mile drainage area within the city limits.

2006: Thomason Development. HSPF 15-minute, 1949-2006 watershed modelling of Dry Gulch. Included alternative detention ponds and influence of urban development on flood peaks.

2006: Montgomery Watson Harza. Developed daily flow files for inflow and downstream local for Shasta Dam, Sacramento River for 1907-2007. Developed program for evaluating the influence of revised operating rules on downstream flood peaks.

2007: City of Anderson. Submitted revised floodplain mapping to FEMA for Anderson Creek, Sacramento Gulch and Tormey Drain.

2007: Ventura County Watershed Protection District. Comprehensive evaluation of stream gage sites in Ventura County. Produced a new design storm and HEC-1 processor.

2009. City of Yreka, California. Analysis of new floodplains for greenway enhancement projects on Yreka and Greenhorn Creeks.

2009. City of Livingston, Montana. FEMA floodplain mapping submittal for a re-study of the Yellowstone River.

Litigation Investigations

1980: City of Seward vs. Century, for plaintiff. Flood flow assessment for Fourth of July Creek, Seward, Alaska. Arbitration testimony. Case settled.

1982: Rogers vs. Jones, for defendant. Flood study for industrial property on Salt Creek in Red Bluff, California. Deposition testimony. Case settled.

1982: Keho vs. Lewis, for plaintiff. Surface water and ground water drainage for residential development in Yreka, California. Case settled.

1982: Plaintiffs vs. Holiday Harbor, for defendant. Meteorological study of wind at Shasta Lake, California. Trial testimony.

1983: Calkari Arms vs. Caltrans, for plaintiff. Storm rainfall and runoff for 1977 cloudburst at Redding, California. Deposition testimony. Case settled.

1983: Phillips vs. Adams, for defendant. Flood and stream bank erosion study for Clear Creek at French Gulch, California. Trial testimony. Defendant won.

1983: Yuba Irrigation District vs. Shell Oil, for defendant. Hydraulic analysis of Cache Creek levee failure near Williams, California. Case settled.

1984: Jones vs. Scott, for defendant. Analysis of natural and manmade drainage systems near Trinity Center, California. Trial testimony. Defendant won.

1984: Tompkins vs. Mallett, for plaintiff. Hydrology study for hydropower facility near Trinity Lake, California. Deposition testimony. Case settled.

1984: California-American vs. U.S. Dept. of Agriculture, for defendant. Sedimentation study for San Clemente Reservoir near Monterey, California. Case settled.

1985: Redway Residents vs. Pacific Lumber, for defendant. Rainfall, runoff, and erosion study for landslide on S. F. Eel River near Redway, California. Deposition testimony. Case settled.

1985: California Fish & Game and FERC vs. Seithe Energies, for defendant. Hydrologic study for hydropower facility on Rock Creek near Placerville, California. Hearing testimony. Case settled.

1986: California Water Rights Board vs. Mega-Renewables, for defendant. Hydrologic study for North Fork Hydro project near Fresno, California. Hearing testimony. Case settled.

1986: California Fish & Game vs. Montgomery Creek Hydro, for defendant. Hydrologic study for Montgomery Creek Hydropower facility near Redding, California. Hearing testimony. Case settled.

1987: Environmental Defense Fund and Sacramento County vs. EBMUD, for plaintiffs. Flow and temperature analysis for American River at Sacramento, California. Trial testimony in Hayward January 1990. Plaintiff won.

1987: Maloughney et al vs. Orange County, for defendants. Analysis of flood event on March 1, 1983 in Fountain Valley, California. Deposition and trial testimony. Defendant won.

1987: Linda Residents vs. California et al, for plaintiffs. Analysis of flooding from levee break on February 19, 1986 at Marysville, California. Case settled.

1988: Alexander et al vs. Orange County et al, for defendants. Analysis of flood event on March 1, 1983 in Huntington Beach, California. Trial testimony in Santa Ana, March 1990. Defendant won.

1988: Achenbaugh et al vs. City of Roseville et al, for defendants. Analysis of flooding resulting for February 19, 1986 cloudburst near Roseville, California. Trial testimony in Auburn March-July, 1992. Defendant won.

1989: Zisk vs. City of Roseville, for defendant. Analysis of flood water levels and erosion potential resulting from floodplain encroachment on Dry Creek in Roseville, California. Case dropped.

1990: Tylstra et al vs. Trinity County, for plaintiffs. Determination of causes of bank erosion induced by airport levee on South Fork Trinity River near Hyampom. Deposition. Case settled.

1990: State of Idaho vs. Truck Transport et al, for defendants. Water quality analysis of Little Salmon River resulting from toxic dye spill. Trial testimony in Boise, Idaho, May 1991. Defendants won.

1990: Winzler vs. Humboldt County, for plaintiff.

Determination of causes of bank erosion induced by USCOE experimental spur dikes and levees on the Eel River near Eureka. Trial testimony in Eureka November 1991. Plaintiff won.

1990: Evergreen Estates vs. Sacramento County, for defendant. Analysis of flood runoff and water

levels on Arcade Creek, Sacramento for February 19, 1986 event. Deposition testimony. Case settled.

1991: Oregon Worsted Co. vs. State of Oregon, et al., for plaintiff. Analysis of effects of proposed bridge on Johnson Creek on fish habitat. Case settled.

1991: Waldport Homeowners vs. State of Oregon Department of Transportation, for plaintiffs. Analysis of effects of bridge demolition on tidal currents in Alsea Bay. Case dropped.

1992: Pleasanton Gravel vs. City of Livermore, for defendant. Analysis of influence of urbanization and city storm drains on flooding downstream. Case settled.

1993: California Department of Fish & Game, et al. vs. City of Big Bear, for defendant. (Downey Brand Seymour Rowher: Kevin O'Brien, Sacramento). Analysis of flushing flow requirements for sand removal and enhancement of fish habitat in Bear Creek downstream of Big Bear Lake. Hearing testimony. Case settled.

1993: Putah Creek Conference, et al. vs. Solano County Water Agency, for defendant. Comprehensive analysis of runoff, storage, evapotranspiration losses, groundwater gains and losses, diversion losses, and irrigation return flows for the 1930-1993 period on Putah Creek and Lake Berryessa. Case settled.

1994: Ludwig vs. Anderson, et al, Yuba City, California, for plaintiff. Hydrologic and hydraulic analyses to determine creek restoration required after topsoil removal. Trial testimony in Yuba City. Plaintiff won.

1994: Plaintiffs vs. Riverside County Flood Control District and Metropolitan Water District of Southern California, for defendant. HEC-1, HEC-2, HEC-6 analyses of influence of channel vegetation on upstream flooding for Murietta Creek at Temecula, California, January 19, 1993. Deposition testimony. Case settled.

1995: Lake Redding Estates Homeowners vs. City of Redding, California, for defendant. Description of standard of care for culvert design. Comprehensive hydrologic and hydraulic analysis of March 23, 1993 flood event on Carter Creek. Trial testimony in Redding. Retrial of similar issues in January 1998. Plaintiffs won. Currently on appeal.

1995: ASARCO Ray Mine, Arizona vs. Arkwright Insurance Company, for plaintiff. Investigation of the probability of mine pit water balances for 1992-1993 wet period for insurance claim. Deposition testimony. Case settled.

1995: Cinnamon, et al. vs. Sacramento County, for defendant. Analysis of flood drainage problems in residential area in Carmichael California. Deposition taken. Case dropped.

1996: Ed Parish, Quail Valley Ranch vs. NRCS, for plaintiff. Analysis of Pit River flooding of alfalfa fields due to new levee project in Lookout California. Deposition pending. Testimony at

arbitration proceeding June 21, 1998, Sacramento. Case settled.

1996: Daniel Darnall vs. Lassen County, for plaintiff. Investigation of causes of property flooding due to inadequate drainage systems in Susanville California. Deposition taken. Case settled.

1996: Kuo vs. California Board of Reclamation, et al, for defendant. Analysis of influence of gravel extraction on Cottonwood Creek bend migration, Orland, California. Deposition taken, trial in Orland, California in February 1998. Defendant won.

1996: Trailer park homeowners vs. Napa County and City of St Helena. For defendants. Analysis of 1986, 1995 and 1996 flood events for the Napa River near St. Helena. Case settled.

1996: Plaintiffs vs. City of Napa, California, for defendant. Analysis of January 9, 1995 flood event at a residential development. Case settled in March 1998.

1997: Cabrera and Provine vs. City of Redding, California, for defendant. Analysis of stormwater drainage system at Harpole Road and Churn Creek Road, Redding, California. Case settled.

1997: Winifred Jones vs. Pacific Gas and Electric Company, for plaintiff. Analysis of influence of pipe crossing sheet piles on bank erosion, Corning, California. Testimony at arbitration hearing in Sacramento. Case settled.

1997: Covert Run Pike Homeowners vs. Sanitation District and City of Bellevue, Kentucky. For defendants. Hydraulic analyses of urban flash floods and potential mitigation. Ongoing as of 2005.

1997: Finley et al vs. City of Redding and Shasta County. For defendants. Meteorologic, hydrologic and stream hydraulic analyses of flood causes and potential mitigation for Clover Creek. Case Settled.

1997: Mahaffy vs. City of Redding and Gold Hills Golf Course. For defendants. Hydrologic analyses of stormwater collection system design. Case settled.

1997: Yountville trailer park homeowners vs. Napa County and Town of Yountville. California. For defendants. Investigation of causes of flooding in 1995 and 1997 floods due to Hopper Creek and the Napa River. Case settled.

1997: York vs. Jaxon Enterprises, Corning California. For defendant. Investigation of causes of riverbank erosion in Stony Creek due to gravel extraction operation. Trial testimony in Corning. Defendant won.

1998: Property owners vs. Gravel Extraction Company and Grays Harbor County, Washington. For defendants. Investigation of historic and predicted migration of Humptulips River channel in vicinity of proposed gravel extraction project. Case Settled.

1998: Farm Corporations vs. State of California. For defendant. Analyses of precipitation and

flooding of Arroyo Pasajero Creek in March 1995 near Coalinga, California. Case settled.

1998: Story vs. Charles Krug Winery, St Helena California. For defendant. Analyses of flooding on Napa River due to cross levees in March 1995 flood. Trial testimony in Napa Superior Court. Defendant won.

1998: Property Owners vs. Modesto Irrigation District, Modesto California. For defendant. Analyses of flooding on Tuolumne River, Dry Creek, San Joaquin River due to releases from Don Pedro Reservoir in January 1997. Deposition taken. Case dropped.

1999: Kernan vs. Marion, Grenada, California. For defendant. Analyses of flooding on Julian Creek and Housman Ditch in January 1999. Arbitration hearing testimony. Case settled.

1999: Youngman vs. State of California, Meeks Bay California. For defendant. Hydrologic analysis of State Highway 89 culvert near Lake Tahoe January 1997. Trial testimony in El Dorado Superior Court in South Lake Tahoe, July 2001. Found for plaintiff.

1999: Aadland et al vs. State of California, et al., Lodi California. For defendant. Investigation of flooding due to State Highway 99 drainage system in February 1998 at Eden Mobile Home Park. Case Settled.

1999: Barnum vs. City of Eureka, California. For plaintiff. Investigation of flooding due to Fairway Drive culvert since its construction in 1960. Deposition and trial testimony in Humboldt County Superior Court. Found for Plaintiff.

2000: State of California Department of Fish & Game vs. Scott Murrison. For defendant. Investigation of water diversion structure on Big Creek near Hayfork. Case Settled.

2000: Wisher's Salvage, et. al., vs. Burlington Northern & Santa Fe Railroad. For defendant. Analysis of causes of flooding on Ashley Creek near Kalispell, Montana in May 1997. Case Settled.

2001: Woolf vs. State of California. For defendant. Investigation of wet weather accident on I-10 near Ontario, California. Case Settled..

2001: Oakdale Mobile Home Park vs. State of California. For defendant. Investigation of flooding for a mobile home park near Oakdale. Case settled.

2001: Seymour vs State of California. For defendant. Investigation of flooding due to runoff from Shasta County property and State Highway 299 in Shasta City. Case settled.

2002: Dube vs. Forty Grand. For defendant. Investigation of the causes of flooding for a July 1998 storm in Fort Thomas, Kentucky. Deposition Report. Case Dropped.

