

YEAR 3 ANNUAL REPORT

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Title: Pacific Estuarine Ecosystem Indicator Research (PEEIR) Consortium:
Modeling & Integration Component

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Research Category: EaGLE Program

Project Period: March 1, 2001 to February 28, 2005

RESEARCH OBJECTIVES:

The overarching goal of this project is to develop a suite of ecological indicators to rapidly assess the integrity and sustainability of wetlands in West Coast estuaries. We propose to develop an integrated suite of indicators to evaluate impacts of stressors across levels of biological organization, trophic structure, life stage, time and space.

PROGRESS SUMMARY:

1. PROGRAM OVERVIEW

The Pacific Estuarine Ecosystem Indicator Research (PEEIR) Group is a consortium of 30 investigators from the University of California Davis (UCD), the UCD Bodega Marine Laboratory (BML), and the University of California Santa Barbara (UCSB). The overarching goal of the team is to develop indicators of wetland ecosystem health with emphasis on west coast salt marsh systems. Our focus is on contaminant effects, but a range of stressors is considered, including: nutrient enrichment, habitat fragmentation, and pathogens. The overall design of the program includes synoptic sampling at 6 sites in northern and southern California. Because sampling by all investigators is conducted at precisely the same sites and stations, unprecedented integration is achieved. Other integration themes that are pursued by the entire consortium include integrative laboratory and field experiments to validate indicators and the use of model organisms for all field and laboratory investigation.

Key contributions include the development of indicators in marsh plants and animals at multiple spatial scales and levels of biological organization. These indicators are intended for various types of applications in marsh restoration, sediment quality protection, and management of specific contaminant inputs and threatened populations. There are three key integrated goals for our project. The first is the development of wetland plant indicators at multiple spatial scales and levels of organization, and the second is the development of fish and invertebrate indicators. These are described below. A third theme is an emerging effort on nutrient dynamics. The products of our program will be devised at three levels of integration with the penultimate

products including synthetic recommendations on salt marsh indicators at multiple scales with succinct case studies and a comparison of synthesis techniques including multivariate statistics, modelling, and application-based suites of measurements.

Indicators in Marsh Plants

Our goal is to develop salt marsh plant indicators at multiple spatial scales and levels of biological organization, which is advantageous in providing cost-effective screening tools and diagnostic techniques to elucidate the stressors. This is an important task, because two of the key limitations of existing ecological indicators are the lack of techniques to ascribe ecological change to specific stressors and the difficulty in prioritizing problems that may occur at large spatial scales. Developing indicators at multiple scales will be advantageous because this provides both ecologically relevant and cost-effective screening tools as well as diagnostic techniques to elucidate the stressors. This is an important task, because it addresses both key limitations of existing ecological indicators: the lack of techniques to ascribe ecological change to specific stressors; and the difficulty in prioritizing problems that may occur at large spatial scales. While the idea of developing indicators at multiple scales is not new, progress has been slow because development and validation of indicators must occur in a completely integrated program. Our integrated research in salt marsh plant indicators is demonstrating the utility of a Center approach to tackle a vital but largely ignored area (Lewis et al., 2001).

Working at the largest spatial scale, our NASA-funded remote sensing team is using a variety of airborne sensors, such as the 224-band hyper-spectral AVIRIS instrument, to produce high spatial resolution data of our sites. These images and other types of remotely sensed data are being used to characterize sites with respect to patch size, disturbance, species distribution, differences in biomass, and biochemical properties including content of chlorophyll and other plant pigments, canopy water content and dry plant litter. These data provide a previously unavailable means to characterize spatially distributed variability in species composition, physiological state, and abundance in wetlands that can be directly related to field-based chemical and physiological measurements. Understanding how these properties function as indicators is based on knowledge of physical factors like hydrologic and micro-topographic information, and biotic factors that we are collecting independently (e.g., using field survey techniques and LIDAR imagery). We have selected sites with varying levels of biomass, presence of contaminants, and history of disturbance within common habitats to provide a basis for comparison.