2002: Corning residents vs. City of Corning. For plaintiff. Investigation of flooding due to urban runoff in Corning. Ongoing in 2005.

2004: EPI Healthcare vs. Philpot Construction. For defendant. Investigation of cloudburst flooding in Richmond, Kentucky from construction activities. Case Settled

2009: Park Marina Village Homeowner's Association vs. Golden State Bridge, Inc. et al. For plaintiff. Investigation of erosion due to Sacramento River Highway 44 bridge construction. Ongoing.

PUBLICATIONS

"Determination of TMDL's for Big Bear Lake, California" Presented at the California Water Agency Conference in San Diego, California, December 5, 2003.

"Determination of Design Storms for Wastewater System Design in Houston, Texas" Presented at the AWWA Annual Meeting in Long Beach, California, October 1997.

"Hydrology Manual Verification Using the March 23, 1993 Storm at Redding, California", Proceedings of the June 25, 1994 Symposium on Predicting Heavy Rainfall Events in California, Sierra College, Rocklin, California.

"Analysis of Flooding Caused by the February 18, 1986 Cloudburst in Placer County, California", Proceedings of the June 25, 1994 Symposium on Predicting Heavy Rainfall Events in California, Sierra College, Rocklin, California.

"Design Cloudbursts and Flashflood Methodology for the Western Mojave Desert, California", Proceedings of the 1990 National Conference on Hydraulic Engineering and the International Symposium on the Hydraulics/Hydrology of Arid Lands, ASCE, New York, NY,

"Hydraulic Characteristics of Steep Mountain Streams During Low and High Flow Conditions and Implications for Fishery Habitat", Proceedings Symposium on Small Hydropower, American Fisheries Society, Denver, Colorado, May 1985.

"Modeling Design Flood Hydrographs for Glaciated Basins in Alaska", Proceedings Cold Regions Specialty Conference, Department of Civil Engineering, University of Alberta, Edmonton, Canada, April 1984.

"Influence of Temperate Glaciers on Flood Events in Maritime Alaska", Managing Water Resources for Alaska's Development, Proceedings American Water Resources Conference, Chena Hot Springs, Fairbanks, Alaska, November 1983.

"Estimating Flows in Instable Channels Using Indirect Methods", Rivers '83, Proceedings

Hydraulic Specialty Conference, American Society of Civil Engineers, New Orleans, Louisiana, October 1983.

"Determination of Flood Levels on the Pacific Northwest Coast for Federal Insurance Studies", Proceedings Hydraulics Specialty Conference, American Society of Civil Engineers, College Station, Texas, 1977.

"Numerical Simulation of Storm Surges on the Pacific Northwest Coast", Proceedings First Conference on Coastal Meteorology, American Meteorologic Society, Boston, Massachusetts, September, 1977.

"Variation of Snowpack Density and Structure with Environmental Conditions", Center for Water Resources Research, Desert Research Institute, University of Nevada, Reno, Nevada, 1974.

"Allocation of Water Resources in the Lake Washington-Cedar River Basin, Washington", presented at the Ninth American Water Resources Conference, Seattle, Washington, 1973.

"Numerical Prediction of Snowpack Temperatures in the Eastside Sierra Nevada Using a Surface Energy Balance Model", PhD. D. Dissertation, University of Nevada, Reno, 1972.

PROFESSIONAL MEMBERSHIP

American Society of Civil Engineers
American Meteorological Society
American Geophysical Society

Biographical Sketch (September 1, 2009)

William V. Sobczak

Associate Professor, Biology Department (2008- present)
College of the Holy Cross

Assistant Professor, Biology Department (2002 – 2008)
College of the Holy Cross

Visiting Scientist, Harvard Forest (2004 – present)
Harvard University

RESEARCH AND TEACHING EXPERTISE

Aquatic Biogeochemistry, Aquatic Ecology, Ecosystem Ecology, and Limnology

PROFESSIONAL PREPARATION

Bucknell University	Biology / English	B.A. 1990
Michigan State University	Zoology / Kellogg Biological Station	M.S. 1993
Cornell University	Ecology and Evolutionary Biology / Institute of Ecosystem Studies	Ph.D. 1999
U.S. Geological Survey	Postdoctoral Associate, Menlo Park, CA	1999-2002

HONORS AND FELLOWSHIPS

Environmental Protection Agency's Science to Achieve Results (STAR) Doctoral Fellowship (1995 – 1998)

Recipient of the American Society of Limnology and Oceanography's 2004 Raymond Lindeman Award given annually "in recognition of an outstanding paper in the aquatic sciences by a young scientist under the age of 35"

Harvard University Bullard Fellow in residence at Harvard Forest in Petersham MA (June 2008 – June 2009)

Inducted as honorary member of Alpha Sigma Nu, the Jesuit Honor Society (2008)

SELECTED REFEREED PUBLICATIONS

Willacker*, J. J., W. V. Sobczak, and E. A. Colburn. 2009. Stream macroinvertebrate communities in coupled hemlock and deciduous watersheds. *Northeastern Naturalist*: 16:101-112.

Rowell*, T. J. and W. V. Sobczak. 2008. Will stream periphyton respond to increases in light following forecasted regional hemlock mortality? *Journal of Freshwater Ecology* 23: 33-40.

- Collins*, B. M., W. V. Sobczak, and E. A. Colburn. 2007. Subsurface flowpaths in a forested headwater stream harbor a diverse macroinvertebrate community. *Wetlands* 27: 319-325.
- Rainey*, J. D., W. V. Sobczak, and S. C. Fradkin. 2007. Zooplankton diel vertical distributions in Lake Crescent, a deep oligotrophic lake in Washington (USA). *Journal of Freshwater Ecology* 22: 469-476.
- Sobczak, W. V. 2005. Lindeman's trophic-dynamic aspect of ecology: Will you still need me when I'm 64? *Bulletin of the American Society of Limnology and Oceanography* 14: 53-57.
- Sobczak, W. V., J. E. Cloern, A. D. Jassby, B. E. Cole, T. Schraga, A. Arnsberg. 2005. Detritus fuels ecosystem metabolism but not metazoan foodweb in the San Francisco Estuary freshwater Delta. *Estuaries* 28: 124-137.
- Aaron M. Ellison, Michael S. Bank, Barton D. Clinton, Elizabeth A. Colburn, Katherine Elliott, Chelcy R. Ford, David R. Foster, Brian D. Kloeppel, Jennifer D. Knoepp, Gary M. Lovett, Jacqueline Mohan, David A. Orwig, Nicholas L. Rodenhouse, William V. Sobczak, Kristina A. Stinson, Pam Snow, Jeffrey K. Stone, Christopher M. Swan, Jill Thompson, Betsy Von Holle, and Jackson R. Webster. 2005. Loss of foundation species: consequences for the structure and dynamics of forested ecosystems. *Frontiers in Ecology and the Environment* 3: 479-486.
- Findlay, S., R. L. Sinsabaugh, W. V. Sobczak, and M. Hoostal. 2003. Metabolic and structural response of hyporheic microbial communities to variations in supply of dissolved organic matter. *Limnology and Oceanography* 48: 1608-1617.
- Sobczak, W. V., J. E. Cloern, A. D. Jassby, and A. Mueller-Solger. 2002. Bioavailability of organic matter in a highly disturbed estuary: The role of detrital and algal resources. *Proceedings of the National Academy of Sciences* 99: 8101-5.
- Sobczak, W. V. and S. Findlay. 2002. Variation in bioavailability of dissolved organic carbon among stream hyporheic flowpaths. *Ecology* 83: 3194-3209.
- Sobczak, W. V., S. Findlay, and S. Dye. 2002. Relationships between DOC bioavailability and nitrate removal in an upland stream: An experimental approach. *Biogeochemistry* 62: 309-327.
- Lovett, G. L., K. W. Weathers, and W. V. Sobczak. 2000. Nitrogen saturation and retention in forested watersheds of the Catskill Mountains, NY. *Ecological Applications* 10:73-84.
- Findlay, S. and W. V. Sobczak. 2000. Microbial communities in hyporheic sediments. IN: *Streams and Ground Waters*. Jones, J. & P. Mulholland (Eds.). Academic Press.

Burton, T. M., D. G. Uzarski, R. S. Stelzer, S. L. Eggert, W. V. Sobczak, and D. M. Mullen. 2000. The impact of extremely low frequency electromagnetic fields on stream periphyton: an eleven year study. *Hydrobiologia* 439: 61-76.

Sobczak, W. V., L. O. Hedin, and M. J. Klug. 1998. Relationships between bacterial productivity and organic carbon at a soil-stream interface. *Hydrobiologia* 386: 45-53.

Findlay, S., R. O. Hall, and W. V. Sobczak. 1998. Book review: *Methods in stream ecology*. *Limnology and Oceanography* 43: 1020-1021.

Findlay, S. and W. V. Sobczak. 1996. Variability in removal of dissolved organic carbon in hyporheic sediments. *Journal of the North American Benthological Society* 15: 143-154.

Sobczak, W. V. 1996. Epilithic bacterial responses to variations in algal biomass and labile DOC during biofilm colonization. *Journal of the North American Benthological Society* 15: 143-154.

Sobczak, W. V. and T. M. Burton. 1996. Epilithic bacterial and algal colonization among a stream run, riffle, and pool: a test of co-variation. *Hydrobiologia* 332: 159-166.

CONFERENCE PAPERS AND PUBLISHED ABSTRACTS (2003 – 2008)

Sobczak, W. V. 2003. Estuarine Research Federation's bi-annual meeting in Seattle, WA. Title: Role of algal and detrital inputs in estuaries: A cross-system comparison.

Sobczak, W. V. and S. Sabater. 2005. Invited tutorial speaker at the international meeting of the American Society of Limnology and Oceanography in Santiago, Spain. The paper was presented by the second author. Title: Ecological importance of autotrophic and heterotrophic relationships in streams and rivers with varying watershed attributes.

Sobczak, W. V. 2005. Plenary address at annual meeting of the American Society of Limnology and Oceanography in Salt Lake City, UT. Title: Lindeman's trophic aspect of ecology: Will you still need me when I'm 64?

Collins*, B. M. and W. V. Sobczak. 2005. Annual meeting of the American Society of Limnology and Oceanography in Salt Lake City, UT. Title: Subsurface flowpaths drive spatial variation in the macroinvertebrate community of an intermittent headwater stream in central New England.

E. A. Colburn, W. V. Sobczak, J. Milam, and B. Collins*. 2006. Annual meeting of the North American Benthological Society in Anchorage, AK. Title: Characterization of headwater stream habitat and biota prior to the invasion of an exotic forest pest.

Sobczak, W. V., B. M. Collins*, J. D. Etter*, C. E. Levenick*, and M. R. Schwarb*. 2006. Annual meeting of the American Society of Limnology and Oceanography in Victoria, Canada. Title: Role of forest pathogens in altering carbon dynamics in stream ecosystems: Will loss of New England's eastern hemlock change regional organic carbon retention?

Sobczak, W. V., P. Raymond, E. Boose, and S. Singh. 2007. Annual meeting of the American Society of Limnology and Oceanography in Santa Fe, NM. Title: Allochthonous organic matter export from a hemlock dominated watershed threatened by an invasive forest herbivore.

Sobczak, W. V. 2007. Bi-annual meeting of the Estuarine Research Federation in Providence, RI. Title: Urban stream syndrome and the impairment of downstream estuarine ecosystems: Blackstone River and Narragansett Bay.

Sobczak, W. V. 2008. Bi-annual meeting of the River Management Society. Portland, ME. Title: Urban stream syndrome and the impairment of downstream estuarine ecosystems: Blackstone River and Narragansett Bay.

Holmes, R. M., W. V. Sobczak and 10 co-authors. 2008. American Geophysical Union meeting in San Francisco, CA. Title: The Polaris Project: Rising stars in the arctic.

INVITED SEMINARS (2003 – 2008)

2003 American Fisheries Society, Santa Cruz, CA
2003 Marine Biological Laboratory, Woods Hole, MA
2003 University of Massachusetts, Amherst
2003 Harvard Forest, Petersham, MA
2004 Cornell University, Ithaca, NY
2006 Blackstone River Valley National Heritage Corridor
2006 Harvard Forest Annual Research Symposium
2006 University of Massachusetts, Dartmouth
2006 Institute of Ecosystem Studies, Millbrook, NY
2007 Harvard Forest Annual Research Symposium
2007 Virginia Commonwealth University
2008 University of New Hampshire
2008 Harvard Forest, Petersham, MA
2009 Cary Institute of Ecosystem Studies, Millbrook, NY

GRANTS AND FUNDING OPPORTUNITIES (2003 -2008)

Holy Cross College's Research and Publication Committee (2003)

American Association of Colleges and University's SENCER program funded travel expenses to their annual conference. SENCER = Science Education for New Civic Engagements and Responsibilities (2005)

3M Foundation Visions Grant administered by Holy Cross to support Freshwater Ecology student research on the Blackstone River and Wachusett Reservoir (2005-2007)

Research mentor included in Harvard University's Summer REU Program in Ecology that is funded by NSF: "Harvard Forest REU Program in Forest Ecology 2005 – 2009: Multi-scale investigations of a forested ecosystem in a changing world"

NSF Research Opportunity Award I as part of Harvard Forest's Long-term Ecological Research Program (2006)

NSF Research Opportunity Award II as part of Harvard Forest's Long-term Ecological Research Program (2007)

Gordon Research Conference on Coupled Biogeochemical Cycles travel grant (2007)

NSF Polar Programs: "The Polaris Project: Rising Stars in the Arctic" (2008-2010) co-PI
Lead PI is Dr. R. Max Holmes at Woods Hole Research Center

3M Foundation Grant: "Monitoring Worcester's Blackstone River in Advance of a Major Restoration Project"

NSF Research Opportunity Award II as part of Harvard Forest's Long-term Ecological Research Program (2008)

UNDERGRADUATE INSTRUCTION

Routinely instruct courses in: 1) Freshwater Ecology with integrated field-based laboratory in which students conduct research projects that address regional ecology issues, 2) Ecosystem Ecology, a novel capstone-seminar organized around the discussion of topical primary literature that addresses human-accelerated environmental change, and 3) Environmental Biology, a foundation course in the college Environmental Studies Program

Instructor in the college's honors seminar on Human Nature and the Environment (2006)

Research mentor for 8 undergraduates as part of the Harvard Forest NSF-funded Summer REU Program (2004-2007) and 13 undergraduates within Holy Cross' Biology Department and Environmental Studies Program (2003-2007)

Devised community-based learning project that fuses independent student projects with community efforts to monitor and restore the headwaters of the Blackstone River National Heritage Corridor (2004-2007)

PROFESSIONAL INVOLVEMENT

Maintain active memberships in the American Society for Limnology and Oceanography, Ecological Society of America, Estuarine Research Federation, and North American Benthological Society

Member of the Pescadero Conservation Alliance's Board of Directors (San Mateo County, CA). The Pescadero Conservation Alliance is a non-profit organization that works to promote research, education, and civic engagement focused on the Gazos Creek watershed on the western slope of the Santa Cruz Mountains which provides critical habitat for several endangered bird, amphibian, and fish populations. (2001 – 2003)

Referee for scientific journals and funding agencies including Archiv fuer Hydrobiologie, Biogeochemistry, Biogeosciences, CALFED Bay-Delta Authority, Freshwater Biology, Ecology, Ecological Monographs, Ecosystems, Estuaries, Hydrobiologia, Journal of the North American Benthological Society, Limnology and Oceanography, Marine and Freshwater Research, Microbial Ecology, National Science Foundation, Maryland Sea Grant, Science of the Total Environment, Water-Air-Soil Pollution

Member of the Blackstone River Coalition's Board of Directors. The Blackstone River Coalition is a non-profit organization that works to promote research, education, and civic engagement focused on the Blackstone River's water quality and restoration.

COLLABORATORS / AFFILIATIONS

Ph.D. Advisors:

Stuart Findlay	Institute of Ecosystem Studies	findlayS@ecostudies.org
Robert W. Howarth	Cornell University	rwh2@cornell.edu
Gene E. Likens	Institute of Ecosystem Studies	likensG@ecostudies.org

Post-doc Advisor:

James E. Cloern	U.S. Geological Survey	jecloern@usgs.gov
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Collaborators (last five years):

Emery Boose	Harvard University
David Butman	Yale University
Elizabeth Canuel	Virginia Institute of Marine Science
Betsy Colburn	Harvard University
Aaron Ellison	Harvard University
Helmut Ernstberger	Yale University
David Foster	Harvard University
Steven Fradkin	Olympic National Park
Karen Frey	Clark University
Julian Hadley	Harvard University
Robert M. Holmes	Woods Hole Research Center
Alan Jassby	U.C. Davis
Karin Limburg	SUNY ESF
Lisa Lucas	U.S. Geological Survey
Leigh McCallister	Virginia Commonwealth University
Anke Mueller-Solger	U.C. Davis
David Orwig	Harvard University
Peter Raymond	Yale University
Sergi Sabater	University of Girona (Spain)
Robert Sinsabaugh	University of New Mexico

Pamela Templer

Boston University

CURRICULUM VITAE

David Gregory Hankin
756 9th Avenue
Trinidad, CA 95570
(707) 677-0633

May 2009

Present Position:

Professor, Department of Fisheries, College of Natural Resources and Sciences, Humboldt State University, Arcata, California 95521

Education:

B.A., Biology, Reed College, Portland, Oregon. 1971.
Ph.D., Fishery Science (Minors in Biometrics, Public Policy), Cornell University, Ithaca, New York. 1978.

Experience:

- 2008-present Acting Associate Dean for Marine Sciences, Humboldt State University
- 2004-2005 Director of Marine Facilities (Telonicher Marine Lab, R/V Coral Sea), Humboldt State University
- 1994-1998, 2001-2006, 2007-2009 Chairman, Department of Fisheries Biology, Humboldt State University.
- 1994 Visiting Scientist, National Institute of Water and Atmospheric Research, Christchurch, New Zealand (sabbatic leave).
- 1985-1987 Visiting Associate Professor, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon (25%: 85-86); Co-leader, Oregon Department of Fisheries and Wildlife's Chinook Salmon Planning Team (75%: 85-86; 100%: 86-87).
- 1984-1985 Visiting Sea Grant Professor, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon. (non-teaching sabbatic leave for academic year)
- 1976-present Assistant/Associate/Full Professor, Department of Fisheries, Humboldt State University. Full-time position in Fisheries program with primary responsibilities in areas of population dynamics, fishery management, and sampling theory. Direction of graduate student (MS) research.

1980-1983 Director of Graduate Studies, College of Natural Resources, Humboldt State University (half-time release for a three year term). Coordination and administration of graduate program, and review and approval of all theses submitted for the M.S. degree in Natural Resources.

Professional Organizations, Technical Committees, Advisory Bodies:

Member, American Fisheries Society; Fellow, American Institute of Fishery Research Biologists; At-Large Appointed Member, Scientific and Statistical Committee, Pacific Fishery Management Council (1987-1992; Vice-Chair 1988-1990); member, Klamath River Technical Advisory Team (1987-1989); member, California Sea Grant Committee (1989-1999); Board member, Westhaven Community Services District (1988-1995; 2007-present); member, Mainstem and Systemwide Peer Review Group, Bonneville Power Authority (1999); Chair, Northern pikeminnow review panel, NWPPC (1999); Member, Technical Recovery Team, Central California Coast (salmonid listings) (2001-present); US Member, Committee for Scientific Cooperation, Pacific Salmon Commission (2001-present); member, Battle Creek Technical Review Teams, CALFED (2003-2006); member, Devils Hole Pupfish ESA Recovery Panels, 2006, 2007; Chair, Expert Panel on the Future of the Coded-Wire Tag Recovery Program, Pacific Salmon Commission, 2004-2005; Chair, Genetic Stock Identification (GSI) Steering Committee, Pacific Salmon Commission, 2007-2008; member, review team, Southern Boundary Enhancement and Restoration Fund, Pacific Salmon Commission, 2006, 2007; member, Review Panel, Causes for Collapse of Sacramento River Fall Chinook Salmon, 2008; Member, review panel, Southern California Steelhead Recovery Plan, 2009..

Grants, Contracts, Awards:

2008-2009 Development of field and statistical methods to estimate total construction of redds by anadromous salmonids in small streams. \$266,000. California Fish and Game (with Seth Ricker, CDFG).

2008-2009 Possible decline in the half-pounder life history among Trinity River fall-run steelhead. \$97,000. Hoopa Tribe (BOR), CDFG Steelhead Stamp Program.

2007-2008 HSU SPF Small Grant for development of protocols for laboratory population-level rearing of white clouds. \$4,500.

2005-2008 Assessment of feasibility of introducing a constant fractional marking program and changing the mix of fingerling and yearling releases of Chinook salmon at Iron Gate Hatchery. \$97,000. Hoopa Tribal Fisheries (BOR), USFWS.

2006-2008 Comparison of design-based and model-based survey designs for estimating the numbers of fish in small streams. \$30,000. National Marine Fisheries Service.

- 2003-2006 Microsatellite comparison of spring- and fall-run chinook salmon returning to Trinity River Hatchery. \$92,000. Hoopa Tribal Council. With Andrew Kinziger, HSU.
- 2004-2006 Hatchery Mating Practices for Chinook Salmon: Phase II. \$78,000. Yurok Tribal Fisheries.
- 2002-2003 Development of a staged implementation plan for marking of chinook salmon at Central Valley Hatcheries. \$74,000. With Ken Newman, U. Idaho. CALFED
- 2002-2005 Survey designs for estimating abundance of juvenile steelhead in the presence of cutthroat trout and hybrids. \$105,000. National Marine Fisheries Service.
- 2002-2004. Presence-Absence surveys of juvenile coho salmon. \$133,000. with Ken Pollock, North Carolina State U. California Fish and Game.
- 2002 Genetic effects of size-selective fisheries (literature review). \$12,000. Northwest Indian Fisheries Commission.
- 2001-2004 California's Dungeness Crab: Conserving the Resource and Increasing the Net Economic Value of the Fishery. (\$203,000 + 2 MS level Sea Grant Trainees at \$16,000/yr each; with S. Hackett, HSU, and C. Dewees, UCDavis). California Sea Grant.
- 2000-2001 Travel Grant to Attend Alaska Crab Symposium. (\$3,500). California Sea Grant.
- 2000-2002 Hatchery Mating Practices for Chinook Salmon. (\$76,000). Yurok Tribal Fisheries.
- 1999 Scholar of the Year, Humboldt State University. (a single faculty member is recognized annually for scholarly accomplishments)
- 1999-2001 Use of Scale Analysis to Identify Race and Release Type of Hatchery Chinook Salmon in the Trinity River system. (\$78,000). Hoopa Valley Tribal Council.
- 1998 Size-Specific Molting Probabilities of Female Dungeness Crabs Following the 1997/98 El Nino. (\$5,500). California Sea Grant
- 1998-2000 The Effects of Habitat Quality on Coho Salmon Survival Rates in Northern California Streams. (\$180,000-220,000/yr; with W. Duffy and T. Roelofs, HSU). National Marine Fisheries Service.
- 1998-2001 Ecosystem and Restoration Analysis of the Smith River Estuary, California, with Emphasis on Anadromous Salmonids. (\$195,000 + 2 MS Trainees; with T. Mulligan and T Roelofs, HSU). California Sea Grant.