Following site selections, our plant physiologists sampled plant biomass and related indicators in the field to develop models and validate predictions. Significant effort is being devoted to comparing multiple types of metrics. We assess plant flowering, stem height, biomass, and other factors as well as photosynthetic processes using fluorometry (Juneau and Popovic, 1999) infrared gas analysis for carbon dioxide uptake, and individual spectroscopy (Bartlett et al., 1990; Gammon and Surfus, 1999; Spanglet et al., 1998; Sanderson et al., 1998; Zhang et al., 1996). Emerging technologies such as metabolomics are being applied to the plant tissues (Fan and Lane, 2000; Fan et al., 2001; Fan et al in press A), and these will permit a phenotypic assessment of perturbations in numerous aspects of plant physiology (Colmer et al., 1996; Fan et al, in press B). The efficacy of markers varies among plant types, but due to the broad distribution of

wetland species such as *Salicornia* and *Spartina*, recommendations on indicators at this level will be broadly applicable.

Because our sampling program is fully integrated, environmental chemists sampled the same plants at precisely the same locations in the sites (using DGPS) to determine whether toxicants vary in plant roots, shoots, and metal-contaminated salt exudates. These sites are also identified in the remote sensing imagery to evaluate how these stressors affect vegetation patterns in the marshes. We have sampled sites that have various levels of toxicant-related stress as well as at an additional site that has a well-characterized nutrient enrichment. We are utilizing state-of-the-art analytical techniques (e.g. Fan et al., 2002) to evaluate levels of metals and organics, but more importantly integrate this with ecosystem functioning. For example, the metal-contaminated salt exudation by cordgrass plants – a byproduct of osmoregulation - is an example of contaminant bioavailability that can span several spatial scales and levels of biological organization. Based on the biochemical basis of osmoregulation in these plants, we hypothesize that pollutant metal exudation by *Spartina* leaves will be dependent on salinity regimes and nitrogen nutrient status, potentially tying into water policies and nutrient runoff management.

In the coming year we will also attempt to link this to variation in the structure of organic matter (OM) at our sites (Higashi et al., 1998; Fan and Lane, 2000; Fan et al, 2000), with the aim of determining whether specific OM signatures in salt marshes are predictive of toxicant bioavailability (Schultz et al., 1999), as is thought to be the case for Hg. Hence, our studies emphasize linkages between toxicant levels in sediment and bioavailability to plants (e.g. Baraud, in press). Such efforts enhance EPA's ability to develop sediment quality criteria for salt marsh systems and result in the development of specific indicators of toxic stress.

Other facets of our design include: experimental studies validating physiologic responses following contaminant exposure in the laboratory, additional direct linkages with other ecological responses, including nutrient cycling and microbial processing, and related intensive study on mercury methylation.

We envision producing a series of highly integrated manuscripts that provide initial recommendations on indicators at each scale of organization, from biochemical to landscape. These publications will emphasize two to three case studies, but factors related to broader application will be expressed in a conceptual model. An accomplishment of this scope can only be achieved through an integrated research Center, and our team for this facet of PEEIR includes: a remote sensing expert who directs a NASA Center of Excellence, two plant physiologists (among the first scientists experimenting with diverse and novel biochemical assays such as metabolomics), three innovative environmental chemists, and a geomorphologist with expertise in wetland monitoring. We believe our expertise spans an effective range from simple methodology to innovation in the most current monitoring techniques. Technology transfer is being achieved through direct linkage with EPA Region IX, the California EPA, the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB), the San Francisco Estuary Institute and The Bay Institute. Our approach already has garnered significant attention, and data will be used to inform regulators (SFBRWQCB) during the restoration of Stege Marsh in San Francisco Bay and to assist in the risk assessment of mercury contamination in Tomales Bay.