- 1996-98 Improved Methods for Assessment of the Contribution of Hatcheries to Production of Chinook Salmon and Steelhead in the Klamath-Trinity River System (\$78,000; with K. Newman, Univ. of Idaho). Hoopa Valley Tribal Council.
- 1997 Validation of a Method Used to Determine Mating Success of Female Dungeness Crabs. \$9,800. California Sea Grant.
- 1996-97 Impacts of the European Green Crab (*Carcinus maenas*) on benthic fauna and fishery resources of Humboldt Bay. (\$14,000). California Sea Grant; HSU Research, Scholarship and Creative Activity Award.
- 1994-95 Survey Designs for Assessment of Abundance and Trends of Juvenile Anadromous Fishes on Private Lands in Northern California. (\$50,000; w/W.S. Overton, Oregon State Univ.). Fish, Farms and Forests.
- 1994-97 Size-Dependence of Molting in Crustaceans: Physiology and Field Tests (\$163,000 + 1 MS Trainee (\$12k/yr); w/ E.S. Chang, UC Davis). California Sea Grant.
- 1994-96 Variation in Reproductive Attributes Contributing to Fitness in New Zealand Chinook Salmon Populations (\$23,500). National Science Foundation International Program (US-New Zealand Cooperative Research).
- 1994-98 Survey Designs for Assessment of Fishery and Habitat Resources in rivers and streams on federal lands (\$60,000). U.S. Forest Service.
- 1994 Six months support for research activities as Visiting Scientist (\$40,000 NZ). National Institute of Water and Atmospheric Research (New Zealand).
- 1991-93 Interannual variation in growth and reproduction of female Dungeness crabs. (\$14,000 + 1 MS Trainee @ \$12k/yr). California Sea Grant
- 1988-92 New methods for analysis of coded wire tag recovery data (\$105,000; with M. Mohr). U.S. Fish & Wildlife Service, Klamath River Restoration Program
- 1990-91 Misspecification of Spawning Stock - Effects on Apparent Stock-Recruit Relations. (\$4,500). HSU Research Award.
- 1989-90 Temporal and Spatial Variation in the Species Composition of the Deep Water Eureka Bottom Trawl Fisheries, with Emphasis on Sablefish. (\$20,000 + 1 MS Trainee @ \$10k/yr). California Sea Grant.
- 1989-90 Assessment of Wild and Hatchery Chinook Salmon Interaction in Battle Creek, a Sacramento River Tributary. (\$20,000). California Department of Fish & Game.

- 1989 Species composition in the Eureka deep water bottom trawl fisheries. National Marine Fisheries Service (\$10,000); Fishermen's Marketing Association (\$4,000)
- 1988 Award for outstanding contributions to Fishery Science, Humboldt Chapter, American Fisheries Society.
- 1985-87 Implications of Variation in Life History Patterns for Management of Chinook Salmon Fisheries (\$50,000). Oregon Sea Grant.
- 1985-88 Assistance in Development of Oregon's Chinook Salmon Management Plan (\$110,000 total). Oregon Department of Fish and Wildlife.
- 1985, 1989 Meritorious Performance and Professional Promise Awards, Humboldt State University (\$2,500 each).
- 1985 Analysis of Release and Recovery Data for Marked Chinook Salmon Released from Klamath River, California, Hatcheries (\$15,000). Bureau of Indian Affairs, Northern California Agency.
- 1984 Data Compilation of Releases and Recoveries of Marked Chinook Salmon Released from Klamath River, California, Hatcheries (\$10,000). Bureau of Indian Affairs, Northern California Agency.
- 1984-85 Partial sabbatic leave support provided by Oregon Sea Grant (\$9,500 salary) as Visiting Sea Grant Professor.
- 1984-90 Preparation of Technical Report on Sampling Designs for Small Streams, and for Assistance with Sampling Programs (\$25,000 total). US Forest Service.
- 1983-86 Chinook Salmon Spawning Behavior (\$22,000 + 1 MS level Trainee @\$9k /yr). California Sea Grant.
- 1980-83 Vital Statistics of the Female Stock of Dungeness Crabs in Northern California. (\$45,000 + 2 MS level Trainees @ \$12k/yr/Trainee). California Sea Grant.
- 1980 Assessment of Fall Chinook Salmon Stocks in the Klamath River System.(\$15,000). Bureau of Indian Affairs, Northern California Agency:

Publications:

Peer-reviewed Publications:

Hankin, D.G., J. Fitzgibbons, and Y. Chen. In Press. Unnatural random mating policies select for younger age at maturity in hatchery Chinook salmon populations. Can. J. Fish. Aquat. Sci. XX:xxx-xxx.

- Hankin, D.G., and M.S. Mohr. 2009. Estimating the Proportions of Closely Related Species: Performance of the Two-Phase Ratio Estimator. *J. Agric. Biol. Environ. Statistics* 14: 15-32.
- Kinziger, A.P., E. J. Loudenslager, D.G. Hankin, E.C. Anderson, and JC, Garza. 2008. Hybridization between spring-run and fall-run Chinook salmon returning to Trinity River, California. *N. Am. J. Fish. Manage.* 28: 1426-1438.
- Webster, R.A., K. H. Pollock, S. K. Ghosh, and D G. Hankin. 2008. Bayesian spatial modeling of data from unit-count surveys of fish in streams. *Trans. Am. Fish. Soc.* 137:438–453.
- Brakensiek, K., and D.G. Hankin. 2007. Estimating overwinter survival of juvenile coho salmon in a Northern California stream: accounting for effects of PIT-tagging mortality and size-dependent survival. *Trans. Am. Fish. Soc.* 136:1423-1437.
- Lamberson, R.H., S. C. McKelvey, J.E. Carroll, T.J. Lauck, and D. Hankin. 2007. Maintaining diversity in an artificially propagated population. *J. Biol. Dynamics* 1: 87-93.
- Baumsteiger, J., D.G. Hankin, and E. Loudenslager. 2005. Genetic analyses of juvenile steelhead, coastal cutthroat trout, and their hybrids differ substantially from field identifications. *Trans. Am. Fish. Soc.* 134:829-840.
- Hackett, S., , M. Krachey, S. Brown, and D. Hankin. 2005. Derby fisheries, individual quotas, and transition in the fish processing industry. *Marine Resources Economics* 20: 47-60.
- Deweese, C.M., K. Sortais, M.J. Krachey, S.C. Hackett, and D.G. Hankin. 2004. Racing for crabs: costs and management options in California's commercial Dungeness crab fishery. *Calif. Agric.* 58: 186-193.
- Miller, T., and D.G. Hankin. 2004. Descriptions and durations of premolt setal stages in female Dungeness crabs, *Cancer magister* Dana. *Marine Biology* 144: 101-110.
- Oh, S., and D.G. Hankin. 2004. The sperm plug is a reliable indicator of mating success in female Dungeness crabs, *Cancer magister*. *J. Crustacean Biology* 24: 314-326.
- Hackett, S., M. Krachey, C. Dewees, and D. Hankin. 2003. An economic overview of Dungeness crab (*Cancer magister*) processing in California. *CalCOFI Reports* 44: 86-93.
- Hankin, D. 2002. A new method to estimate duration of molt stages in crustaceans. pp. 351-366 IN *Crabs in cold water regions: biology, management and economics*. Alaska Sea Grant College Program. AK-SG-02-01.
- Hankin, D.G. , and D. McCanne. 2000. Estimating the number of fish killed in the Cantara Spill and the proportions of wild and hatchery trout. *Calif. Fish Game* 86(1): 4-20.

- Hankin, D.G., T.H. Butler, Wild, P.W., and Q-L. Xue. 1997. Does intense fishing on males impair mating success of female Dungeness crabs? *Can. J. Fish. Aquat. Sci.* 54:655-669.
- Allendorf, F.W., D. Bayles, D.L. Bottom, K.P. Currens, C.A. Frissell, D. Hankin, J.A. Lichatowich, W. Nehlsen, P.C. Trotter, and T.H. Williams. 1997. Prioritizing Pacific salmon stocks for conservation. *Conservation Biology* 11: 140-152.
- Welsh, H.H., L.M. Ollivier, and D.G. Hankin. 1997. A habitat-based design for sampling and monitoring stream amphibians with an illustration from Redwood National Park. *Northwestern Naturalist* 78: 1-16.
- Castleberry, D.T., J.J. Cech, D.C. Erman, D. Hankin, M. Healey, G.M. Kondolf, M. Mangel, M. Mohr, P.B. Moyle, J. Nielsen, T.P. Speed, and J.G. Williams. 1996. Uncertainty and instream flow standards. *Fisheries* 21: 20-21.
- Hankin, D.G., J.W. Nicholas, and T.W. Downey. 1993. Evidence for inheritance of age of maturity in chinook salmon, *Oncorhynchus tshawytscha*. *Can. J. Fish. Aquat. Sci.* 50: 347-358
- Butler, T.H., and D.G. Hankin. 1992. Comment on mortality rates of Dungeness crabs (*Cancer magister*). *Can. J. Fish. Aquat. Sci.* 49: 1518-1521.
- Hankin, D. G., N. Diamond, M. S. Mohr, and J. Ianelli. 1989. Growth and reproductive dynamics of adult female Dungeness crabs, *Cancer magister*, in northern California. *J. Cons. int. Explor. Mer.* 46: 94-108.
- Mohr, M. S., and D.G. Hankin. 1989. Estimation of size-specific molting probabilities in adult decapod crustaceans based on postmolt indicator data. *Can. J. Fish. Aquat. Sci.* 46: 1819-1830.
- Hankin, D. G. 1988. Book Review: C. Walters, "Adaptive Management of Renewable Resources". *Trans. Am. Fish. Soc.* 117(2): 219-220.
- Hankin, D. G., and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. *Can. J. Fish. Aquat. Sci.* 45: 834-844.
- Fujiwara, S., and D. G. Hankin. 1988. Sex ratio, spawning period, and size and age at maturity of sablefish off northern California. *Nippon Suisan Gakkaishi* 54: 1333-1338.
- Fujiwara, S., and D. G. Hankin. 1988. Aging discrepancy related to asymmetrical otolith growth for sablefish *Anoplopoma fimbria* in Northern California. *Nippon Suisan Gakkaishi* 54: 27-31.

- Hankin, D. G., and M. C. Healey. 1986. Dependence of exploitation rates for maximum yield and stock collapse on age and sex structure of chinook salmon stocks. *Can. J. Fish. Aquat. Sci.* 43: 1746-1759.
- Diamond, N., and D. G. Hankin. 1985. Movements of adult female Dungeness crabs (*Cancer magister*) in northern California based on tag recoveries. *Can. J. Fish. Aquat. Sci.* 42: 916-926.
- Hankin, D. G., and R. McKelvey. 1985. Comment on fecundity of chinook salmon and its relevance to life history theory. *Can. J. Fish. Aquat. Sci.* 42: 393-394.
- Hankin, D. G. 1984. Multistage sampling designs in fisheries research: applications in small streams. *Can. J. Fish. Aquat. Sci.* 41: 1575-1591.
- Hankin, D. G. 1982. Estimating escapement of Pacific salmon: marking practices to discriminate wild and hatchery fish. *Trans. Am. Fish. Soc.* 111: 286-298.
- Hankin, D. G. 1980. A multistage recruitment process in laboratory fish populations: implications for models of fish population dynamics. *Fishery Bulletin* 78: 555-578.
- McKelvey, R., D. Hankin, K. Yanosko, and C. Snygg. 1980. Stable cycles in multistage recruitment models: an application to the northern California Dungeness crab (*Cancer magister*) fishery. *Can. J. Fish. Aquat. Sci.* 37: 2323-2345.
- Hankin, D. G. 1978. New fluorescent fish scale marker. *Prog. Fish-Cult.* 40: 163-164.

Symposia Proceedings:

- Xue, Q-L., and D.G. Hankin. 2002. Estimating molting probabilities of female Dungeness crabs (*Cancer magister*) in northern California: A multi-stage latent variable approach. *In* A.J. Paul, et al. (eds). *Crabs in cold water regions: biology, management, and economics*. Univ. Alaska Dea Grant, AK-SG-02-01, Fairbanks.
- Hankin, D.G., and Q-L. Xue. 1996. Preliminary report on interannual variation in size-specific molting probabilities of adult female Dungeness crabs, *Cancer magister*, in northern California. *In* Proc. Internat. Symp. Biol, Manage., and Economics of Crabs from High Lat. Habitats. Alaska Sea Grant Report AK-SG-96-02: 425 - 441
- Hankin, D. G. 1985. Proposed explanations for fluctuations in abundance of Dungeness crabs: a review and critique. pp. 305-326 *In* Proc. Symp. on Dungeness Crab Biol. and Manag., Alaska Sea Grant Report No. 85-3.
- Hankin, D., N. Diamond, M. Mohr, and J. Ianelli. 1985. Molt increments, annual molting probabilities, fecundity and survival rates of adult female Dungeness crabs in northern

California. pp. 189-206 In Proc. Symp. on Dungeness Crab Biol. and Manage., Alaska Sea Grant Report No. 85-3.

Diamond, N., and D. Hankin. 1985. Biases in crab tag recovery data. pp. 341-356 In Proc. Symp. on Dungeness Crab Biol. and Manage., Alaska Sea Grant Report No. 85-3.

Maeda, R., and D. Hankin. 1983. Age and growth of sablefish landed in Eureka, California: a comparison of conventional surface ages with otolith section ages. pp 81-93 In Proc. Internat. Sablefish Symp., Alaska Sea Grant Rep. 83-8.

Hankin, D. G. 1983. California policy and management for natural Pacific salmon production. pp. 226-252 In Proc. Ocean Studies Symp., Asilomar, CA.

Hankin, D. G. 1982. Indian fishing rights and mathematical models: alternative interpretations of court-mandated allocation of salmon harvests. pp 74-81 In Proc. First Pac. Coast Conf. on Math. Models of Renew. Resources, Humboldt State University, Arcata, CA.

Hankin, D. G. 1982. Salmon enhancement strategies and wild stocks: evaluation of enhancement success and wild stock impacts. pp 52-61 In Propagation, enhancement and rehabilitation of anadromous salmonid populations in the Pacific Northwest, Humboldt State University, Arcata, CA.

Significant Contract/Technical Reports

Logan, E., and D. Hankin. 2008. A Detailed Review of the Annual Hatchery Production Cycle at Iron Gate Hatchery. Contract report for Hoopa Tribe (BOR). 60 pp.

Beamish, R., C. Busack, A. Cass, J.H. Clark, D. Hankin (Chair), R. Kope, G. Morishima, S. Pennoyer, L. Richards, B. Riddell, and L. Rutter. 2008. Recommendations for Application of Genetic Stock Identification (GSI) Methods to Management of Ocean Salmon Fisheries; Special Report of the GSI Steering Committee and the Pacific Salmon Commission's Committee on Scientific Cooperation. PSC Technical Report 23. 44 pp.

Hankin, D.G. (Chair), J.H. Clark, R.B. Deriso, J.C. Garza, G.S. Morishima, B.F. Riddell, and C. Schwarz. 2005. Report of the expert panel on the future of the coded wire tag recovery program for Pacific salmon. Pacific Salmon Commission Technical Report No. 18. 230 pp.

Newman, K.B., A.C. Hicks, and D.G. Hankin. 2004. A marking, tagging, and recovery program for Central Valley hatchery Chinook salmon. Contract report for CALFED.

Newman, K.B., and D.G. Hankin. 2004. Statistical procedures for detecting the CVPIA natural Chinook salmon production doubling goal and determining sustainability of production increases. Contract report for USFWS.

- Hankin, D.G., and J. Fitzgibbons. 2003. Long-term effects of mating practices and size-selective ocean fisheries on age and sex composition of Chinook salmon (*Oncorhynchus tshawytscha*) populations returning to hatcheries. Contract report for Yurok Tribe.
- Hankin, D.G., E.J. Loudenslager, and J. Baumsteiger. 2003. Reliability of visual identification of juvenile (0+ and 12+) coastal cutthroat trout (*Oncorhynchus clarki clarki*), steelhead (*Oncorhynchus mykiss*) and their hybrids. Final report for NOAA-Fisheries contract # 43-AB-NF-107125 and 40-AB-NF-215496. 10 pp executive summary.
- Hankin, D.G., and J. Fitzgibbons. 2003. Review of the age-, size-, and sex-selective effects of selective fisheries on Chinook salmon: Executive summary. Northwest Indian Fisheries Commission. 11 pp.
- Fitzgibbons, J., and D.G. Hankin. 2001. Tabular summary of mating practices at Chinook salmon hatcheries in California, Oregon and Washington, with special focus on usage of jacks in matings. Contract report for Yurok Tribe. 30 pp.
- Hankin, D. G., and J. Richards. 2000. The Northern Pikeminnow Management Program: An Independent Review of Program Justification, Performance, and Cost-Effectiveness. Prepared for the Northwest Power Planning Council, Portland, OR. 28 pp.
- Hankin, D., and K. Newman. 1999. Improved methods for assessment of the contribution of hatcheries to production of chinook salmon and steelhead in the Klamath-Trinity system. Final Report prepared for Hoopa Tribal Council. 44 pp.
- Zajanc, D., and D. Hankin. 1998. A detailed review of the annual production cycle at Trinity River Hatchery: with recommendations for changes in hatchery practices that would improve accuracy of estimation of numbers released. Contract Report prepared for Hoopa Tribal Council. 35 pp. + appendixes
- Dolloff, C.A., D.G. Hankin, and G.H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. U.S. Forest Service, General Technical Report SE-83. 25 pp.
- Hankin, D.G., and M.S. Mohr. 1993. New methods for analysis of coded wire tag recovery data. CA Coop. Fish. Res. Unit Agreement No. 14-16-0009-1547. Final Report.
- Hankin, D. G. 1990. Effects of month of release of hatchery- reared chinook salmon on size at age, maturation schedule and fishery contribution. Oregon Dept. of Fish and Wildlife, Information Report 90-4 37 pp.
- Nicholas, J., and D. G. Hankin. 1988. Chinook salmon populations in Oregon's coastal river basins: Description of life histories and assessment of recent trends in run strength. Oregon Dept. of Fish and Wildlife, Information Report 88-1. 359 pp.

- Hankin, D. G. 1986. Sampling designs for estimation of the total number of fish in small streams. Research Paper PNW-360, Pacific Northwest Research Station, U.S. Forest Service, Portland, OR. 33 pp.
- Hankin, D. G. 1985. Analyses of recovery data for marked chinook salmon released from Iron Gate and Trinity River Hatcheries, and their implications for management of wild and hatchery chinook stocks in the Klamath River system. Bureau of Indian Affairs, Northern California Agency, Hoopa, CA. 117 p.
- Hankin, D. G. 1980. Some alternative data analysis techniques and hatchery management practices for evaluation of Klamath River system fall chinook salmon stocks. Bureau of Indian Affairs, Hoopa Agency, Hoopa, CA. 60 pp.
- Hankin, D., and G. Reeves. 1980. A review and critique of sampling programs and estimation procedures used to determine run size and escapement of fall chinook salmon in the Klamath River system, 1978 and 1979. Bureau of Indian Affairs, Hoopa Agency, Hoopa, CA. 72 pp.

RONALD MARK THOM

Staff Scientist
Marine Sciences Laboratory
Pacific Northwest National Laboratory
Sequim, Washington

EDUCATION

A.S.	Natural Sciences, Long Beach City College	1969
B.S.	Biological Sciences, California State College, Dominguez Hills	1971
M.A.	Biology, California State University, Long Beach	1976
Ph.D.	Fisheries, University of Washington	1978

PROFESSIONAL BACKGROUND

Ron, who leads the Coastal Assessment and Restoration technical group at the Marine Sciences Laboratory in Sequim, Washington, has conducted research in coastal and estuarine ecosystems since 1971. His research includes habitat construction and restoration; adaptive management of restored systems; effects of pollution; benthic primary production; climate change; and ecology of fisheries resources. He has worked on programs in systems in California, Washington, Oregon, Alaska, Massachusetts, New York, Nebraska, Alabama, and most recently in the southern Gulf of Mexico. Ron has directed approximately 200 multidisciplinary ecological studies. He has published sixteen book chapters, over 60 peer reviewed journal articles, hundreds of reports, and made hundreds of professional presentations. Ron serves as an Affiliate Associate Professor, School of Aquatic and Fisheries Sciences, University of Washington, and as an Adjunct Professor for Western Washington University Huxley Environmental Studies program. He also serves as subject editor for the journal *Marine Biology Research*. From 1985-1989 he chaired the Technical Advisory Committee of the Puget Sound Estuary Program. Ron was recently appointed to serve on the new Science Team of the Straits Commission.

PROFESSIONAL EMPLOYMENT

1971-1974 – Marine Biologist, Los Angeles County
1974-1975 – Fisheries Biologist, University of Washington
1975-1978 – Graduate research Assistant, University of Washington
1979-1980 – Fisheries Biologist, University of Washington
1980-1982 – Fisheries Biologist, Seattle District Corps of Engineers
1982-1990 – Fisheries Biologist, University of Washington
1990-present – Scientist and Technical Group leader, Marine Sciences Laboratory, PNNL

Cumulative Effects of Multiple Habitat Restoration Projects on the Columbia River Estuary Ecosystem

(2004-present). The primary goal of this multi-year study is to develop a framework and methodology to measure and evaluate the cumulative effects of habitat restoration actions in the CRE aimed at increasing population levels of listed Columbia Basin salmon. This framework and methodology will ensure comparable data sets across multiple restoration monitoring efforts estuary-wide. The management implications of this research are two-fold in that it is expected to provide techniques allowing decision-makers to 1) evaluate the ecological performance of the collective habitat restoration effort in the CRE and its effects on listed salmon, and 2) apply knowledge from comparable datasets for ongoing monitoring to prioritize future habitat restoration projects. The project is being conducted for the U.S. Army Corps of Engineers (Corps) by the Marine Sciences Laboratory of the Pacific Northwest National Laboratory, the Pt. Adams Biological Field Station of the National Marine Fisheries Service, and the Columbia River Estuary Study Taskforce. Measurement of the cumulative effects of ecological restoration projects in the Columbia River estuary is a formidable task because of the size and complexity of the estuarine landscape and the meta-populations of salmonids in the Columbia River basin. Despite the challenges presented by this system, developing and implementing appropriate indicators and methods to measure cumulative effects is the best way to enable estuary managers to track the overall effectiveness of investments in estuarine restoration projects. This project is intended to both develop methods for quantifying the effects of restoration projects and lay a foundation for effectiveness evaluation and validation of cumulative restoration activities in the CRE.

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Adaptive Management Framework for Habitat Restoration in the Columbia River Estuary (2006-present).

The purpose of this project is to develop an adaptive management framework and process that can be used to guide the habitat restoration program in the Lower River and Estuary. The outcome will be a report detailing the structure of the framework and the adaptive management (AM) process. The intent is to initiate an on-going AM process that is repeated periodically, and that results in improvements in the siting, design, and implementation of habitat restoration projects. The process will involve periodic acquisition of information on projects, analysis of the information, recommendations, and dissemination of information and recommendations. Critical elements include a simple, yet effective framework for conducting the process, active and cooperative participation by practitioners, monitoring and evaluation of projects, and incorporation of new scientific research.

Restoration of Eelgrass in Narragansett Bay, Rhode Island (U.S. Navy; 2005-2006). The McAllister Point landfill is located along the shores of Narragansett Bay in Middletown, Rhode Island. Prior to dredging in April 2001, the eelgrass bed growing along the point was 0.9 acre in size and was present in water depths ranging from approximately 3-11 ft. After dredging, the size of the eelgrass bed had been reduced to 0.57 acre as of May 2002, principally from removal of the shoreward portion of the eelgrass bed and development of an unvegetated trough feature. The objective of this project is to restore approximately 0.5 acre (~2,700 m²) of eelgrass near McAllister Point Landfill, Naval Station Newport, RI. In May 2006, 5,400 shoots of eelgrass were harvested and planted within suitable areas of the Site to establish the maximum number of viable eelgrass patches. We used bare root planting units consisting of a number of shoots with rhizomes attached to anchoring material and a basket-type planting system called TERFS. Among other objectives, these two methods are being evaluated for efficacy at this site and for the greater Bay. In addition, TERFS may be effective in minimizing crab damage often observed immediately following planting.

NOAA National Guidance Document of Salt Marsh Restoration (NOAA Restoration Center, 2005-ongoing).

The purpose of this document is to provide a national review of salt marsh ecosystem restoration and to formulate guidance for conducting restoration of these systems. We have been conducting interviews with experts throughout the country regarding methods for restoring salt marshes, and are documenting project success and monitoring. The guidance document will be available through NOAA nationally.

NOAA National Estuarine Eutrophication Panel (NOAA, 1996 and 2006). NOAA is tracking and reporting on the status of eutrophication in the Nation's estuaries. They are doing this through an expert panel as well as input from scientists knowledgeable regarding specific systems. Dr. Thom participated on the original national panel in the mid 1990's and recently participated in the national re-assessment conducted in 2006. Dr. Thom was one of five scientists representing west coast estuaries.