Indicators in Fish and Invertebrate Model Animals

Assessment of ecological condition, **diagnosis** of specific stressors and **forecasting** of potential changes in populations are the most significant applications of ecosystem indicators (Pretti and Cognetti-Varriale, 2001). Integrating responses of exposure to contaminants across different levels of biological organization is considered key to understanding mechanistic linkages and usefulness of indicators (Clements, 2000). These applications require the use of many types of measurements, including both stressor and ecosystem responses; yet, the options for integration of such responses are still limited (Strobel et al., 2000). A key goal of the PEEIR program is to develop a suite of integrated approaches for ubiquitous model organisms widely distributed in salt marsh ecosystems of the Pacific coast. We initially selected an invertebrate and a fish species with limited dispersal in most life stages and which inhabit mud burrows where exposure to sediment contamination is greatest, allowing us to study both within-marsh and among-marsh variations in indicators. We selected the mudsucker, *Gillichthys mirabilis*, as a model fish because it inhabits mud burrows and remains in the same sites (<30 m range) for its juvenile and adult phases. The shore crab, *Pachygrapsus crassipes*, was chosen as the representative invertebrate as it is highly abundant, found along the entire West coast, inhabits mud burrows, and can be found in a reproductive state during portions of the year. Limited investigations with a third species, the clam *Macoma nasuta*, were added in the third year to enhance the bridging between environmental chemistry and effects research, as well as to ensure that species at multiple trophic levels were represented. Investigations at the chemical, molecular, physiological, organismal, and population levels have been implemented with these three organisms, and these will result in the initial development of individual indicators as well as suites of indicators that are integrated within models and a single conceptual framework. In addition, characterization of the community structure within the habitat of these three model species is also being conducted.

Organism-level indicators are the fundamental metrics that are used to alert us to potential changes in a subpopulation at any given site. Such metrics are intuitive, and they point us to potential detrimental effects; yet, without supplemental information they cannot inform about the potential causes of stress (Carignan and Villard, 2002). For example, if an alteration in growth or reproduction is observed, managers have little information to determine why that alteration may have occurred. Also, the absence of an observed change in growth or reproduction does not preclude changes whose primary effects are seen elsewhere in the food chain. We believe that if early-warning, mechanistically-based indicators, can be used to detect the stressors that managers are most concerned about then improvements in the protection of aquatic life within a given wetland will result (Cherr, 2002; Van Dam et al., 1998; Heath, 1998).

A focus of our program is discriminating the effects of toxic substances from other habitat alterations. Hence, we directly address a limitation of previous work -- the difficulty in establishing "cause and effect". Prior studies have typically correlated a chemical concentration to change in a population or even simply used toxicity test data with surrogate species. Our approach is more mechanistic. Another value of our integrated indicators is that resident species, rather than surrogate test species, are used in the construction of definitive measures of chemical exposure, absorbed dose, biochemical response, and evaluation of fitness parameters including growth and reproduction. Evaluation of the growth and physiologic data in models then permits

forecasting of population data into the future and can simulate varied exposure scenarios. To accomplish this goal, we have implemented an integrated program of field sampling as well as field and laboratory experiments. The program requires synoptic sampling by all investigators at all sites.

Our approach involves quantifying molecular, cellular, and biochemical responses in individual organisms collected from stressed and less-stressed wetlands, and along possible gradients within wetlands. Experiments in the field are being conducted concurrently with these efforts. This involves fish, crabs, and clams being outplanted at specific stations for up to 2 months, followed by a suite of measurements that include molecular, biochemical, and physiological parameters which are all being directly linked to growth/condition indices at the level of individual organisms. We are also measuring contaminant levels both at the outplant sites and in tissue levels of these contaminants (bioavailability) in these organisms. Dissection teams remove appropriate tissues following field collection at well-characterized sites, and they distribute these tissues to seven different investigators. Measurements include: 1) DNA strand breaks in red blood cells using the Comet assay, 2) acetylcholinesterase enzyme activity to assess organophosphate and carbamate pesticide exposure, 3) apoptosis or programmed cell death in multiple tissues, 4) metallothionein levels to evaluate metal exposure and toxicity, 5) cytochrome p450 enzymes to quantify exposure to many types of organic contaminants, 6) choriogenin proteins in male/non-reproductive fish to evaluate potential endocrine disruption, and 7) levels of metal and organic contaminants in subsets of matched fish. In addition, chemical extracts of sediment from the sites are shared among teams of analytical chemists and a molecular biology laboratory where screening for endocrine disrupting chemicals is underway. These techniques discern exposure to, and effects of, various classes of toxic substances (e.g., Huggett, et al, 1992). To determine whether they are valuable indicators, variability in field sites, relation to chemical exposure, and cost and level of effort are all being considered. Multivariate analyses relating biomarker responses to growth impairment are a key part of the integration effort.