A National Framework for Risk Analysis for Ecological Restoration Projects in the U.S. (U.S. Army Corps of Engineers, 2001-2005). Description: "A Framework for Risk Analysis for Ecological Restoration Projects in the U.S. Army Corps of Engineers" is an Institute for water Resources report that was published in 2005 as a chapter (Diefenderfer et al. 2005) in a CRC Press book. This framework document provides the general planner with a basic understanding of risk analysis in each of the six steps of the USACE ecosystem restoration planning process. Its focus is on risk analysis: identifying the range of possible outcomes from alternative ecosystem restoration actions, assessing the potential for achieving the desired outcome, characterizing the likelihood of adverse consequences, and communicating these findings to stakeholders and decision makers. A conceptual model of the project site and landscape is advocated as a central organizing structure within the six-step process to achieve USACE ecosystem restoration objectives. Conceptual and empirical models are employed to identify uncertainty in planning variables from the formulation of alternative plans through plan selection. In plan comparison, ranges of potential outcomes are considered to incorporate uncertainty. Risk and uncertainty information contributes to eliminating alternatives with unacceptable risk. A fully developed example of a tidal wetland restoration planning process demonstrates the application of this approach. The approach integrates concepts and tools from the science of ecological restoration with proven federal project planning processes and incorporates risk analysis into restoration planning. Publication: Diefenderfer HL, RM Thom, and K Hofseth. 2005. "A Framework for Risk Analysis for Ecological Restoration

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Projects in the U.S. Army Corps of Engineers." Chapter 4 in Economics and Ecological Risk Assessment: Applications to watershed Management, Environmental and Ecological Risk Assessment Series, vol. 5, ed. Randall J. F. Bruins, Matthew T. Heberling, pp. 57-105. CRC Press, Boca Raton, FL.

Washington State Aquatic Lands Habitat Conservation Plan (Washington State Department of Natural Resources, 2005-2006). In order to quantify, predict and minimize the impacts of permitted activities on state-owned aquatic lands, the WDNR required development of a habitat conservation plan (HCP). The first step was the development of impacts assessment from a broad array of permitted activities. This document provides the basis for further analysis and development of avoidance and minimization measures, as well as effectiveness monitoring programs.

Lower Columbia River Restoration Prioritization Framework (Lower Columbia River Estuary Partnership, 2004-2006). The Restoration Prioritization Framework was designed as a decision-making tool for the Lower Columbia River Estuary Partnership, to help identify the highest priority sites for restoration. The Framework is composed of three parts, which are intended for use together: 1) an overview of the concepts and description of Framework tools (this document), 2) a Microsoft Excel™ workbook containing detailed data, formulas, and workflow for the actual site prioritization, and 3) a Geographic Information System (GIS) database containing source and processed geospatial datasets. The Prioritization Framework uses the conceptual model-based approach outlined in these documents to assign priority scores to sites. The conceptual model states that the physical controlling factors in a location drive the habitats that can form, and ultimately, the ecological functions that develop. The Framework uses this model to evaluate impacts to these controlling factors, using a variety of human impact "stressor" datasets, such as diking, agriculture, over-water structures, and flow restrictions. Methods are also described for evaluating specific projects or proposals, using information on cost, expected functional change, site size, and predicted probability of success. This provides a tiered approach through which the Estuary Partnership can screen for impacted areas, prioritize areas based on desired ecological criteria, and evaluate selected projects.

Lower Columbia River and Estuary Habitat Monitoring Project (LCREP/BPA, 2004-ongoing). In 2004, the Lower Columbia River Estuary Partnership, with technical support from Battelle, University of Washington (UW), and US Geological Survey (USGS), drafted the Columbia River Estuary Habitat Monitoring Plan as part of the Estuary Partnership's Ecosystem Monitoring program. Due to the complexities of the lower Columbia River system and the relative lack of previous studies in the tidal freshwater reaches, the habitat monitoring sampling plan was divided into two parts, with the first phase serving as an inventory of existing conditions and the second establishing the sampling design for a long-term status and trends monitoring program. The inventory phase began in 2005, with assessment of seven study sites within two (of eight total) reaches of the lower Columbia River. Using a hydrogeomorphic classification system developed by UW and USGS, shallow water tidal wetlands were identified and sampled for vegetation occurrence and abundance, elevation, and water quality. Additionally, a feasibility study using QuickBird remotely sensed imagery was completed. In 2006 we will continue the inventory work (in a new reach) and will improve on sampling design from 2005 and incorporate additional metrics, such as submerged aquatic vegetation (to the extent possible, using shore-based surveys). Our current proposal is for the second phase, which would build on the inventory to develop a long term status and trends monitoring plan. In each reach, we proposed to sample one core site for vegetation, fish (including presence/absence, diet, and toxicology), and water quality. In addition, on a rotational basis, we will focus on one reach and include 6-10 additional sites. This approach will capture interannual variability at the core sites, while also providing a more accurate assessment of individual reaches on a four-five year cycle.

Monitoring Protocols for Salmon Habitat Restoration Projects in the Lower Columbia River and Estuary (U.S. Army Corps of Engineers, Portland District, 2004-ongoing). This document describes a set of protocols developed by the Pacific Northwest National Laboratory, the National Marine Fisheries Service, and the Columbia River Estuary Study Taskforce with the support of the US Army Corps of Engineers. The protocols will be used to assess habitat restoration projects as part of the Cumulative Ecosystem Response Evaluation effort begun in 2004 and to conclude in 2010. The goal of these restoration activities in the lower Columbia River and estuary (CRE) is to repair the connectivity and function of wetland habitats, and thereby to allow juvenile salmon to regain benefit from

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these important rearing and refuge areas. To do this effectively, researchers and managers require the means to 1) evaluate the results of individual restoration activities, 2) compare results among projects, and 3) determine the long-term and cumulative effects of habitat restoration on the overall estuary ecosystem. To achieve this, we are developing a standardized set of research and monitoring protocols. We limited the number of metrics to a proposed "core" set and selected measurement methods that are straightforward and economical to use. We selected core metrics based on the following criteria: 1) metrics correspond to commonly held restoration project goals; 2) are applicable to all sites; 3) represent controlling factors, ecosystem structure, and ecosystem function; 4) are relevant to both present and future investigations; and 5) are practical in terms of available level of effort. Monitoring protocols are provided for hydrology (water surface elevation); water quality (temperature, salinity, dissolved oxygen); elevation (bathymetry, topography); landscape features; plant community (composition and cover); vegetation plantings (success); and fish (temporal presence, size/age structure, species).

Lower Columbia River Ecosystem Health Indicators (U.S. Environmental Protection Agency; 12/03 - present). Dr. Ron Thom is Manager of this program in support of a Plan adopted in 2000 by the Lower Columbia River Estuary Partnership to assess the health of the lower Columbia River estuary. The first task involved a review of metrics that have been most effective in programs relevant to the lower Columbia River estuary, including those presented in the 2000 National Research Council report, "Ecological Indicators for the Nation." Current tasks include further review and refinement of identified health-indicator metrics and the development of criteria for metric selection. In addition, Dr. Thom is providing guidance to environmental program managers on how to incorporate metrics into current programs that can be used to provide meaningful and relevant data toward the monitoring of ecosystem health indicators of the lower Columbia River estuary. Some of these programs involve the development of a conceptual model, habitat monitoring, water quality and toxics monitoring, and the evaluation of cumulative effects of restoration projects on the estuarine system. Through the alignment of mutual objectives, data from other programs in the region can be directly applied toward the refinement of assessment protocols and the evaluation of the health of the lower Columbia River estuary.

Lower Columbia River and Estuary Restoration Plan (9/02- present): Project investigator. Dr. Thom is a primary contributor to a comprehensive plan that will be used to guide restoration of the lower Columbia River and estuary. The plan utilizes a process-based approach to planning and implementing restoration.

Port of Portland Columbia River Navigation Deepening (2/01 – 3/02): Program Manager. Dr. Thom serves as Scientific Advisor on the review of background documents regarding the reconsultation project, including the environmental sections and technical appendices of the Corps of Engineers' Channel Improvements EIS, the Corps' Biological Assessment for the Channel Improvement EIS, the National Marine Fisheries Service's Biological Opinion, and the NMFS Biological Opinion Withdrawal. Tasks include development of a Biological Assessment and participation in Strategy Development Workshops to address ESA issues in the Lower Columbia River and estuary. He and Dr. Walt Pearson developed a conceptual model that identifies key functions and interactions of physical and biological factors affecting salmonid support in the ecological system.

WSDOT Marine Biology Programs (1994 - present): Dr. Thom has served as Program Manager for three On-Call contracts with WSDOT and recently won a fourth term for 2004-2007. The numerous task orders under these contracts have required the coordination of a wide variety of scientific disciplines and subcontractors, and the coordination of varying schedules and milestones to meet requirements for field operations and project deliverables. The primary focus of these projects has been on the assessment and mitigation of impacts of ferry terminal development and ferry operations on eelgrass and other nearshore habitats. Tasks have included studies on habitat enhancement, benthic resources, fish behavior, culvert designs, eelgrass growth requirements, innovative dock design, and shoreline protection. Battelle has applied a variety of tools to these studies, including underwater videography, hydroacoustics, the development of specialized sensors, and mapping technologies. The original eelgrass research program at several ferry terminals resulted in high technical reviews from resource agencies and allowed WSDOT to move ahead with terminal development work. In 1997, this program received the "Environmental Excellence Award" from the Federal Highway Administration, which recognizes excellence in

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environmental work that supports “a safe, efficient, and effective transportation system that fits harmoniously within our natural environment, our neighborhoods, and our communities.” The WSDOT programs have been instrumental in advancing the science of restoration in nearshore environments.

Isolated Wetlands Functional Assessment (EPA; 1999-2001). Dr. Thom managed this high-profile project to develop a review of the ecological functions and economic values of isolated wetlands. A lawsuit filed by the EPA against a developer challenged the quality of data on isolated wetlands. Battelle was asked to conduct a national review of current information, which included discussions with scientists, consultants, regulators, developers, and a variety of other experts and individuals. The project resulted in the first comprehensive review of its kind. The difficulties included finding relevant data and developing a report with both technical merit and layperson readability. Numerous changes in project scope required extensive discussions with the client. Each issue was handled through open discussions that focused on the real target for the report. The final report played a key role in the case review by the U.S. Supreme Court. Because of the level of effort, quality of the work, and willingness to work through difficult problems, the EPA returned to Battelle in 2003 to do an updated review of research since the initial project, and to again orient the report toward laws protecting U.S. wetlands and waters. Battelle was chosen for this program for its objectivity, scientific integrity, its willingness to undertake controversial issues, and its ability to focus the scope directly on the client's needs. This report may represent a landmark change in the national management of isolated wetlands and waters.

Morro Bay National Estuary Program (NEP) Monitoring Program Support (EPA; 6/02 - 2/04). Dr. Thom has managed an ongoing, small program with the NEP to identify indicators of health of the bay ecosystem. The program has involved data collection; facilitation of a series of technical meetings and workshops; planning, scheduling, and advising work necessary to produce a quality public Comprehensive Conservation Management Plan on schedule; identification of critical data gaps; development of presentation materials; and obtaining stakeholder buy-in. In addition, Dr. Thom and other MSL staff have assisted the NEP in developing monitoring programs for both eelgrass and sediment dynamics, which have resulted in greater efficiency, reduced costs, and increased quality of data. The NEP program demonstrates that Dr. Thom can work successfully to help an agency address complex technical issues, and to assist a diversity of stakeholders, public interest groups, technical committees, and agencies advance a high-profile program toward meeting identified objectives. Mr. Michael Multari, Director of the Morro Bay NEP, has recommended Dr. Thom to other NEPs that need to work incrementally through their technical issues.