Growth rates are being compared at contaminated and reference sites and among fish with high, medium and low biomarker responses, using daily growth increments measured in otoliths taken from the same fish utilized above. In addition, laboratory validation studies are underway to pinpoint selected mechanistic relationships between biomarkers and growth. We are developing new approaches based on Dynamic Energy Budget Models (Kooijman 200; Nisbet et al. 2000) to analyze variability in growth among individuals and assess factors that contribute to population change (Brooks, 1999). Fish growth is determined by multiple factors, so simple observation of a growth difference gives little information that managers can use with confidence. We will test whether a combination of biomarkers, growth determinations and modeling provides a clearer picture and helps to test our understanding and confidence in the level and nature of any detrimental effect (see below).

In parallel with the above measurements, we are conducting measurements of the ratios of stable isotopes of carbon and nitrogen at the study sites. These ratios can vary because of changes in the diet of our study animals and/or because of variations in the elemental composition of inputs to the marsh.

The dynamic energy budget models of individual organisms will characterize growth and reproduction in a range of environments, and the stable isotope studies will help elucidate trophic relationships. Supplemented by information on mortality, it is possible to project (sensu Caswell 2001) long-term consequences on population dynamics of observed changes in individual performance. Our extensive database on population dynamics of mudsuckers over six years at a number of locations in the Carpinteria Marsh (Brooks, 1999) will be used as the basis of testing these projections (see below).

As with the plant work, the animal model work has relied on a multifaceted team of chemists, molecular biologists, physiologists, fisheries scientists, and modeling experts. Two graduate students in Pharmacology and Toxicology, one graduate student in ecological modeling, a fisheries graduate student, and three postdoctoral researchers have been trained to work in this interdisciplinary environment. Several undergraduate assistants have also contributed to this working group. Technology transfer for this work involves extensive coordination with the San Francisco Bay Regional Water Quality Control Board, EPA Region IX, and the CALFED Bay Delta program. Our efforts will be used to inform the restoration of Stege Marsh because matching funds permit us to explicitly compare our indicators to a currently available approach that is used in management, the Sediment Quality Triad.

2. MODELLING WORK GROUP SUMMARY

Individual Growth as an Indicator of Estuarine Conditions

We are evaluating potential use of differences in growth patterns in fish and invertebrates as an indicator of environmental stress. Using a stochastic dynamic energy budget (DEB) model, we studied possible effects of environmental variability and internal energy reserves on growth rate and size of animals (Fujiwara *et al* 2004). This theoretical study showed that more than simple summary statistics of individual growth and size data are needed to understand the effects of environmental variability on growth rate and animal size.

Motivated by the above result, we have developed a new method of fitting the stochastic individual growth model to growth data of fish and invertebrates. A complication is that the model includes internal energy reserve, which is unobservable. This difficulty was overcome by using a computer-intensive method based on non-linear forecasting to estimate model parameters.

A central assumption underpinning our use of DEB models is that the effects of sub-lethal levels of contaminants may be described in terms of changes in the rates of assimilation of food and of respiration by individual organisms. We are testing these assumptions – and our fitting methodology – on experiments performed by the BRC group on the growth of young topsmelt (*Atherinops affinis*) in controlled environments, where food consumption and respiration rate were measured directly. The modeling studies described above will continue. Provided technical issues relating to mudsucker otoliths are resolved, we shall attempt to fit model parameters to data from natural populations and from the outplant experiments. We shall start work on a population model for mudsuckers.

We shall attempt some multivariate analyses on the diversity of microbial communities and the invertebrate fauna, with the aim of relating these to the stressor information obtained for some sites.

Dynamics of Stable Isotopes

PEEIR is gathering extensive data sets on carbon and nitrogen isotope ratios from many species at our study sites. Much current methodology on the interpretation of such information assumes reasonably constant conditions, not the extreme fluctuations in nitrogen supply that exist in the PEEIR study sites. We are completing a modeling study that recognizes the following facts:

- The mechanisms of nitrogen fractionation in animals are not fully understood, but there is a fairly consistent and widespread enrichment of ^{15}N in animal tissues above the food of about 3.4 ‰ per trophic level.
- Animals are commonly observed to have ^{15}N enriched feces and tissues but ^{15}N depleted urine.
- Assimilation involves potential for microbial fractionation in the gut and a two-way flow of nitrogen across the gut wall. Excretion is much simpler with no microbe involvement and a one-way flow.

Our model describes changes in nitrogen isotope ratios during growth and in the presence external fluctuations. We disagree with one published account that says that growing and non-growing adult animals should have the same concentration of heavy nitrogen. Our results suggest that growing animals should have a lower ^{15}N concentration than adults.

Evaluation of Index of Biological Integrity (IBI)

This work is continuing, with the issues becoming clearer with growing experience. We have reviewed the arguments by users of IBIs, with particular attention on the advantages and disadvantages of combining indicator scores into an index. Our concerns are mostly not new, though we aim to clarify them in the context of PEEIR work. The most serious is that combining measures of different things into a scalar index necessarily loses information when what you want to describe is multidimensional: if many “indicators” are indicating the same problem, we may not need all of them; if they are indicating different problems, then combining them obscures the individual information. We are also addressing some practical problems, one of which is that many IBI studies try to compare sites to an undisturbed reference, but this may not exist, and the comparison may not be appropriate. We are attempting to evaluate alternatives. We aim to develop some guidelines, more or less along decision theory lines, where remediation costs and the importance of the site (e.g., its popularity or proximity to population centers, or importance for other reasons) are considered (as they are not with IBI).

3. ARCHIVAL DATA WORK GROUP SUMMARY

The Ecological Scorecard

While our theory group examines possible alternatives to the IBI, the PEEIR outreach program has partnered with Dr. Anitra Pawley at The Bay Institute to support publication of the application-based “Bay Index.” Dr. Pawley’s Bay Index takes a portfolio-type approach,

establishing scores for selected management questions. Many efforts are underway to improve the health of San Francisco Bay. The Bay Institute's Ecological Scorecard (www.bay.org), released in October, 2004 by the Bay Institute, is intended to improve our understanding of how the entire Bay watershed is doing, to monitor how effective our stewardship of this vital resource is, and to identify future directions for management, monitoring, and research. The 2003 Bay Index focuses on the Bay itself, which is the first of four major ecological regions of the estuary—Bay, Delta, San Joaquin River and Sacramento River—proposed to be assessed as part of the Ecological Scorecard project. The Scorecard's Bay "Index" uses science based indicators to grade the condition of the Bay region: how well its ecological resources are faring, how much human activities are harming or helping the Bay, and how human uses of the Bay's resources are affected by the Bay's health. These indicators are combined into eight Indexes that track the Bay's environment (Habitat, Freshwater Inflow, Water Quality), its fish and wildlife (Food Web, Shellfish, Fish), our management of its resources (Stewardship), and its direct value to the people who use it (Fishable-Swimmable-Drinkable). The grading system compares current conditions in the Bay and its watershed to historical conditions, environmental and public health standards, and restoration targets. Figure 1 provides an example of the water quality index and the composite San Francisco Bay Scorecard. PEEIR has contributed to this project and in the upcoming year, Dr. Anitra Pawley will complete a peer-reviewed article to be submitted in the winter.

Benthic Index Review

An additional activity in PEEIR has been to thoroughly review existing benthics data for San Francisco Bay. Benthic invertebrate community measurements, particularly in the form of standardized indexes can serve as important measures of contaminant stress and tools for effective communication of sediment quality condition to the public. Despite the fairly long history of index development in freshwater systems, the study of these areas has lagged behind those in freshwater systems so the development of indexes in estuarine system is relatively nascent. We are currently completing a review of the methods used to study community level benthic effects due to contaminants including indexes since Pearson and Rosenberg's (1978) review of the effects of organic enrichment on marine benthic invertebrates and address the issues that impede the development of reliable invertebrate community measures. At this time, a variety of indexes and diagnostic approaches have been proposed, each with their respective histories, strengths and weaknesses. There are several categories of methodological techniques that are based on differences in the responses of benthic species, taxa, and functional groups to various types of anthropogenic disturbance. They include pollution scoring techniques based on species occurrences, multivariate diagnostic approaches, multimetric indexes, and the use of higher level community measures such as total species abundance, diversity and biomass. We categorize, compare and contrast benthic indexes and approaches, and evaluate which methods are best suited for use in variable environments. We also compare the findings derived from these studies, look for common features and assess disagreements in order to provide insights to guide future research. Figure 2 illustrates a comparison of the habitats assessed in the multimetric indexes developed to date.