Aquatic Ecosystem Restoration Programs for the U.S. Army Corps of Engineers (USACE; 1994 - present). The Institute for Water Resources (IWR) provides planning guidance to national Corps district offices. In 1994, the IWR contracted with Battelle to have Dr. Thom provide a national review of non-corps aquatic ecosystem restoration projects. This review, which included both ecological and economic information, was the first such review of its kind. Based on this information, Dr. Thom developed guidance on standardizing performance monitoring in restoration projects, which was further developed into a training module given twice a year to Corps planners. Dr. Thom and other Battelle staff have been recently working with IWR on developing guidance for evaluating and incorporating risk and uncertainty in restoration projects. Through extensive discussions and reworking of approaches to problems, Dr. Thom has effectively worked with the IWR staff, district planners, and engineers to better understand their needs and the practicalities of their work. The net result is a planning process with an effective, systematic approach to risk evaluations in ecosystem-based projects. The Corps strongly feels that an integrated risk-based planning process will result in cost savings and enhanced success. The process toward this type of innovative thinking within an organization steeped in traditional approaches was not easy. Dr. Thom has brought together key experts within and outside Battelle to directly address the Corps needs. The project has been managed within time and cost constraints, and is favorably viewed by the Corps technical representatives.

The Pacific Northwest Coastal Ecosystem Regional Study (PNCERS) addresses how salmon are affected by variabilities in climate, marine ecosystems, estuarine and riverine ecosystem productivity, and human activities, and the socio-economic consequences of ecosystem change. Dr. Thom manages the habitat portion of this program. The full program includes analysis of effects of climatic and geologic variability and human-induced stressors on salmon production; development of methods to assess cumulative effects of stressors on ecosystems; development of

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methods to control undesirable introduced species; refinement of GIS technologies and numerical models for assessing damage and planning restoration; identification of the vulnerability of ecosystem components to variability; cost/benefit analysis of restoration strategies; and development of an adaptive management system.

Remedial Investigation and Ecological Risk Assessment of the McCormick-Baxter Superfund site in Stockton, California. Dr. Ron Thom was manager of the ecological risk assessment portion of this study for the U.S. Environmental Protection Agency, conducted at a former wood preserving facility that operated from 1942 to 1990. This assessment provided defensible scientific information that will be used by the EPA to determine the level of site clean up that is required and to weigh clean up alternatives against costs. The study addressed the difficult task of sorting out contamination from the site from effects of contamination from other sources. This was critical to the site clean up decision process.

Effects of Petroleum Products on Bull Kelp. This project, which provided the first experimental data other than for birds, demonstrated damage from the Tenyo Maru oil spill off Cape Flattery, Washington.

The Gog-Le-Hi-Te Wetland System in the Puyallup River Estuary, Washington. Dr. Thom managed the design, planting and monitoring of this 10 acre wetland constructed as mitigation by the Port of Tacoma. This system has become a national wetlands demonstration site for the Waterways Experiment Station, US Corps of Engineers. The project resulted in an award for the Port of Tacoma in 1988 as the most environmentally aware port in the nation.

Elk River Saltmarsh Restoration. This is an on-going project to document the progress of restoration of a formerly diked salt marsh in Grays Harbor. The study is the first of its kind in the state and now has a seven-year data base. This is jointly being done by Battelle and the Washington State Department of Fish and Wildlife.

Light, temperature, and enriched CO₂ Effects on eelgrass and kelp productivity. This is a research project investigating the effects of global climate change on these two important marine systems. This research is the first of its kind in the US and results are used by the US Department of Energy and others to evaluate the effects of climate change on marine ecosystems. In addition, these data are useful in evaluating potential eelgrass mitigation and restoration sites.

A Review of Eelgrass (*Zostera marina* L.) Transplant Projects in the Pacific Northwest. This critical review determined the status of transplanting projects from San Francisco through British Columbia, and has been used to formulate state and federal policies regarding eelgrass transplanting in the Northwest.

Shoreline Armoring Effects on Coastal Ecology and Biological Resources in Puget Sound. This study was conducted to document published and unpublished accounts of impacts of shoreline armoring on the ecology and biological resources of Puget Sound. Dr Thom managed this portion of a larger study on the topic of shoreline erosion. The results are being used to help the State department of ecology develop guidelines for armoring shorelines.

Restoration of Urban Estuaries: New Approaches for Site Location and Design. This study applied, for the first time, landscape ecology principles to siting and design of restoration projects in northwest estuaries. The study is used by Washington State Department of Natural Resources to help determine aquatic lands that should be preserved for restoration vs. lands that could be commercially leased by the State.

Intertidal and Shallow Subtidal Benthic Ecology. Dr. Thom managed a two-year study of nearshore systems in the vicinity of the proposed METRO sewage outfall in Seahurst Bight, central Puget Sound. This study was the most comprehensive study of its kind in that region and was used by METRO to justify resiting the outfall in a less environmentally sensitive area.

***Spartina* ecology in Willapa Bay.** This is a joint project with the University of Washington which is investigating

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the ecological differences between *Spartina* patches and native (mudflat) habitats in Willapa Bay. Dr. Thom is conducting studies on below-ground spread, benthic microflora, benthic respiration, and marsh accretion rates. The results can be used to help determine best control practices and for evaluating the ecological effects of invasion of this plant on native systems. The sponsor is Washington State Sea Grant.

Ecological studies of seagrass productivity and grazing in Padilla Bay National Estuarine Research Reserve. Dr. Thom conducted three years of research documenting the production dynamics and effects of herbivores on the most extensive eelgrass and mudflat system in Washington State for NOAA's National Estuarine Research Reserve program. These data were used in court to document the ecological importance of this system relative to claims for commercial development in the Bay.

Effects of Graveling on the Primary Productivity, Respiration, and Nutrient Flux of Estuarine Tidal Flats.

This study was conducted for the Washington State Department of Fisheries and evaluated the effects of gravel placement on mudflats for enhancement of clam resources. This study provided much needed data to the State to help them evaluate this methodology in light of expanding needs for shellfish resources.

Lincoln Park Shoreline Erosion Control Project: Monitoring for Surface Substrate, Infaunal Bivalves and Eelgrass. Dr. Thom has managed this project since 1984, which is being conducted for the U.S. Army Corps of Engineers, Seattle District. The results are being used to evaluate the impacts of placement of gravel to re-nourish an eroding beach in west Seattle.

Eelgrass (*Zostera marina* L.) Transplant Monitoring in Grays Harbor, Washington. Dr. Thom transplanted and has monitored planted eelgrass associated with crab/shell mitigation in Grays Harbor for the U.S. Army Corps of Engineers, Seattle District, since 1990. This project is used by the USACE to document the potential for successful eelgrass transplanting in this system and elsewhere.

Accretion rates of low intertidal salt marshes in the Pacific Northwest. This project measured the accretion rates of sediments and organic matter in coastal marshes throughout the northwest to determine for the US Department of Energy if these marshes would succumb to advanced rates of sea level rise. The data provide an important source of information on sediment trapping rates that can be used to understand, for example, how breaching of dikes around former marshes might reduce sediment loads to estuaries.

Long-Term Changes in the Aerial Extent of Tidal Marshes, Eelgrass Meadows and Kelp Forests of Puget Sound. This report documents for the first time changes in all major nearshore habitats into Region 10, U.S. Environmental Protection Agency.

Abundance, Biomass, and Trophic Structure of the Subtidal Infaunal Communities of the Eastern Side of Central Puget Sound. Dr. Thom managed this first comprehensive sampling of 100 sites in the central Puget Sound region. This study documented possible benthic impacts from the discharge of sewage in central Puget Sound for METRO.

PROFESSIONAL AFFILIATIONS

American Association for the Advancement of Science
American Society of Limnology and Oceanography
Estuarine Research Federation
Pacific Estuarine Research Society
Society of Wetland Scientists
Society of Ecological Restoration

ACADEMIC APPOINTMENTS

RONALD MARK THOM (continued)

Affiliate Associate Professor, School of Aquatic and Fisheries Sciences, University of Washington (1993 - present)
Adjunct Faculty, Western Washington University (1994 - present)
Instructor, Chapman College (1986 - 1987)

PUBLICATIONS

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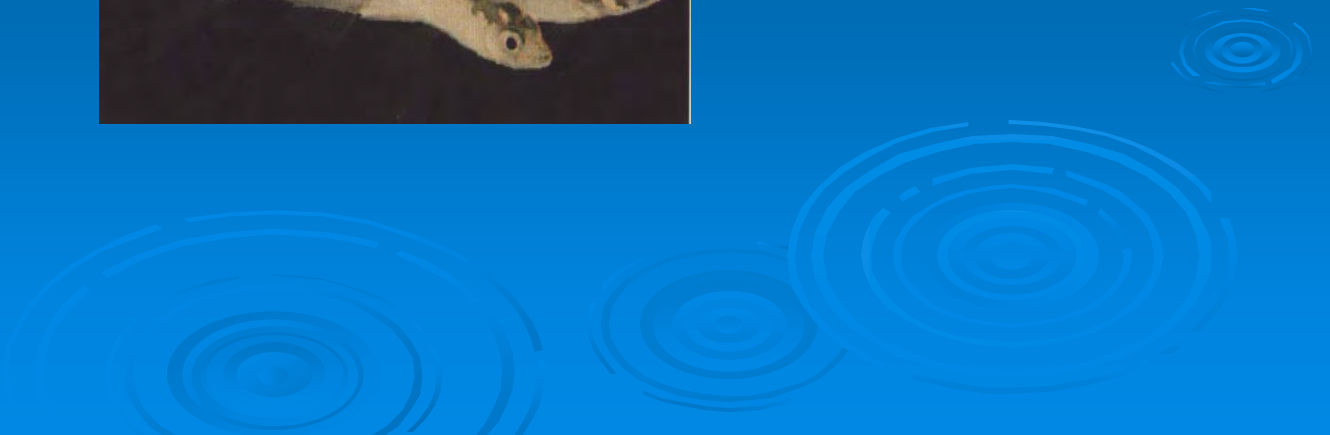
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Attachment 2 – USFWS PowerPoint Presentation

Background information on the Delta Smelt Biological Opinion



Consultation under the Endangered Species Act

- Project Proponent (Reclamation) provides Biological Assessment (BA)
 - Includes Project Description
 - Effects of the proposed action
- Service uses information in BA to develop its biological opinion (BO)

Biological Opinion Development

- Service determines effects of proposed project (future operations) on top of ongoing operations and other effects to delta smelt in the delta (contaminants, food web changes)
- Service determines if proposed project will result in jeopardy to the delta smelt and/or adverse modification of delta smelt critical habitat
- Service's BO effects analysis is based on Calsim II modeling and historical data

Responsibility to provide best scientific and commercial data available

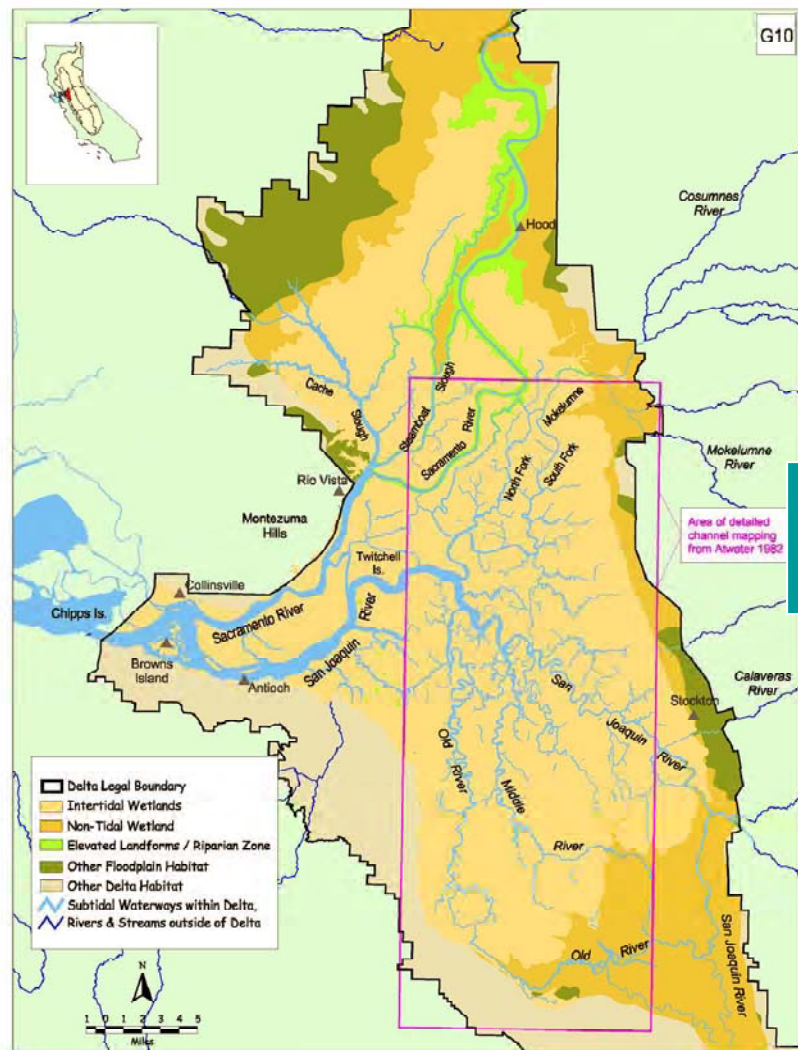
- The Federal agency requesting formal consultation shall provide the Service with the best scientific and commercial data available or which can be obtained during the consultation for an adequate review of the effects that an action may have upon listed species or critical habitat. This information may include the results of studies or surveys conducted by the Federal agency or the designated non-Federal representative. (§402.14 50 CFR CH. IV)