SAN FRANCISCO BAY INDEX

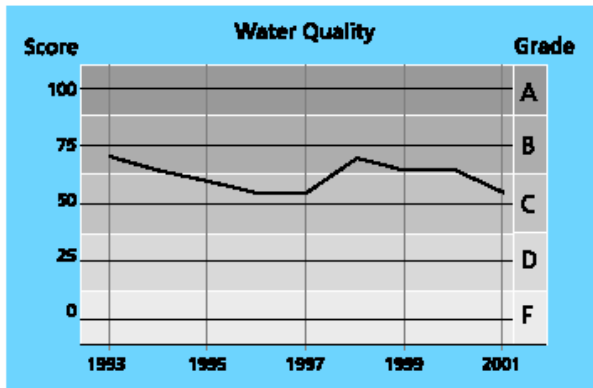










Figure 1. The Water Quality Index is one of eight Scorecard indexes providing a broad overview of San Francisco Bay ecosystem health. The index aggregates the scores of five indicators (contaminant groups) calculated from RMP data: pesticides, trace elements, PCBs, PAHs, and dissolved oxygen. The score for 2001 is 55 and the grade is a C. The water quality index has fluctuated from a B to a C indicating good to fair conditions during the recent time period and the trend is relatively stable. Limited historic data indicate that for some contaminants, conditions have improved, hence the upward arrow for the long-term trend.

Ecological Scorecard

	D+ Score = 32	Habitat Bay habitat loss is slowly being reversed, but it could take nearly 200 years to reach the tidal marsh restoration goal.	↓ long-term short-term ↑
	D Score = 29	Freshwater Inflow Reduced inflows are still degrading the Bay ecosystem, and recent gains from wetter years and new standards are being eroded.	↓ long-term short-term ↓
	C Score = 55	Water Quality Open waters are cleaner, but standards are not met in parts of the Bay. Toxic sediments and storm runoff are a major problem.	↑ long-term short-term ↔
	F Score = 10	Food Web Plankton levels in the upper Bay have crashed, reducing food sources for fish and birds. Alien species are locally dominant.	↓ long-term short-term ↔
	B- Score = 63	Shellfish Crab and shrimp numbers are increasing, but commercial harvest is still down from previous high levels.	↓ long-term short-term ↑
	C- Score = 39	Fish After a long decline, fish populations are stable at low levels, but some species are still endangered.	↓ long-term short-term ↔
	D+ Score = 31	Fishable-Swimmable-Drinkable Fish are harder to catch, and unsafe to eat. Beach closures are up, drinking water violations are down.	↓ long-term short-term ↔
	C- Score = 43	Stewardship Water conservation, pollution limits, monitoring, and restoration efforts are finally underway, but progress is slow.	↓ long-term short-term ↔

(Note that figure 2 is currently being revised)

Figure 2: Multimetric indicators are generally developed for discreet habitat types to minimize the effects of natural variability. This table lists the multimetric indexes and the habitat types and/or the parameters used to define habitat types for segregating multimetric analyses. Note that salinity and sediment type are primary factors structuring benthic communities.

ns= not significant

Author	Year	Habitat										Parameters						
		# of defined habitat types	Tidal Freshwater (0-0.5‰)	Oligohaline (0.5-5‰)	Low Mesor	High	Oligohaline-Mesohaline (≤18 ppt)	Polyhaline (18-27 ppt)	Polyhaline-Euhaline (> 27 ppt)	All (0-40 ppt)	Salinity	Sediment type (sand vs silt)	Latitude/geographical location	TOC	Depth	Hydrographic characteristics		
Thompson and Lowe	2004	2				1		1				x						
Llansó et al.	2003																	
Llansó et al.	2002	9	1	1	1	1		4		1		x	x	x				
Macauley et al.	2002	1																?
Anderson et al.	2001	1																?
Hunt et al.	2001	1																?
Paul and	2001	1																?
Dauer and Weisberg	2000	7	1	1	1	2			2			x				x	x	
van Dolan et al.	1999	4				1		3				x	ns	x	ns			
Engle and Summers	1999	1								1		x	x	x	x			salinity adjusted measures
Engle and Summers	1998	1								1		x						shannon-weiner index adjusted for salinity
Macauley et al.	1999	1																?
Weisberg et al.	1997	7	1	1	1	2			2			x	x					
Engle et al.	1994	1								1		x						salinity adjusted measures

not entered but in text

Ranasinghe et al. 19xx move from text

Hunt 2002 move from text

red = mentioned in paper IBI section

black = not mentioned in IBI section

need to address ? No habitats defined

PUBLICATIONS & PRESENTATIONS:

Publications

Fujiwara, Masami, Bruce Kendall & Roger Nisbet, Growth autocorrelation and animal size variation, *Ecology Letters* 7 (2004): 106-113.

Presentations

A bioindicator approach to assessing the effects of contaminants on estuarine species. Estuarine Research Federation Program and Abstracts. Seattle, WA September 14-18, 2003.

A bioindicator approach to evaluating reproductive health of estuarine organisms. Society of Environmental Toxicology & Chemistry Annual Meeting Program and Abstracts. Austin, TX, November 9-13, 2003.

Presentation on PEEIR Consortium at State of the Estuary Conference in Oakland, CA. October 21, 2003.

Public Outreach

Briefing on PEEIR Consortium to California EPA Secretary Hickox & colleagues at BML. July 7, 2003.

Briefing on PEEIR Consortium for EPA Region X, Portland, OR. September 13, 2003.

Briefings on PEEIR Consortium for EPA Region IX, San Francisco, CA. March 27, 2003 and October 9, 2003.

SUPPLEMENTAL KEYWORDS:

watersheds, estuary, ecological effects, bioavailability, ecosystem indicators, aquatic, integrated assessment, EPA Region IX.

REFERENCES:

Baraud, F., Fan, T.W-M., Higashi, R.M. Interactive effect of cadmium and soil humates on metal acquisition and sequestration in wheat. *Environmental Chemistry*, E. Lichtfouse, S. Dudd, D. Robert, eds., in press.

Bartlett, DS, GJ Whitting, and JM Hartman. 1990. Use of vegetation indices to estimate intercepted solar radiation and net carbon dioxide of a grass canopy. *Remote Sensing of the Environment* 30:115-128

Brooks, A.J. (1999) PhD Thesis, University of California at Santa Barbara.