Service's 2008 Biological Opinion

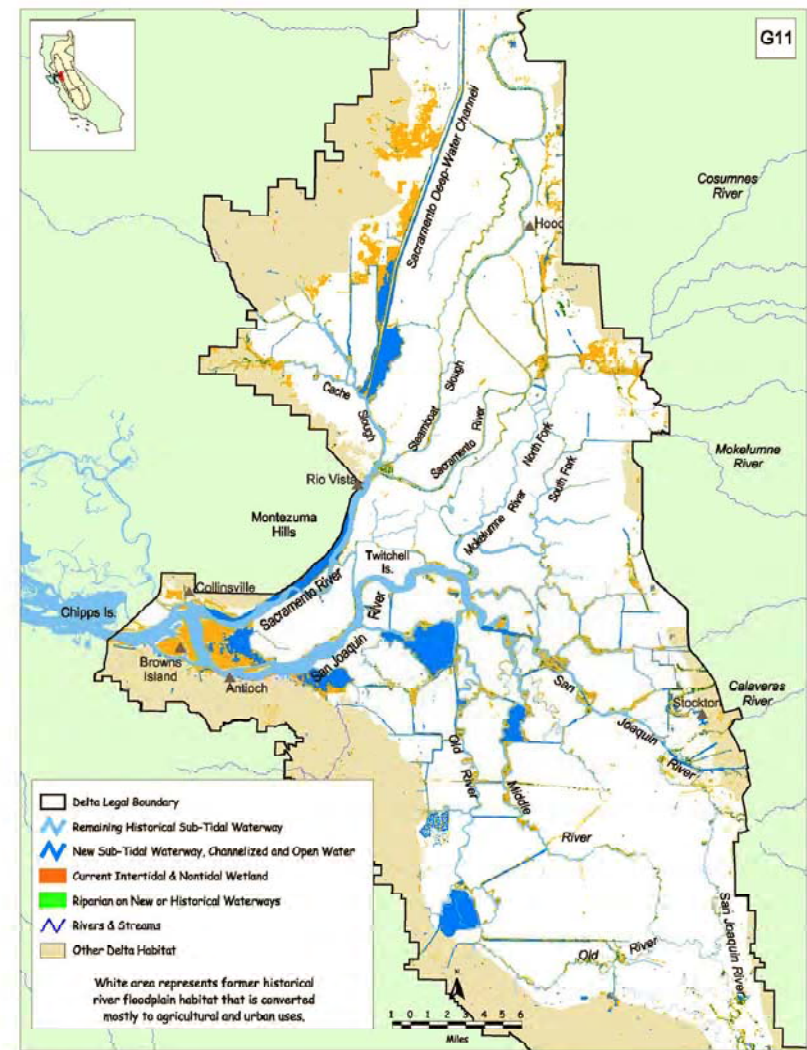
- BO found that project resulted in jeopardy to delta smelt and adverse modification of delta smelt critical habitat
- BO includes Reasonable and Prudent Alternative (RPA) to remove jeopardy and adverse modification

The Changed Delta

From "From the Sierra to the Sea" by the Bay Institute, 1998

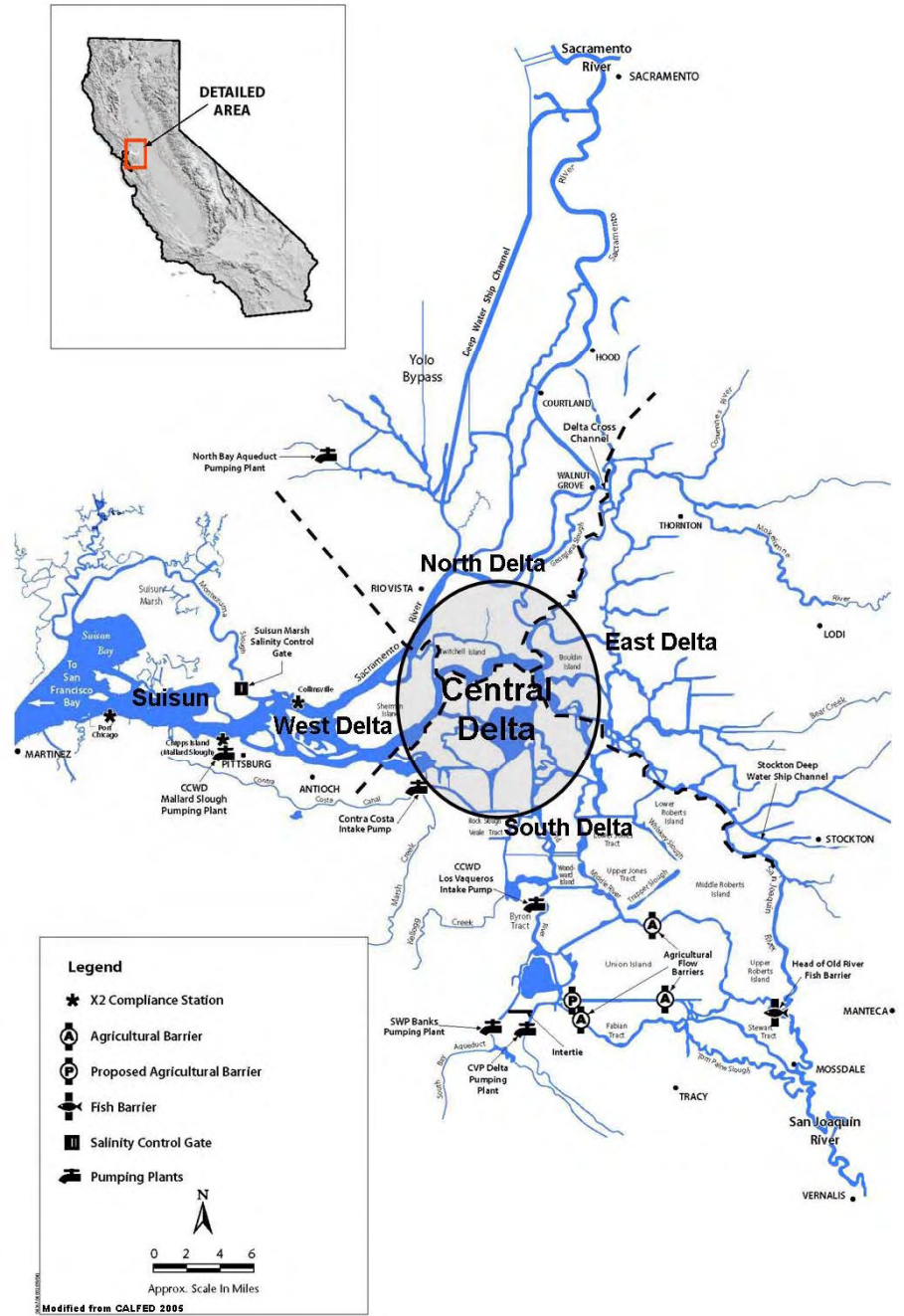
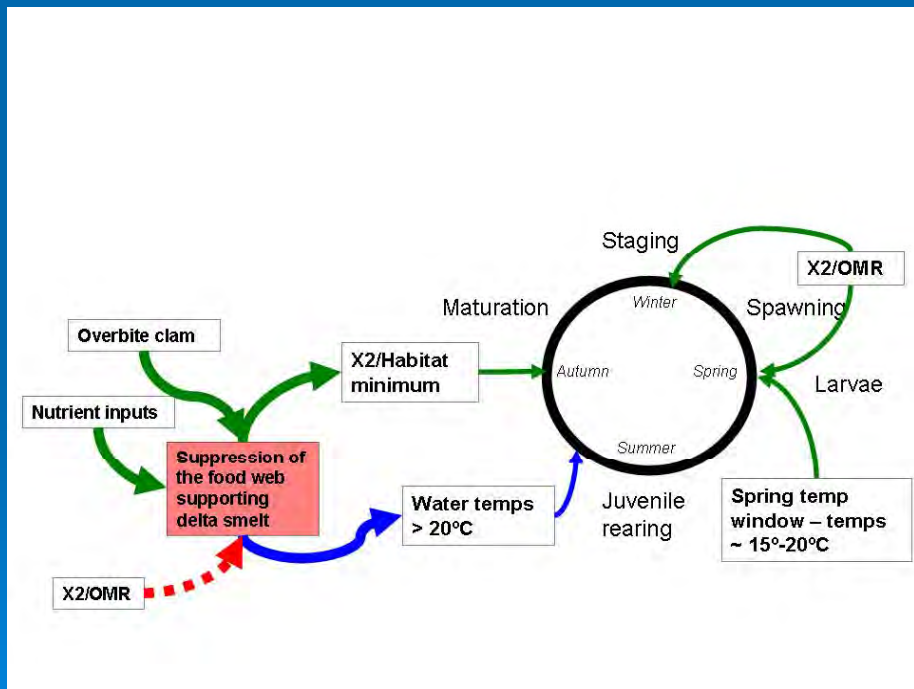


The Delta Historical Aquatic Ecosystem



The Delta Current Ecosystem

Delta Smelt Lifecycle



RPA Components

- Overall goal of RPA is to keep delta smelt away from the influence of the pumps and in suitable habitat
- Component 1 – Protection of the Adult Delta Smelt Life Stage
- Component 2 – Protection of Larval and Juvenile Delta Smelt
- Component 3 – Improve Habitat for Delta Smelt Growth and Rearing
- Component 4 – Habitat Restoration
- Component 5 – Monitoring and Reporting

Component 1 - Adults

- Control Old and Middle River flows (OMR) to protect prespawning adults from Dec-Mar
 - Protect upmigrating delta smelt (Action 1)
 - 14-day export reduction to reduce flows towards the pumps
 - Protect delta smelt after migration prior to spawning (Action 2)
 - OMR range between -1,250 and -5,000 cfs determined using adaptive process until spawning detected

Component 2 – Larval/Juveniles

- Improve flow conditions to allow larval and juvenile delta smelt to rear in the Delta and migrate downstream
 - OMR range between -1,250 and -5,000 cfs determined using adaptive process until June 30th or when Delta water temperatures reach 25 degree Celsius, whichever comes first



Adaptive Process for Components 1 and 2

- Smelt Working Group (SWG) (Service, CDFG, Reclamation, DWR biologists use real time information to assess action needed to protect smelt
- Utilize real-time flow, temperature, salinity, turbidity data
- Results of delta smelt distribution survey
- Particle tracking model results
- Counts of delta smelt entrained at the export facilities
- SWG makes weekly recommendation on action needed to protect delta smelt to the Service that ultimately goes to Regional Director of the Service and other Agency Directors

Component 3 – Improve Growing and Rearing Habitat

- Increase fall habitat quality and quantity only during above normal and wet years
 - Additional increment of Delta outflow in September, October, and November
 - Includes an adaptive management/monitoring element

Component 4-Habitat Restoration

- Requires DWR to create or restore 8,000 acres of intertidal and subtidal habitat in the Delta and Suisun Marsh

Component 5-Monitoring and Reporting

- Requires monitoring efforts in the Delta to continue as well as reporting requirements