- Carignan, V. and M.A. Villard. 2002. Selecting indicator species to monitor ecological integrity: A review. *Env. Monit. Assess.*, 78:45-61.
- Caswell, H. (2001) *Matrix Population Models: Construction, Analysis and Interpretation*, 2nd Ed. Sinauer Associates, Sunderland, Massachusetts, USA.
- Cherr, G.N. 2002. Can we develop and utilize indicators of ecological integrity to successfully manage ecosystems? In: *Managing for Ecosystem Health*, Third International Congress on Ecosystem Health, C.O. Qualset, D.J. Rapport, D. Ralston and B. Lasley, eds. CRC Press, pp227-229.
- Clements, W.H. 2000. Integrating effects of contaminants across levels of biological organization: an overview. *J. Aquatic Stress and Recovery*, 7:113-116.
- Colmer, T.D., T.W-M. Fan, A. Läuchli, and R.M. Higashi. 1996. Interactive effects of salinity, nitrogen and sulphur on the organic solutes in *Spartina alterniflora* leaf blades. *Journal Of Experimental Botany*, 47 (296): 369-375.
- Fan, T.W-M., Higashi, R.M., Lane, A.N. 2000. Chemical characterization of a chelator-treated soil humate by solution-state multinuclear two-dimensional NMR with FTIR and pyrolysis-GCMS. *Environmental Science and Technology*, 34: 1636-1646.
- Fan, T.W-M. and Lane, A.N. 2000. Nuclear magnetic resonance in analysis of plant soil environments. *Encyclopedia of Analytical Chemistry*, John Wiley and Sons, New York, pp. 4082-4108
- Fan, T.W-M., Lane, A.N., and Higashi, R.M. In press A. *In vivo* and *in vitro* metabolomic analysis of anaerobic rice coleoptiles revealed unexpected pathways. *Russian J. Plant Phys.*
- Fan, T.W-M., Lane, A.N., and Higashi, R.M. In press B. An electrophoretic profiling method for thiol-rich phytochelatins and metallothioneins, *Phytochemical Anal.*
- Fan, T.W-M., Lane, A.N., Shenker, M., Bartley, J.P., Crowley, D., Higashi, R.M. 2001. Comprehensive chemical profiling of gramineous plant root exudates using high-resolution NMR and MS. *Phytochemistry* 57: 209-221.
- Gamon JA, Surfus JS. 1999. Assessing leaf pigment content and activity with a reflectometer. *New Phytologist*. 143:105-117.
- Heath, A.G. 1998. Physiology and ecological health. In: *Effects of Multiple Impacts on Ecosystems*. J.J. Cech, B.W. Wilson, and D.C. Crosby, eds. Lewis Publishers, Chelsea, MI. pp59-89.
- Higashi, R.M., T. W-M. Fan, and A.N. Lane. 1998. Association of deferrioxamine with humic substances and their interaction with cadmium(II) as studied by pyrolysis-gas chromatography-mass spectrometry and nuclear magnetic resonance spectroscopy. *The Analyst*, 123: 911-918.
- Huggett, et al., Ed., *Biomarkers: Biochemical, Physiological, and Histological Markers of Anthropogenic Stress*, A SETAC Publication, Lewis Publishers, 1992.

- Juneau, P and R Popovic. 1999. Evidence for the rapid phytotoxicity and environmental stress evaluation using the PAM fluorometric method: importance and future applications. *Ecotoxicology* 8:449-455.
- Kooijman (2000) *Dynamic Energy and Mass Budgets in Biological Systems*, 2nd Ed. Cambridge University Press, Cambridge, UK
- Lewis, M. A., Weber, D. E. , Stanley, R. S. , Moore, J. C. The relevance of rooted vascular plants as indicators of estuarine sediment quality. *Arch. Environ. Contam. Toxicol.* 40: 25–34.
- Nisbet, R.M., Muller, E.B., Lika, K., & Kooijman S.A.L.M. (2000) From molecules to ecosystems through dynamic energy budget models. *Journal of Animal Ecology*, 69: 913-926.
- Pretti, C. and A.M. Cognetti-Varriale. 2001. The use of biomarkers in aquatic biomonitoring: example of esterases. *Aquatic Conserv.: Mar. Freshw. Ecosyst.*, 11:299-303.
- Sanderson, E.W., M. Zhang, S.L. Ustin, and E. Rejmankova. 1998. Geostatistical scaling of canopy water content in a California salt marsh. *Landscape Ecology* 13:79-92.
- Schultz L.F., Young T.M., Higashi R.M. Sorption-desorption behavior of phenanthrene elucidated by pyrolysis GCMS studies of soil organic matter. *Environmental Toxicology and Chemistry*, 18:1710-1719.
- Spanglet, H., S. Ustin and E. Rejmankova. 1998. Remote detection of plant community characteristics of a California subalpine marsh. *Wetlands* 18 (3):307-319.
- Strobel, C.J., Paul, J.F., Hughes, M.M., Buffum, H.W., Brown, B.S., and J.K. Summers. 2000. Using information on spatial variability of small estuaries in designing large-scale estuarine monitoring programs. *Env. Mon. Ass.*, 63:223-236.
- Van Dam, R.A., Camilleri, C., and Finlayson, C.M. 1998. The potential of rapid assessment techniques as early warning indicators of wetland degradation: A review. *Environ. Toxicol. Water Qual.*, 13:297-312.
- Zhang, M., S.L. Ustin, E. Rejmankova, and E.W. Sanderson. 1996. Remote sensing of salt marshes: Potential for monitoring. *Ecological Applications* 7(3): 1039-1053.